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EU Petroleum Refining Fitness Check: Impact of EU Legislation on Sectoral Economic Performance

Ruslan Lukach, Robert Marschinski, Dilyara Bakhtieva, Marian Mraz, Umed Temurshoev, Peter Eder and Luis Delgado Sancho

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Abstract
This report presents the results of the quantitative assessment of the impact on the petroleum refining sector of legislative measures, identified in the process of European Commission's analysis and stakeholder consultations as being of significant relevance for petroleum refineries, and as such included in the mandate of the fitness check. This quantitative assessment took into account the impact of the legislation on costs and revenues of the EU petroleum refining industry and therefore on its capacity to remain internationally competitive.

This analysis, mostly of a quantitative nature, was accompanied where possible and relevant by a qualitative assessment in accordance with the Commission's general approach to fitness checks. In particular, the report analysed how coherently and consistently the EU legislation, identified as relevant for the sector, works together, whether it is effective and efficient, and whether it is associated with excessive regulatory burdens, overlaps, gaps, inconsistencies or obsolete measures. Since this fitness check addressed a specific industry sector rather than a policy area, it had a specific focus on the cumulative impact, effectiveness, efficiency and coherence of the measures with respect to the oil refining sector.

As stated in the mandate of the fitness check, the analysis in this report was retrospective and concentrated on the impact of the relevant legislation on the petroleum refining sector in the period between 2000 and 2012.

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0. <u>Executive Summary</u>

0.1. Background

As part of its smart regulation policy, the European Commission announced in its Work Programme for 2010[1] its intention 'to keep current regulation fit for purpose' by 'reviewing, from this year onwards, the entire body of legislation in selected policy fields through "fitness checks". The purpose is to identify excessive burdens, overlaps, gaps, inconsistencies and/or obsolete measures which may have appeared over time.' Four pilot projects were launched in 2010, covering specific policy areas. The Industrial Policy Communication Update[2] announced the Commission's intention to undertake a Fitness Check for the petroleum refining sector. This fitness check intended to 'focus on the implementation and interaction of those policies that are most important for the competitiveness' of the sector.

There are currently around 100 mainstream petroleum refineries operating in the EU. In recent years, total demand for the refining industry's products has been steadily declining, mostly due to lower demand for gasoline and fuel oil. At the same time, one of the most important characteristics of demand for petroleum products, dieselisation, contributed both to the overall decline in demand and to a structural shift from gasoline to diesel as a motor fuel. In addition, in line with a significant increase in air transport activities, consumption of jet fuel and kerosene has been growing recently. In line with the decreasing demand, the overall production of refining products has been declining, although at a slower pace and still preserving a strong imbalance between production and consumption of gasoline. These trends to a large extent explain the steady underutilisation of the EU refineries which, in turn, contributes to the pressure to close excess refining capacities.

In addition, compared to refining in other parts of the world, refining in the EU faces relatively high operating costs, one component of which, energy costs, are also among the highest in the world. Net cash margins in recent years for EU refiners have been lower than for refiners in several competing regions. Against the backdrop of these general trends, it is of particular importance to understand whether the legislation affecting the EU petroleum refining sector remains fit for purpose, and whether its associated costs allow the sector to remain internationally competitive.

Transparency and stakeholder involvement were given high prominence within this fitness check. In March 2013, DG ENTR set up an Inter-Service Steering Group, including representatives of the Commission services: SG, BEPA, ENER, MOVE, ENV, CLIMA, JRC and TAXUD. The main body ensuring the involvement and consultation of interested parties, including, among others, Member States, the European Parliament, industry and trade unions, was the EU Refining Forum, meeting approximately twice a year starting from April 2013. Several additional meetings and stakeholder consultations were organised, where the methodology and intermediate results of the exercise were presented and discussed.

The research work by the JRC-IPTS, with the aim to quantitatively assess the cumulative impact of the relevant legislation on the petroleum refining sector, took place between June 2013 and May 2015.

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[1] COM(2010) 135 of 31 March 2010.

[2] COM(2012) 582 of 10 October 2012.

0.2. Scope and main focus

The main objective of this study was to quantitatively assess the impact on the petroleum refining sector of legislative measures identified in the process of the European Commission's analysis and stakeholder consultations as being of significant relevance for petroleum refineries, and as such included in the mandate of the fitness check. This quantitative assessment took into account the impact of the legislation on costs and revenues of the EU petroleum refining industry and therefore on its capacity to remain internationally competitive.

This analysis, mostly of a quantitative nature, was accompanied where possible and relevant by a qualitative assessment in accordance with the Commission's general approach to fitness checks[3]. In particular, the report analysed how coherently and consistently the EU legislation identified as relevant for the sector works together, whether it is effective and efficient, and whether it is associated with excessive regulatory burdens, overlaps, gaps, inconsistencies or obsolete measures. Since this fitness check addressed a specific industry sector rather than a policy area, it had a specific focus on the cumulative impact, effectiveness, efficiency and coherence of the measures with respect to the oil refining sector.

As stated in the mandate of the fitness check, the analysis in this report was retrospective and concentrated on the impact of the relevant legislation on the petroleum refining sector in the period between 2000 and 2012.

The pieces of EU legislation identified as the most relevant for the sector and therefore included in the mandate of the fitness check were:

- the Renewable Energy Directive[4];

- the Energy Taxation Directive[5];

- the EU Emissions Trading System[6];

- the Fuel Quality Legislation[7];

- the Directive on Clean and Energy-Efficient Vehicles[8];

- the Industrial Emissions Directive[9] (together with the Integrated Pollution Prevention and Control Directive (IPPCD) and the Large Combustion Plants Directive (LCPD));

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[3] See http://ec.europa.eu/smart-regulation/evaluation/docs/fitness_checks_2012_en.pdf.

[4] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

[5] Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity.

[6] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC and subsequent amendments.

[7] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.

[8] Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles.

- the Strategic Oil Stocks Directive[10];

- the Marine Fuels Directive[11];

- the Energy Efficiency Directive[12];

- the Air Quality Directive[13].

It needs to be noted that this study did not attempt to perform an exhaustive overview or cost-benefit analysis of the relevant legislation, as it concentrated on its application to a specific sector. Within the above directives, all provisions of significant relevance for the petroleum refining sector were taken into account for further analysis. Additionally, whenever relevant impacts of the respective directives stemmed from the predecessor pieces of legislation, such measures were also taken into account for the assessment. Where it was clear that significant changes in the legislation taking place after 2012 could lead to a need to reassess its impacts on the oil refining sector in the near future, some relevant qualitative considerations were presented. Any formal analysis of impacts beyond 2012 was, however, outside the scope of this report.

0.3. Methodological approach

0.3.1. Cost impact channels

To systemise the legislative cost impacts, our analysis considered three main channels through which the legislation could potentially impact the sector: one direct channel and two indirect ones. Namely, the most direct way in which a piece of legislation imposes costs for the refining sector is by impacting the way a refinery has to be operated. The impact of such legislation can be expressed by the implied increase in variable and fixed (including investment) costs (for example, the one-off costs for a new filter or the price of required emission permits).

In a different way, the legislation can have an impact on refineries by imposing quality requirements on refined petroleum products. The legislation's economic effect on refineries is in this case indirect, i.e. it occurs only by means of changes in the demand function the refinery faces (note that a refinery could legally choose to only produce for foreign markets not covered by similar legislation). The economic impact may be expressed as the – ceteris paribus – additional variable and fixed costs (including investments) incurred by the refinery for meeting the required product specification.

Thirdly, and again representing an indirect effect, legislation can cause shifts in the relative and absolute demand for existing petroleum products. Demand shifts of this type might also arise as a

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[9] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

[10] Council Directive 2009/119/EC of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products.

[11] Directive 2012/33/EU of the European Parliament and of the Council of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels.

[12] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[13] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

secondary effect of legislation on product quality, when a new quality requirement drives up the product price and leads to substitution. Economically speaking, the changes in absolute and relative demand can cause a costly loss of efficiency for a refinery, at least in the short term, in terms of its utilisation rate and product mix. In the case of relatively minor shifts in demand, this might lead to only small increases in variable costs, but to keep up with larger market shifts sizeable investments in additional units might be needed (for example, to increase secondary conversion capacity). Overall, the economic impact of any legislation may be judged as relevant only if it leads to a significant increase in unit costs (with appropriate rescaling of incurred fixed/investment costs). It may, in a second step, be judged to be relevant with regard to international competitiveness only if the cost increase cannot be passed on through the value chain.

The fitness check assesses the effect of European regulation on the refining sector that is additional to the effects of the corresponding national regulation measures. In cases where national regulation imposes stricter norms or higher goals than the corresponding measures at the EU level, the additional effect of the EU legislation is considered to be negligible. The actual interactions between national and EU-level legislation are handled in detail in the analyses of individual measures.

0.3.2. Assessment of benefits, effectiveness, efficiency, coherence and relevance

This report has also systemised and assessed, as much as possible, benefits related to the implementation of relevant legislation in the petroleum refining sector. Importantly, while certain benefits may relate to the refining sector itself (e.g. due to EU-wide harmonisation of product specifications), positive impacts of the environmental legislation predominately occur for the society as a whole and not at the sector level. Therefore, this study did not intend to perform a cost-benefit analysis of the relevant legislation or systematically compare benefits of the legislation with its costs for the sector. Rather, it performed an assessment of whether the regulatory framework for the sector in the period in question was fit for purpose, coherent and achieved its objectives effectively and efficiently.

A qualitative assessment analysed, in accordance with the Commission's methodological approach to fitness checks, the effectiveness, efficiency, coherence and relevance of the legislation. While a full assessment in this respect was not possible within the scope of the exercise, the following main questions were addressed to the greatest possible extent in this report:

(1) Concerning *effectiveness*, were the achievements of the identified legislation with regard to the refining sector in line with the stated objectives? What progress was made over time towards achieving the objectives? Which main factors (e.g. implementation by Member States, action by stakeholders, cooperation between producers) contributed to – or conversely stood in the way of – achieving these objectives? Beyond these objectives, did the legislation achieve any other significant results?

(2) Concerning *efficiency*, were there regulatory gaps, inconsistencies, overlaps or evidence of excessive administrative burdens for the refining sector? To what extent did Member States and industry respond to the requirements of different policies in terms of administrative cooperation and policy coordination? What were the policies in place in Member States and at the EU level to support the sector? Was availability of and access to funding a constraint in the implementation of the relevant legislation? What were the costs and benefits associated with the implementation of the specific legislation? Could any costs be identified that are out of proportion with the benefits achieved?

(3) Concerning *coherence*, what was the degree of integration of all instruments covered by the fitness check? Was the scope for integration fully exploited? Were there unintended consequences and collateral effects? Could any specific inconsistencies and unjustified overlaps (e.g. in terms of definitions and key concepts) across the pieces of legislation concerned and between them and other parts of EU law be identified? What was the cumulative impact of the measures on the performance of the refining sector?

(4) As regards *relevance*, to what extent did the policies covered by the fitness check and their objectives address the challenge of a competitive and sustainable EU refining industry along with their wider economic, social or environmental challenges? What was the value added of the EU legislation?

0.3.3. Data sources

This report made use of the multitude of existing sources of relevant empirical data, such as Eurostat databases, regulatory and industry publications (primarily from internationally recognised sources, for example, reports by the International Energy Agency and European Environmental Agency), and, where relevant, sector studies performed at the EU or national levels. Apart from the publically available data sources, quantitative analysis in the report relied on three main sources of data, assembled and acquired specifically for the purpose of this study.

Solomon Associates database of the EU refineries

HSB Solomon Associates LLC (Solomon) is a global consulting service for industries such as refining, chemicals, pipeline, terminals, power generation, and crude/gas production etc. Its main focus is proprietary comparative analysis based on the industry best practices to help clients identify areas for performance improvement and supporting clients through the improvement process.

The data used in this report is a subset of the data collected as part of the 'Fuels Study' and covers the *time period of 1998-2012* on a *biennial basis*. It only includes the EU refineries. The total number and composition of refineries in each year can vary, as not all refineries participated in the study in all years. It needs to be emphasised that data is provided only for refineries for which data had already been collected as part of the 'Fuels Study' databases. In each two-year period the data covers on average 80 refineries.

Indicators include, *inter alia*: capacity, Solomon Index for Refinery Complexity, quantities of all inputs, quantities of all outputs, refinery units and their capacities, for-profit investments in new units, regulatory investments, processing of biofuel components, various types of operational costs, refinery energy balance, emissions of SO_x, NO_x, CO_2.

Concawe refinery survey

The data used in this report was collected as a result of a survey specifically developed and conducted by Concawe[14] and the JRC-IPTS for this fitness check in 2014. In particular, refineries were surveyed with regard to three directives analysed in the fitness check: the Industrial Emissions Legislation and Air Quality Directive (with questions on the amounts of capital and operational

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[14] Concawe is the scientific and technical organisation of the European petroleum refining industry, whose 43 members are all companies operating refineries in the EU. Concawe routinely monitors and evaluates the major factors affecting the EU refining industry.

expenditures related to the different pollution prevention and control measures) and the Renewable Energy Directive (costs for biofuel storage and infrastructure). The questionnaire was sent to 82 (Concawe member) refineries operating in the EU-28,. The resulting response rate was 77 %.

Data from IHS Consulting

The JRC-IPTS purchased a comprehensive set of refinery-level data, which includes *simulated* costs, revenues, and margins. This data was supplied by IHS consultancy (formerly Purvin & Gertz), a well-known provider of information in several European industries, including oil refining.

The data is presented as a time series covering the period from 2000 to 2013, with detailed indicators in the following categories: structural and capacity data; production structure; costs; crude prices; product prices; revenues and margins. For each year, the dataset covers all the EU refineries considered in the fitness check, with the exception of three smaller plants. In addition to the data on EU refineries, several key variables were provided for the non-EU regions to enable comparative analysis. The data points were in part simulated with the use of IHS's proprietary *Refinery Simulation Model*. The model simulates product yields by calculating flows of intermediary products between refinery units and blending components to meet final product specifications.

Data sources' complementarity

These three main data sources were complementary and used in the report for different purposes. The data source most extensively employed throughout the report was the Solomon Associates (2014) database. It served for the analysis of the state of play and trends in the EU petroleum refining sector, and provided crucial inputs for assessing the impacts of the legislation on the sector. At the same time, the database contained no data on refining revenues and margins in the EU or in the competing regions. In addition, given the level of aggregation in the database, the data was available at the level of the EU, EU regions and refining complexity groups, however, not at the level of individual refineries.

Whenever the analysis needed to be fine-tuned at the level of individual refineries, the study employed the data of IHS (2014). While this database provides very detailed information at the refinery level, its important limitation is that to a large extent it relies on simulations (with the use of IHS's proprietary Refinery Simulation Model, as described above) and therefore on certain restrictive assumptions regarding the parameters of refineries operation. This does not concern the variables obtained from publicly available sources, such as capacities and throughputs of refinery units. Potential limitations of IHS (2014) data were taken into account for the analysis and reporting of results. In particular, this data was not used in the assessment of overall regulatory costs for the sector.

Finally, the survey of the EU refineries conducted by Concawe provided additional insights into the capital and operational expenditures related specifically to pollution prevention and control measures. This data is extensively used for the analysis of the impacts of the Industrial Emissions Directive and the Renewable Energy Directive in the respective chapters of the report.

0.4. EU refining sector overview

The EU oil refining sector constitutes a substantial part of the world's total refining capacity and accounts for a visible share of the manufacturing value added in Europe, as well as contributing to employment, and demonstrating a substantial turnover. Refining products continue to play an important role in satisfying the energy demand in Europe and are an essential component of the

EU's energy security. Furthermore, the refined petroleum products are an important element of extra-EU trade, accounting for the major part of the EU energy exports and imports. It has been observed that, in terms of the share of domestically produced refining products, the EU is not in the zone of high risk regarding the security of supply, but appears to have become more imports-dependent during the last decade.

We identified a number of internal and external factors and features of the EU's refining sector potentially affecting its global competitive position. In this section we review the main findings of this analysis.

0.4.1. Internal factors

Location

The overview shows that refining is a mature industry, fairly evenly distributed across the EU territory. In terms of geographic location, the proximity to crude sources and/or main crude transportation media determines the primary composition of EU refineries' crude diet. The effects of location on the product mix composition are weaker and the differences between regional clusters are mostly visible in relative shares of gasoline and diesel fuel production.

Refining Complexity and Types of Units

The average complexity of oil refineries in Europe has grown visibly since 2000. Throughout the observed time period the most complex refineries were located in Germany, Benelux, the UK and Ireland, while the least complex ones were found in Iberia, central Europe and France.

Most complex refineries tend to specialise in the heaviest crudes, which could explain the fact that the strongest complexity growth was observed in the regions that have, on average, higher shares of FSU crudes.

Regarding the specific types of refining units that are responsible for most changes in complexity, hydrotreating, hydrocracking, and coking units appear to be the main drivers of increasing complexity at European refineries. Also, hydrogen production capacities exhibited visible growth in order to satisfy the increased hydrotreating and hydrocracking needs.

Investments

In general, we observe a steady growth in all kinds of investments during the pre-crisis (before 2009) period in absolute volumes and per tonne of net raw material input and other feedstock processed. The share of regulatory/environment-related investments has been increasing against the backdrop of declining non-regulatory (profit improvement) capital investments in the aftermath of the economic crisis. The above results provide an indication that regulatory/environmental obligations may be restricting refineries' flexibility in adjusting their capital investments.

Energy use

The time evolution of the energy use per tonne of processed crude and other inputs in different complexity groups remained stable over the past decade, although there is evidence of an increasing share of gaseous fuels in the total energy use mix.

The energy intensity of refining (GJ consumed per tonne of processed crude and other feedstock) appears to be more strongly associated with the complexity of the installed refining capacity (more complex – more energy-intensive) than with the characteristics of the processed crude, such as the sulphur content or the crude API gravity.

The weight of energy costs in the total expenditures structure of European refineries has steadily increased in the past decade. In particular, the price for natural gas has been substantially higher in the EU than in the US, to a large extent because of the latter's shale gas revolution.

Related to the above, the extent of use and, therefore, the ease of access to gaseous and liquid fuels are the main distinguishing factors for clustering the regions according to their energy use.

Operational efficiency and utilisation rates

During the reviewed period we observe a clearly visible pattern of growth in both fixed and variable operating expenditures per tonne of net raw material input processed. In the global setting, the operating costs of the EU refineries seem to be relatively higher than those in several other world regions. The currently available data suggests that the likely explanation for this upward trend comes mainly from the changes in energy prices and personnel costs.

The gross margin indicators for refineries in all world regions show a positive trend in the period between 2000 and 2012, but with the EU lagging behind its main international competitors. The declining trends in crude throughputs of EU refineries are persisting against the backdrop of a continuously improving situation for refineries in the US.

Given the fact that the refining capacity in the EU remains substantially underutilised (also in comparison to the competing regions) we can expect that, despite the recent wave of refinery capacity reduction, the process of refining capacities closure will continue into the near future.

0.4.2. External factors

Crude supply and prices

The EU refinery sector works with a rather diversified stream of crude inputs with a wide range in API gravity and sulphur content. Still, among all types of crude, the relative shares of North Sea, FSU and Middle East crudes are the main components determining the crude diet of refineries and changes in their capacity. In the past decade, the main characteristics of crude inputs shifted towards heavier and more sour crudes (coming mostly from the FSU), although not in all EU refining regions.

There is particular uncertainty about the stability of the composition of crude imports as a consequence of the unstable political situation in the main crude-producing regions. This problem is exacerbated by the continuing depletion of the domestic crude sources and growing oil prices.

Refinery products demand

The data shows a clear tendency for dieselisation of transport and greater demand for other middle distillate fuels due to the declining general demand for fuels. On the process side, the industry reacted by expanding capacity for conversion units to boost production of middle distillates, closing unprofitable (mostly less complex and 'gasoline-favouring') plants; but still the

imbalance between domestic production and consumption of gasoline and middle distillates persists.

The international trade in refined products provides an important mechanism to correct for imbalances in the domestic production and consumption of refining products. Nonetheless, there are doubts about the sustainability of trade in gasoline with the US as a channel to compensate for excess gasoline production in Europe. Fuel exports will thus also be dependent on demand and supply conditions in the other regional markets. In terms of the share of other domestically produced refining products, the EU is not in the zone of high risk regarding security of supply, but appears to have become more imports-dependent during the last decade, especially for middle distillate products.

The declining demand for fuels in Europe together with the persisting low utilisation rate contribute to pressure towards further closure of excess refining capacity.

International competition

The global market for refining products is undergoing substantial transformation, where the EU competitors are changing and building up their capacity at a fast pace.

A more detailed competitiveness analysis section of the report formally examines the international competitiveness of the EU refining sector using a number of generally accepted indicators. Additional costs of compliance with environmental regulations, which undoubtedly play an important role in the refining industry, are also a subject of discussion in the relevant sections of the report.

0.5. Refining-relevant EU legislation: review and economic impacts

0.5.1. Renewable Energy Directive

- The Directive was successful in bringing the share of biofuels in transport from virtually zero in 2000 to 5.1 % in 2012. However, due to indirect land-use effects, the expected benefits in terms of GHG reductions could only be partially realised (during the time period considered here). A positive effect in terms of lower import dependence on oil and oil products can be affirmed, given that 82 % of EU biofuel is produced in the EU, with 64 % of the feedstock being of EU origin.
- For EU refineries the most relevant implication of the Renewable Energy Directive is the potential reduction of EU demand for fossil-based fuels due to their substitution by biofuels. However, at the aggregate EU-wide level this was very likely _not_ the case for biodiesel–which accounted for 80 % of all EU biofuels from 2000 to 2012–because at the aggregate level Europe has an overall shortage of diesel production capacity and is thus a net importer of diesel. EU diesel net imports have at all times exceeded its consumption of biodiesel.
- Thus, the presence of biodiesel has partially softened the EU's dependence on diesel imports, and on energy imports in general, given that (in 2010) 60 % of the biodiesel consumed in the EU was produced from feedstock of EU origin. If the production of biodiesel had not been promoted by EU and Member State policies, and had EU biodiesel consumption remained at its

year 2000 level, then year 2012 EU imports of fossil diesel would have had to be 74 % higher to fill the domestic supply gap, and 23 % higher cumulatively over 2000-2012.[15] The fact that a few EU-28 Member States like the Netherlands and Italy were net exporters of diesel does not invalidate this argument, given that they have neighbouring countries (France, Germany, Austria) which, cumulatively, are relatively larger net importers.

- However, EU refineries are negatively impacted by the demand-reducing impact of biogasoline, as there is a surplus production of conventional gasoline at the EU level. If, hypothetically, biogasoline consumption had remained at its year 2000 level, then the EU demand for conventional gasoline in transport would have been 3.4 % higher in 2012, and 1.1 % higher cumulatively over 2000-2012. A model-based analysis by IHS suggests an associated impact on average EU refining margins between EUR 0.01 and EUR 0.20 per barrel of throughput during 2006 to 2012, and between EUR 0.01 and EUR 0.35 in 2012. Nevertheless, the overall drop in EU gasoline demand exceeded the policy-driven increase in biogasoline consumption by a factor of more than 10. Biogasoline is, consequently, only a minor cause of the current EU gasoline surplus.

- EU biogasoline decreases demand but, as refining is a coupled production, the product yields of existing refineries cannot be easily shifted towards a 'max. diesel' mode. It can be done to some extent by shifting to heavier crudes and higher conversions (with the associated incremental costs), since a direct transformation of gasoline into diesel is not possible. As an alternative way of adjusting to the increased gasoline surplus, the oil refining industry may restructure either by disinvesting gasoline units (FCC and reformers) or by shutting down whole refineries. But a reduction of EU overall refining capacity would also increase the EU's mid-distillate deficit and thus its dependence on third countries for such imports.

- As a secondary impact, it would be expected that refineries' electricity costs have increased due to the EU-wide expansion of electricity from renewable sources, as mandated by the RED. However, lacking the required Member State-specific information on applicable electricity surcharges and relevant derogations, a quantitative estimate could not be provided here.

- A final impact on the refining sector consists of additional expenditures associated with the blending, storage, and transportation of biofuels. According to industry data (Concawe 2014), these amounted to EUR 0.5 million annually per refinery during 2000-2012, and EUR 0.9 million annually during 2008-2012. In relative terms, both of these numbers correspond to about EUR 0.01 per barrel of refineries' throughput.

0.5.2. Energy Taxation Directive

- The ETD's main objective of reducing divergent tax rates across the EU countries was largely achieved by 2010 in the case of gasoline and diesel oil used as propellant, as measured by the reduction observed in cross-country excise tax variability. Thus, the ETD has played a positive role in improving the functioning of the internal market by reducing distortions in competition between Member States due to their divergent gasoline and diesel tax rates.

- Given that the overwhelming majority of the excise duties for heating gasoil (business and non-business use), heavy fuel oil (heating, business, and non-business use), and LPG used for motor fuels were relatively stable over the 2002-2013 period, they contributed much less to the

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[15] Own calculation based on Eurostat (2014, 2014a) data.

narrowing of the differences between these taxes across the EU countries than those of gasoline and diesel oil.

- Concerns were raised, in particular in the European Commission proposal for a revision of the ETD in 2011 (see EC COM(2011) 169/3), about the effectiveness of the ETD in relation to its other two objectives of encouraging more efficient use of energy and improving the functioning of the internal market by reducing distortions in competition between mineral oils and other energy products. Such concerns are related to the fact that the current minimum tax rates are based on the volume of energy products, and as such they do not reflect the CO_2 emissions or the energy content of these products.

- Regarding the ETD's impact on the refining sector, we find a negligible reduction in total EU demand for gasoline and diesel. Relative to the observed EU-27 consumption, the average demand reductions for the 2004-2008 period are estimated to be 0.17 % for gasoline and 0.10 % for diesel, while those for the 2009-2013 period are 0.27 % and 0.32 %, respectively.

- The gasoline and diesel tax levels of, respectively, 17 and 16 Member States, representing 85-88 % and 77-78 % of the total EU-27 gasoline and diesel markets, were not affected by the ETD, because their tax levels were already higher than the minimum ETD levels before these minimum excise rates were adopted.

- Up to 11 Member States (from Bulgaria, Cyprus, Czech Republic, Estonia, Spain, Greece, Lithuania, Luxembourg, Latvia, Malta, Poland and Romania) were found to be affected by the ETD's minimum tax levels for gasoline and diesel excise duties. The assessed average Member State-level demand reductions for gasoline and diesel account for up to only 3.3 % and 2.2 %, respectively. The largest reduction, of 4.4 %, is obtained for Bulgaria in the case of gasoline consumption during the 2009-2013 period.

- At the EU level, we did not find any discernible impact of the ETD in terms of the European consumption switch from gasoline to diesel. However, for seven Member States (Bulgaria, Czech Republic, Lithuania, Latvia, Malta, Poland and Romania) the ETD seems to have only marginally contributed to their diesel to gasoline demand switch, given that their diesel to gasoline demand ratios in the counterfactual environment without the ETD were assessed to decrease, on average over the two periods, by 0.63 % to 2.07 %.

0.5.3. EU Emissions Trading System

After reviewing the legislation on the EU Emissions Trading System (EU ETS) since its inception in 2005 and analysing its key implications for the EU oil refining sector in the 2005-2012 period (Phases 1 and 2 of the ETS), our main conclusions can be summarised as follows:

- At the oil refining sector level, the average greenhouse gas emission levels per refinery stayed relatively stable between 2006 and 2012, while an increase in the average complexity of refineries was observed. This suggests that emission levels were influenced by some offsetting factors, such as energy consumption management and fuel switching by refineries, which is further supported by additional data.

- We cannot precisely conclude on the extent to which the EU ETS contributed to preventing potential growth in emissions, given the multiplicity of factors at play and difficulties with constructing a suitable baseline scenario. The available assessments and empirical data indicate that during the first two phases of the EU ETS, improvements in carbon emission performance were achieved due to improved energy efficiency and fuel switching. These were

driven by production cost optimisation where the carbon emission-related cost played a relatively minor role during that period.

- On the basis of statistical data analysis, we conclude that, on the one hand, carbon emission abatement scope and options differed between the EU regions and were determined by region-specific factors, and on the other hand, that across all the EU regions the emission performance of refineries was strongly linked to refining complexity.

- The refining sector incurred indirect costs through the ETS-induced increase in the prices of key inputs, most importantly, electricity. The magnitude of such costs could differ between the EU regions; however, a cost increase of this type can be estimated as an insignificant part of refineries' operating expenditures overall. Potentially, certain refineries producing excess electricity could derive benefits from higher electricity prices by selling internally produced electricity to the grid when allowances for emissions related to electricity production were distributed to the sector free of charge – notably, such refineries only constitute a minority of the sector.

- Empirical analysis of the EU refineries' emission trading positions during the first two phases of the ETS shows that, in total, allowances allocated to the sector exceeded its total verified emissions in both phases (by 6.1 % in the first phase and by 7.6 % in the second). At the same time, we observe that in both trading periods slightly more than a quarter of the installations (27.2 % and 28.3 % correspondingly) in the refining sector were short of emission allowances.

- Statistical analysis of the emission trading data, matched with the characteristics of respective refineries, suggests that, while operational characteristics and emission levels of refineries played a role in determining resulting emission trading positions, the 'shortage' of emission allowances was also a result of the initial allocation of allowances. This suggests that the approach to emission allowance allocation by national regulatory authorities is an important consideration for the analysis of the two initial phases of the ETS.

- The immediate impact of the EU ETS on refinery margins depended on the sector's ability to pass the associated costs on to fuel consumers. Based on the available estimates, we conclude that the EU refineries had the possibility, at least in the short term, to pass the ETS-associated costs on to final consumers (however, to different extents in different markets, depending on various factors such as market structure and degree of exposure to international trade). Overall, the available empirical evidence is not conclusive with respect to the degree of ETS-related costs pass-through actually exercised.

- Overall, we conclude that, during its first two phases, the EU ETS was not associated with significant costs for the oil refining sector as a whole; rather, the EU refineries were on average able to receive additional income due to the surplus of emission allowances. The limited impact of carbon trading on emission abatement investments was to a certain extent explained by the rather 'generous' overall allocation of allowances in the first two phases, together with the lower than expected levels of economic activity and resulting low prices of carbon.

0.5.4. Fuel Quality Legislation

The legislation on fuel quality regulates the specification of petrol/gasoline, diesel, gas oils and inland heavy fuel oil in terms of their content of sulphur, metallic additives, biofuel components, etc. The main findings of our analysis are the following:

- The continuous decline in average sulphur content in road fuels in the EU-27 countries provides evidence that road fuel quality improved. This is expected to impact on exhaust emissions. In particular, it shows how the two most important thresholds were met, namely the 50 ppm threshold for diesel and gasoline fuels in 2005, and the 10 ppm threshold in 2009, showing that the sector is on track in complying with the objectives of the legislation.

- The effects of the fuel quality legislation in terms of the GHG emissions are less straightforward. In general, meeting the stricter fuel quality standards involves more processing capacity and more severe modes of operation for the existing units. Almost all of these changes go together with more energy use (assuming no other energy efficiency-improving measures are undertaken) and, hence, carbon dioxide emissions.

- Regarding the economic impact on the sector of measures for meeting fuel quality requirements, a look at the declared investment costs for fuel specifications compliance during 2000-2012 for the EU-28 provided by Solomon Associates (2014) gives an estimate of the average annual capital investment costs:
  - meeting specifications for all clean fuels: EUR 8.5 million per refinery per year or EUR 0.14 per barrel of throughput;
  - meeting the gasoline specifications: EUR 3.4 million per refinery per year or EUR 0.06 per barrel of throughput;
  - meeting the corresponding diesel and gasoil specifications: EUR 4.9 million per refinery per year or EUR 0.08 per barrel of throughput.

- Our estimate of the total increase in annual operating costs attributable to additional fuel quality-related efforts over the 2000-2012 period amounts to EUR 8.9 million per refinery per year or EUR 0.15 per barrel of throughput.

- It was observed that the majority of the energy costs increase (regardless whether it is fuel quality-related or not) in EU-28 refineries most likely comes from growing energy prices.

- The economic impact is to a great extent associated with the Directive's limits on the sulphur content of fuels. Other provisions of the fuel quality legislation did not result in tangible economic impacts during 2000-2012:
  - investments for meeting vapour pressure requirements occurred before 2000;
  - reducing the content of polycyclic aromatic hydrocarbons takes place in parallel with hydrodesulphurisation, hence results in negligible additional costs;
  - lead-based additives to gasoline were phased out before 2000;
  - the use of methylcyclopentadienyl manganese tricarbonyl (MMT) in European countries was avoided as a result of a consensus among users and producers;
  - there is no reliable way to provide an estimate of the additional costs related to FAME regulation incurred within the main refineries' operations.

- The estimates of the monetary benefits associated with decreasing the SO_2 emissions amounts to EUR 196.8 million per average EU-28 refinery during 2001-2011. It should be pointed out that for the above estimates we used the lower limit of the monetary benefits from avoided SO_2 emissions estimated by the EEA. The assessment based on the higher limit estimate would result in the total benefits being three times higher.

- The total additional costs incurred by the refineries during the same period are estimated at EUR 202 million per refinery (EUR 103 million in investment costs and EUR 98 million in operating costs).

- Based on the available information we did not detect any other visible contradictions or non-productive redundancies in prescribed fuel quality specifications, norms and limits.

- In relation to priorities in other pieces of legislation for decreasing CO_2 emissions, it should be noted that, given the current state of technology, improving fuel quality requires more extensive and intensive processing, which is more energy-intensive and, holding all other parameters equal, leads to additional GHG emissions.

0.5.5. Directive on Clean and Energy-Efficient Vehicles

- We do not consider this particular Directive relevant for further quantitative analysis as we conclude that its impact on the EU oil refining sector is minimal and empirically indiscernible. While the Directive has now been successfully transposed into national legislation, this happened with a delay in the majority of MS.
- The short time since transposition does not allow the effects of the adopted measures to be empirically observed yet. In addition, as the Directive specifically targets vehicle procurement in the public sector, its overall short- to medium-term impacts on the car markets are expected to be insignificant. Its potential effect on the oil refining sector is second-order and can be foreseen to be negligible as well.

0.5.6. Industrial Emissions Directive

The Industrial Emissions Directive (IED) 2010/75 required transposition by January 2013 and hence is—formally speaking—not included in the scope of this fitness check. However, given that the IED is a recast of seven pre-existing directives, large parts of it were actually established earlier.[16] In view of this, this section focuses on the preceding legislation with relevance for the EU refining sector. In particular, this includes the Integrated Pollution Prevention and Control Directive 2008/1 (IPPC, going back to 1996/61) and the Large Combustion Plants Directive 2001/80.[17]

The most important findings can be summarised as follows:

- The EU refining sector's SO_2 and NO_X emissions have decreased both in absolute terms (data for 2007 to 2012) and in terms of the average emission intensity (emissions per throughput, data for 2004 to 2012).
- In the 2000-2012 period, each EU-28 refinery on average incurred capital expenditures of EUR 5 million per year for compliance with emissions and effluents regulation, with a notable increase between 2000-2006 (average EUR 3.8 million per refinery) and 2007-2012 (average EUR 6.4 million per refinery). These investments accounted for a fairly constant share of 10 % of refineries' total annual capital investments.
- Complexity and, to a lesser extent, capacity influence a refinery's capital costs related to pollution regulation. Using the concept of equivalent distillation capacity to adjust for these two factors shows that the average capital cost impact from pollution regulation differs by up to a factor of two between EU regions.

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[16] Apart from bringing together and consolidating different pieces of legislation, the IED also increases the legal obligation of local competent authorities to base permit conditions on the so-called BAT conclusions.

[17] The other five directives regard waste incineration, solvent emissions, and waste from the titanium dioxide industry.

- The cost burden from the observed capital and estimated associated operational expenditures is EUR 0.13 per barrel of throughput (EUR 0.09/bbl during 2000-2006 and EUR 0.16/bbl during 2007-2012). The operational cost component had to be estimated from the reported capital costs based on a rule-of-thumb percentage value, and hence has a relatively higher uncertainty. Also, the cost impact from switching to cleaner refinery fuels (high-sulphur to low-sulphur fuel oil or natural gas) could not be analysed due to lack of data.

- Data for capital expenditure on pollution control in other global refinery regions indicates higher numbers for the US Gulf and East Coast than in the EU and not much lower numbers for the Middle East, with increasing convergence between these regions in recent years. For Russia, the numbers were significantly lower at all times. Hence, the overall competitiveness impact vis-à-vis the US and the Middle East is judged to be rather low. It appears to be more significant vis-à-vis Russia, where refiners have a capital cost burden from pollution regulation of about one third of that in the EU, and associated operational costs might also be lower, e.g. due to lower energy prices.

- An important secondary impact from EU pollution regulation is its contribution to the roughly 50 % demand drop for inland fuel oil observed during 2000-2012, by about 30 million to 45 million tons in absolute terms. The concomitant reduction of supply was achieved through–in decreasing order of importance–(i) increased conversion capacity, (ii) increased uptake of fuel oil by the marine fuels market, and (iii) shut-down of EU refining capacity. A negative competitiveness impact from this secondary legislative effect seems likely, but could not be quantified in this section.

0.5.7. Strategic Oil Stocks

- Based on the existing evaluations and evidence, the overall benefits of emergency stockholding are generally seen as high given its importance for the EU and national energy security policies.

- Analysing the MS-specific arrangements, we conclude that the obligation is generally financed in a competitiveness-neutral way; where the obligation is imposed on the industry, strong indications exist that the costs of stockholding can be (fully) passed on to end consumers. Competition on a 'level playing field' is, however, a necessary condition for the full pass-through to occur.

- Under certain national arrangements, the oil refining industry can benefit from stockholding obligations by renting out its spare storage capacity and/or by selling 'tickets'.

- The latest Council Directive (2009/119/EC) aims at further optimising the system with a number of specific measures. Since the Directive allowed for a transposition period until the end of 2012, with additional exceptions for certain MS until the end of 2014, it appears premature to precisely assess its impacts at the moment.

0.5.8. Marine Fuels Directive

A review of the relevant European and international legislation regarding the sulphur content of marine fuels and our own data analysis have led to the following main findings:

- EU and international sulphur regulation for marine fuels did not result in significant additional investment costs for refineries. This is the case because:

- the supply of regulation-compliant residual marine fuels was achieved by drawing on the existing pool of fuel oils and blending high-sulphur variants with low-sulphur variants, rather than investing in new desulphurisation capacity;
- it is also highly unlikely that European refiners have had to invest in additional distillation capacity to meet marine diesel/gasoil demand, given the very low observed production level (≈0.6 % of refinery production and declining).

- Marine fuels sulphur regulation has not driven fuel oil-based products out of the EU bunker market: even though their relative share stopped growing in 2008, and since then has perhaps weakly trended downwards, there is no switchover towards distillate-grade marine fuels.

- Price impacts from the regulation have been absent or profit-neutral for refineries (i.e. costs for higher-priced inputs, like low-sulphur fuel oil, were passed on to markets):
  - global (outside SECA) limit of 4.50 % and later 3.50 %: no discernible price impact;
  - SECA limit of 1.50 % and later 1.00 %: a mark-up of USD 20-80 per tonne vis-à-vis non-SECA bunkers, consistent with the price difference observed between very heavy high-sulphur and light low-sulphur crude oils;
  - marine gasoil shift from 0.20 % to 0.10 %: small price impact of about USD 10 per tonne.

- Given that no significant investment costs were incurred and that price impacts only reflected the natural scarcity of low-sulphur crude oil (i.e. higher input prices that were passed on to markets), we conclude that the cumulative economic impact from marine fuel legislation during 2000-2012 on the refining sector can–within the purpose of this study–be neglected (apart from minor logistical costs related to transport and blending).

- EU refineries were negatively affected by a declining demand for residual-grade products in general, but this was driven by lower inland industrial consumption (see section on the IED), while the demand for residual marine bunkers–apart from a dip after the financial crisis in 2009–grew overall.

- Independent from marine fuels regulation, the price of *all* residual-grade bunker fuels (low- and high-sulphur) experienced a systematic rise in 2009, narrowing the gap to gasoil by about 15 percentage points, which should provide refiners with some financial compensation for the overall shrinking fuel oil market.

- While in steady decline on an EU average level, residual fuel oil retains importance, especially in the Baltic countries, Benelux, France, and Iberia, with shares from 16 % to 20 % of the refinery output barrels in 2012. Refineries in these regions depend on marine fuel markets as an outlet for their residual fuel oil and are therefore potentially vulnerable if future legislation reduces its usability as a marine fuel.

0.5.9. Energy Efficiency

Taking into account the existing evaluations, our overall assessment of the EU energy efficiency policy in the 2000-2012 period is as follows:

- The two directives previously addressing energy efficiency in the EU – the ESD and the CHP Directives – were admittedly not sufficiently effective in reaching their objectives, and their impacts were marginal. This can be attributed to their open wording and the non-binding nature of the obligations.

- The current Directive on energy efficiency was due to be transposed into national legislation by June 2014. Due to the insufficient time since transposition, the effectiveness and impacts of the sets of specific measures implemented by national governments are difficult to measure meaningfully at this stage.

- As a general observation, the Directive has the potential to achieve its objectives more efficiently than the predecessor directives, as it introduces binding measures together with indicative energy efficiency targets, with the possibility of recourse to binding national targets in the future.

- The impact of the Directive on the oil refining sector can potentially be twofold and stem from the operational requirements and/or from the demand side. However, without knowledge of specific energy-saving measures at the national level and the related cost-benefit data, the magnitude, and even the direction, of the overall impact are at the moment indiscernible.

- Moreover, it can be expected that the EU's energy-saving progress would be determined to a large extent by emission reduction and renewable energy targets rather than energy efficiency measures on their own – for this reason, the impact of the Energy Efficiency Directive is inherently difficult to separate out empirically.

0.5.10.   Air Quality Directive

- The observed effectiveness in achieving the objectives of the EU air policy was mainly attributed to the effective EU-level source control measures – most importantly, fuel quality policies and instruments addressing large emission sources such as the Large Combustion Plants Directive, the Waste Incineration Directive, and the Integrated Pollution Prevention and Control Directive, all currently consolidated in the new Industrial Emissions Directive[18].

- Therefore, the impacts of the Ambient Air Quality Directives (AAQDs) can arguably only be observed indirectly, in terms of the impacts of more specific, targeted policy measures. The EU petroleum refining sector is directly subject to regulation under the fuel quality legislation as well as the industrial emissions legislation. We thus conclude that in 2000-2012 the above-mentioned fuel quality (FQD) and industrial emissions (IED) policy instruments addressed the air quality-related issues in the oil refining sector in a much more targeted way than the AAQDs. In our assessment, we therefore do not attempt to disentangle the analysis of the AAQDs' impacts from that of the FQD and IED, which are analysed in the respective chapters of this report.

- The 2013 ex post review of the EU Air Quality Policy Framework by the European Commission (EC, 2013) concluded that the overall EU air quality policy was coherent and achieving its objectives effectively. Actions leading to these successes have also been found to be efficient and in accordance with the 'polluter pays' principle.

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[18] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). See also the relevant section in this report.

0.6. Economic impact of the analysed directives on the EU oil refining sector's competitiveness

In the methodology proposed for this fitness check we consider three main impact channels by which the relevant legislation can affect the competitiveness of the refining industry. First, in the most direct way, a piece of legislation can require a costly effort from the refining sector by impacting the way a refinery has to be operated. Second, a legislation package may impose particular specification/quality requirements on petroleum products sold in the European markets, which indirectly affects the refineries' operations. Third, and, again, representing an indirect effect, a legislation package can also result in changes in the relative and absolute demand for existing petroleum products. In Table 0.6.1 to Table 0.6.3 we present a summary of the identified impacts along each of the impact channels correspondingly.

Table 0.6.1: Impact on refineries' operations in 2000–2012 via direct regulation

	Associated capital investments	Associated operating costs	Cost[19] per barrel of throughput
EU Emissions Trading System (EU ETS)	No evidence of investments specifically targeting abatement of CO_2 emissions.	– No direct impact at sector level (permit costs for CO_2 emissions) until 2012, because sector on average received more free permits than verified emissions – Indirect impact: possible higher price for electricity purchased by the refineries, but very limited due to the refineries also producing electricity, for which there is no free allocation in the ETS.	Until 2012 only indirect effects could be experienced, but the purchased electricity is <10 % of the average refining energy consumption, and the electricity costs grew at the same pace or slower than for the other energy sources. Thus, the attributable impact likely negligible.
Integrated Pollution Prevention and Control Directive (IPPC) and the Large Combustion Plants Directive	Annual average of EUR 5 m per refinery, higher (EUR 6.4 m) after 2006.	Estimated as 6.3 % of capital investments, yielding EUR 1.8 m annually per refinery.	EUR 0.13 per barrel over 2000 to 2012.
Strategic Oil Stocks Directive (SOSD)	Implementation mechanisms differ greatly at national level. Majority of the costs incurred before 2000.	Considered of low relevance for refineries and affects them in a competitiveness-neutral way.	Own additional cost for refineries is negligible.
Energy Efficiency Directive (EED)	Only transposed very recently. The impact cannot be disentangled from the impacts of other legislation, as well as the cost optimisation goals of refineries.		Own additional effect is not discernible.
Air Quality Directive (AQD)	The impact cannot be disentangled from the impacts of the emissions and effluent regulation, FQL and MFD.		Own additional effect is not discernible.

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[19] Capital and Operating costs.

Table 0.6.2: Impact on refineries in 2000-2012 through product specifications

	Associated capital investments	Associated operating costs	Cost per barrel of throughput
Renewable Energy Directive (RED)	New blending, storage, and transport facilities: EUR 0.5 m per year per refinery (Concawe 2014).	Not estimated.	EUR 0.01 per barrel over 2000 to 2012.
Fuel Quality Legislation (FQL)	On average EUR 8.5 m reported investments per year per refinery.	Estimated as EUR 8.9 m annually per refinery over 2000 to 2012.	EUR 0.29 per barrel over 2000 to 2012.
Marine Fuels Directive (MFD)	Negligible, given that the required fuel specifications were achieved by using low-sulphur crude oil and by reblending.	Only logistical costs associated with reblending.	Likely negligible due to use of existing blending capacities.

Table 0.6.3: Impact on refineries in 2000-2012 via market demand-related impact channels

	Demand impact	Contributed to 'Dieselisation'?	Impact on refineries
Renewable Energy Directive (RED)	1 % reduction in average gasoline demand during 2000-2012, 3 % reduction in 2012.	No. Has helped to limit an increase in the EU diesel deficit.	Could have marginally contributed to the utilisation rate reduction (between 0.9 % and 1.9 %). The OURSE model estimates the possible forgone revenues from utilisation reduction at 3.7 euro cents per barrel of processed crude.
Energy Taxation Directive (ETD)	Estimated reduction of 0.2 % in average annual demand for both gasoline and diesel.	No. But nor did it contribute to the work against it.	Likely negligible due to a very small effect on fuel demand.
Directive on Clean and Energy-Efficient Vehicles (DCEEV)	During 2000-2012 the impacts on the car and, thus, fuel markets were insignificant.	Not known so far, expected contribution in the short to medium term insignificant.	The potential effect on the oil refining sector is second-order and is so far negligible as well.
Integrated Pollution Prevention and Control Directive (IPPC) and the Large Combustion Plants Directive	Reduction of heavy fuel oil demand from power sector (combined effect with Directive on the sulphur content of fuels).	No. Likely to be neutral as deeper conversion increases both gasoline and diesel production.	Requires refineries to react to reduced fuel oil demand: deeper conversion, orientation towards marine fuels, or shut down. The average effect cannot be quantified directly.
Energy Efficiency Directive (EED)	The impact cannot be disentangled from the impacts of the RED, ETD and IED.		Own additional effect is negligible.
Air Quality Directive (AQD)	The impact cannot be disentangled from the impacts of the FQL, MFD and IED.		Own additional effect is negligible.

0.7. Short overview of identified legislation's benefits

This study does not intend to perform a detailed and comprehensive cost-benefit analysis of the legislation packages relevant for the European refining sector. In this section we present a short overview of the identified positive benefits produced by legislation and present them in the context of the refining industry in accordance with the identified impact channels.

As already mentioned while discussing the cumulative costs of legislation, a concrete assessment of benefits is only possible for the legislation packages that require compliance with clearly defined limits and standards, as in the case of the fuel quality legislation and the Industrial Emissions legislation package. For other directives the estimates are much less precise or only qualitative in nature.

The identified benefits are presented in Table 4.5.1 with the goal of providing a general overview, which is not yet suitable for a consistent cost-benefit analysis. For such an analysis one needs to form a balanced view on the broad societal benefits of legislation, but also on the benefits provided by the industry (e.g. job creation, GDP), and the possible societal costs (such as the loss of economic activity caused by refineries shutdown).

Table 0.7.1: Overview of the legislation's benefits identified in the course of the study

Legislation	Identified benefits
The Renewable Energy Directive (RED)	• Biofuels are estimated to generate less greenhouse gas emissions than a comparable amount of conventional fossil fuels. However, these numbers do not include additional emissions from indirect land-use changes or agricultural intensification. • The positive effect in terms of a reduced crude oil and oil product import dependency.
The Energy Taxation Directive (ETD)	• An evident benefit of excise duties is that they generate additional tax-related income that could be used for a 'growth-friendly tax shift' (for example, allowing the reduction of the tax on labour and/or the stimulation of environmentally friendly activities, green investments, and research and development). • The increase in fuel prices due to the increase in taxes reduces the demand for private transport, while increasing the demand for public transport. • It contributes to development of a more uniform common EU market for refining products which can also have positive effects on refining sector.
The EU Emissions Trading System (EU ETS)	• Emission trading schemes are commonly acknowledged as an economically efficient mechanism of emission control. They do so by creating the corresponding markets and infrastructure for emissions permits trading, embedding the 'polluter pays' principle in steering the incentives of potential polluters and making it attractive for them to implement emission-reducing technologies. • The initial phases of the ETS provided a valuable learning experience. The ETS process during 2005-2012 was not immune to several inefficiencies, such as: the lack of a level playing field due, for example, to heterogeneous definitions and allocation methods used by Member States; generally overoptimistic emission projections while allocating allowances; as well as the long and cumbersome procedures of National Allocation Plans'

Legislation	Identified benefits
	approval. These have been addressed in the next phases.
The Fuel Quality Legislation (FQL)	• The broad general estimates of the monetary benefits associated with decreasing the damage from the SO_2 emissions avoided by complying with the transport fuel sulphur standards. amount to around EUR 16.2 billion in total during 2001-2011. • The higher quality road fuels allow the reduction of particulate matter emissions from the older (pre-2005) vehicles without retrofitting them with additional scrubbers or filters. • The fuel quality standards contribute to the development of a more homogeneous EU market for refining products.
The Directive on Clean and Energy-Efficient Vehicles (DCEEV)	• Specific impacts of this legislation were not observed for the 2000-2012 period.
Integrated Pollution Prevention and Control Directive (IPPCD) and the Large Combustion Plants Directive (LCPD)	• The broad general benefits estimates are available only for avoided SO_2 and NO_X emissions. The volume estimates show that from 2005 to 2012 the average EU-15 refinery has abated nearly 12 000 tons of SO_2 and 4000 tons of NO_X emissions. • An estimated total SO_2 and NO_X abatement benefit per average EU-15 refinery is EUR 108.4 million. Multiplication by the total number of EU-15 refineries, 63 mainstream refineries were operating at the end of 2011 in the EU-15, and taking into account incurred costs, yields total net benefits of around EUR 4 billion.
The Strategic Oil Stocks Directive (SOSD)	• Most of the Member States hold sufficient oil stocks to meet the minimum requirements or are close to reaching those targets. This seems to provide an adequate buffer to cope with potential supply disruptions and contribute to the EU's enhanced energy security. • Theoretically, the societal advantages of strategic stockholding in terms of oil supply safety are considered to be high. These benefits result, in particular, from reducing GDP losses and import costs in the event of a supply shock.
The Marine Fuels Directive (MFD)	• Sulphur reductions allow SO_2 emissions to be avoided.
The Energy Efficiency Directive (EED)	• In the Commission's impact assessment, the potential energy savings resulting from the current system of legislation were estimated as significant; however, the scale of the actual savings, depends on specific national implementation and the individual reactions of consumers. • It can be expected that the EU's energy-saving progress would be determined to a large extent by emission reduction and renewable energy targets rather than energy efficiency measures on their own.
The Air Quality Directive (AQD)	• In general terms, the estimates of wider benefits of air quality regulation have a wide range of values. They include both direct health costs and indirect losses for the economy, such as workdays and productivity decreases. • It is likely that these benefits would be determined to a large extent by

Legislation	Identified benefits
	more targeted measures (such as the FQD, IED, etc.) rather than the AQD measures on their own.

0.8. Main findings

Observed developments in EU-28 international competitiveness vis-à-vis main competing world regions

Compared to the net margins observed in the main competitor regions (the US East Coast, the Middle East, Russia, South Korea and Singapore), the EU margin exhibits a relative decrease of USD 2.1/bbl over the 2000-2012 period. This trend is taken as an indication of a relative loss of competitiveness as it puts pressure on the investment possibilities of the European refining sector.
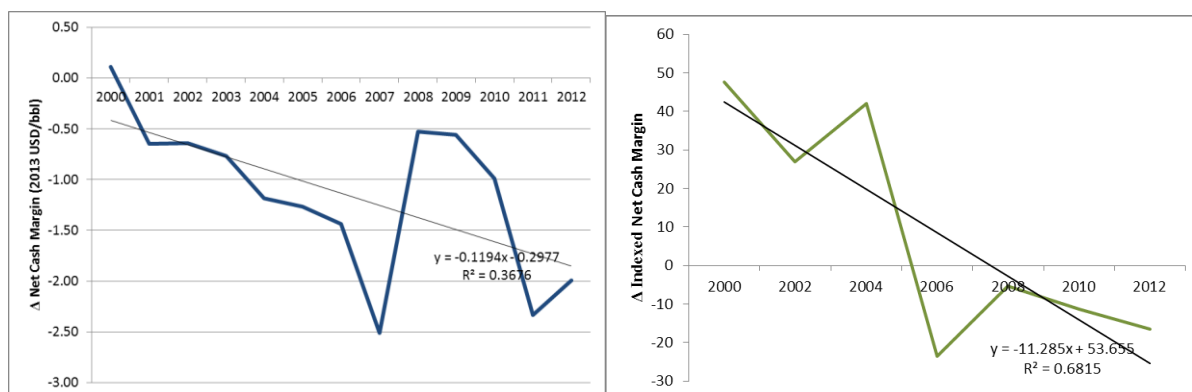
Figure 0.8.1: EU-28 net cash margin vs average margins of US GC, US EC, ME, K/S[20], and Russia/FSU[21]
Source: IHS (2014) on the left and Solomon Associates (2014a,c) on the right.

The data shows that this competitiveness loss can be attributed to the relative increase in energy costs in EU refining, where the increase in energy prices has been the main driver. The effect of increasing energy prices adds to the effect of a regulation-related increase in energy consumption by the European refineries.

In absolute terms, the EU energy costs per barrel have increased almost fourfold over 2000-2012, while in the competitor regions they have exhibited a twofold increase on average. Among the

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[20] US (East Coast) PADD 1 & 3, Middle East, Russia, South Korea and Singapore.

[21] The dataset also includes net cash margins for Russia and India, but not for the entire time horizon. For India, only the two points 2010 and 2012 are available, which is deemed insufficient for a trend analysis. For Russia, the years 2004, 2008, 2010, and 2012 are available. A consistent integration of the data for Russia into the trend analysis can be achieved by first rescaling it such that the weight of each individual Russian data point for the four available years is the same as the weight of the total (across available years) corresponding to Russia's average in the total average of the four other regions. This means that integrating Russia's data will only influence the slope or the curve and not cause a sudden jump in the intercept.

competing regions, the Middle East and the US East Coast have a visible energy costs advantage, while only refiners in Asia are in a similar position to those in the EU.

All forms of energy sources experienced similar strong user price growth, therefore the energy costs increase in the EU refining sector cannot be attributed to the changes in energy source mix that might have favoured more expensive energy sources. Natural gas appears to be the main energy source whose weight in the total refinery's energy balance determines its competitive position in terms of energy expenditures.

At the level of individual refineries, we can talk about increasing differences between the best- and worst-performing refineries during 2000-2012. In general, the international competitiveness of the bottom 50 % of EU refineries declined more than that of the top 50 %. The observed performance gap (measured by their net margins) between the EU-28 refineries widened. The spread between the groups of the 20 best-performing and 20 worst-performing refineries in the sample increased more than twofold from about USD 2.7 to USD 5.9/bbl of throughput despite the fact that the EU closed a number of refineries during 2000-2012.
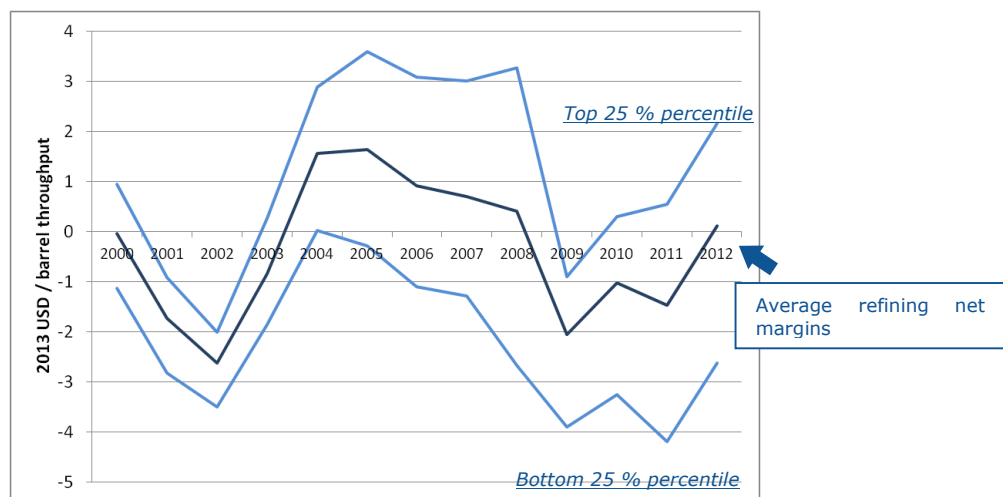
Figure 0.8.2: Variability in EU refineries' net margins
Source: IHS (2014).

If we look at the particular characteristics of the European refineries and compare the top performers with the bottom ones, it is observed that the top 20 EU refineries considered in this study are on average larger and have 65 % higher capacity than the bottom 20 EU refineries, and that they have a larger share of the mid-distillates in their product mix.

The EU refining industry still exhibits large differences among regions in terms of the net margins. These differences appear to be fairly persistent for the worst-performing regions as they have average net margins below the EU average, while the performance of the top regions exhibited considerable shifts during 2000-2012.
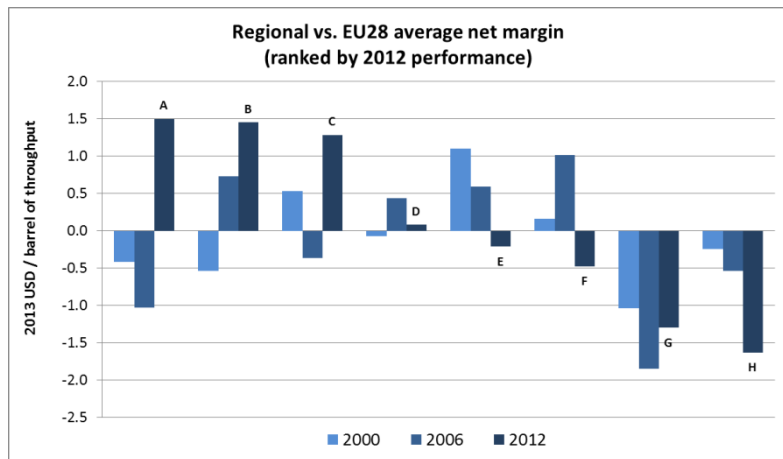
Figure 0.8.3: Comparison of regional net margins compared to Europe-wide average net margins in 2012

Source: Own calculation based on estimated margins of individual refineries from IHS (2014).

Impact of EU legislation on investments in the EU refining industry

Among the legislation packages investigated in this study, the fuel quality legislation and the Industrial Emissions legislation have been identified as ones leading to sizable additional investments by refineries in desulphurisation and emission abatement capacities.

The fuel demand shift due to the Renewable Energy Directive's impact could have contributed to decreasing utilisation rates at European refineries and some foregone revenues. The European refineries have also invested in additional logistic and blending capacities related to biofuels in compliance with the Renewable Energy Directive.
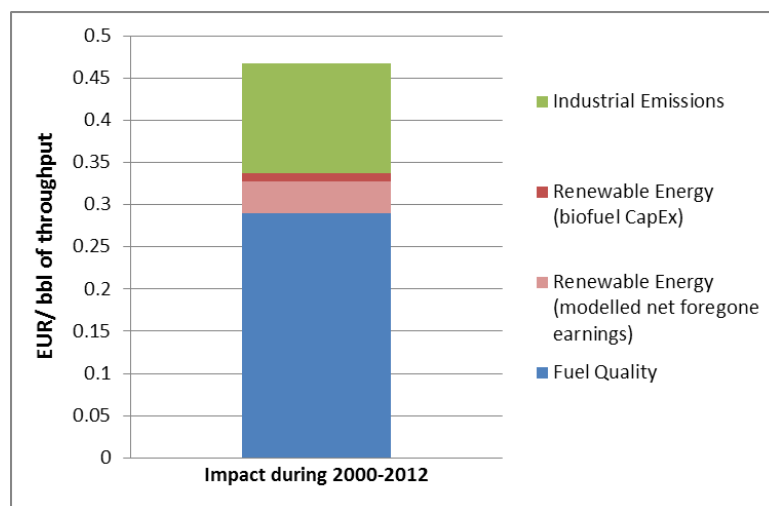
Figure 0.8.4: The average estimated quantifiable impact of the legislation on EU refineries during 2000-2012 per barrel of throughput

Source: IHS (2014), Solomon Associates (2014a b,c) and own calculations with OURSE model.

The refineries' compliance with the norms imposed by the fuel quality legislation requires more extensive and intensive processing of the feeds and product, which leads to increased energy consumption and, thus, higher operating costs.

The requirements of the pollution and emissions legislation (such as the Industrial Emissions legislation, the Integrated Pollution Prevention and Control Directive and the Large Combustion Plants Directive) have encouraged refineries to switch towards low-sulphur (which is generally more expensive) fuel oil for refinery energy needs.

The impacts of the market demand for refining products in the EU exhibited by the Renewable Energy Directive, Energy Taxation Directive, and the Industrial Emissions legislation have partially contributed to reducing refineries' utilisation rate (as indicated by OURSE modelling), which can negatively affect refineries' energy and operating efficiency.

The impact of EU legislation on the competitiveness of EU refineries
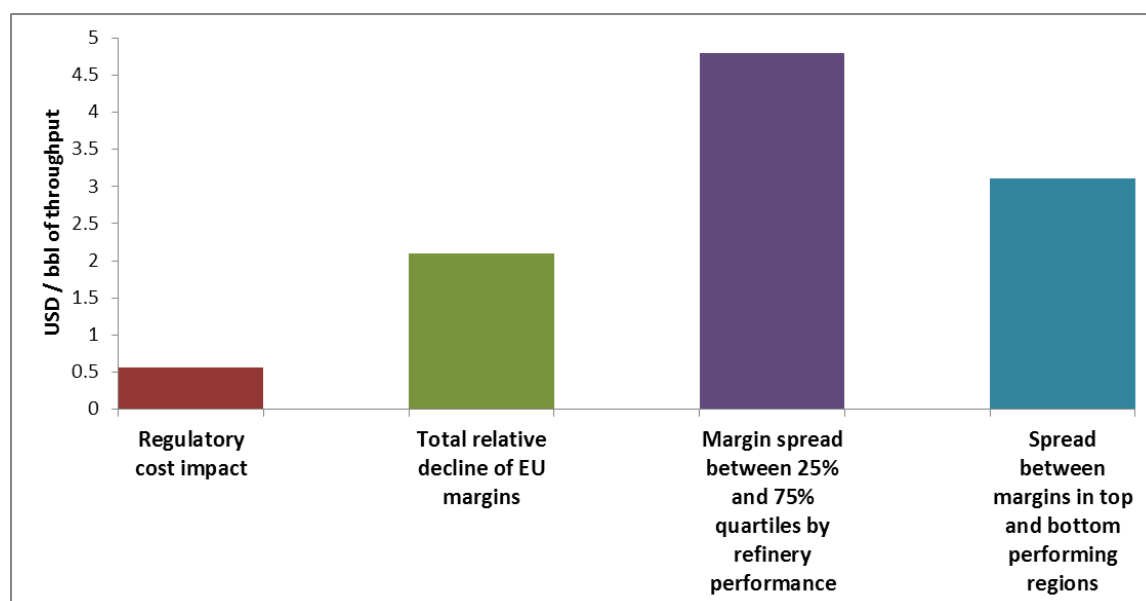
Figure 0.8.5: Comparison of the quantified total cost effect of legislation with other performance parameters of EU refineries
Source: IHS (2014), Solomon Associates (2014a,b,c) and own calculations with OURSE model.

The cumulative quantified cost impact per barrel of processed throughput from the investigated regulation packages is significant. The regulatory cost effect has been increasing from 2000 to 2008 and appears to stabilise afterwards until 2012.

The identified cost impacts of regulation on refineries' performance primarily imply the diversion of revenues towards regulatory compliance investments and operating costs rather than making other investments and operation adjustments that improve competitiveness.

For comparison, this quantified average regulatory cost impact corresponds to, at most, 25 % of EU refineries' observed net margin decline relative to competitor regions during 2000-2012, which indicates at presence of other factors that had a stronger influence on the refineries' economic performance. Among such factors, we can name the refinery's configuration, size and location which are associated with the large variability in EU refineries' input costs, product slates, revenues, operating costs, and, therefore, net margins.

Has EU legislation affected EU refineries in a coherent manner?

It has been observed that the effects of more horizontal (initially cross-industry) pieces of legislation (such as the Air Quality Directive and Energy Efficiency Directive) are likely to be

implicitly covered within the impact of more focused regulation which establishes tangible norms and limits (such as, for example, the fuel quality legislation and Industrial Emissions legislation) which can be directly linked to particular changes in investment and operating expenditures.

The efforts made by the EU refineries to meet the requirements of the Industrial Emissions legislation and Renewable Energy Directive during the analysed period have also contributed to meeting the objectives of the Air Quality Directive and Energy Efficiency Directive which do not address the refining sector specifically.

In terms of general and focused regulations' objectives with regard to GHG emissions, the analysis shows that the requirements imposed by EU legislation that lead to increased energy consumption create tensions between the objectives of higher fuel quality and lower industrial emissions on one hand and the objectives of decreasing GHG emissions on the other (such as those specified in the EU Emissions Trading System and fuel quality legislation). At the same time it should be noted that the increasing energy costs create additional incentives for refineries to make efforts to improve their own energy efficiency, which is the main objective of the Energy Efficiency Directive.

1. <u>Introduction</u>

1.1. **Background and procedural aspects**

As part of its smart regulation policy, the European Commission announced in its Work Programme for 2010[22] its intention 'to keep current regulation fit for purpose' by 'reviewing, from this year onwards, the entire body of legislation in selected policy fields through "fitness checks". The purpose is to identify excessive burdens, overlaps, gaps, inconsistencies and/or obsolete measures which may have appeared over time.' Four pilot projects were launched in 2010, covering specific policy areas. The Industrial Policy Communication Update[23] announced the Commission's intention to undertake a Fitness Check for the petroleum refining sector. This fitness check intended to 'focus on the implementation and interaction of those policies that are most important for the competitiveness' of the sector.

The 2010 Commission Staff Working Document on refining and the supply of petroleum products in the EU[24], having analysed the key facts and challenges relevant for the sector, pointed out trends such as falling demand for certain petroleum products (gasoline) and growing demand for other products (gasoil/diesel), increased global competition, overcapacity and reduced refining margins. The impact of legislation, such as fuel specifications, regulation of emissions from refineries and promotion of non-fossil fuels, was also found to be important. Subsequently, the Commission's 'Energy Roadmap 2050'[25] stated that 'keeping a European presence in domestic refining – though one that is able to adapt capacity levels to the economic realities of a mature market – is important to the EU economy, to sectors that depend on refined products as feedstocks such as the petrochemical industry, and for security of supply.'

There are currently around 100 mainstream petroleum refineries operating in the EU. The EU oil refining sector constitutes a substantial part of the world's total refining capacity and accounts for a visible share of the manufacturing value added in Europe. It also contributes to employment, and demonstrates a substantial turnover. Refining products continue to play an important role in satisfying the energy demand in Europe and are an essential component of the EU's energy security. Furthermore, refined petroleum products are an important element of extra-EU trade, accounting for the majority of the EU energy exports and imports.

In recent years, total demand for the refining industry's products has been steadily declining, mostly due to lower demand for gasoline and fuel oil. At the same time, one of the most important characteristics of global demand for petroleum products, dieselisation, contributed both to the overall decline in demand and to a structural shift from gasoline to diesel as a motor fuel. In addition, in line with a significant increase in air transport activities, consumption of jet fuel and kerosene has been growing recently. The EU economy closely follows these general tendencies. The overall production of refining products has declined as well, although at a slower pace and still preserving a strong imbalance between the production and consumption of gasoline. These trends to a large extent explain the steady underutilisation of the EU refineries which, in turn, contributes to the pressure to close excess refining capacities.

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[22] COM(2010) 135 of 31 March 2010.

[23] COM(2012) 582 of 10 October 2012.

[24] SEC(2010) 1398 of 17 November 2010.

[25] COM(2011) 885 of 15 December 2011.

In addition, compared to refining in other parts of the world, refining in the EU faces relatively high operating costs, one component of which, energy costs, are also among the highest in the world. Net cash margins in recent years for EU refiners have been lower than for refiners in several competing regions. Against the backdrop of these general trends, it is of particular importance to understand whether the legislation affecting the EU petroleum refining sector remains fit for purpose, and whether its associated costs allow the sector to remain internationally competitive.

In May 2012, Energy Commissioner Oettinger convened the EU Refining Roundtable to discuss with Member States, MEPs and stakeholders the state of the sector and share their assessment of the situation and recommendations. Concern was expressed about the combined impact of EU policies affecting the refining sector. Subsequently, in October 2012, the Commission's Joint Research Centre (JRC) organised a 'Roundtable on Scientific Support to EU Refining Capacity' to consider key challenges for the sector and identify where scientific expertise and research should be targeted. In particular, participants to the JRC Roundtable asked for further specific analysis of the sector's situation, based on increased modelling and foresight capacities, and also for a more solid, evidence-based assessment of the cumulative impact of EU legislation. Finally, a conference on EU refining was organised by DG Energy in November 2012, in which the fitness check for the sector was discussed and welcomed by the participants. During the same conference, the Commission announced the establishment of the EU Refining Forum as a permanent body for discussion of relevant proposals and initiatives with potentially significant impacts on the industry and on security of supply. The mandate for this fitness check was adopted in June 2013.

In March 2013, DG ENTR set up an Inter-Service Steering Group, including representatives of the SG, BEPA and DGs ENER, MOVE, ENV, CLIMA, JRC and TAXUD. Transparency and stakeholder involvement were given high prominence within this fitness check. The main body ensuring the involvement and consultation of interested parties, including, among others, Member States, the European Parliament, industry and trade unions, was the EU Refining Forum, meeting approximately twice a year starting from April 2013. Several additional meetings and stakeholder consultations were organised, where the methodology and intermediate results of the exercise were presented and discussed.

The research work by the JRC-IPTS, with the aim to quantitatively assess the cumulative impact of the relevant legislation on the petroleum refining sector, took place between June 2013 and May 2015.

1.2.   Scope and main focus of the report

The main objective of this study was to quantitatively assess the impact on the petroleum refining sector of legislative measures identified in the process of the European Commission's analysis and stakeholder consultations as being of significant relevance for petroleum refineries, and as such included in the mandate of the fitness check. This quantitative assessment took into account the impact of the legislation on costs and revenues of the EU petroleum refining industry and therefore on its capacity to remain internationally competitive.

This analysis, mostly of a quantitative nature, was accompanied by a qualitative assessment in accordance with the Commission's general approach to fitness checks[26]. In particular, the report analysed how coherently and consistently the EU legislation identified as relevant for the sector works together, whether it is effective and efficient, and whether it is associated with excessive

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[26] See http://ec.europa.eu/smart-regulation/evaluation/docs/fitness_checks_2012_en.pdf.

regulatory burdens, overlaps, gaps, inconsistencies or obsolete measures. Since this fitness check addressed a specific industry sector rather than a policy area, it had a specific focus on the cumulative impact, effectiveness, efficiency and coherence of the measures with respect to the oil refining sector.

As stated in the mandate of the fitness check, the analysis in this report was retrospective and concentrated on the impact of the relevant legislation on the petroleum refining sector in the period between 2000 and 2012.

The pieces of EU legislation identified as the most relevant for the sector and therefore included in the mandate of the fitness check were:

- the Renewable Energy Directive[27];
- the Energy Taxation Directive[28];
- the EU Emissions Trading System[29];
- the Fuel Quality Legislation[30];
- the Directive on Clean and Energy-Efficient Vehicles[31];
- the Industrial Emissions Directive[32] (together with the Integrated Pollution Prevention and Control Directive (IPPCD) and the Large Combustion Plants Directive (LCPD));
- the Strategic Oil Stocks Directive[33];
- the Marine Fuels Directive[34];
- the Energy Efficiency Directive[35];
- the Air Quality Directive[36].

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[27] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

[28] Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity.

[29] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC and subsequent amendments.

[30] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.

[31] Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles.

[32] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

[33] Council Directive 2009/119/EC of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products.

[34] Directive 2012/33/EU of the European Parliament and of the Council of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels.

[35] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[36] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

This study did not attempt to perform an exhaustive overview or cost-benefit analysis of the relevant legislation, as it concentrated on its application to a specific sector. Within the above directives, all provisions of significant relevance for the petroleum refining sector were taken into account for further analysis. Additionally, whenever relevant impacts of the respective directives stemmed from the predecessor pieces of legislation, such measures were also taken into account for the assessment. Where it was clear that significant changes in the legislation taking place after 2012 could lead to a need to reassess its impacts on the oil refining sector in the near future, some relevant qualitative considerations were presented. Any formal analysis of impacts beyond 2012 was, however, outside the scope of this report.

1.3. Methodological approach

1.3.1. Cost impact channels

As discussed above, the main objective of this fitness check was to quantitatively estimate the impact of the relevant legislation on the EU petroleum refining industry, with a particular focus on the sector's competitiveness. To construct a suitable background for such analysis, the report outlines the general theoretical fundamentals of petroleum refining. It then proceeds to the overview of the EU petroleum refining sector, its main characteristics, economic contribution and recent trends therein. While the central component of this report is the analysis of the cumulative impact of the legislation, each of the relevant legislative pieces is also discussed separately, including an assessment of its impact on the sector, its effectiveness and efficiency.

To systemise the legislative cost impacts, our analysis considered three main channels through which the legislation could potentially impact the sector: one direct channel and two indirect ones. Namely, the most direct way in which a piece of legislation imposes costs for the refining sector is by impacting the way a refinery has to be operated. Examples of such a direct impact include the absolute limits on how much of certain substances can be discharged into the air or ground, or the requirement to purchase permits for the release of such substances under cap-and-trade mechanisms. The impact of such legislation can be expressed by the implied increase in variable and fixed (including investment) costs (for example, the one-off costs for a new filter or the price of required emission permits). It should be pointed out that different refinery products may be affected differently by such regulation, as, for example, energy generation processes become more strictly regulated and some refinery products inherently require more energy than others. In the same way, different types of refineries, such as more or less complex refineries, may also be affected differently.

In a different way, the legislation can have an impact on refineries by imposing quality requirements on refined petroleum products. For instance, it may prescribe minimum or maximum concentrations of wanted or unwanted fuel components. The legislation's economic effect on refineries is in this case indirect, i.e. it occurs only by means of changes in the demand function the refinery faces (note that a refinery could legally choose to only produce for foreign markets not covered by similar legislation). The economic impact may be expressed as the – ceteris paribus – additional variable and fixed costs (including investments) incurred by the refinery for meeting the required product specification. An important difference between the first and second impact channels is that, in the first case, the legislation can only impose additional costs on producers located in the EU, while, in the second case, the production costs for all firms selling in the EU refined petroleum product markets are affected.

Thirdly, and again representing an indirect effect, legislation can cause shifts in the relative and absolute demand for existing petroleum products. For example, the legislation on energy efficiency

standards may lead to an absolute reduction in demand for fuels, but also to a shift of demand from one type of fuel towards another. Demand shifts of this type might also arise as a secondary effect of legislation on product quality, when a new quality requirement drives up the product price and leads to substitution. Economically speaking, the changes in absolute and relative demand can cause a costly loss of efficiency for a refinery, at least in the short term, in terms of its utilisation rate and product mix. In the case of relatively minor shifts in demand, this might lead to only small increases in variable costs, but to keep up with larger market shifts sizeable investments in additional units might be needed (for example, to increase secondary conversion capacity).

It should be noted that, while this classification is well-suited to capture and formalise the primary channel through which the immediate impact of the different pieces of legislation occurs, in the longer term impacts will extend across all the three categories due to the general equilibrium effects. Hence, the three types of impacts are not mutually exclusive. For instance, regulation that sets pollution limits and thus impacts the refinery directly can have indirect impacts through a longer term reduction in demand due to increased prices. On the other hand, there can be direct costs associated with legislation on product quality, because the refinery may be forced to change its operations. Figure 1.3.1 summarises the conceptual framework, showing how a generic directive translates into the three cost impact channels, with implications in terms of refining costs and, ultimately, in terms of competitiveness.
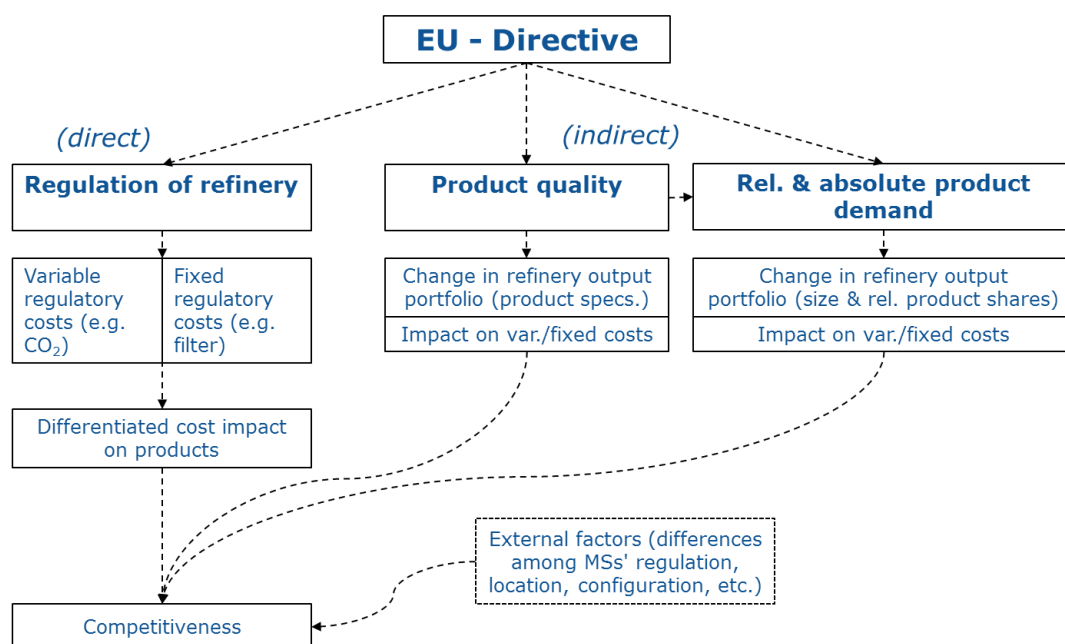
Figure 1.3.1. Conceptual representation of legislation's cost impact channels

Overall, the economic impact of legislation may be judged relevant only if it leads to a significant increase in unit costs. It may also be judged relevant with regard to international competitiveness only if the cost increase cannot be passed through the value chain. Cost pass-through is generally not possible in a market where consumers can buy perfect substitutes from non-regulated outside suppliers or where consumers are not willing to buy the good at higher market prices (i.e. their demand is strongly elastic), or both. It is important to identify which of the two cases hold (if any), as the regulation's effectiveness might be impaired in their presence if pollution could just be displaced without being necessarily reduced (leakage effect). In addition, short- and long-term impacts need to be differentiated, since costs might be successfully passed through in the short-run, but in the longer-term a negative demand-side reaction to higher prices may occur and lead to

a contraction of the sector's home (EU) market and thereby impair its competitive position. In order to discern the impact of EU legislation on the refining sector, it was necessary to analyse other factors and wider conditions potentially affecting the sector's competitiveness, which are discussed in the relevant sections of the report.

This fitness check assesses the effect of the European regulation on the refining sector in addition to the effects of the corresponding national regulation measures. In cases, where national regulation imposes stricter norms or higher goals than the corresponding measures at the EU level, the additional effect of the EU legislation is considered to be negligible. The actual interactions between the national and EU-level legislations are handled in detail in the analyses of individual measures.

To assess the competitiveness implications, where feasible and meaningful, regulation-related costs are presented alongside relevant and generally accepted cost and profitability indicators. Where possible, the analysis of impacts was carried out taking into account differences between the regions within Europe, for example, in order to be able to capture specificities related to emission abatement potential or energy costs. Our data gathering process, as discussed below, provided information for nine EU regions.

1.3.2. OURSE model

Further insights into the impact of the considered legislative acts on the performance and international competitiveness of the EU oil refining sector were obtained from ex post impact assessments with the OURSE model. OURSE (Oil is Used in Refineries to Supply Energy) is a global oil refining optimisation (i.e. cost minimisation) model developed by IFPEN Energies Nouvelles (Paris, France) and the JRC-IPTS in 2005, updated in 2012 (see Lantz et al., 2005; 2012), and further improved by the JRC-IPTS for the purpose of this fitness check. It models nine aggregated world regions (North and Central America, Latin America, North Europe, South Europe, CIS, Africa, Middle East, China, and Other Asia and Oceania), which are allowed to trade crude oil and refined products with each other. A representative refinery characterises the refining industry in each region, which takes into account the main techno-economic characteristics of the region's refining sector. Within the current study, the OURSE model has been transformed by the JRC-IPTS from a linear programming optimisation problem into a quadratic programming model, which guarantees calibration of the observed base year data and allows for more realistic (smoother) output responses in any simulation environment. A detailed technical description of the model is presented in the Annex.

1.3.3. Assessment of benefits, effectiveness, efficiency, coherence and relevance

It needs to be noted that a sectoral fitness check does not attempt to perform an exhaustive evaluation or cost-benefit analysis of the relevant legislation, as it focusses on its application to a specific sector. The full cost benefit analysis of a piece of legislation should comprise benefits and costs across all sectors, a task clearly beyond the scope of this fitness check. Comparing costs and benefits of regulation for a specific sector makes little sense as in general they occur at different levels (i.e. costs in one sector, benefits in other) and the sectoral nature of this fitness check excludes covering all sectors in which the analysed legislation has impacts[37]. However the fitness

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[37] There is one exception to this rule, fuel quality legislation. Here costs are borne only by the refining sector and benefits provided by the lower pollutant content of fuels. Nevertheless, a full fledge evaluation of this legislation is currently being

check has reviewed the existing literature on positive benefits produced by legislation and presents them in the context of refining industry. Figure 1.3.2 illustrates with theoretical examples how different types of benefits from legislation can be conceptually linked to the petroleum refining sector.
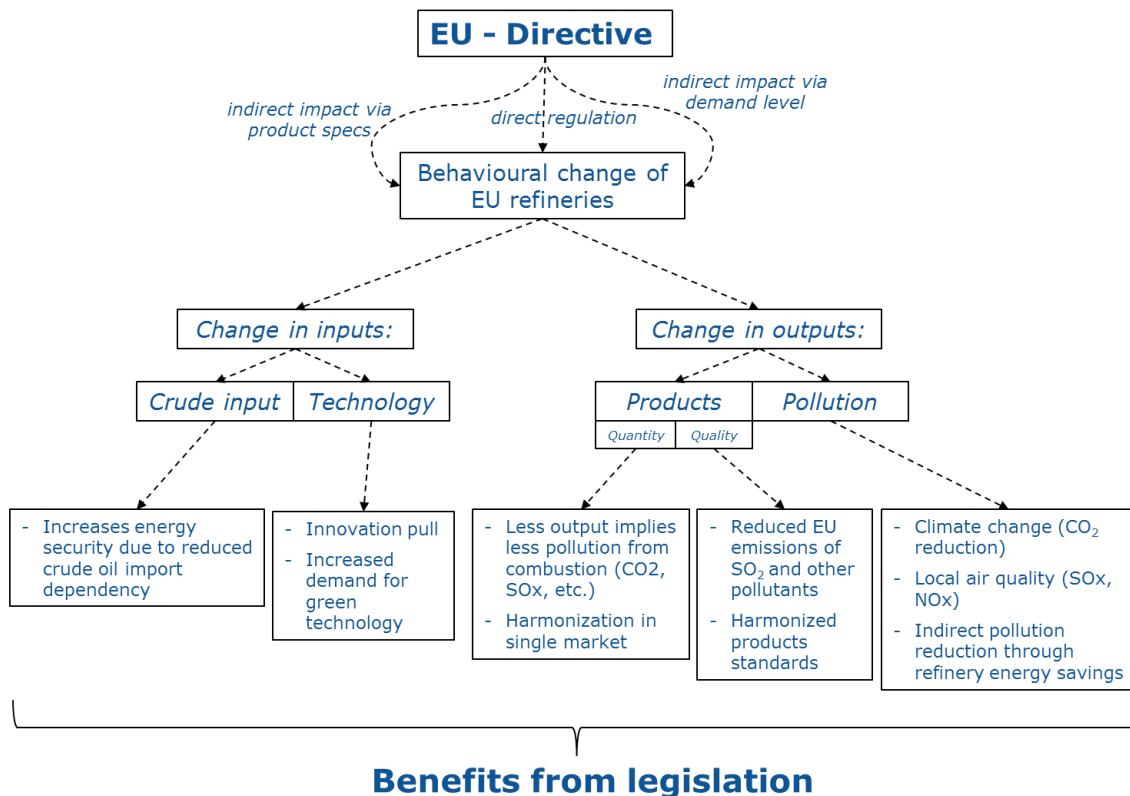
Figure 1.3.2. Conceptual representation of legislation's benefit impact channels

A qualitative assessment analysed, in accordance with the Commission's methodological approach to fitness checks, the effectiveness, efficiency, coherence and relevance of the legislation. While a full assessment in this respect was not possible within the scope of the exercise, the following main questions were addressed to the greatest possible extent in this report:

(1) Concerning *effectiveness*, were the achievements of the identified legislation with regard to the refining sector in line with the stated objectives? What progress was made over time towards achieving the objectives? Which main factors (e.g. implementation by Member States, action by stakeholders, cooperation between producers) contributed to – or conversely stood in the way of – achieving these objectives? Beyond these objectives, did the legislation achieve any other significant results?

undertaken by the Commission and this fitness check just reports estimates available of benefits and provides new data on costs.

(2) Concerning *efficiency*, were there regulatory gaps, inconsistencies, overlaps or evidence of excessive administrative burdens for the refining sector? To what extent did Member States and industry respond to the requirements of different policies in terms of administrative cooperation and policy coordination? What were the policies in place in Member States and at the EU level to support the sector? Was availability of and access to funding a constraint in the implementation of the relevant legislation? What were the costs and benefits associated with the implementation of the specific legislation? Could any costs be identified that are out of proportion with the benefits achieved?

(3) Concerning *coherence*, what was the degree of integration of all instruments covered by the fitness check? Was the scope for integration fully exploited? Were there unintended consequences and collateral effects? Could any specific inconsistencies and unjustified overlaps (e.g. in terms of definitions and key concepts) across the pieces of legislation concerned and between them and other parts of EU law be identified? What was the cumulative impact of the measures on the performance of the refining sector?

(4) As regards *relevance*, to what extent did the policies covered by the fitness check and their objectives address the challenge of a competitive and sustainable EU refining industry along with their wider economic, social or environmental challenges? What was the value added of the EU legislation?

One of the deliverables of the exercise was a diagram illustrating the *intervention logic* of the measures, showing how they work together and highlighting their respective objectives, means and impact channels (presented with a detailed description in the Annex).

1.3.4. Data sources

This report made use of the multitude of existing sources of relevant empirical data, such as Eurostat databases, regulatory and industry publications (primarily from internationally recognised sources, for example, reports by the International Energy Agency and European Environmental Agency), and, where relevant, on sector studies performed at the EU or national levels. Apart from the publically available data sources, quantitative analysis in the report relied on three main sources of data, assembled and acquired specifically for the purpose of this study.

I. Solomon Associates database of the EU refineries

HSB Solomon Associates LLC (Solomon) is a global consulting service for industries such as refining, chemicals, pipeline, terminals, power generation, and crude/gas production etc. Its main focus is proprietary comparative analysis based on the industry best practices to help clients identify areas for performance improvement and supporting clients through the improvement process.

For a number of years, Solomon has been conducting its biennial *'Fuels Study'*, for which it collects comprehensive data for (currently) more than 300 participating refineries worldwide. Its aim is to understand the on-going activities and trends in the refining industry, and determine the status of each refinery with respect to key performance areas.

The data used in this report is a subset of the data collected as part of the 'Fuels Study' and covers the *time period of 1998-2012* on a *biennial basis*. It only includes the EU refineries. The total number and composition of refineries in each year can vary, as not all refineries participated in the study in all years. It needs to be emphasised that data is provided only for refineries for which data

had already been collected as part of the 'Fuels Study' databases. In each two-year period the data covers on average 80 refineries.

Data is available as averages of the following groups: EU-28, EU-15, EU-13 accession countries, Baltic countries, Benelux, Germany, France, Central Europe, UK and Ireland, Iberia, Mediterranean, and South East Europe. It is also split according to the so-called complexity groups: Hydroskimming and Thermal, Gasoil Conversion complexity A, Gasoil Conversion complexity B, Gasoil Conversion complexity C, and Gasoil Conversion complexity D. A final group includes all refineries with petrochemical integration.

Indicators include, *inter alia*: capacity, Solomon Index for Refinery Complexity, quantities of all inputs, quantities of all outputs, refinery units and their capacities, for-profit investments in new units, regulatory investments, processing of biofuel components, various types of operational costs, refinery energy balance, emissions of SO_x, NO_x, CO_2.

The EU refining data from Solomon was purchased by Fuels Europe and DG ENTR. It was then made available – subject to a Confidentiality Agreement – to the JRC-IPTS for the purpose of this fitness check analysis.

In the fitness check report this data is referred to as:

Solomon Associates (2014). Data of EU refining industry, years 1998 to 2012. Compiled for Fuels Europe and the ENTR Directorate of the European Commission.

A limited amount of data on extra-European refineries (regarding regulatory investments) was acquired by the JRC-IPTS directly from Solomon Associates, and is referred to in the report as:

Solomon Associates (2014a). Regulatory investments in the European Union and in selected extra-European regions, years 1998 to 2012. Compiled for the JRC Directorate of the European Commission.

II. Concawe refinery survey

Concawe is the scientific and technical organisation of the European petroleum refining industry, whose 43 members are all companies operating refineries in the EU. Concawe routinely monitors and evaluates the major factors affecting the EU refining industry.

The data used in this report was collected as a result of a survey, specifically developed and conducted by Concawe and the JRC-IPTS for this fitness check in 2014. In particular, refineries were surveyed with regard to three directives analysed in the fitness check: the Industrial Emissions Directive and Air Quality Directive (with questions on the amounts of capital and operational expenditures related to the different pollution prevention and control measures) and the Renewable Energy Directive (costs for biofuel storage and infrastructure). The questionnaire was sent to 82 (Concawe member) refineries operating in the EU-28,. The resulting response rate was 77 %.

Information was collected for the years 1998-2012 on a yearly basis. The data points provided to the JRC-IPTS were aggregated in the same way as in the Solomon Associates database above: by groups 'EU-28', 'EU-15', 'EU-13', per region (see above), by complexity group (see above) and separately for petrochemical-integrated sites. For each peer group, the following aggregates were reported:

- the total number of 'No', 'Yes', 'Data Unavailable' and 'Not Applicable'[38] responses given for CapEx or OpEx incurred for the relevant abatement measure;
- the count of non-zero responses in the aggregation group;
- the EUR value of the lowest non-zero response in the aggregation group;
- the EUR value of the highest response in the aggregation group; and
- the EUR sum of all the reported CapEx figures in the aggregation group;
- with respect to six different types of biofuel components, the EUR value of CapEx for additional storage capacity and infrastructure investment costs at the refinery site.

There was no commercial agreement with respect to this data.

In the fitness check report this data is referred to as:

Concawe (2014). Survey of European refineries on costs related to pollution control and biofuels.

III. Data from IHS Consulting

Although the data provided for this study by Solomon Associates and Concawe is reasonably comprehensive, it does not include information on commercially sensitive aspects, in particular, revenues and costs of the sector and of individual refineries.

For a detailed quantitative analysis of these issues, the JRC-IPTS purchased a comprehensive set of refinery-level data, which includes *simulated* costs, revenues, and margins. This data was supplied by IHS consultancy (formerly Purvin & Gertz), a well-known provider of information in several European industries, including oil refining.

The data is presented as a time series covering the period from 2000 to 2013, with detailed indicators in the following categories: structural and capacity data; production structure; costs; crude prices; product prices; revenues and margins. For each year, the dataset covers all the EU refineries considered in the fitness check, with the exception of three smaller plants. In addition to the data on EU refineries, several key variables were provided for the non-EU regions to enable comparative analysis.

The data points were in part simulated with the use of IHS's proprietary *Refinery Simulation Model*. The model simulates product yields by calculating flows of intermediary products between refinery units and blending components to meet final product specifications. It uses industry standard costs as a basis for evaluating refinery costs; costs are evaluated for each unit within the refinery, and then summed up to obtain the total operating costs figures. IHS reconciles national-level crude production, imports and exports with individual refinery crude slates, and national-level oil product outputs with individual refinery product yields, to ensure that the model fits the reality as closely as possible.

In the fitness check report this data is referred to as:

IHS (2014). Global refining database, years 2000 to 2013. Compiled for the JRC Directorate of the European Commission.

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[38] 'Not Applicable' responses indicate the number of refineries that are not equipped with the specific operating unit, e.g. 57 refineries have reported 'Not Applicable' for coke calcining non-regenerative scrubbing in 1998 because they were not equipped with coke calciners in 1998.

These three main data sources were complementary and used in the report for different purposes. The data source most extensively employed throughout the report was the Solomon Associates (2014) database. It served for the analysis of the state of play and trends in the EU petroleum refining sector, and provided crucial inputs for assessing the impacts of the legislation on the sector. At the same time, the database contained no data on refining revenues and margins in the EU or in the competing regions. In addition, given the level of aggregation in the database, the data was available at the level of the EU, EU regions and refining complexity groups, however, not at the level of individual refineries.

Whenever the analysis needed to be fine-tuned at the level of individual refineries, the study employed the data of IHS (2014). While this database provides very detailed information at the refinery level, its important limitation is that to a large extent it relies on simulations (with the use of IHS's proprietary Refinery Simulation Model, as described above) and therefore on certain restrictive assumptions regarding the parameters of refineries operation. This does not concern the variables obtained from publicly available sources, such as capacities and throughputs of refinery units. Potential limitations of IHS (2014) data were taken into account for the analysis and reporting of results. In particular, this data was not used in the assessment of overall regulatory costs for the sector.

Finally, the survey of the EU refineries conducted by Concawe provided additional insights into the capital and operational expenditures related specifically to pollution prevention and control measures. This data is extensively used for the analysis of the impacts of the Industrial Emissions Directive and the Renewable Energy Directive in the respective chapters of the report.

For supplementary statistical data and contextual information, the study relied on publicly available sources, as well as on discussions with the industry representatives and relevant European Commission services. Valuable expert advice was received from the industry consultancies IHS and Solomon Associates. Key inputs for the assessment of wider societal benefits of the legislation were provided by the study performed by the European Environmental Agency, which estimated in monetary terms the costs of damage to health and the environment caused by different air pollutants (EEA, 2014).

1.4. Structure of the report

The rest of the report is structured as follows:

Chapter 2 presents an overview of the European Union petroleum refining sector, with a view to introducing fundamentals for the subsequent economic analysis. It starts with the main concepts and definitions, including refining processes, main refined products and refinery configurations. It proceeds to a short discussion on the economics of refining, underlining the main factors determining refining competitiveness. The chapter presents a number of key facts, characterising the economic contribution of the petroleum refining industry in Europe and its role for the EU's energy security. The discussion proceeds to the EU oil refining landscape, summarises the characteristic features of the EU refineries and puts them in the context of the international refined oil product markets. The chapter concludes with a brief discussion on recent developments in these markets and their potential implications for the EU oil refining sector's international competitiveness.

Chapter 3 analyses the refinery-relevant EU legislation, including its economic impacts on the sector, and is comprised of the following individual subsections:

- the Renewable Energy Directive (RED);
- the Energy Taxation Directive (ETD);
- the EU Emissions Trading System (EU ETS);
- the Fuel Quality Legislation (FQD);
- the Directive on Clean and Energy-Efficient Vehicles (CVD);
- the Industrial Emissions Directive (IED);
- the Strategic Oil Stocks Directive (SOD);
- the Marine Fuels Directive (MFD);
- the Energy Efficiency Directive (EED);
- the Air Quality Directive (AQD).

Each of the pieces of legislation is analysed following the same structure and includes the following parts: objectives and measures of the legislation; effectiveness of the legislation; impact on the EU refining sector; efficiency of the legislation.

Chapter 4 summarises and extends the analysis of the preceding chapters to present the cumulative economic impact of the analysed directives on the EU oil refining sector. In particular, according to the cost impact channels identified above, it concentrates on: impact on refineries' operations; impact through product specifications; and impact via market demand shifts. The overall impact of the relevant legislation on the oil refining sector is thus identified and discussed. The section is completed with an overview of the identified legislation's benefits and some relevant qualitative considerations beyond 2012.

Chapter 5 examines the evolution of the international competitiveness of the EU petroleum refining industry in the 2000-2012 period. After assessing whether and how the competitiveness of EU refining has changed, the main driving factors of this observation are identified. The role of energy expenditures and energy per unit costs are analysed in more detail, as they presumably play a key role in the deterioration of EU refineries' performance and their international competitiveness.

Chapter 6 concludes the report with a summary of the main findings.

REFERENCES TO RELEVANT SOURCES

COM(2010): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Commission Work Programme 2010 Time to act, COM/2010/0135 final

COM(2011): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Energy Roadmap 2050, COM/2011/0885 final

COM(2012): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Stronger European Industry for Growth and Economic Recovery Industrial Policy Communication Update, COM/2012/0582 final

SEC(2010): Commission Staff Working Paper on refining and the supply of petroleum products in the EU, Accompanying document to the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Energy infrastructure priorities for 2020 and beyond – A Blueprint for an integrated European energy network {COM(2010) 677 final}, SEC/2010/1398 final

2. <u>**Overview of the European Union petroleum refining sector**</u>

This chapter provides a qualitative overview of the EU petroleum refining sector with a view to introducing necessary fundamentals for the analysis in the subsequent chapters. After outlining some essential concepts, we discuss the overall size and general characteristics of the sector. Its contribution to the EU economy in terms of value added and employment generation is estimated; the sector is considered as an important industrial input provider and one of the key energy-producing sectors. The chapter continues by outlining the main structural features of the EU oil refining market; it provides insights into the geographical distribution, infrastructure and economics of the sector. Some key issues and recent trends in the EU are identified and put in the context of global markets for crude oil and refined oil products. Finally, the chapter lays out some general considerations on the competitiveness of the EU petroleum refining sector in the global economic setting, which is our main focus throughout the report.

2.1. Main concepts and definitions[39]

2.1.1. *Refining process, properties of crude oil, main refined products and refinery configurations*

<u>*Refining process*</u>

The refining industry is a necessary link between the upstream production of crude oil and the end markets for useable oil products, as well as the petrochemical/chemical industry. Petroleum refinery is generally defined as a combination of processing units with the function of converting crude oil into final and intermediate products, as well as supporting units and facilities. A typical petroleum refinery's goal is to process as much crude oil into marketable products as economically practical. Although refineries may produce a wide range of products, their main outputs in terms of volume are transportation fuels – such as gasoline, diesel and turbine (jet) fuels – and heating oils (importantly, some refineries also produce valuable non-fuel products such as feedstock for chemical and petrochemical industries, bitumen and lube base oils).

Modern refineries tend to be very complex; moreover, each refinery has its unique processing scheme determined by the available equipment, crude oil characteristics, operating costs and product demand. It might therefore not be straightforward to generalise oil refining as a sequence of standardised steps. An example of the refining process in a complex refinery is schematically presented in Figure 2.1.1 below.

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[39] For further technical details on these issues interested readers might refer, for example, to Gary et al., 2007.
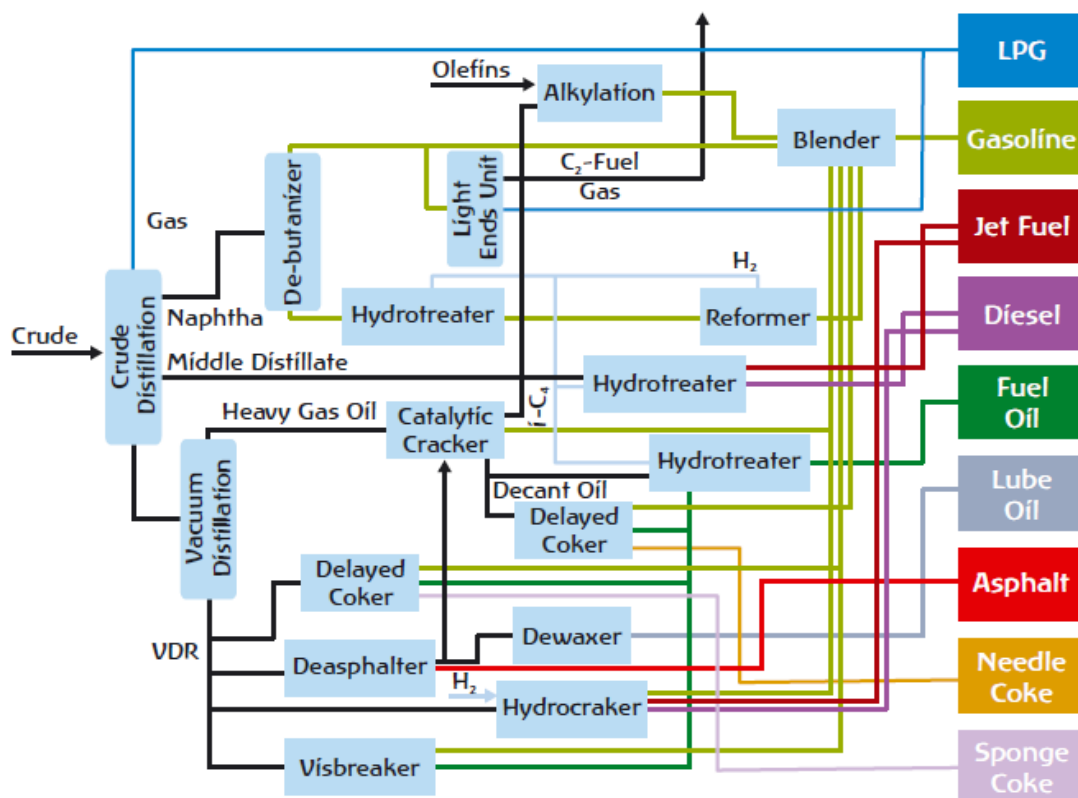
Figure 2.1.1: Example of a complex refinery operation scheme
Source: IEA Energy Statistics Manual © OECD/IEA 2005, fig. A1.6, p. 155.

The refining process is largely based on the boiling ranges of different components, which are determined by their molecular weight. In general, the process can be separated into two phases and a number of supporting operations. The first phase is the desalting of crude oil and its subsequent distillation into various components or 'fractions', such as middle distillate blending components. Further distillation of the lighter components and naphtha is carried out to recover methane and ethane for use as refinery fuel, LPG (propane and butane), gasoline blending components and petrochemical feedstock. This kind of separation is done in every refinery.

The second phase can include three different types of processes: combining, breaking and reshaping of fractions. These processes change the molecular structure of hydrocarbon molecules either by breaking them into smaller molecules, joining them to form larger molecules, or reshaping them. The goal of this is to convert some of the distillation fractions into marketable petroleum products. The kind of process used defines the various refinery configurations, of which the simplest is 'hydroskimming'. Hydroskimming desulphurises and catalytically reforms selected outputs from the distillation unit – in this case, the amounts of different products obtained are determined almost entirely by the crude oil composition. Hydroskimming refineries can improve the quality of final products by hydrotreating (removing impurities using hydrogen), reforming and isomerisation (changing molecules shape to increase the octane number).

In order to obtain more products with a higher value, refineries normally convert heavier fractions into lighter fractions. For this, they separate the atmospheric residue resulting from the first phase by distillation under high vacuum, and then feed the outputs to appropriate conversion units. In this way, the *product slate* (proportions of refined products obtained by refining a barrel of crude) can be altered according to market requirements. Any refinery has an atmospheric distillation unit, and most refineries have a vacuum distillation unit. In contrast, there are a large number of different conversion units and possible combinations.

The simplest conversion unit is the thermal cracker, where the residue is subjected to temperatures high enough that larger hydrocarbon molecules convert into smaller ones ('break'). Thermal crackers can handle virtually any feed, but produce relatively small quantities of light products. Thermal cracking is often regarded as 'yesterday's technology', being cost-effective but producing relatively low quality final products and a high yield of very poor quality residue. An improved type of thermal cracker is the coker, in which all the residue is converted into distillates and a coke product. In order to increase the degree of conversion and improve product quality, a number of different catalytic cracking processes have evolved, of which fluid catalytic cracking and hydrocracking are the most prominent.

Fluid catalytic crackers (FCC) are able to produce a high yield of good quality gasoline, but only low quality diesel, and are for this reason increasingly less used in Europe. To some extent FCCs are used to produce petrochemical feedstock (propylene). FCC gasoline is, on the other hand, the predominant source of sulphur in gasoline (in some refineries it is the only source). Sulphur-free gasoline can be achieved by hydrotreatment of the FCC feed (FCC feed pretreatment) or by applying various sulphur removal technologies (FCC gasoline post-treatment). Hydrocracking is currently the most sophisticated and costly conversion technology, and is flexible as to full or partial conversion of the feed; it is optimal for producing high quality middle distillates.

Importantly, while refineries can, through investment in complex facilities, improve their conversion rates and to some extent alter the final product composition and quality, there exists a certain rigidity in the refining process. Namely, as the product slate is ultimately to a large extent predetermined by the molecular composition of crude oil – the crude basket, the final output cannot be tailored to exactly meet the current needs of a particular market (for example, it would not be possible to produce a certain amount of diesel without at the same time obtaining gasoline, fuel oil and other products). For this reason, even if overall in a region there exists refining overcapacity, it might still be the case that the regional demand for a particular product is not met and needs to be compensated through global trade.

Crude oil

The basic input of refineries is petroleum, or crude oil[40]. Crude oil is a complex mixture of hydrocarbons and a small amount of impurities – sulphur, nitrogen and metals. The hydrocarbons present in crude petroleum are classified into three general types: paraffins, naphthenes and aromatics. In addition, there is a fourth type, olefins, that is formed during processing by dehydrogenation and/or cracking of paraffins and naphthenes. While the elementary composition of petroleum does not vary significantly, small differences in its structure may greatly affect its physical properties, processing requirements and product slate.

Except for the low-boiling components, refineries do not normally analyse the precise molecular composition of each crude oil type. Instead, in order to evaluate crude oil as a feedstock for a particular refinery, the available crude types are compared on the basis of several properties. The most important of them are:

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[40] As part of their feedstock, refineries can also purchase intermediate products from other refineries, such as cracker feedstock, as well as non-petroleum materials for blending, such as alcohols.

API gravity

Introduced by the American Petroleum Institute, API gravity is a generally accepted measure for the density of oils. It is an inverse measure of their relative density with respect to that of water. It is used to compare relative densities of liquids – in particular, if one liquid floats on another, it has a greater API gravity. Although mathematically API gravity has no units, it is generally reported in 'degrees'. Crude oil gravity may range from less than 10 °API to over 50 °API but most crudes fall in the 20 °API to 45 °API range. Crude oil is generally classified as 'light' or 'heavy' according to its API gravity, with light crude oil defined as having an API gravity above approximately 30 ° (the boundary is inexact). Naturally, the heavier the crude oil, the more effort required to process it into light and middle distillates, requiring more complex and costly facilities.

Sulphur content

The amount of sulphur in crude oil is expressed as per cent by weight (wt %) and varies in relation to the region of the crude oil's origin from less than 0.1 wt % to greater than 5 wt % (with a worldwide average in 2010 of around 1.15 wt %[41]). As sulphur is an undesirable component in petroleum products, particularly in transportation fuels, crudes with a greater sulphur content require more extensive processing than those with a lower sulphur content. The term 'sour' crude has become generally accepted to refer to oils with a relatively high sulphur content. There is no clear-cut division between 'sour' and 'sweet' crudes; 0.5 wt % sulphur content is frequently used as a threshold.

Distillation range

The boiling range of the crude gives an indication of the quantities of the various products to be obtained from it. It is generally measured as a true boiling point (TBP) distillation and refers to a distillation performed in equipment that accomplishes a reasonable degree of fractionation.

Acidity

The acidity of crude oil is measured in terms of a total acid number (TAN) index. Acidity above a certain level may be of concern for refineries as it leads to corrosion of equipment. This can be rectified by installing special equipment or blending. Acidity has historically been a minor factor in determining the quality of crude. However, with more unconventional sources of oil being explored, it could become more important in the near future.

Other characteristics of crude oils include carbon residue, salt content, nitrogen content and metals content.

While all these properties are important for the final product slate, processing requirements and thus the relative attractiveness of different types of crude for a particular refinery, the two properties which have the greatest influence on the value of crude oil are the sulphur content and the API gravity. As discussed above, these two characteristics can be used to categorise crude oils into generic groups, the most common of which are 'heavy sour' and 'light sweet'.

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[41] Source: OPEC world oil outlook 2014, p.166.

The effort required to process oil into saleable products and the percentage of high-value products in the final output, which are naturally the main concerns for refineries, may vary significantly depending on the density and sulphur content of the crude. As discussed above, the properties of crude oil almost entirely determine the outcome of hydroskimming; however, a refinery can improve its product slate and adjust to processing heavier and sourer crudes by increasing complexity. Therefore, while typically 'high quality' crude sells for higher prices than 'low quality' crude, 'quality' can mean different things to different buyers. The value of crude oil is in reality determined by the value of the products that a particular refinery can produce from it. In practice, crude oil sales are typically indexed with respect to the benchmark crude in each group. The differentials in prices between different benchmark oils reflect the perceived quality differences and can change depending on market conditions.

Later in this chapter, we will look at the types of crude oil predominantly used in the EU and discuss their main properties. We will also touch upon regional differences across the EU in this respect, revealed by the empirical data.

Main refined products

While the variety of refined petroleum products is quite high, there are several most important ones that dictate refineries' design and basic refinery processes. Refined products are traditionally grouped with respect to the temperature at which they can be recovered from crude oil by distillation:

- Light products, which can be obtained at the lowest temperatures. This group includes LPG, naphtha and gasoline.
- Middle distillates, which are recovered at medium temperatures. The important products in this group are jet fuel, kerosene and gas/diesel oil.
- Heavier fractions that need very high temperatures to be separated, such as fuel oil, lube base oils and bitumen.

Most outputs of the distillation process need further refining, not only to improve the properties of the final products, but also to increase their quantities. As storage and waste disposal are expensive, it is optimal for a refinery to convert as much of the crude oil as possible into useable products, and sell or internally consume all of them (even if some, such as high-sulphur heavy fuel oil and fuel-grade coke, are sold at prices lower than the cost of crude oil).

In this report, we will consider the following main oil products:

Liquefied petroleum gas *(LPG),* which is composed primarily of propane and butane. It is used for both energy and non-energy purposes, for example in domestic or residential heating and cooking, for agricultural purposes, and increasingly in the road transport sector as a fuel for internal combustion engines. In terms of non-energy use, it serves as feedstock for petrochemical processes, such as steam cracking. Propane is also sometimes used as a refinery fuel[42], while butane is also used as a component of gasoline and in refinery processing.

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[42] Use of propane as a refinery fuel is generally avoided because propane has a higher market value than other gaseous fuels such as methane and ethane.

Naphtha – a light, easily vaporised, clear liquid. It is used for further processing into petrochemicals, as a solvent in dry cleaning fluids, paint solvents and other quick-drying products. It is also an intermediate product that can be further processed for producing gasoline.

Motor gasoline (petrol) – a complex mixture of hydrocarbons with a typical boiling range from 38 °C to 205 °C. It is primarily used as a fuel for cars and light trucks. Gasoline, as well as gas/diesel oil and jet fuels, is blended from the various components produced by different refinery streams to arrive at the lowest-cost blend that meets specifications. Most refiners produce gasoline in two or three grades, the principal difference between them being the anti-knock performance. Gasoline specifications have lately been undergoing significant changes due to the environmental considerations. For example, lead, which was used to boost the octane number of gasoline, has been largely eliminated in most countries – other additives and oxygenates improving fuel combustion are now used (such as butane, aromatics, (bio-)alcohols and (bio-containing) ethers). Moreover, with the aim of further reducing pollution, biofuels are increasingly used to either be blended with or replace gasoline.

Gas/diesel oil – includes transport diesel, heating oil and other gasoil. All of these products are blends of different components. Transport diesel oil is used to power diesel engines in buses, trucks, trains, cars and industrial machinery. Heating oil is produced for heating residential and commercial buildings, as well as industrial boilers. It is also used for power generation, although to a much smaller extent than fuel oil. The main differences between diesel and heating oil are the sulphur content, the maximum density, the cold flow properties and Cetane index.

Jet fuel, also known as turbine fuel – blended for use by both commercial aviation and military aircraft. There are several commercial and military jet fuel specifications. For most refineries, the primary source of jet fuel blending stock is the straight-run kerosene fraction from the atmospheric distillation unit. For refineries with a hydrocracker, kerosene boiling range hydrocarbons from this unit can also meet jet fuel specifications and are a major contributor to jet fuel production. The two basic types of jet fuel are naphtha and kerosene. Naphtha jet fuel is produced primarily for the military and is a wide-boiling-range blend which extends through the gasoline and kerosene boiling ranges.

Fuel oil – composed of the heaviest parts of crude oil and considered a by-product. It has historically sold for very low prices (about 70 % of the price of the crude from which it is produced). It is used by the power generation utilities to produce electricity and heat, by industrial users for process heat and by the commercial sector to provide heating fuel for buildings. Fuel oil is also the most important fuel for international marine bunkers. Its critical specifications are viscosity and sulphur content. Demand for fuel oil for power generation has dropped quite rapidly over recent decades, because of its displacement by other fuels for cost-optimisation reasons and due to growing environmental requirements.

There are also several speciality products produced by refineries, such as bitumen, lube base oils, solvents, waxes, petroleum coke and aviation gasoline.

Refining complexity

As discussed above, there can be significant differences between refineries as regards their configurations and the technological processes employed. In fact, every refining process is unique and determined by several factors, such as market conditions, crude oil blend, local fuel specifications and environmental regulations. A generally accepted way for comparing and classifying refineries with respect to the technological units they possess is by assigning them with levels of 'complexity'.

While the first phase of the refining process, distillation of crude oil into its various components according to their boiling temperatures, is performed in any refinery, *complexity* refers to the types of processes used in the second phase of refining – for treating, conversion and transformation. There are several standardised approaches to defining complexity. Sometimes, refineries are simply classified into several complexity types according to the presence of certain refining units. For example, one may distinguish between:

- a *topping* or *skimming* refinery, which is limited to distillation of crude oil;
- a *hydroskimming* refinery, which can provide additional treatment to improve the quality of final products, such as hydrotreating, reforming and isomerisation;
- a *vacuum gasoil (VGO) cracking* refinery, which possesses, in addition to the hydroskimming block, a VGO (thermal, fluid catalytic or hydro-) cracker.
- a *deep conversion* refinery, which can additionally process the residue by visbreaking, coking or residue hydrocracking.

A very common way to measure refinery complexity is using the *Nelson complexity index*. Developed by Wilbur L. Nelson in a series of articles published in the Oil & Gas Journal in 1960 and 1961, this indicator is a composite measure of secondary processing capacity. It is calculated by assigning a factor to each upgrading unit, determined as the ratio between the cost of building this unit and the cost of a crude distillation unit of identical capacity. Complexity is then calculated as the sum of the unit capacities multiplied by the corresponding complexity factors, divided by the pure crude distillation capacity. In this approach, conversion units are assigned the highest factors – as a result, conversion refineries tend to have a higher complexity than the other types of refineries.

A similar way to address complexity is the so-called Equivalent Distillation Capacity (EDC[TM]) developed by Solomon Associates. The EDC[TM] provides a statistically tested method to compare the cash operating costs of refineries of different types and sizes. Similarly to the Nelson indicator, the EDC[TM] factor for a specific process unit is the ratio of that unit's type costs to the equivalent costs for an atmospheric crude distillation unit on a per barrel basis[43]. The costs include maintenance, staffing, energy, catalysts, chemicals and refinery support services. For reporting on complexities in the rest of this section, we use the Solomon Refining Complexity Index, developed by Solomon Associates specifically for this study. The index is calculated as follows:

$$Solomon\ Refining\ Complexity\ Index = \frac{Process\ EDC\ (bbl/d)}{Total\ Crude\ Capacity\ (bbl/d)},$$

where $Process\ EDC = \sum Unit\ Capacity * EDC\ Factor$ for all the on-site process units including Amine and Merox contractors, caustic treating, sulphur recovery units, and tail gas recovery units.

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[43] The Solomon EDC[TM] factor, and hence Refining Complexity Index, is based on unit operating cost, whereas the Nelson complexity is based on unit investment cost. Overall, both Nelson and Solomon refinery complexities are of the same order of magnitude.

Later in this chapter, we will discuss the observed complexity of the EU refineries, including regional differences in this respect.

2.1.2. 'Economics' of refining

The refining industry is a link between crude oil and refined product markets, which means that it builds its profits on margins between the prices in these two markets. Naturally, refineries incur different types of costs in the process, starting from the purchase of feedstock through actual refining operations to the distribution of final products. Although this is the case for all refineries, in reality profits can vary profoundly from one refinery to another as they differ in their configuration, location, process management and other characteristics. As such, refining profitability is a dynamic outcome of the interplay of multiple drivers. Below we discuss some of the most important factors determining refining profitability. Building on these elements, we list several indicators that can be used to evaluate the profitability and competitiveness of any specific refinery.

Among the factors that influence a refinery's competitiveness, one can distinguish between variables that are within the control of an individual refinery and those that are external and apply to any refinery, independently of how it is constructed and managed. Among such external factors are, for example, general requirements on product and process specifications, or global market conditions determining the prices of crude oil and refined products. In turn, within the factors that can be controlled by a refinery, some are related to logistics (access to infrastructure and relevant markets; costs of inputs such as labour and energy; crude oil blend), others to a refinery's configuration and complexity (economies of scale; energy efficiency; product slate and quality achievable), and some fall under operational efficiency (cost management; staffing levels and labour productivity; timeliness of maintenance). These factors are schematically summarised in Figure 2.1.2 – below we consider some of them in more detail.

It needs to be noted that internal (refinery-specific) factors are presented in ascending order by the degree of control that a refinery can exercise over these factors. For instance, a refinery's location is practically impossible to change and can only be decided when a new refinery is constructed. Adjusting the configuration and complexity of a refinery is theoretically possible; however, it is a long-term project involving significant capital expenditures (as discussed in more detail below). At the same time, operational efficiency is something that can be improved in a refinery over a reasonably short period of time.
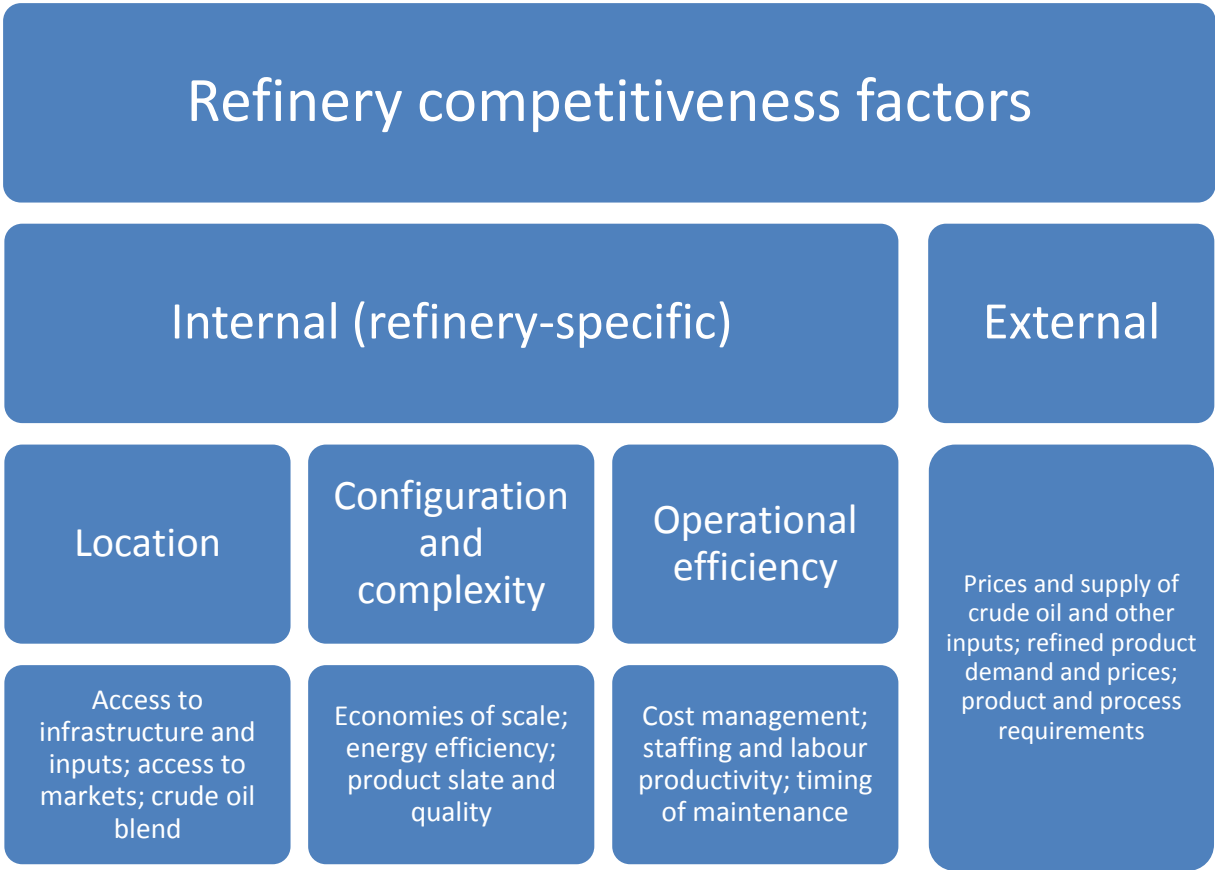
Figure 2.1.2: Main factors of a refinery's competitiveness
Source: Own elaboration.

Crude oil markets

Naturally, a crucial component of costs for any refinery is the price at which it buys its main input – crude oil. Oil has been internationally traded for decades; in the early 1980s a spot market developed, now accounting for around a third of all physical trades. There are currently around 160 internationally traded types of crude oil. The benchmark types are Brent, West Texas Intermediate (WTI), and Dubai. Spot and forward crude prices are published in a variety of industry-accepted sources; the prices for term and over-the-counter contracts are not published and are often confidential. Such contracts specify their duration, which can be from three months to several years, delivery point and a floating price that is typically based on the spot price of a benchmark crude adjusted for quality; they may include restrictions on resale. Most OPEC crude oil is traded using term contracts.

The spot crude oil market is transparent, with prices reflecting the characteristics, quality, and market penetration of the crude. Benchmark crudes are often used in setting the prices of other oils, where a discount or a premium is applied to the benchmark price, depending on the quality of the crude and the distance from the trading hub. Crude oil prices are highly volatile, depending, among others, on supply and demand conditions or concerns about deliverability. The global oil market has in recent decades developed to offer complex hedging instruments such as futures contracts, derivatives and swaps.

Whether delivery costs are included in the price of crude is indicated as: Free on Board (FOB), meaning that the crude is purchased at a point of embarkation and the buyer needs to cover

transport costs; or Costs, Insurance and Freight (CIF), where the crude is purchased at the point of delivery.

While theoretically the prices of crudes should reflect variances in their composition and the different product slates that result from their distillation (with the implication that lighter sweeter crudes should be trading at a premium), in practice this is typically but not always the case. For example, as some refineries are not able to process heavier, sour blends, those refineries will likely bid the value of lighter and sweeter crudes up when supply of the latter is restricted, with the price differential between high and low quality crudes beyond its theoretical value. On the other hand, when the availability of cheaper, lower quality crudes is limited, demand for heavy and sour oil (coming from the refineries that invested in facilities suitable for processing these types of crude) could exceed that for light and sweet oil, with oil prices eventually reflecting that.

Figure 2.1.3 shows the spot crude oil prices in the period from 1861 to 2013. In addition to observing that the price of oil is inherently volatile and sensitive to economic and political events, one can see that oil prices were reaching historical highs towards 2011-12.
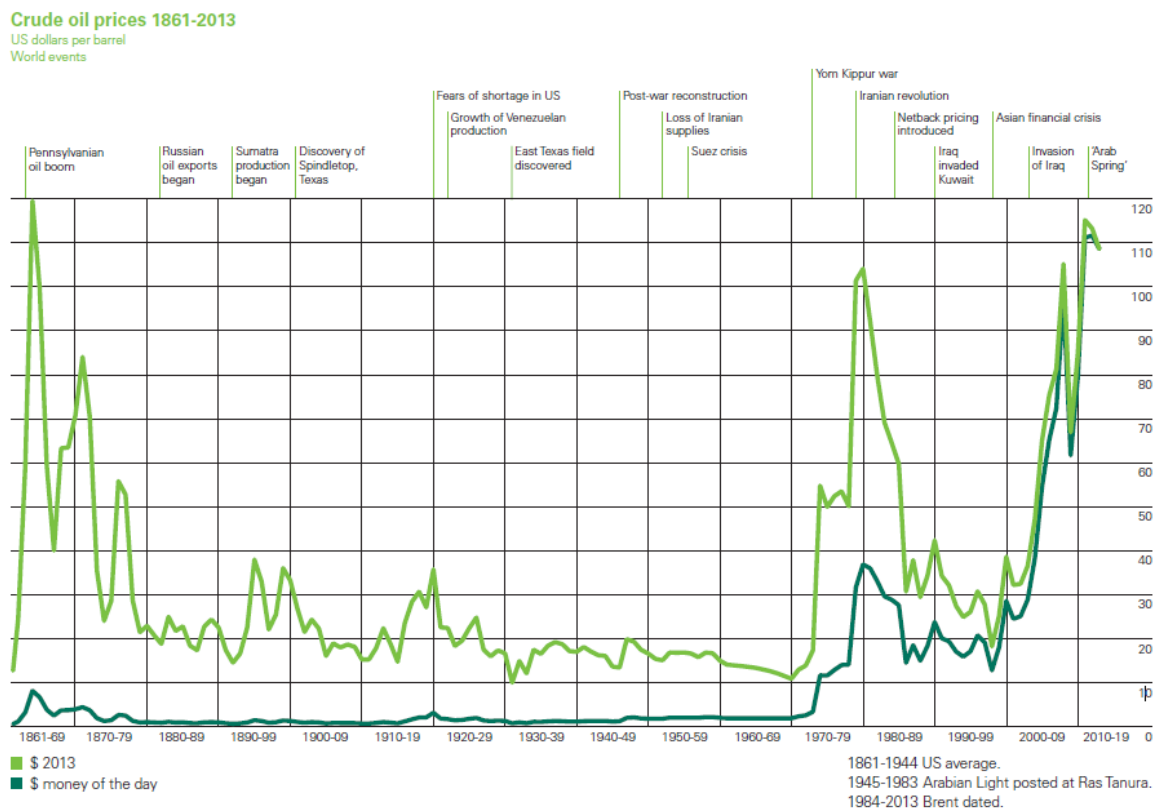
Figure 2.1.3: Crude oil prices in 1861–2013
Source: BP, 2014.

Refined product markets

As in any market, a key determinant of refineries' profitability is demand for their products. A characteristic feature of oil product demand is its seasonality. Namely, demand for refined oil

products strongly varies throughout the year, peaking, for example, during the driving season for gasoline and diesel, and during the heating season for gasoil.

Similarly to the global crude oil markets, international refined product markets are transparent, with prices usually not varying between the regions by more than the freight costs. The dynamics of global supply and demand conditions therefore impact refined oil product prices all over the world. In other words, refining profit margins are to a large extent defined by, on the one hand, global prices of crude oil and, on the other hand, global pricing of refined products.

Refined product prices reflect supply and demand balances for each product and the costs of producing them. Product inventories, through their influence on perception of low or high stock levels of certain products, can have a significant impact on market demand and the prices of these products. Relatively few large world markets determine spot prices for oil products (these prices are reported in industry-specific publications), while in other locations prices are determined indirectly, taking into account freight costs and other conditions. In Europe, large spot oil product markets are located in the north-west and Mediterranean regions. As with crude oil, refined products can be traded on CIF or FOB terms.

Evidently, refined oil products are valued differently by the market. Most refined products sell at a premium compared to heavy fuel oil. Moreover, while market prices of premium refined products typically grow with the price of crude oil, in the case of heavy fuel oil the availability of inexpensive alternatives (such as coal or natural gas) caps potential price increases. In this sense, complex refineries, able to convert more of the fuel oil into higher value products, will be expected to have better profit margins. However, this is not always the case – sometimes market forces can drive the fuel oil prices up, squeezing the profit margins of complex refineries that purchase fuel oil externally for further processing.

Sometimes a refinery can gain a competitive edge by developing *speciality products* capacity - for example, lube base oil, aromatics, solvents and anode-grade coke often offer higher margins than bulk fuels. However, these products are usually produced in small volumes, which limits their overall impact on profitability.

Refinery configuration and complexity

Oil refining is very capital-intensive, and building or upgrading a refining unit is normally a high-scale and expensive project[44]. On the other hand, investment costs may vary depending on the size of a refinery, its location (for example, with respect to land and construction costs, as well as local environmental regulations), the crude oil blend to be processed and the required product slate.

These investments need to be balanced with the potential benefits derived from size and complexity of a refinery. Namely, economies of scale are a very important factor in refining profitability. Larger refining facilities allow for better spreading of fixed costs over outputs, and are more efficient and flexible with respect to changing product specifications or cyclical shifts in business activity. However, large refineries sometimes tend to duplicate units, which adds to their flexibility, but somewhat negates the economies of scale.

There are several advantages to a refinery of adding secondary processing units, or increasing complexity:

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[44] As an example, ExxonMobil is currently going to invest more than USD 1 billion in its refinery in Antwerp, Belgium for building a coker unit.

- Improved product slate. In simple refineries, product yields are almost fully predetermined by the composition of the crude oil used. Complex refineries can achieve a product slate with a higher percentage of high-value outputs, including light distillates (gasoline, naphtha) and middle distillates (gas/diesel oil, jet fuel, kerosene), and a lower percentage of fuel oil.
- Flexibility with respect to crude oil blend. In simple refineries, profits are crucially dependent on the quality of the crude oil feedstock, with light and sweet crudes providing better margins. Complex refineries, on the other hand, are much more flexible as regards the range of crude oils they can use. As they are able to efficiently process heavier and sourer crudes, they can in addition benefit from their lower market prices. Complexity thus provides a particularly important competitive advantage in times of high heavy-light crude price differentials.
- Flexibility with respect to product specifications. Complex refineries have the advantage of being able to more easily control the quality of their products and meet certain specifications, which are increasingly stringent in the case of transportation fuels.
- Flexibility with respect to market conditions. With increasing throughput, a complex refinery might increasingly use less sophisticated processes in addition to the complex ones, in order to optimise the use of its existing capacity.

A disclaimer needs to be made that complexity, while associated with significant additional capital and operating costs (generally, the higher the complexity, the higher the total energy demand of a refinery), does not necessarily guarantee correspondingly higher returns. First of all, market conditions can simply turn out to be less favourable than expected at the time of investment. Moreover, it is possible that a refinery's equipment is highly complex, yet directed towards the products that are currently in excessive supply in the market. For example, the fluid catalytic cracking process is geared towards production of gasoline, which is currently in decreasing demand in Europe, and is not well-suited for producing high quality diesel, for which the demand is constantly increasing. Reorientating a refinery towards higher production of diesel not only requires the construction of an expensive hydrocracker, but also the idling or scrapping of the existing equipment.

Therefore, while the complexity and flexibility of a refinery are strongly correlated, they do not necessarily mean the same. Similarly, it should not be directly assumed that complexity ensures the capacity to process any type of crude oil – a refinery can be highly complex, and yet not well-suited to process heavy and sour oil blends.

Location and transportation costs

Together with the size, configuration and complexity of a refinery, location is one of the most important determinants of profitability. The most basic division here is between coastal and inland plants. Most importantly, the type of location determines the freight costs for crude oil and product despatch, whereby coastal refineries often have low crude supply costs and better access to export markets, and are also primary access points for product imports.

Petroleum products can be transported via pipelines, ships or rail; distance and mode of transport are the determinants of costs. Pipeline and marine tankers are the preferred modes for transporting crude oil as they are the cheapest. Pipeline, ship and rail are all used to transport products from refineries to terminals located near major markets, from where the fuels are usually delivered to retail outlets by trucks.

There is generally more flexibility in transporting crude oil than refined products, as the latter are less stable and more sensitive to contaminants. Therefore, the costs of transporting finished products are normally higher relative to the costs of crude oil delivery. In general, the costs of delivery will decrease from an inland refinery with no access to pipelines; to an inland refinery with a pipeline connection; to a coastal refinery close to a port; and will be the lowest for a refinery linked to an oilfield by pipeline.

At the same time, refineries located in relatively isolated inland markets might be predominantly oriented towards local demand for their products, and may be specifically configured to serve these markets. They thus might be able to capture a higher profit margin due to the limited competition in certain specific markets. Naturally, refineries – depending on their location – may pay significantly different prices for the same kind of crude oil and yet compete in the same final product market.

Location and access to infrastructure affect not only the costs of delivery, but also access to different sources of crude oil and consequently the crude blend used by a refinery. Location of a newly built refinery may thus be a function of the access to crude oil of certain quality. Importantly, location also determines the operating costs that a refinery will be facing. These include, above all, labour, energy and local legislation compliance expenditures. Naturally, the optimal operational mode and configuration of a refinery may change over time as a result of the above factors' dynamics, as well as shifts in market demand.

A separate point can be made on the refineries associated with petrochemical plants. Given the strong process interrelationships between the two, such a locational choice eliminates the transport costs for refined products used as petrochemical feedstock and for backflows from petrochemical processes to refining. Refineries that are part of a petrochemical complex have greater flexibility in optimising their intermediate product streams, as well as benefitting from shared operating costs. Such integration may thus significantly improve refining profitability[45].

Operational efficiency

The operational efficiency of a refinery essentially refers to the optimisation of its *fixed* and *variable operating costs*.

Variable costs are those that are needed to support the operation of a refinery. The main components in this category are energy, chemicals and water. Given that refining involves complex separation and upgrading processes, which can be very energy-intensive, by far the most important element of variable costs is *energy*. Energy efficiency is thus a very important consideration in optimising a refinery's design and operation. A substantial proportion of the energy used by refineries is usually self-generated within the refining process. Part of it needs to be externally purchased (electricity, natural gas, and/or steam), whereby the local energy prices might have a major influence on refining profitability.

Fixed costs are independent of throughput and are a necessary overhead – they include, most importantly, equipment maintenance and personnel costs, as well as insurance, administration and depreciation. Fixed costs per unit of output can be reduced by increasing efficiency, economies of

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[45] According to Concawe, out of 82 refineries currently active in the EU, 31 are linked to petrochemical facilities. TOTAL's refinery in Antwerp, Belgium is one example of a fully integrated petrochemical refinery.

scale and investment in automation. Manpower per unit of capacity and labour productivity are very important efficiency parameters in this category.

Since the fixed costs of operating a refinery are quite high, optimising equipment *maintenance periods* is very important for sustaining profitability. This is particularly the case for high value added and high cost units, such as crackers. In general, modern refineries are shut down for major maintenance approximately once every five years, with the shutdown generally planned during periods with lower market activity or milder climate conditions (for example, in spring and autumn). The utilisation rate of a refinery is an important component of profitability – a typical sustainable utilisation rate is 80–85 %.

In general, operating a refinery efficiently is a complex task, requiring mathematical precision. Nowadays, linear programming models are widely used in refining to simulate the operation of different units and processes, in order to make optimal business decisions.

Profit indicators

Most often, refining returns are measured in terms of 'margins'. Given that the crude oil and refined product prices are readily visible, it is straightforward to obtain an indication of the gross profit margin that can be achieved at a particular moment. Referred to as an *'indicator' margin* or more commonly *crack spread*, this measure represents the revenue that can be generated from turning a barrel of crude into saleable products. It does not, however, take into account the costs of doing so.

For calculating crack spreads, simple assumptions are made on the output structure of a local refinery. For example, a commonly quoted Gulf Coast 3–2–1 crack spread assumes that for every three barrels of oil, two barrels of gasoline and one barrel of gasoil/diesel are produced. Other spread ratios can be used to reflect the refining specifics of a region. One can also consider individual product crack spreads versus fuel oil – most commonly, gasoline and diesel fuel oil crack spreads are used to illustrate the value of converting a barrel of fuel oil into gasoline or diesel.

In order to account for costs, and therefore actual refining profits, the performance of refineries is measured in terms of *net cash margins*, calculated as *gross revenue* (product yields multiplied by product prices) minus the *feedstock costs*, *variable* and *fixed costs.*

Refining margins are extensively used for business decisions by the industry and published in specialised sources. The International Energy Agency (IEA) regularly provides information on estimated refinery margins in different world regions (north–west Europe, the Mediterranean, the US Gulf Coast and Mid–continent, and Singapore). These margins are calculated for various complexity configurations, each optimised for processing a specific crude blend. They account for energy costs, but not for other types of costs.

Definitions of profitability indicators commonly used in the sector are schematically presented below (

Figure 2.1.4).
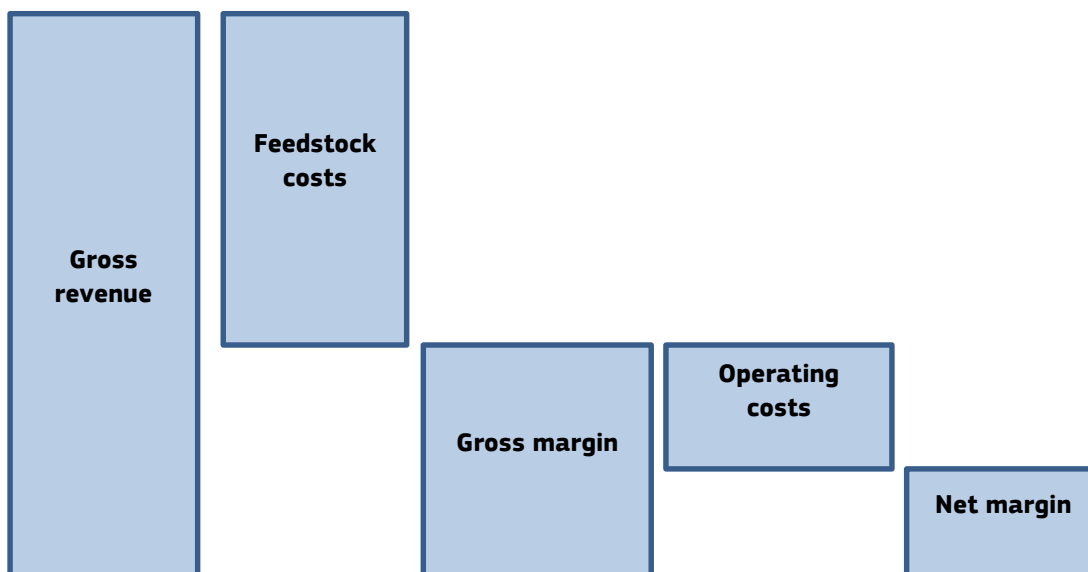
Figure 2.1.4. Schematic presentation of profitability indicators commonly used in the oil refining sector

2.2. Economic contribution of the EU petroleum refining industry

2.2.1. Key statistical facts

We start the overview of the EU petroleum refining sector with the following important facts:

The EU oil refining sector accounts for a visible share of the manufacturing value added, contributes to employment, and demonstrates a substantial turnover

According to the latest available data (Eurostat, 2011), the EU oil refining sector (represented by NACE 19.20 in the Eurostat Structural Business Statistics database) directly contributed around 1.2 % to the total value added in manufacturing[46].

Around 119 000 people are directly employed in the sector. It pays around EUR 6.3 billion in wages and salaries annually.

The EU refining industry has a total annual turnover of around EUR 600 billion or around EUR 5 million per person employed.

The EU refining industry constitutes a substantial part of the world's total refining capacity

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[46] Following the Eurostat definition of value added in factor prices.

There are currently around 100 petroleum refineries operating in the EU[47]. The EU total crude refining capacity is around 14.7 million barrels daily, which corresponds to 15.5 % of the total world refining capacity (BP, 2014).

The EU refineries' throughputs were 11.62 million barrels daily in 2013 (BP, 2014).

Refined petroleum products are an important element of extra-EU trade accounting for the majority of EU energy exports

The total consumption of oil products in the EU in 2013 was 12.77 million barrels daily, or 605.2 million tonnes (BP, 2014), which, compared to the above data on production, means that the EU is a net importer of refined oil products.

In 2013, imports of refined oil products into Europe[48] totalled 159.0 million tonnes, or 3.3 million barrels daily (BP, 2014).

In the same year, Europe exported 96.6 million tonnes, or approximately 2 million barrels daily of refined products, resulting in net imports of 89.4 million tonnes (BP, 2014). Refined petroleum products are an important component of extra-EU trade and constitute the majority of EU energy exports[49].

The main petroleum products traded outside the EU in terms of volume are gasoline and gas/diesel oil, including heating oil. Gas/diesel oil is the main petroleum product imported in the EU (the major trading partners being the Former Soviet Union (FSU) and then the United States), while gasoline accounts for the largest share of exports (mainly to the US, although this export outlet has shrunk significantly in recent years with the development of US light tight oil production). The EU is also significantly import-dependent on jet fuel and kerosene, for which it mainly relies on a number of Middle Eastern countries (EC, 2010).

Given its limited natural reserves (0.4 % of the proved world oil reserves at the end of 2013 – BP, 2014), the EU is a large net importer of crude oil. In 2013, net imports of oil into Europe amounted to 444.9 million tonnes, or 8.9 million barrels daily (BP, 2014). Suppliers of crude oil to the EU are diverse, with important trade partners in the FSU, OPEC countries and Norway.

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[47] The exact number of refineries reported varies depending on the chosen definition of a refinery and the reporting methodology. According to Concawe (European Oil Company Organisation for Environment, Health and Safety), there were 95 mainstream refineries operating in the EU in 2008, of which 82 are still operating in 2014. In addition, Concawe reports that there are 15 small non-mainstream refineries currently operating in the EU, dedicated to the production of bitumen and lubricants or processing petroleum condensates. On the other hand, Eurostat reports over 1000 enterprises with their main activity in NACE sector 19.2 ('Manufacture of refined petroleum products'), which has a wider coverage. It must be noted that this NACE code includes a large number of manufacturing enterprises unrelated to refineries, such as biofuel blenders and manufacturers of hard-coal fuel briquettes, lignite fuel briquettes, peat briquettes, petroleum briquettes and various speciality products such as lubricants, greases, vaseline, etc. The macroeconomic indicators in this section, based on the data published by Eurostat, cover NACE sector 19.2 as a whole.

[48] Includes Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Republic of Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK, Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Former Yugoslav Republic of Macedonia, Gibraltar, Malta, Romania, Serbia and Montenegro.

[49] Eurostat 'International trade and foreign direct investment' pocketbook, 2013 edition.

2.2.2. Contribution to other industries in the EU economy

In this section we present the results of an assessment of the EU refining sector's contribution to the European economy based on the European Input-Output tables for the period 2008-2011 (provided by Eurostat). In the methodology behind these tables the refining sector is defined within CPA/NACE 19: Manufacture of coke and refined petroleum products. This division includes the transformation of crude petroleum and coal into usable products. In terms of the total share in value added, the dominant process is petroleum refining, which involves the separation of crude petroleum into component products through such techniques as cracking and distillation. Therefore, while the results of this analysis might overestimate the role of refining, the upward bias is considered to be very minor. This division also includes manufacturing of gases such as ethane, propane and butane as products of petroleum refineries[50].

In 2011, the wages paid to employees of EU refineries accounted for 43.4 % of the total value added. The remaining 56.7 % includes capital consumption, other taxes on production minus the subsidies and profits (gross operating surplus).

The largest share of the refining sector's production volume is delivered to satisfy the final demand

The contribution of the EU refineries by providing intermediate products to other sectors of the EU economy amounted to EUR 29.7 billion of value added in 2011. This represents 8.1 % of the total output of the EU refineries sector. Around 96.2 % of the value added generated by the EU refineries was linked to refined petroleum products during the period 2008-2011, while the remainder was linked to other products that indirectly influenced the production of refinery products (e.g. transport services). This figure remained stable over the years and is quite similar for the other variables like employment and output. Of the output of refined petroleum products, 54.4 % was used as intermediates to produce other goods and services in the same period.

The total direct and indirect contributions calculated for the EU refining sector from Input-Output relations in 2011 amounted to around 0.9 % of the EU GDP and 0.6 % of the total employment of the EU economy

Below we discuss the direct and indirect effects of the refining sector on the EU economy. Direct effects include the impacts on employment, value added and production to satisfy the final demand for refinery products. They include the so-called initial and first round effects, where we consider inputs delivered to the refining sector from other sectors of the economy. Indirect effects refer to second, third and subsequent rounds (following the inter-industry links upstream). Furthermore, the induced effects refer to the response of the economy to changes in the household expenditures attributable to the income generated by the direct and indirect effects.

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[50] This division also includes manufacturing for own purposes of characteristic products (e.g. coke, butane, propane, gasoline, kerosene, fuel oil etc.) as well as processing services (e.g. custom refining). It does not include manufacturing of such gases in other units (20.14), manufacture of industrial gases (20.11), extraction of natural gas (methane, ethane, butane or propane) (06.20), or manufacture of fuel gas, other than petroleum gases (e.g. coal gas, water gas, producer gas, gasworks gas) (35.21). The manufacture of petrochemicals from refined petroleum is classified in division 20.

Table 2.2.1: EU refineries' contribution to the EU economy

	2011 Refineries	2008-2011 % linked to petroleum refined products	2011 Total effects	2008-2011 % direct effects	2008-2011 % indirect effects	2008-2011 % induced effects
Output	368,854	96.1%	520,650	47.5%	10.8%	41.8%
Employment	160,200	95.9%	1,318,507	34.6%	23.9%	41.4%
Value added	29,722	96.2%	103,579	42.6%	20.7%	36.7%
Labour income	12,906	96.1%	46,964	39.5%	23.1%	37.5%
Gross operating surplus	16,816	96.2%	56,614	45.2%	18.7%	36.1%

Units: Mio. € and number of workers

Source: Own elaboration from Eurostat data

Via all the different direct and indirect effects, the EU refining industry supported 1.32 million jobs in 2011, of which on average (during 2008-2011) around two out of five jobs could be attributed to the induced effects (41.4 %). Direct effects and indirect effects amounted to nearly 60 %. In terms of value added, 42.6 % of the effects were on average direct effects while indirect and induced effects for the same period (2008-2011) represent 20.7 % and 36.7 %, respectively. As a general rule for all other variables depicted in Table 2.2.1, induced effects played a prominent role on the total effects of the final demand for refinery products in the EU during 2008-2011.

With respect to the EU economy, the total effects calculated for the EU refineries sector in 2011 amounted to around 0.9 % of the EU GDP and 0.6 % of the total employment of the EU economy.

2.2.3. Contribution to research and innovation activities

The EU refining industry puts considerable effort into process and product innovation activities and employs mostly high and medium skilled labour

While intangible and therefore difficult to measure quantitatively, there can be important positive externalities associated with the oil refining industry, such as knowledge spillovers from research and innovation. Figure 2.2.1 shows the levels of product and process innovation taking place in different industry sectors across the EU. The immediate observation is that the sector 'Manufacture of coke and refined petroleum products' (NACE sector 19)[51] is one of the most active industries in product and process innovations.

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[51] It is generally estimated that the 'Manufacture of refined petroleum products' accounts for the majority of sector 19 in terms of the main indicators.
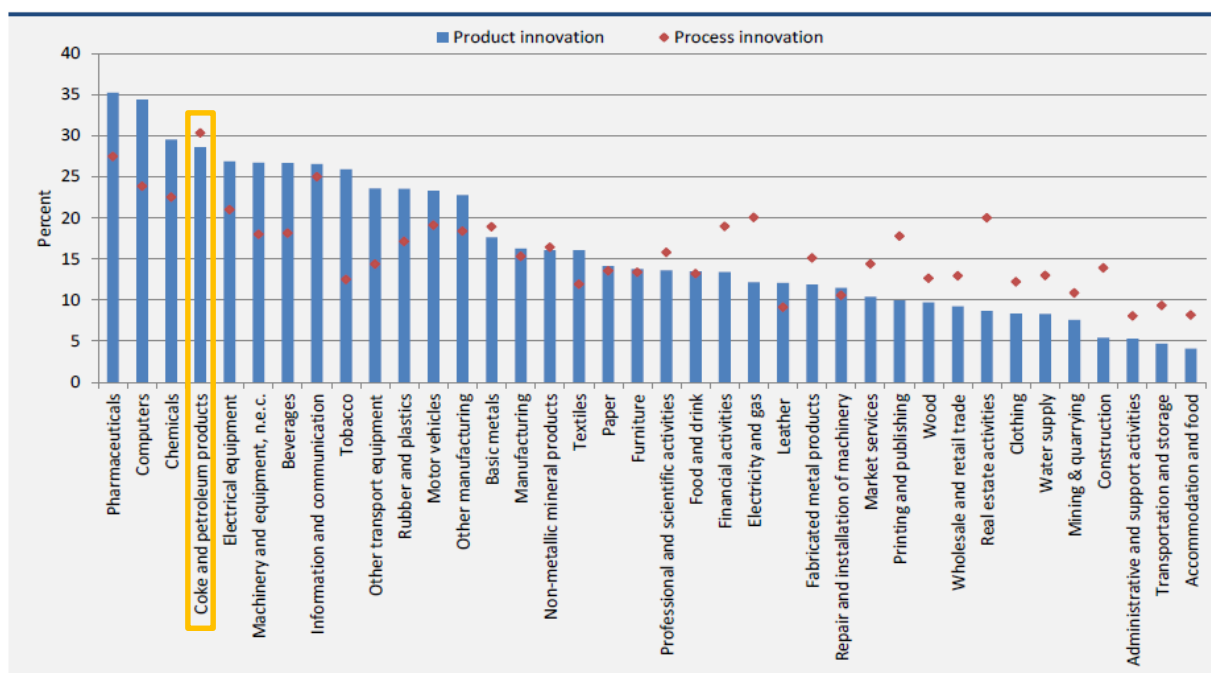
Figure 2.2.1: Product and process innovation in the EU, 2010 (share of the Community Innovation Survey respondent companies reporting product and process innovation activities)
Source: EC, 2013 (sector highlighted by IPTS).

As regards the knowledge intensity of the sector, Eurostat includes NACE sector 19 ('Manufacture of coke and refined petroleum products') in the list of 'Knowledge Intensive Activities' (KIA), which are identified on the basis of the shares of tertiary educated persons employed in the sector (the sector is considered knowledge-intensive if this share is greater than 33 %). In Figure 2.2.2, showing the shares of 'high', 'medium' and 'low' skills employees in the overall employment of different sectors, one can clearly observe that sector 19 employs mostly medium and highly skilled labour.

2.2.4. Oil refining industry and the EU's energy security

With regard to the economic contribution of the oil refining sector, one aspect deserving separate discussion is its importance in terms of the secure supply of energy. As a major net importer of energy sources, the EU places energy security high on its political agenda[52]. Formally, the International Energy Agency (IEA) defines energy security as 'uninterrupted availability of energy sources at an affordable price' (IEA, 2014). Alongside uninterrupted availability, energy security involves aspects such as supply of energy in line with economic developments and environmental needs. In this respect, broader issues such as reducing fuel consumption and developing renewable alternatives can be seen as contributors to energy security.

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[52] For example, see the European Commission's communication on the European energy security strategy, available at: http://ec.europa.eu/energy/security_of_supply_en.htm.
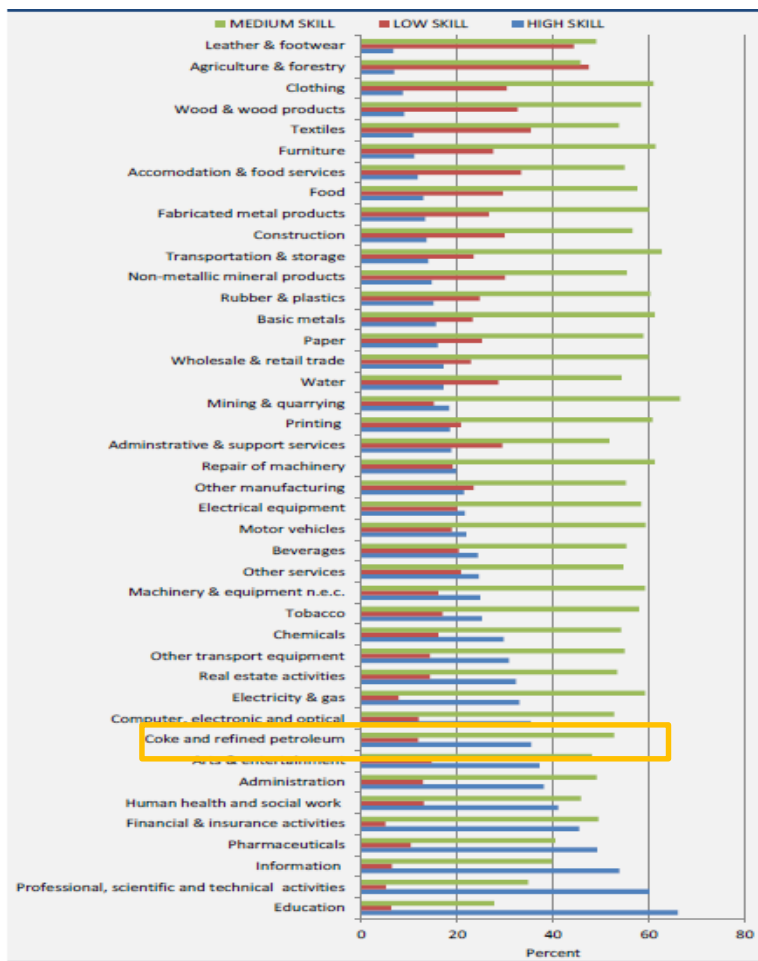
Figure 2.2.2: Skill and knowledge intensities (% of total employment)
Source: EC, 2013 (sector highlighted by IPTS).

It is most likely that energy security will stay a focus of political attention in the foreseeable future – according to the prognosis of the IEA's World Energy Outlook 2014 (IEA, 2014), in the central forecast scenario, global energy demand is set to grow by 37 % by 2040. Demand would grow for all forms of energy, while fossil fuels would remain the principal source of energy, their share in primary energy demand going down to just under three quarters in 2040.

Refining products continue to play an important role in satisfying the energy demand in Europe

In the EU, along with natural gas[53], oil continues to be one of the crucial components of domestic energy demand[54]. In 2013, it represented around 36 % of total fuel consumption (BP, 2014). In 2013, the EU was the second largest consumer of oil products in the world after the US, with about 14.5 % of global consumption (BP, 2014).

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[53] Being a traditional back-up to oil, natural gas is in increasingly high demand in the electricity sector and has thus become less readily available as a substitute fuel (IEA, 2014).

[54] Aware of the need to prevent potential oil product shortages, the EU has put in place an obligation for Member States to maintain minimum stocks of crude oil and/or petroleum products (Directive 2009/119/EC of 14 September 2009), which will be discussed later in this report.

A common way to look at the energy security of an economy is the Model of Short-Term Energy Security (MOSES), developed by the IEA to evaluate energy security risks for its member countries (Jewell, 2011). MOSES considers energy security from the energy systems point of view, taking into account potential risks at all the levels of the supply chain from crude feedstock supply to transformation and distribution to end users. For this, it uses several risk and resilience indicators that characterise each primary energy source and secondary fuel. With respect to refined oil products, these are: net import dependence, diversity of suppliers, entry points (ports and pipelines), number of refineries, flexibility of refining infrastructure and stock levels. It thus emerges that, as refined products can either be refined domestically or imported with different kinds of risks associated with the two supply streams, energy security can be guaranteed by either reliable domestic refining and stock capacity or secure channels of international trade, or both.

In terms of the share of domestically produced refining products, the EU is not in the zone of high risk but appears to have become more imports-dependent during the last decade

MOSES suggests estimating import dependency in terms of the 'refining cover' for specific products, calculated as the percentage of demand covered by domestic refining. The high-risk import dependency for refined oil products is benchmarked at 45 %; for countries that refine more than 55 % of their oil products internally, energy security risks come mostly from the vulnerability of their crude oil supply, as well as the number and flexibility of domestic refineries. Currently, according to Eurostat's energy production and consumption statistics, the refining covers for the most important refined oil products are as follows (Table 2.2.2).

Table 2.2.2: Production to consumption ratios for some refined oil products in the EU in 2000 and 2012
Source: IPTS on the basis of Eurostat database [nrg_102a].

Refined product	Refining cover in 2000	Refining cover in 2012
Gasoline	117 %	159 %
LPG	88 %	65 %
Naphtha	92 %	71 %
Kerosene and jet fuel	91 %	75 %
Gas/diesel oil	98 %	96 %
Fuel oil	106 %	169 %

It seems that none of the products are currently in the zone of high risk as regards import dependency (notably, the gap between the domestic production and consumption of some important products has been growing recently – for example, refining cover has decreased for kerosene/jet fuel, naphtha and LPG; see Figure 2.2.3). Therefore, the security of oil products supply in the EU is mostly of an internal nature, important components of it being the size and flexibility of domestic refining and stock capacity. However, reliable sources of crude oil supply into the EU, as well as sustainable export outlets, are also of crucial importance. We will look at these components and recent trends therein later in this section.
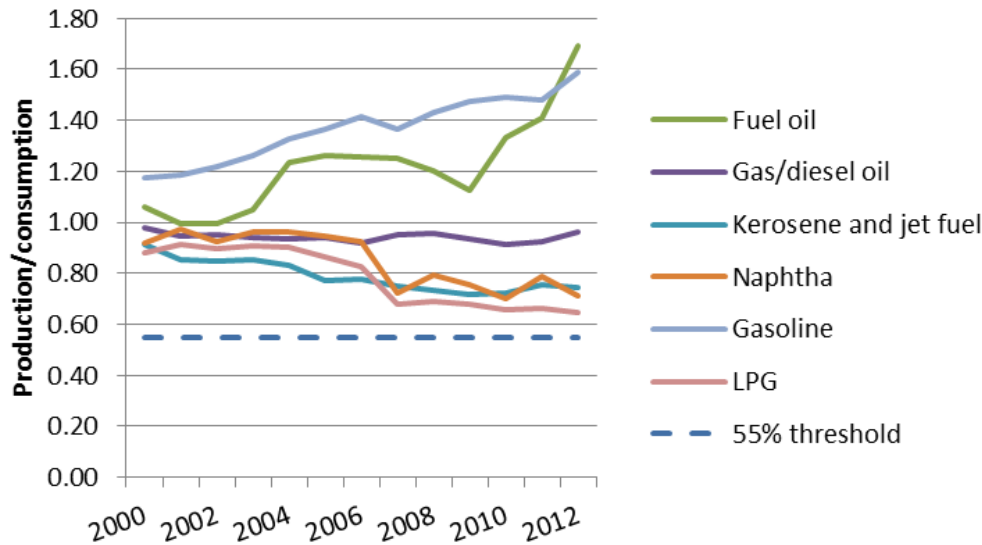
Figure 2.2.3: Production to consumption ratios for selected refined oil products in the EU in 2000-2012
Source: IPTS on the basis of Eurostat database [nrg_102a].

2.3. The EU oil refining landscape[55]

In this section we present an overview of the historic evolution and the current state of affairs in the EU oil refining industry. We introduce the most recent information about various aspects of the industry's position and activities such as:

- the geography and structure of the industry in Europe;
- the crude oil sources used for refining;
- the analysis of refining complexity;
- refineries' investments and operating costs;
- recent developments in refined products markets.

We further supplement the general picture of the industry with the results of a deeper statistical analysis[56] of systematic patterns characterising the oil refining activities in Europe where we considered the groups of geographic regions and the refinery complexity classes according to similarities exhibited by the variables in the following dimensions:

- the combinations of different types of refining capacities installed;
- the relative shares of the different crudes used;
- the relative shares of the main refining products produced;
- the combinations of different types of energy sources used for refining activities.

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[55] This subsection uses comprehensive descriptions of the EU oil and refined products markets provided in Pöyry, 2009 and EC, 2010. We supplement and update these overviews with the latest statistics and events related to the sector.

[56] Several cluster analyses have been implemented using the method of hierarchical clustering with an average linkage function (for technical details see Annex). Given the fact that the database of available indicators is rather extensive, a cluster analysis is a suitable tool to detect the major systematic patterns in these indicators and identify the evident similarities and differences between regions and/or refinery complexity groups.

2.3.1. Geography and structure

Refining is a mature industry, fairly evenly distributed across the territory of EU

While the history of refining in the EU can be traced back to the end of the 19th century[57], it was not until the 1950s that refining operations in Europe began to experience significant growth. Refining capacity continued to grow through the 1960s and early 1970s and peaked in the mid to late 1970s. After this, it began to decline until the late 1980s and stabilised thereafter. Between 1985 and 1999 there was continued consolidation and rationalisation, with reductions in the number of refineries and throughput and investment in upgrading facilities to produce greater volumes of light and middle distillates (Pöyry, 2009). In the last decade, the EU's refining capacity has been declining, with 15.9 million barrels daily in 2003 and 14.7 million barrels daily in 2013 (BP, 2014)[58].

This indicates that very few new refineries have been built recently in the EU – indeed, around 83 % of the refineries were constructed before 1970, around 95 % before 1980, and 100 % before 1990[59]. This reflects general global trends, whereby, with limited growth in refined oil product demand, the bias of investment during the last decades has been towards increasing the complexity of existing refineries rather than expanding capacity. Most of the refineries in the EU have been upgraded and expanded; however, this mostly took place during the 1980s, with the expectation of continued growth in demand for petroleum products, especially gasoline. Due to the long investment cycles in the industry, the EU's refining capacity to a large extent inherits from this past demand structure.

Until approximately the mid-1970s, the sector was dominated by highly vertically integrated international oil companies (IOCs); more recently, other types of players have emerged. At present, in addition to IOCs, several distinctive types of players are representative of the EU refining sector (Pöyry, 2009):

- national, former state-owned/controlled, oil companies (NOCs);
- pure-play refiners specialising only in refinery operations;
- refiners and marketers integrating refining with retail product marketing;
- niche refineries active in a specific product market, such as bitumen plants.

Recently, the market has been increasingly populated with independent refiners, distributors, transportation and storage companies, formerly parts of the vertically integrated oil companies; all types of companies are increasingly active in product markets beyond their national borders. The EU refining market thus seems to have evolved into an oligopolistic structure, with a significant presence in the form of several large companies and a large number of smaller players.

As we mentioned earlier, by the end of 2012 there were around 100 mainstream petroleum refineries operating in the EU. Figure 2.3.1 illustrates their geographic locations (see the Annex for the full list of refineries considered in this study).

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[57] Rijeka Oil Refinery in Croatia started its operation in 1883 and can be technically considered the first European industrial oil refining plant (Industrija Nafte, d.d., http://www.ina.hr/default.aspx?id=269).

[58] The decline in total refining capacity in the EU reflects recent refinery closures: in 2010 three oil refineries were closed, and in 2012 a further nine. In January 2012, a major refining player Petroplus filed for insolvency, with two of its refineries closing since then.

[59] Source: Concawe.

One can observe that refining facilities are relatively evenly distributed across the EU: there are refineries in 22 EU Member States (with the exception of Cyprus, Estonia, Latvia, Luxembourg, Malta and Slovenia). Refineries are often concentrated near major sea ports, large rivers or pipelines. Such refining clusters often correspond to the large wholesale oil product markets, by far the largest of which is the Amsterdam-Rotterdam-Antwerp (ARA) market[60]. The refining capacity is slightly more concentrated in the north-western part of the EU (NWE), close to the North Sea crude oil sources.
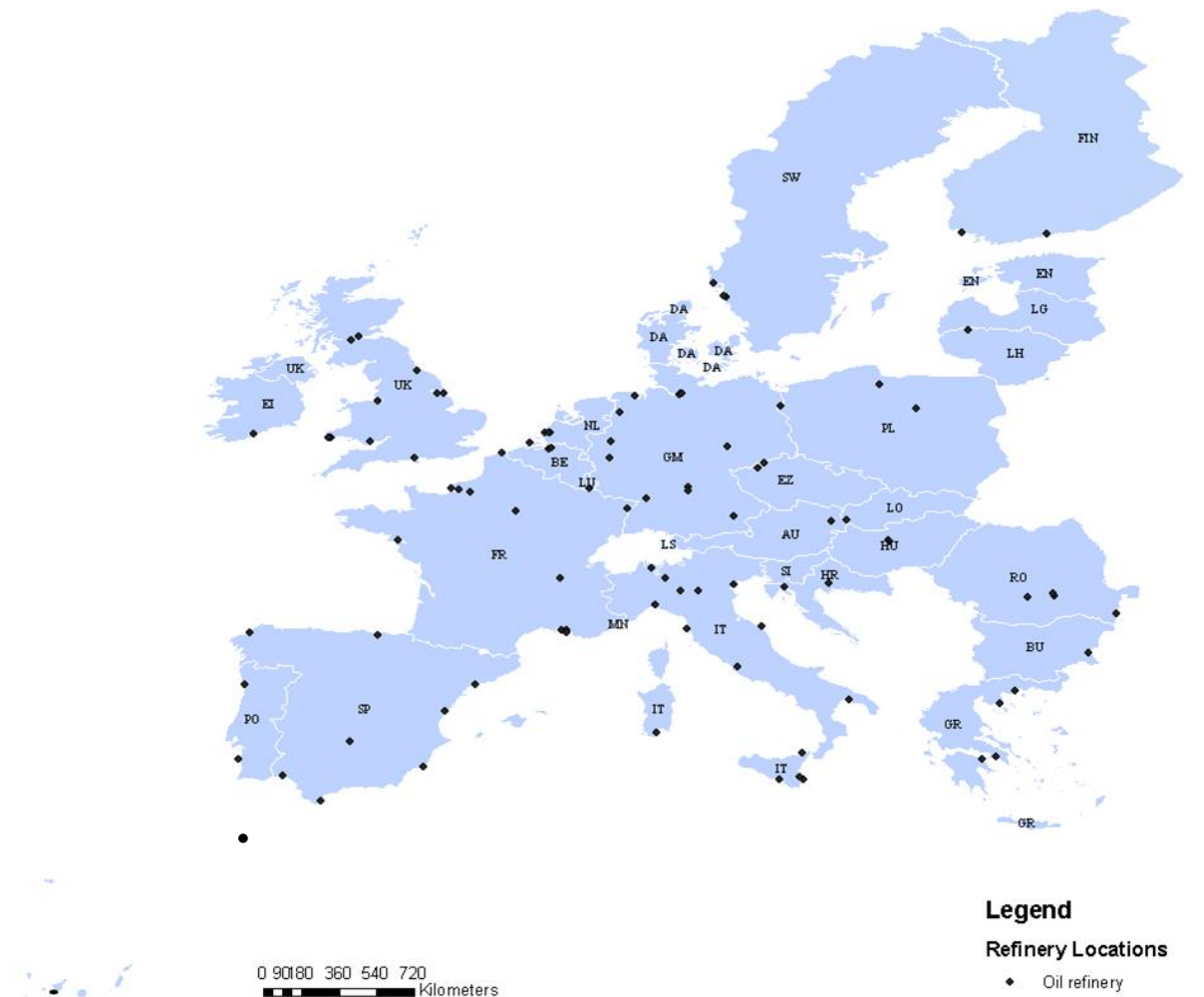
Figure 2.3.1: Refineries in the EU (situation by 2012)
Source: IPTS.

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[60] The other refining hubs are located in Le Havre, France; Syracuse, Sicily; Hamburg, Germany; Marseille, France; and Ploesti, Romania (Pöyry, 2009).

Table 2.3.1: Refining regions' capacities from Solomon's *Fuels Study*
Source: Solomon Associates (2014).

Region	Code	MS included[61]	Number of participating refineries (2012)	Total refining capacity (2012), kbbl/day
Baltic	BAL	Denmark, Finland, Sweden, Lithuania	7	1016
Benelux	BNX	Belgium, Netherlands	7	1968
Germany	GER	Germany	9	1900
Central Europe	CEU	Austria, Czech Republic, Hungary, Poland, Slovakia	7	1260
UK & Ireland	UKI	UK, Ireland	8	1663
France	FRA	France	8	1429
Iberia	IBE	Spain, Portugal	11	1963
Mediterranean	MED	Italy, Greece	12	2284
South-East Europe	SEE	Bulgaria, Romania, Croatia	6	600

Table 2.3.1 and Figure 2.3.2 provide an indication of the geographical distribution of refining capacity across different regions in the EU in 2012, based on the data provided by Solomon Associates. In the remainder of this section we will use this data to report on aggregate characteristics of the EU oil refining sector. The data is split across nine regional groups, shown in the table below, corresponding to the regions used by Concawe in its linear programming model of the EU refining industry. The information is aggregated from existing data forming part of the *Fuels Study* by Solomon Associates, and spans the period from 1998 to 2012 on a biennial basis. Data in each given year covers only the refineries that provided data for that year[62].
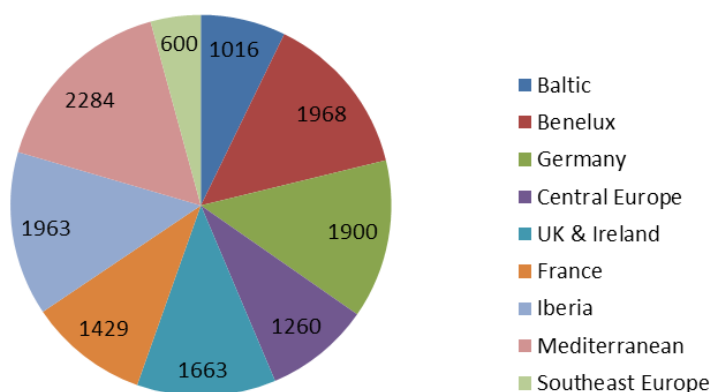
Figure 2.3.2: Refining capacity in the EU by region, 2012 (kbbl/day)
Source: Solomon Associates (2014).

The European refineries' capacity remains consistently underutilised

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[61] Only the countries with refineries are shown.

[62] Refineries may choose not to participate in a study year. The population of each group can thus vary from year to year, depending on participation in the surveys.

Largely as a result of the domestic and global demand dynamics, the EU refining sector has been characterised by significant underutilisation of capacity during the last decade (Figure 2.3.3).
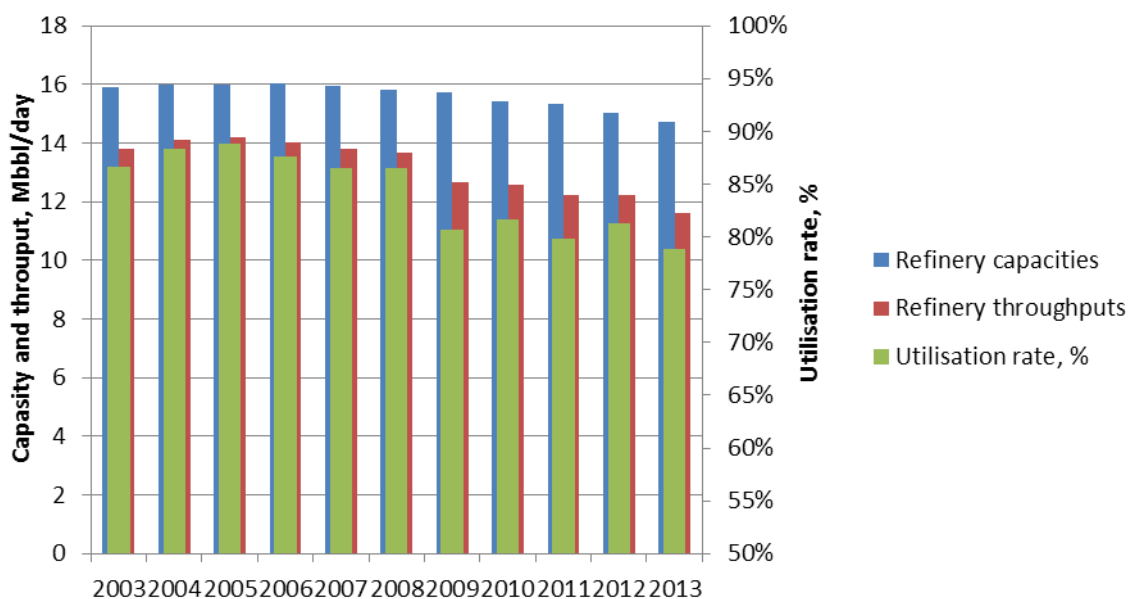
Figure 2.3.3: Refinery capacities and throughputs in the EU in 2003-2013
Source: Based on BP, 2014.

2.3.2. Crude oil sources

Crude oil – the main refining input – is not a homogenous product. It can have strongly varying qualities, and crudes may substantially differ in characteristics depending on their origin. They are most commonly classified by the geographic location where they are produced, their API gravity (measuring density or 'heaviness', with low API crudes being more dense or 'heavy' than high API 'light' crudes), and their sulphur content ('sweetness'). It is important to remind of the implications of crude oil qualities for the costs of refining. Namely, the heavier and sourer the crude, the more effort required to process it into final products, implying more complex refining facilities and higher operating costs. The need for different degrees of treatment means that the choice of the type of crude predominately used by a refinery will be influenced by its configuration, complexity, product slate, and will in turn have an impact on its investments, expenditures and operating results.

Rather diversified stream of crude inputs with a wide range in gravity and sulphur content

Figure 2.3.4 depicts the main world sources of crude petroleum. While the EU possesses its own oil sources, located mainly in the North Sea (more precisely, the EU's internal crude production comes from Denmark, the UK, the Netherlands, Italy and Romania), these are not significant in comparison to the other oil-producing world regions. With declining production in the North Sea, the EU is increasingly dependent on extra-EU imports: it currently relies on external sources for 88.7 % of its domestic crude oil demand (BP, 2014), importing most notably from Norway, OPEC countries and Russia. Naturally, depending on the geographic location within the EU, refineries will have easier access to the crude oil of certain origins, which will be predominant in their crude oil input mix.
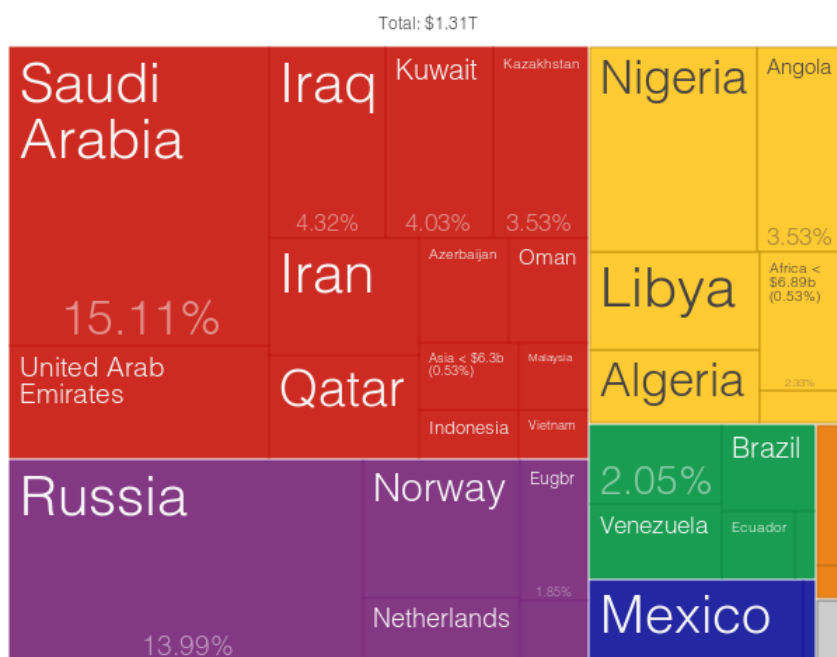
Figure 2.3.4: Countries exporting crude petroleum (2012)
Source: Observatory of economic complexity. Available at: http://atlas.media.mit.edu/.

Table 2.3.2 and Figure 2.3.5 provide a summary of the crude oil blend processed in the EU in 2012 and the main characteristics of crude types by origin.

Table 2.3.2: Origins and characteristics of crude oil used in the EU, 2012
Source: Solomon Associates (2014).

Crude oil origin	Processed in EU-28, 2012, t/yr per refinery	Processed in EU-28, 2012, % mass by origin
Middle East, S: 2.17 wt %, API: 32.2	1 016 578	13.5 %
North African[63], S: 0.33 wt %, API: 40.3	759 183	10.1 %
West African[64], S: 0.25 wt %, API: 34.1	839 410	11.2 %
Asian, S: 0.34 wt %, API: 28.7	46 006	0.6 %
FSU, S: 1.19 wt %, API: 33.5	3 118 000	41.5 %
North Sea, S: 0.43 wt %, API: 35.4	1 108 979	14.8 %
All Other European, S: 0.64 wt %, API: 38.7	328 876	4.4 %
Mexico and Venezuela, S: 2.98 wt %, API: 22.8	177 231	2.4 %
All Other American[65], S: 1.05 wt %, API: 21.0	118 798	1.6 %
Total crude processed	7 513 060	100.0 %

The existing infrastructure and established trade agreements suggest that the dominant sources of oil in each region might be relatively constant, although there is a clear indication of the increasing

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[63] Algeria, Libya, Egypt, Tunisia.

[64] Angola, Gabon, Nigeria, Cameroon, Congo, Zaire.

[65] Incl. North and South America.

relative share of the FSU crude. The data from Solomon Associates' *Fuels Study* to a large extent corresponds to these general observations. Figures in the Annex illustrate the detailed crude oil inputs breakdown for all nine EU regions in 2002 and 2012.
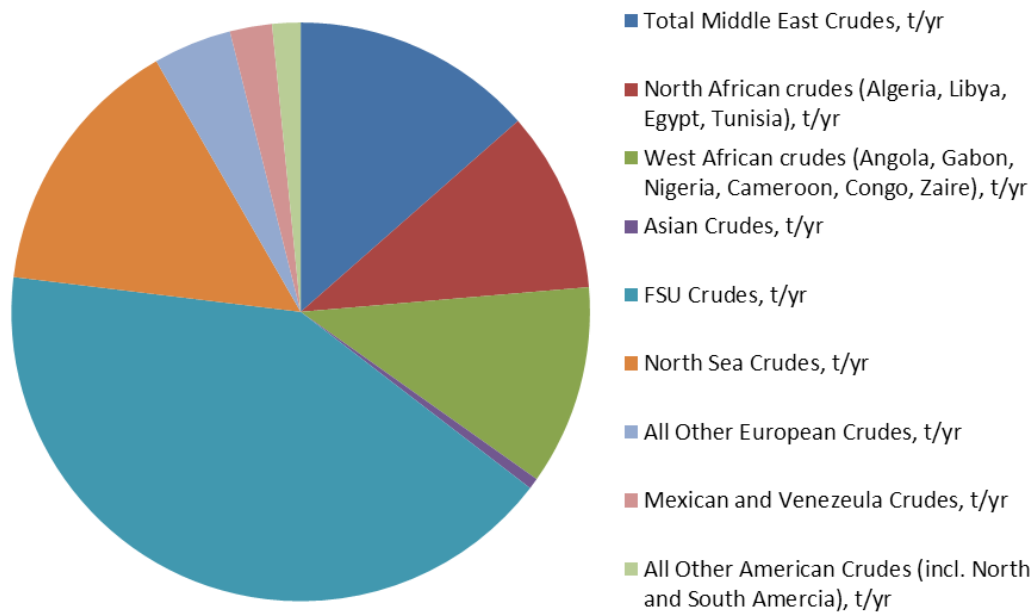
Figure 2.3.5: Breakdown of crude oil used in the EU by origin, 2012
Source: Solomon Associates (2014).
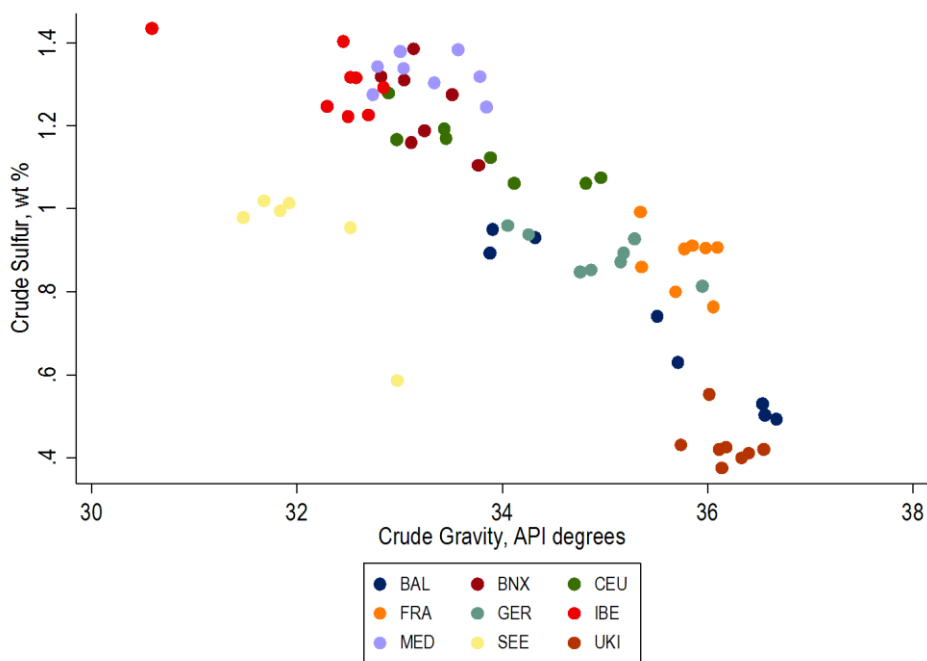
Figure 2.3.6: Average annual sulphur content and API gravity of the crude mix at European refineries (a dot in the graph corresponds to one annual average observation in the period 1998–2012)
Source: Solomon Associates (2014).

The main characteristics of crude inputs shifted towards heavier and sourer crudes, although not in all EU refining regions

Looking at characteristics of the crude mix such as average sulphur content and average API gravity, one can observe a rather intuitive general link between the lighter crude oil mix and the lower sulphur content. In certain regions the gravity and the sulphur content of the crude mix did not change substantially in the last decade, as can be observed in regions such as the UK and Ireland, France, Spain and Portugal, and Benelux.

On the other hand, refineries in the Baltic states, Germany, central Europe and south-east Europe processed crudes with a wide variety of gravities and sulphur contents, indicating much less stability in their crude mix. And examining the time evolution of the processed crude mixes in these regions presented in Figure 2.3.7, we observe a shift towards heavier crudes with a higher sulphur content. Compared to the situation in 1998, the crudes in these regions in 2012 are on average at least two degrees heavier. The sulphur content, though, increased differently depending on the region, with the most noticeable increases in the Baltic states and in southern and eastern Europe, which is most likely to be explained by the increasing share of the FSU crudes.
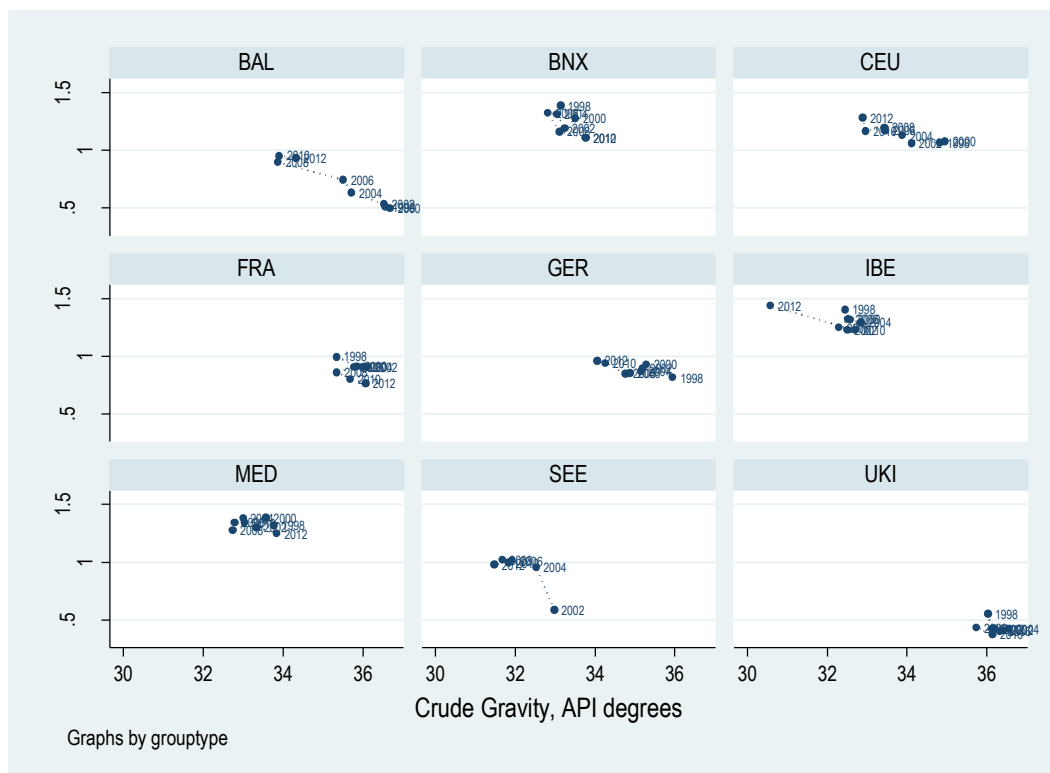
Figure 2.3.7: Average annual sulphur content and API gravity of the crude mix evolution at European refineries by individual regions (a dot in the graph corresponds to one annual average observation in the period 1998-2012)

Source: Solomon Associates (2014).

Table 2.3.3: Refinery region clustering by crudes use
Source: Solomon Associates (2014).

Region	Crude mix
UKI – UK, Ireland	7.47% / 2.71% / 0.77% / 6.72% / 0.35% / 74.10% / 3.17% / 4.71%
BNX – Belgium, Netherlands FRA – France IBE – Spain, Portugal MED – Italy, Greece	3.94% / 23.44% / 30.70% / 3.69% / 12.73% / 1.02% / 14.22% / 10.26%
CEU – Austria, Czech Republic, Hungary, Poland, Slovakia SEE – Bulgaria, Romania, Croatia	15.26% / 1.70% / 0.66% / 3.26% / 5.62% / 73.39%
GER – Germany BAL – Denmark, Sweden, Finland, Lithuania	2.27% / 4.70% / 43.05% / 6.30% / 0.70% / 6.57% / 36.21%

Legend:
- FSU
- Mexico and Venezeula
- All Other American (incl. North and South Amercia)
- West Africa (Angola, Gabon, Nigeria, Cameroon, Congo, Zaire)
- Total Middle East
- North Africa (Algeria, Libya, Egypt, Tunisia)
- North Sea
- All other

Four major regional clusters can be identified based on the used crude mix. The relative shares of North Sea, FSU and Middle East crudes are the main drivers

When looking for broader regional patterns in the crude mixes processed by the EU refineries, we identified four main regional clusters that exhibit similarities in the average use of crudes from different sources (shown in Table 2.3.3). These clusters are not necessarily formed according to the geographic proximity principle, although there are several identifiable factors that contribute to similarities.

One European region clearly stands apart from others in terms of the crude diet – the United Kingdom and Ireland. The inputs structure in this region is characterised by an overwhelmingly large share of the internally extracted North Sea crude. On the other side of the spectrum we see a cluster of central European and south-eastern European countries where the similarly large share of the crude diet is occupied by the crudes from Former Soviet Union. In these two clusters the proximity to sources plays a dominant role.

The refineries in Germany and in the Baltic states process a slightly more balanced mix of crude inputs. The FSU oil and North Sea oil have comparable but still rather large shares with an addition of visibly large volumes from the Middle East and North Africa.

The most diversified inputs portfolio is observed in refineries located in Benelux, France, Spain, Portugal, Italy and Greece. All these countries use predominantly marine transport to ship their crudes, which allows them to have a diversified mix of crudes from the Middle East (the largest share), FSU, North Sea, North and West Africa, and all other areas of the world.

Regarding the patterns of crude use in different refinery complexity groups, the cluster analysis detected no reliably identifiable differences or similarities in the crude mix processed there. There is an indication that the refineries with lower complexity tend to process a larger share of North Sea crude (which is lighter and sweeter), but this is also observed in many of the more complex refineries.

In general, we observe that, on the inputs side of the European refining sector, there are three main types of crude that play major role in the refineries' diet: the North Sea, the Middle East and the FSU crudes. As will be seen below, the relative shares of these three types of crude play an important role in determining the other characteristics of the sector's activities.

A visible shift towards greater use of the FSU crudes by European refineries

The internal crude production in the North Sea has recently been declining (BP, 2014): in Denmark it dropped from 17.9 million tonnes (Mt) in 2003 to 8.7 Mt in 2013 (a decrease of around 51 %), while the UK's production fell from 106.1 Mt to 40.6 Mt over the same period (around 62 %). This trend is generally expected to continue. This means that European refineries that are relying on the North Sea crude inputs need to either source sweet light crudes from elsewhere, upgrade existing capacities or invest in new ones so that they can process higher volumes of heavier and sourer crudes, and/or import larger volumes of oil products. Sweet light crudes could be sourced from a number of locations worldwide, including: Norwegian production in the North Sea (which also follows the declining production trend); North African Saharan blends from Libya and Algeria; West African crudes from Nigeria and Angola; and Caspian crudes from Azerbaijan and Kazakhstan.

The proximity to crude sources and/or main crude transportation media determines the primary composition of EU refineries' crude diet

It appears that regions with easier sea access use a more diverse crude blend, such as with a higher share of the Middle East crude, while those that are inland have a few predominant sources to which they are linked with established infrastructure. Indeed, according to the data, some of the EU regions (Benelux, France, Iberia, Mediterranean) process quite a balanced mix from different crude oil suppliers.

There is particular uncertainty about the stability of the composition of the crude imports as a consequence of the unstable political situation in the main crude-producing regions

Although a general shortage of crude oil should not be expected in the near future (according to BP Statistical Review of World Energy 2014, 'total world proved oil reserves reached 1687.9 billion barrels at the end of 2013, sufficient to meet 53.3 years of global production'), recent political happenings have highlighted the importance of diversification in the extra-EU crude oil sources. The recent Ukrainian crisis is one of them – Ukraine is a transit country for Russian crude exports to central European countries as the southern leg of the Druzhba pipeline runs through northern Ukraine (in 2013, Slovakia imported 100 % of its crude via Druzhba, Hungary 94 % and the Czech Republic 65 %[66]). Political turmoil in several regions of the Middle East and North Africa (MENA) since the beginning of the 'Arab Spring' in December 2010 also raises questions on the long-term reliability of MENA as a crude oil supplier.

Clear observed tendency towards greater use of non-crude oil inputs

It is useful to look, in addition to the crude oil, at the other inputs the EU refineries use as part of their feedstock. Figure 2.3.8 provides a quick insight into this by illustrating the evolution of non-crude oil refining inputs in the EU-28 in 1998-2012.
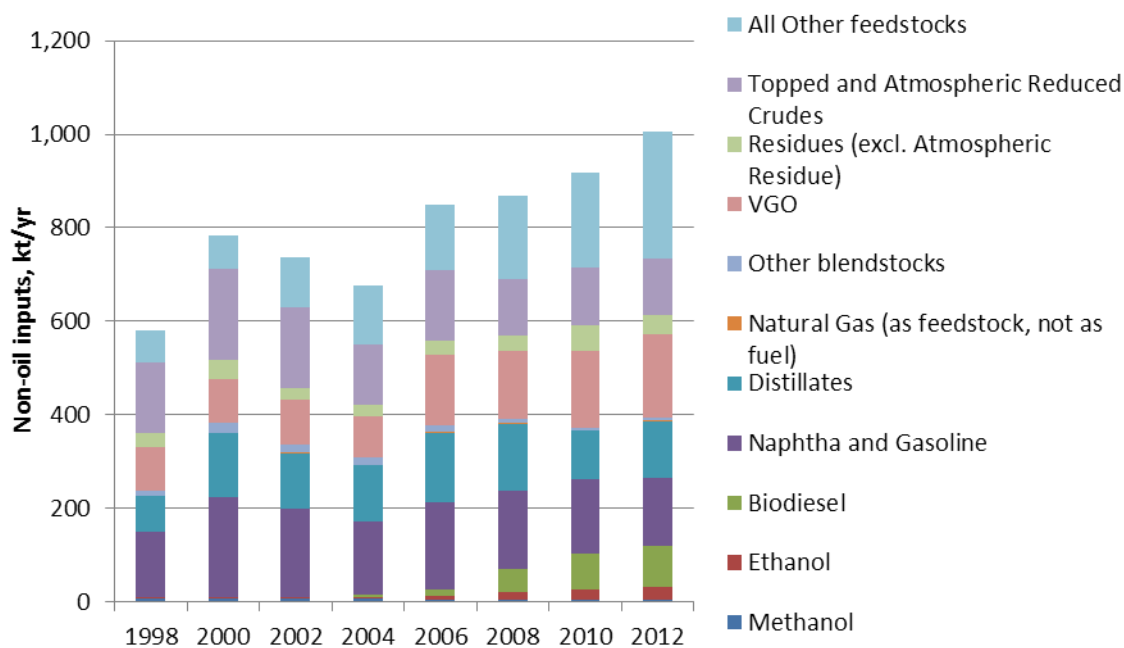
Figure 2.3.8: Non-crude oil inputs processed and blended in the EU-28 (thousand t/yr per refinery on average)
Source: Solomon Associates (2014).

Overall, other non-crude inputs have grown in volume during the period. The rising demand for vacuum gasoil (VGO) and natural gas as external feedstocks reflects the increasing capacity of secondary conversion units, mainly hydrocrackers, and hydrogen production units. In general, this shows that trade in intermediates (i.e. purchases of feedstocks processed in other refineries) has increased quite significantly over time.

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[66] IEA, http://www.iea.org/newsroomandevents/news/2014/march/iea-facts-in-brief-russia-ukraine-europe-oil--gas.html

Another tendency that can be clearly observed is a strongly growing proportion of biodiesel and ethanol used by the EU refineries as inputs. Figure 2.3.9 below illustrates the increasing consumption of bio-feedstock for blending in 1998-2012.
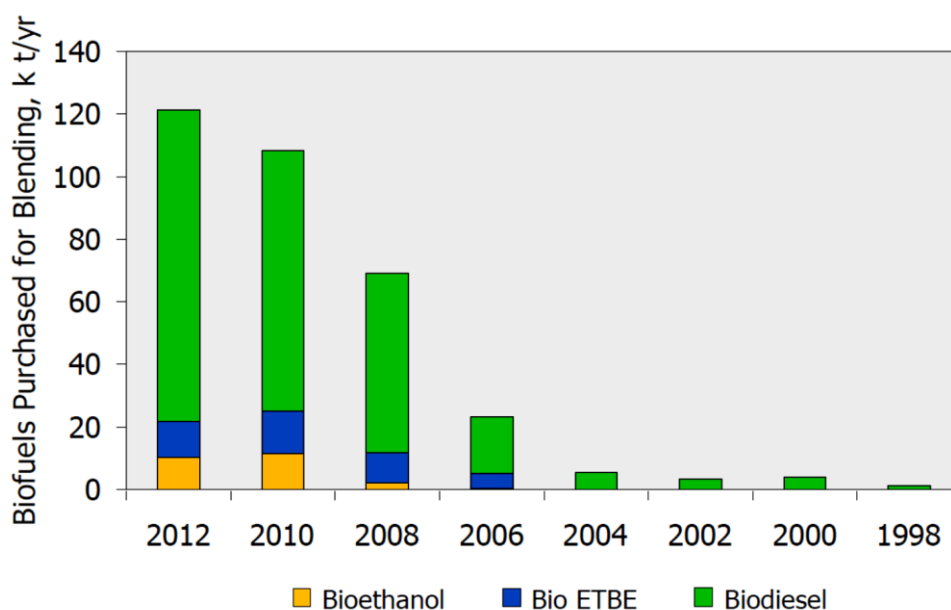
Figure 2.3.9: Biofuels purchased for blending inside the refinery boundary[67] in the EU-28, 1998-2012 (thousand t/yr per refinery on average)
Source: Solomon Associates (2014).

2.3.3. Refining capacity and complexity

As discussed earlier, one of the most important characteristics of a refinery is its complexity, which refers to its capacity for secondary conversion in addition to simple distillation. Refineries with more complex configurations can generally achieve higher yields of light and middle distillates, efficiently use crude oil of lower quality, can easier meet certain product specifications, and may be expected to achieve better overall operating results. For reporting on complexities in this subsection, we use an index based on the *Equivalent Distillation Capacity* and developed by Solomon Associates specifically for this study, as discussed above.

Throughout the observed time period the most complex refineries are located in Germany, Benelux, the UK and Ireland, while the least complex are in Iberia, central Europe and France

As of 2012, the average complexity index of the EU refineries is reported at 9.0 (Figure 2.3.10) and has grown significantly from 7.3 in 1998[68]. Based on the available data, in 2012 the highest refining complexity is observed in Germany, the Baltic region and central Europe, while refineries with, on average, the lowest complexity are in Iberia, Benelux and France.

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[67] Ethanol is often blended outside the refinery boundary.

[68] This could, among others, reflect the closures of less complex refineries. According to Solomon Associates, most of the recently closed refineries in the EU were in Hydroskimming or GOC B complexity groups.
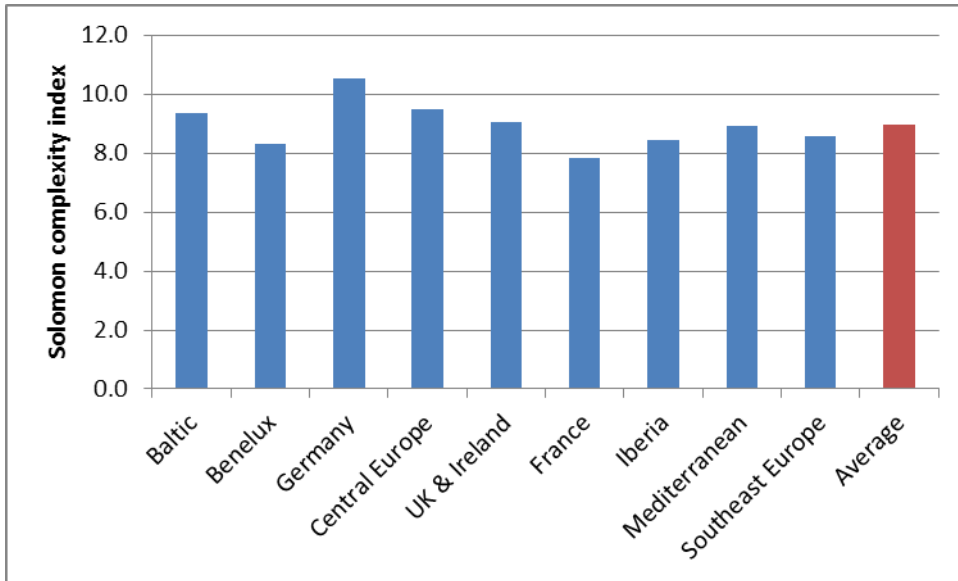
Figure 2.3.10: Average index of complexity by region, 2012
Source: Solomon Associates (2014).

The average complexity of oil refineries in Europe has grown visibly since 2000

The strongest complexity growth was observed in the regions that have, on average, higher shares of FSU crudes

Figure 2.3.11 shows the development of the average refining complexity in different EU regions in 2002-2012.
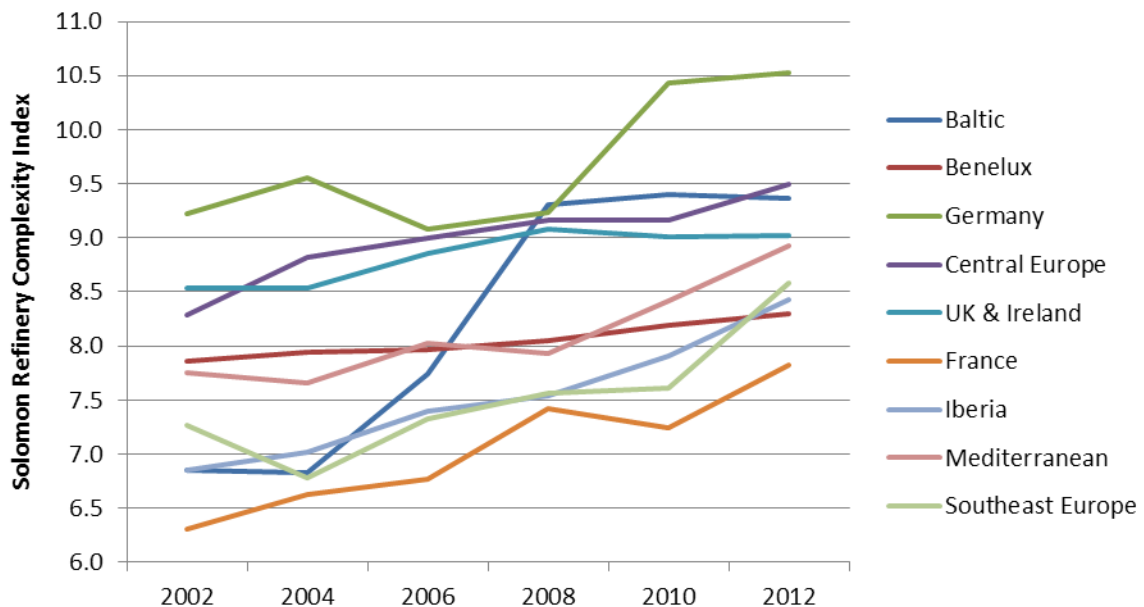
Figure 2.3.11: Development of complexity by region, 2002–2012
Source: Solomon Associates (2014).

One can observe that, in general, complexity has increased across all the EU regions. The highest growth of complexity index is observed in central Europe, where it increased from 6.5 in 1998 to

9.5 in 2012, while the level of complexity was relatively stable in Benelux and the UK and Ireland. Combining this observation with the findings in the previous section, we notice that the highest complexity growth in central Europe appears to go together with an increasing share of processed FSU crudes.

For the purpose of this analysis, Solomon Associates defined several complexity groups based on the Solomon Refinery Complexity Index (as defined above):

1. Refineries with hydroskimming and thermal units;

2. Gas Oil Conversion (GOC) A – Complexity Factor <6.9;

3. GOC B – 6.9 ≤ Complexity Factor <8.0;

4. GOC C – 8.0 ≤ Complexity Factor <9.5;

5. GOC D – 9.5 ≤ Complexity Factor.

Over the last decade we observe continuous shifts in the number of refineries between the complexity groups as can be seen from the evolution of the refining complexity groups in the EU shown in Figure 2.3.12 below.
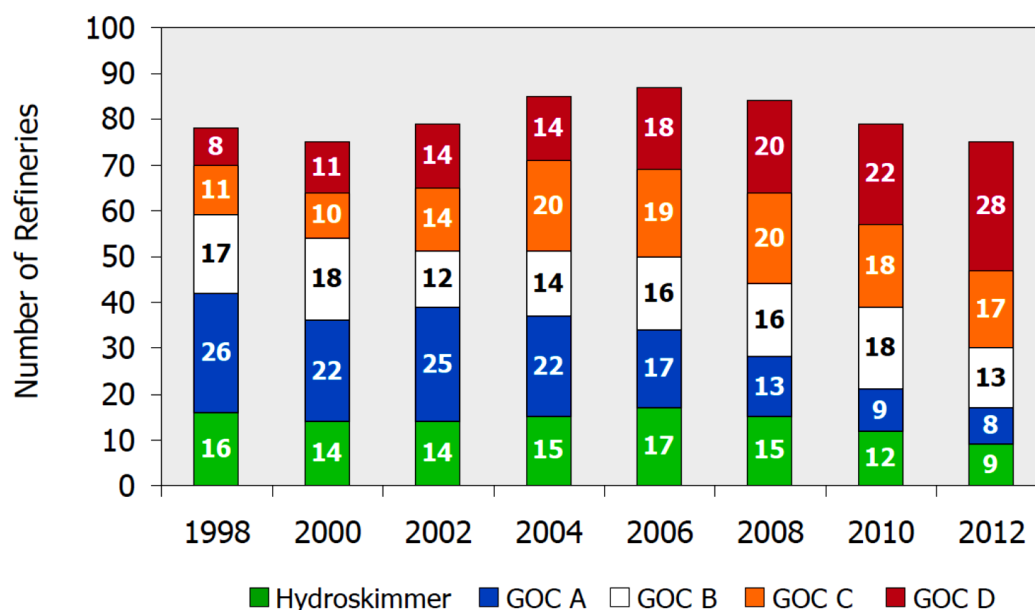
Figure 2.3.12: Development of complexity groups, 1998–2012
Source: Solomon Associates (2014).

Most complex refineries tend to specialise in the heaviest crudes

We also observe that the more complex refineries (GOC C and D) tend to process a slightly heavier mix of crudes than the less complex ones (Hydroskimming and GOC A and B) as can be seen in Figure 2.3.26 and Figure 2.3.27 in the further analysis below.

Judging from the average number, the increase in complexity appears to be mostly associated with an increase in the number of several types of secondary conversion units' capacities[69] (presented as a percentage of crude oil distillation capacity on average in the EU-28 in 1998-2012 in Figure 2.3.13), which are mostly the different types of hydrotreating units (hydrotreating of naphtha, distillate and VGO/residual oils).
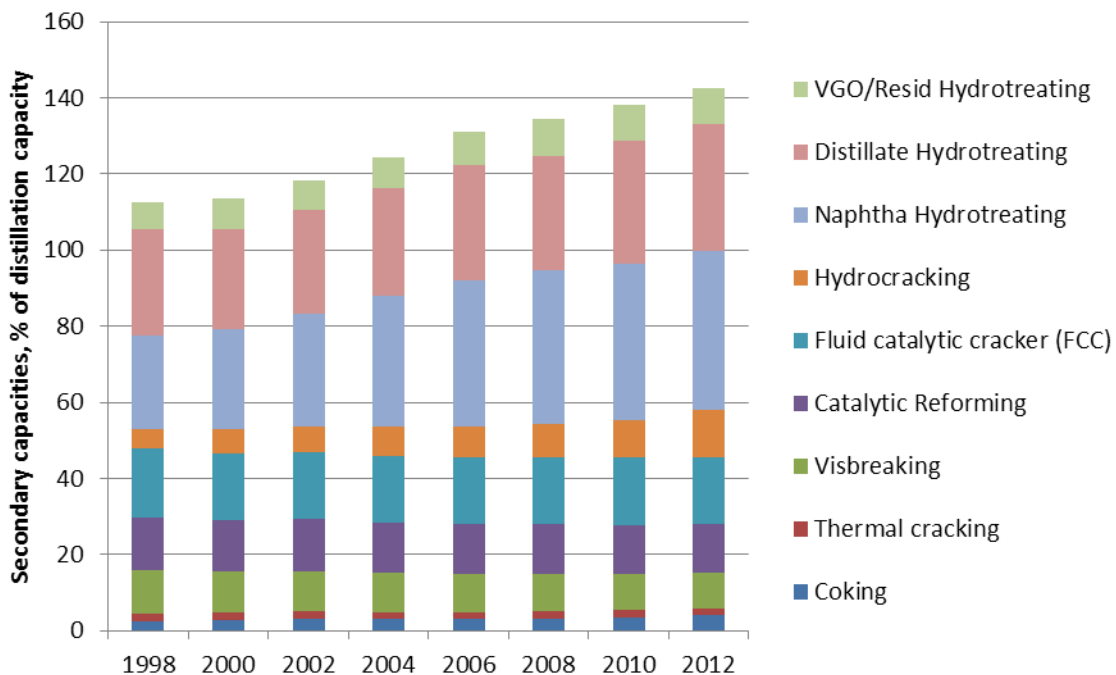
Figure 2.3.13: Secondary conversion units' capacities as a share of crude distillation capacity (in weight), EU average, 1998–2012
Source: Solomon Associates (2014).

Hydrotreating and hydrocracking units appear to be the main drivers of increasing complexity in European refineries

In addition to the growing capacity for secondary conversion, an immediate observation is that the EU refineries are increasingly investing in hydrocracking capacity – namely, it has increased from a 5 % crude distillation capacity in 1998 to almost 13 % in 2012. As a reminder, hydrocracking units produce mainly diesel and jet fuel by cracking lower quality vacuum gasoil feedstock at high pressure and in the presence of hydrogen.

At the same time, fluid catalytic cracking (FCC) capacity remained relatively stable, given that FCC is decreasingly popular with the EU refineries as it is geared towards a high yield of gasoline but only produces a low quality diesel or petrochemical feedstock. The increasing capacity for

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[69] Unit capacity is defined by Solomon as the highest average daily feed rate demonstrated over a continuous 30-day period in the last six years. Average annualised capacities are shown.

hydrotreating of different distillation outputs reflects the effects of higher demand for transportation diesel and tightening of fuel product specifications.
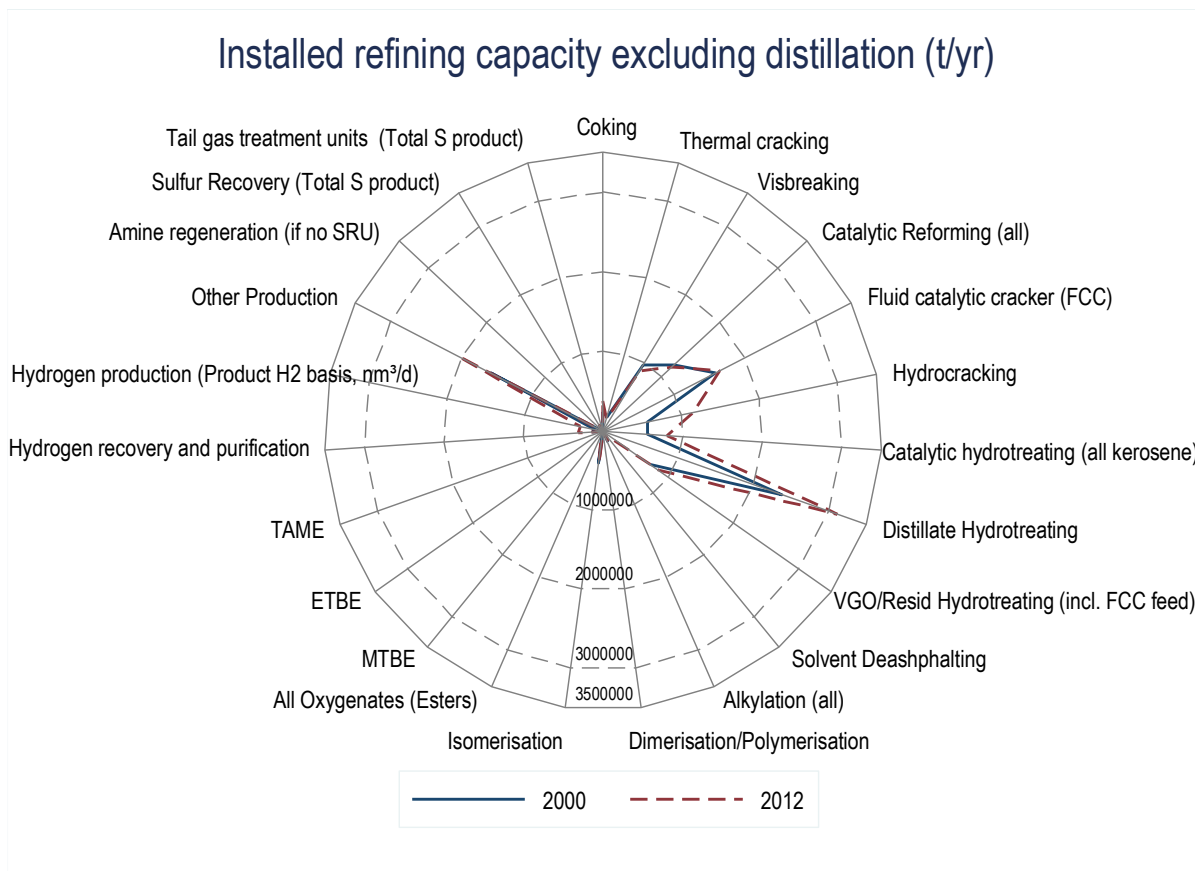
Figure 2.3.14: Detailed breakdown of the main types of installed refining capacity (excluding distillation) on average in the EU-28 in 2000 and 2012
Source: Solomon Associates (2014).

At the level of the refinery as a whole it is still the case that the largest part of the throughput comes from the crude distillation and vacuum distillation units. Further hydrotreating of the distilled products is the next largest part of the installed capacity, which also appears to have grown the most in the past decade (as seen in Figure 2.3.15).

Hydrogen production capacities have also grown in order to satisfy the increased hydrotreating needs

We also observe that the expansion of the hydrotreating capacities goes together with the expansion of capacities devoted to hydrogen production and recovery which are important 'feeders' of these processes.
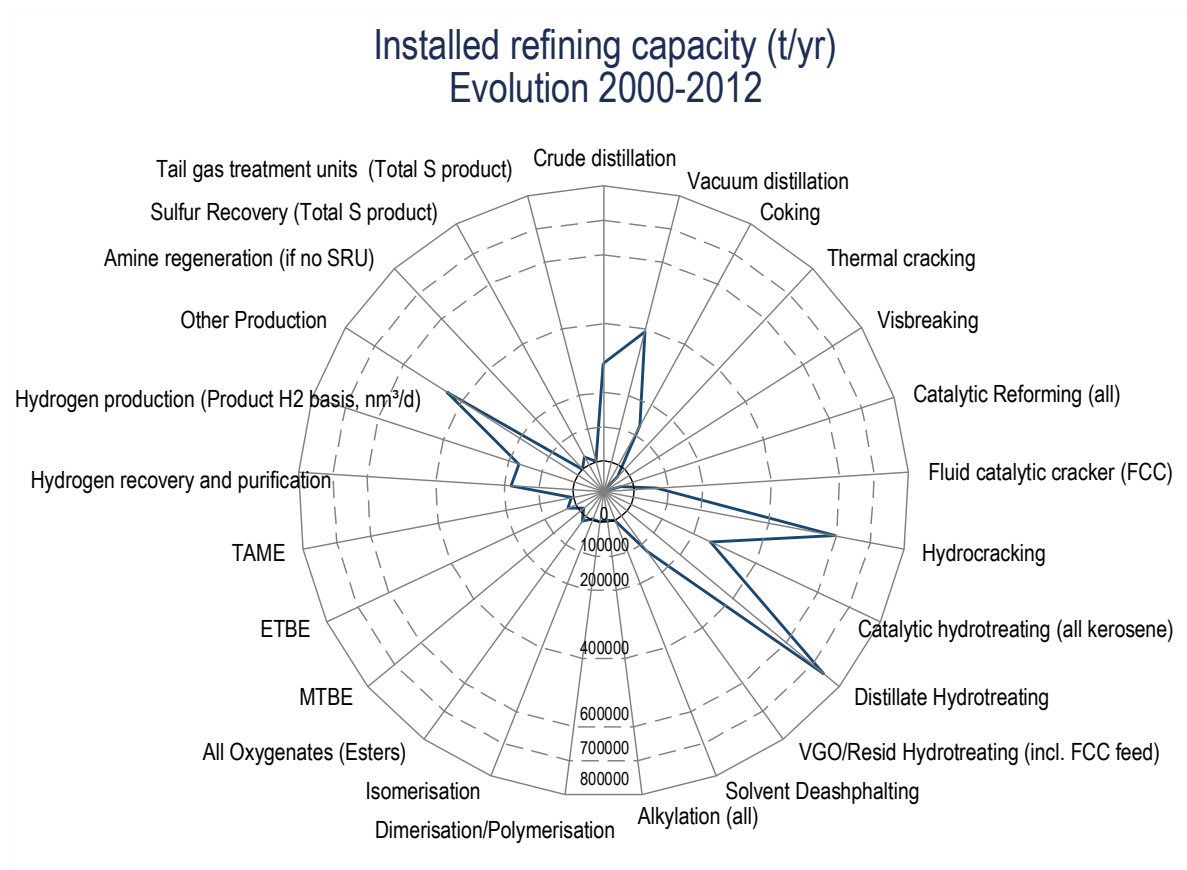
Figure 2.3.15: The average 2000–2012 changes in the installed refining capacity in the EU-28
Source: Solomon Associates (2014).

The energy use intensity in different complexity groups remained stable

At the same time we observe that the above developments in the installed refining capacity have a limited effect on the energy use intensity (expressed as total energy use per tonne of net raw material input and shown in Figure 2.3.16) evolution of refineries in different complexity groups. Regardless of the complexity degree of refineries, their energy use per tonne of net raw material input remained fairly stable during the past decade.

It appears that it is difficult to achieve improvements in energy intensity within a particular complexity group due to technological constraints. It is evident that the energy efficiency consideration has always been one of the points of attention with respect to the refineries' profitability, therefore one can expect that the EU refiners already operate at the frontier of energy efficiency and use the available energy-saving technologies to the full.
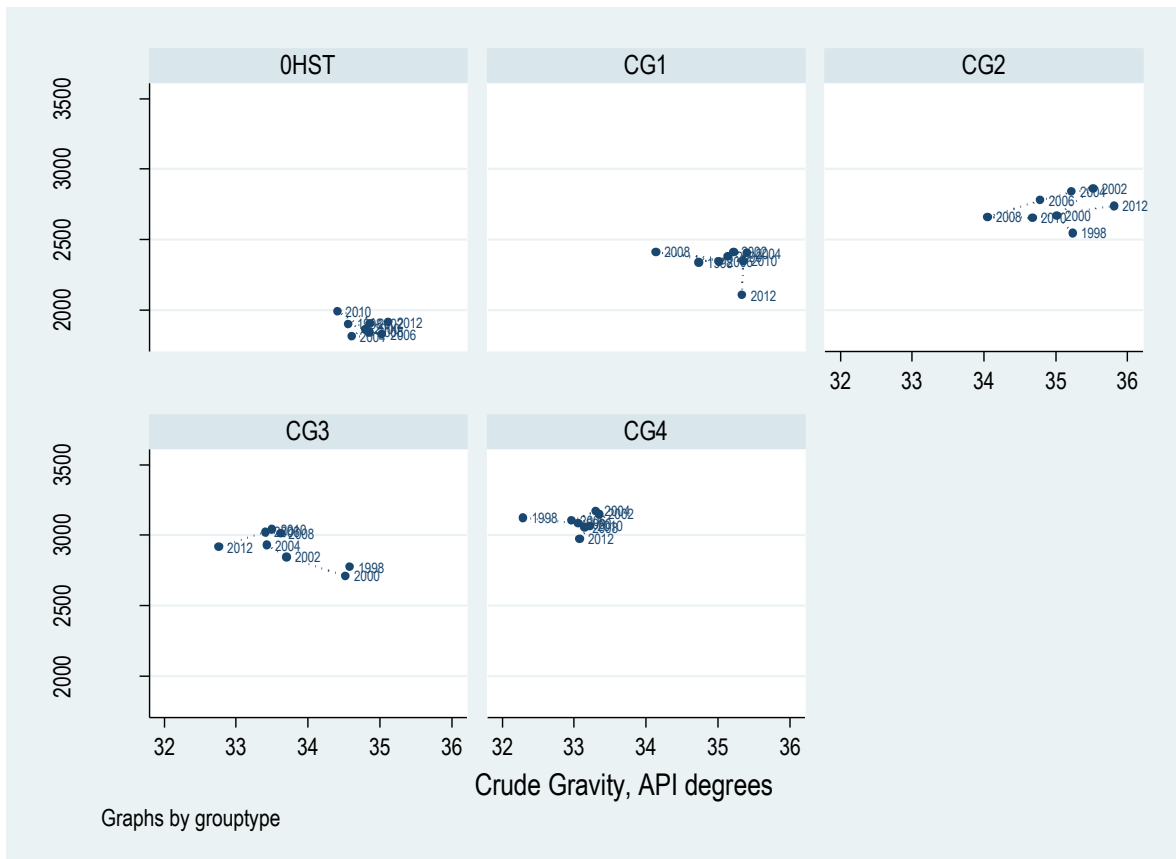
Figure 2.3.16: Energy use per 1000 tonne of net material input at European refineries by complexity groups (a dot corresponds to one annual average observation in the period 1998–2012)
Source: Solomon Associates (2014).

The cluster analysis with respect to the complexity of installed refining capacity has shown that their composition in different European regions is rather diverse and in general no systematic differences have been reliably detected among the regions. It seems that all of them on average have a similar relative composition of different refining capacity types.

The composition of European refining capacities by the type of installed units identifies hydrocracking and coking units as the main drivers of complexity

Furthermore, we analysed the structures of the refining capacity types between different complexity groups using the cluster analysis. This exercise provides us with additional insights into the methodology of the complexity factor variable provided in the Solomon Associates database. Comparing the structure of relative sizes (expressed as a percentage of the crude distillation) of installed capacities, we observe that the systematic difference can be detected between slightly more aggregated complexity groups.

The first group, the hydroskimming and thermal cracking type, is clearly distinguished from two other groups comprised of pairs of complexity types: GOC A and B (cracking type), and GOC C and D (coking and hydrocracking type), as shown in Table 2.3.4.

Table 2.3.4: Installed capacity (in % of CDU) for refinery complexity groups
Source: Solomon Associates (2014).

Hydroskimming and Thermal cracking	
+ Gasoil Conversion A and B, Complexity factor < 8.0	
+ Gasoil Conversion C and D, 8.0 ≤ Complexity factor	

Legend:
- Vacuum distillation
- Visbreaking
- Hydrocracking
- VGO/Resid Hydrotreating
- Coking
- Catalytic Reforming (all)
- Naphtha Hydrotreating
- Thermal cracking
- Fluid catalytic cracker
- Distillate Hydrotreating
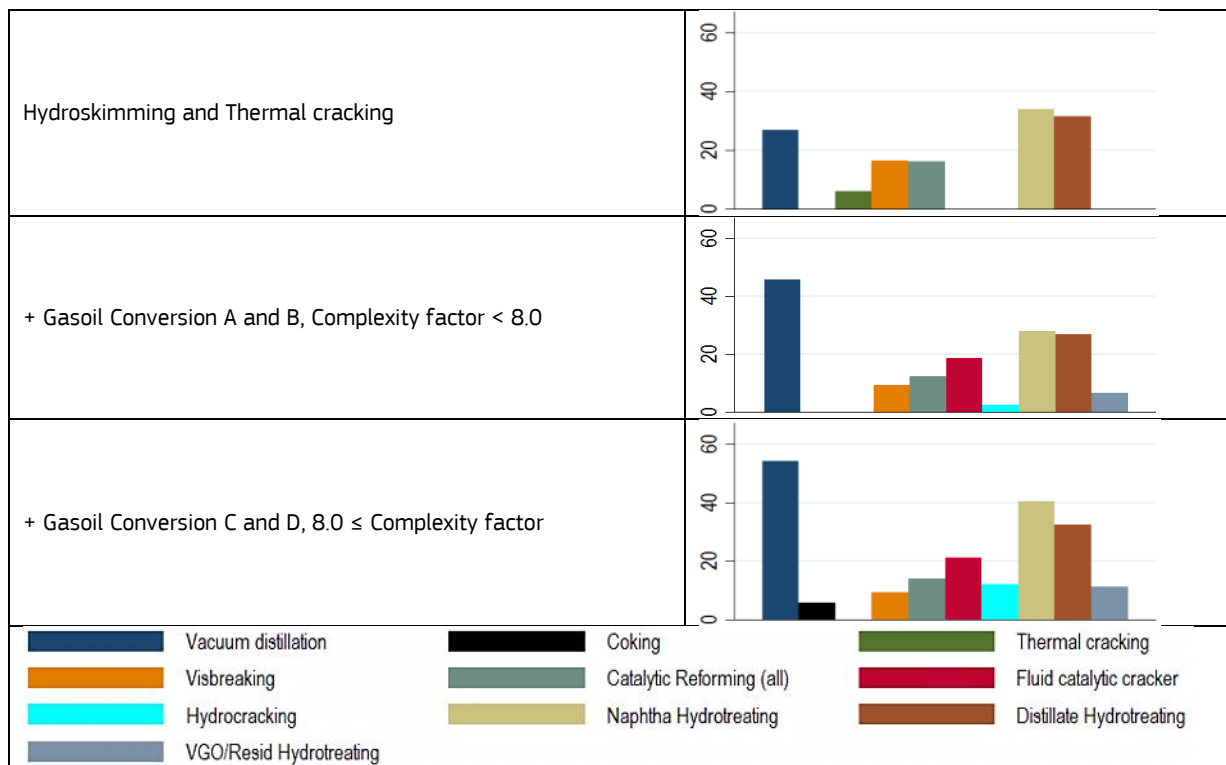
It is observed that, compared to hydroskimming, the higher complexity groups contain larger capacities in vacuum distillation, hydrocracking, VGO and residual hydrotreating, and fluid catalytic cracking. The thermal cracking capacity is inherent only to the hydroskimming complexity group. The main differences between the pairs of GOC A+B and GOC C+D complexity groups come from the differences in the relative sizes of hydrocracking, VGO and residual hydrotreating, and naphtha and distillate hydrotreating, all of which are considerably larger in a more complex cluster of GOC C+D groups. The most complex group is also characterised by the visible presence of coking capacity.

In general, the above results allow us to better understand and assess the effects of investments in different types of refining capacities on their complexity. Nonetheless, it became evident (and will be further discussed later on) that the actual differences in terms of installed refining capacity between the individual GOC complexity groups are not clearly identifiable based on the available data, which calls for caution in using the complexity indicator as a strong criterion for policy targeting or differentiation.

2.3.4. Capital investments

As we discussed before, oil refining is a very capital-intensive industry, where the instalment or upgrade of processing units requires large-scale investments. It is therefore useful to spell out recent patterns in the capital spending of the EU refineries. Figure 2.3.17 presents the breakdown of investments by refineries covered by Solomon's *Fuels Study* into several categories: new process

units, process constraint removal, energy conservation, non-process-related, as well as capital spending related to regulation[70].

Steady growth in all kinds of investments during the pre-crisis period in absolute volume and per tonne of net raw material input
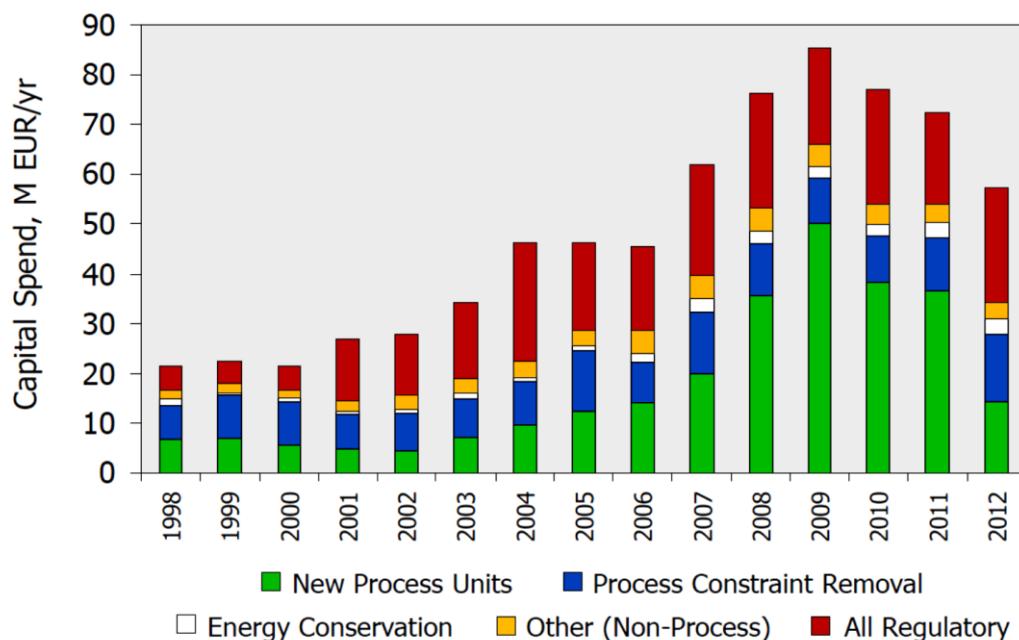
Figure 2.3.17: Capital investment (average per refinery) per year, EU-28, 1998-2012
Source: Solomon Associates (2014).

When looking at the dynamics of capital investments corrected for the activities of the sector (tons of net material inputs), we also detect a tendency for growth, although not that pronounced as in the case of absolute volume (as shown in Figure 2.3.18).

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[70] New units such as hydrocrackers are reported as new process units although they boost the production of clean fuels (10 ppm diesel).
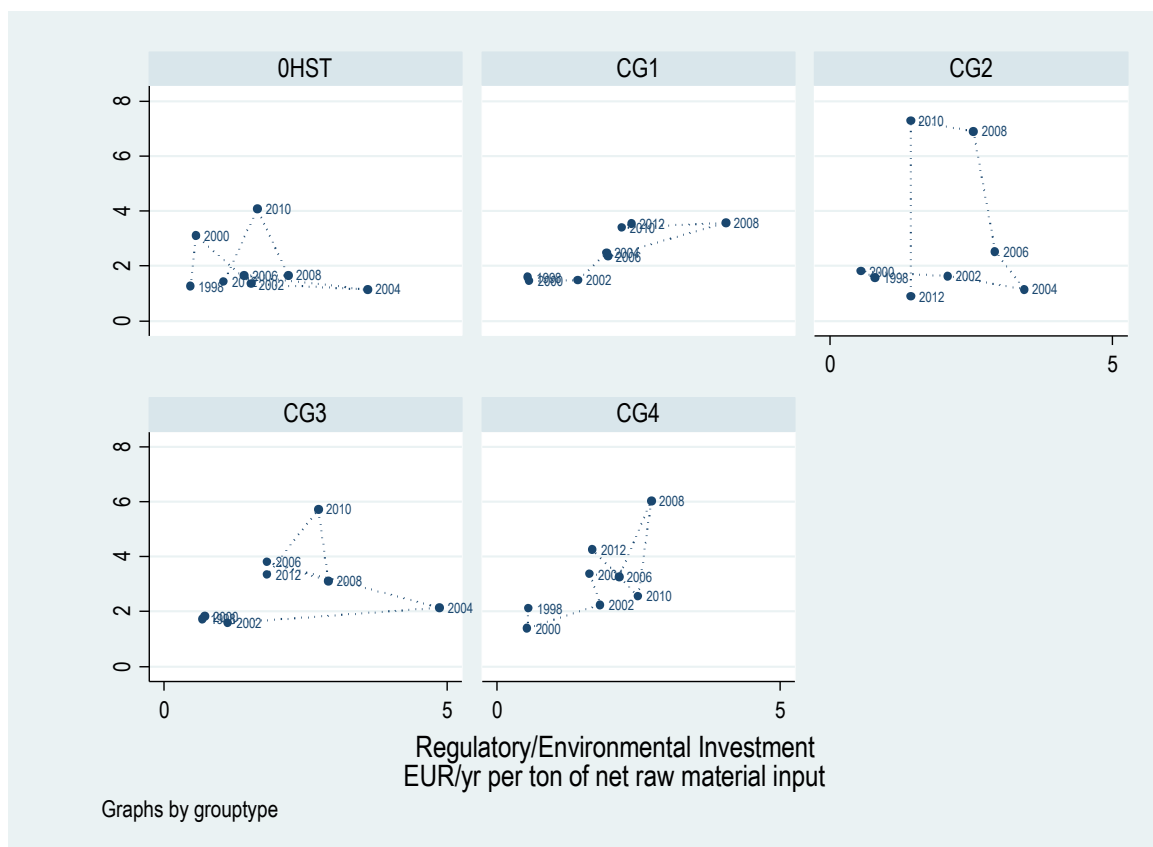
Figure 2.3.18: Time evolution of non-regulatory (including new process units) and regulatory/environmental investments (a dot in the graph corresponds to one annual average observation in the period 1998-2012)
Source: Solomon Associates (2014).

As the overall capacity of the EU refining sector did not increase over the period considered, one can conclude that growing capital investment in the periods before the 2008-2009 economic crisis, especially in new process units, reflects the upgrade in complexity of the European refineries. Also, given the fact that the investment in new hydrocracking capacity is placed in the category of new process units, the profit improvement investment can have a certain effect on fuel quality as well.

Increasing share of regulatory/environmental investments at the backdrop of declining non-regulatory investment in the aftermath of the economic crisis

At the same time, it is evident that regulation-related investments form a substantial part of the overall capital spending; they have also increased significantly over the years considered. The latter can be further broken down into the following categories: those associated with emissions and effluent (such as atmospheric emissions and waste water treatment, as well as handling and treatment of hazardous solid wastes); those associated with modifications for clean fuels (which are further split into investments for meeting gasoline, diesel/gasoil and other fuel specifications); and those associated with safety and other regulations (investments in new safety facilities), as shown in Figure 2.3.20.

Indication of less flexibility to adjust the regulatory/environmental investments compared to non-regulatory ones

In the period before the economic crisis of 2008-2009 the non-regulatory and regulatory investments showed similar tendencies for growth. Yet we observe that after 2009 the non-

regulatory investments declined much faster than the regulatory ones, resulting in a greater relative share of the regulatory investments in the total volume. There is an indication that under changing economic conditions, refineries probably have less freedom in scaling the regulatory investments down compared to the non-regulatory ones (also seen in Figure 2.3.19).
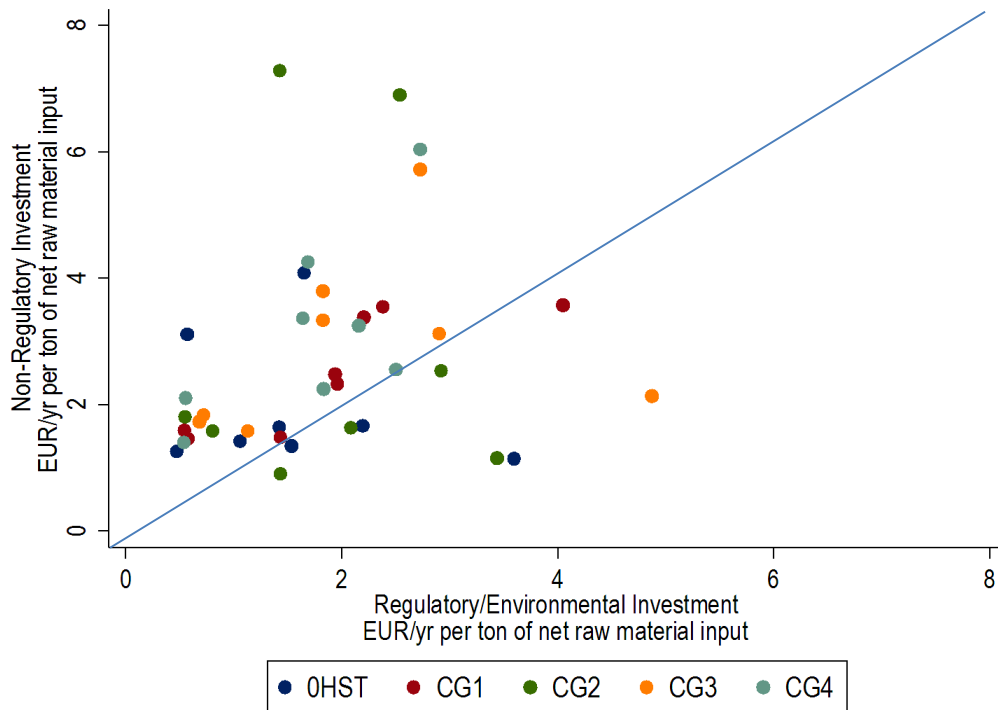
Figure 2.3.19: Average non-regulatory and regulatory/environmental investments by complexity groups (a dot in the graph corresponds to one annual average observation in the period 1998-2012)
Source: Solomon Associates (2014).

All three categories of regulation compliance investments seem to play an (increasingly) important role in the capital spending of the EU refineries. Naturally, their proportions in the overall regulatory investment fluctuate from one year to another, reflecting specific regulatory developments. As we will examine relevant changes in the EU legislation during this period and their potential effects on refineries' spending in detail in the following sections of the report, we are not focusing on them here.
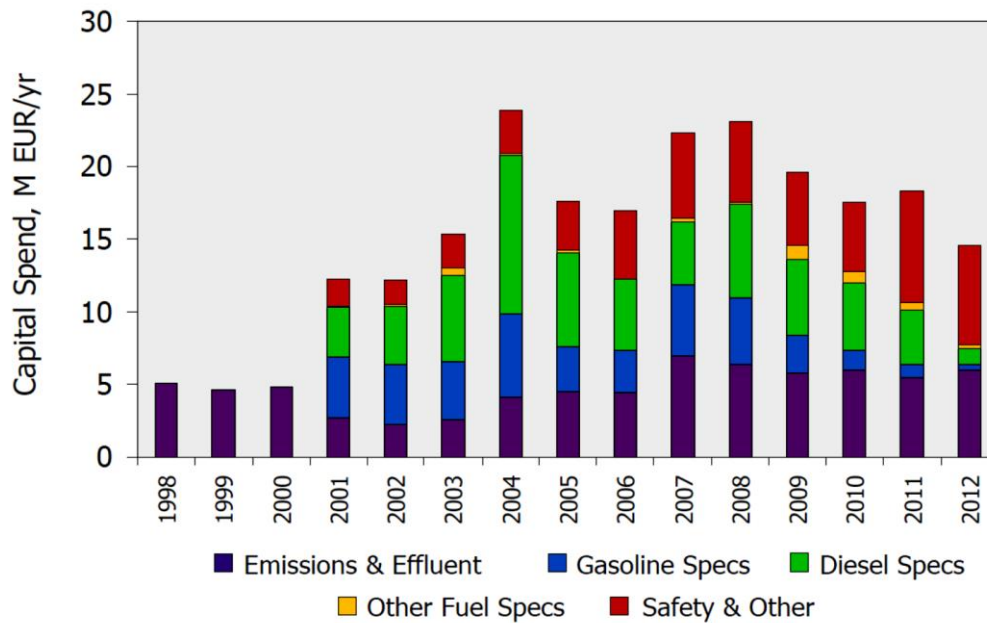
Figure 2.3.20: Regulatory spending breakdown, EU-28, 1998-2012.
Source: Solomon Associates (2014).

2.3.5. Operating costs

As already mentioned, the operating expenditures of a refinery are comprised of variable and fixed costs. The major element in the variable cost category is energy. Figure 2.3.21 illustrates the evolution of the EU refineries' variable and fixed costs in 1998-2012 (the graphs show *average operating costs per refinery*).

A clearly visible increase in both fixed and variable operating expenditures

Observing the time evolution of the fixed and variable operating costs of European refineries per tonne of net material (crude and non-crude) inputs in Figure 2.3.21, we observe a clear tendency for growth during the last decade across all geographic regions.

Variable operating costs

Rather stable levels of energy consumption with an increasing share of gaseous fuels

It is immediately observable that average energy costs have been steadily increasing, reflecting the increase in fuel prices (Figure 2.3.22).
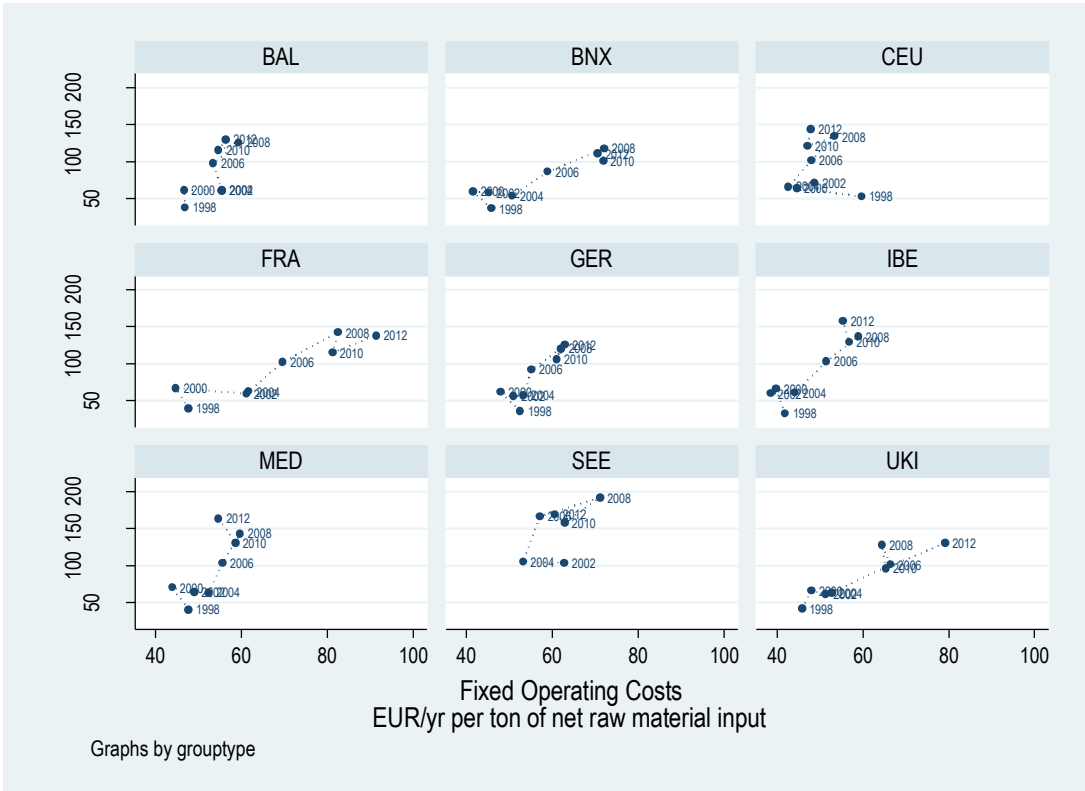
Figure 2.3.21: Evolution of fixed and variable operating costs of European refineries (a dot in the graph corresponds to one annual average observation in the period 1998–2012)
Source: Solomon Associates (2014).
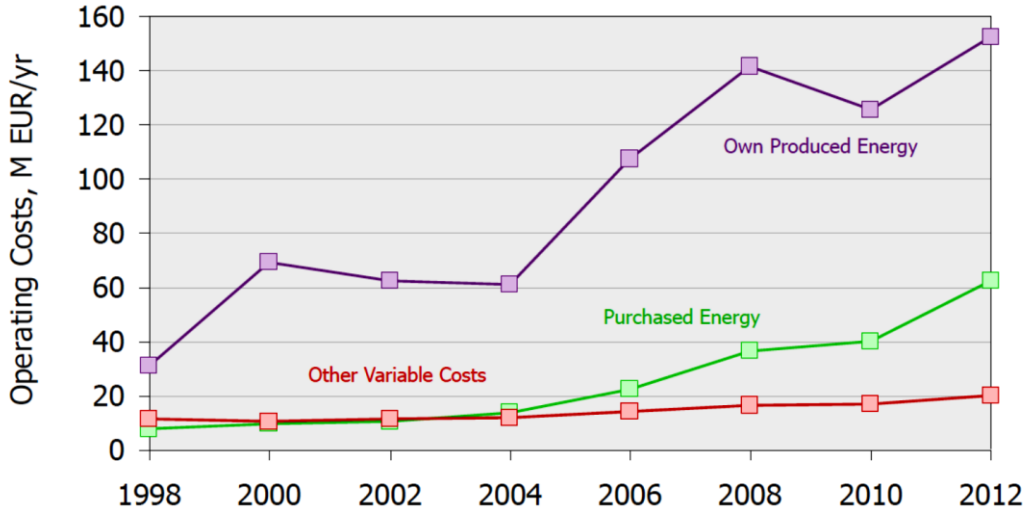
Figure 2.3.22: Variable operating expenses per refinery, EU-28, 1998–2012
Source: Solomon Associates (2014).

In fact, energy expenditure reached 60-70 % of total operating costs in 2012. The share of externally purchased energy (mainly natural gas and electricity) in total operating costs has grown from 7 % in 1998 to 18 % in 2012, displacing own produced energy[71] (as shown in Figure 2.3.23).
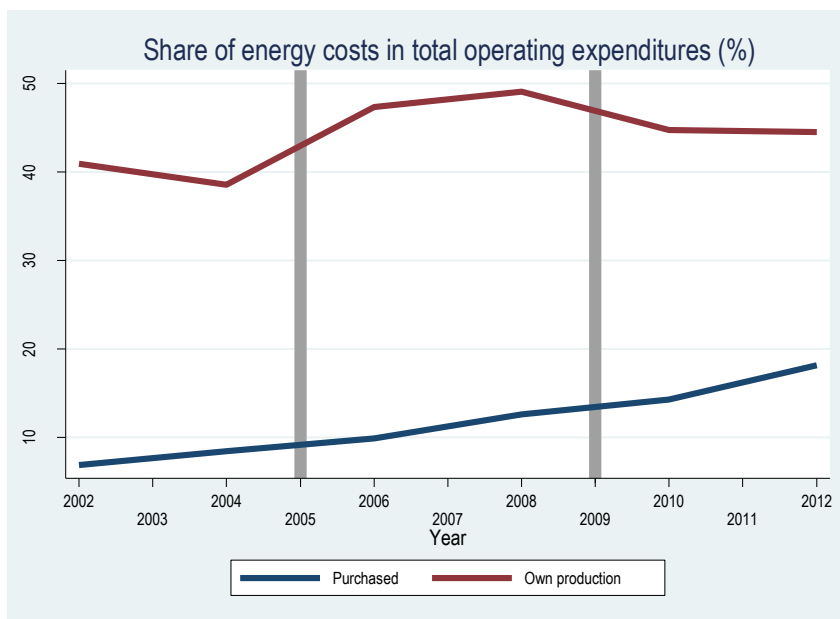
Figure 2.3.23: Share of energy costs in total operating expenditures of EU-28 refineries
Source: Solomon Associates (2014)
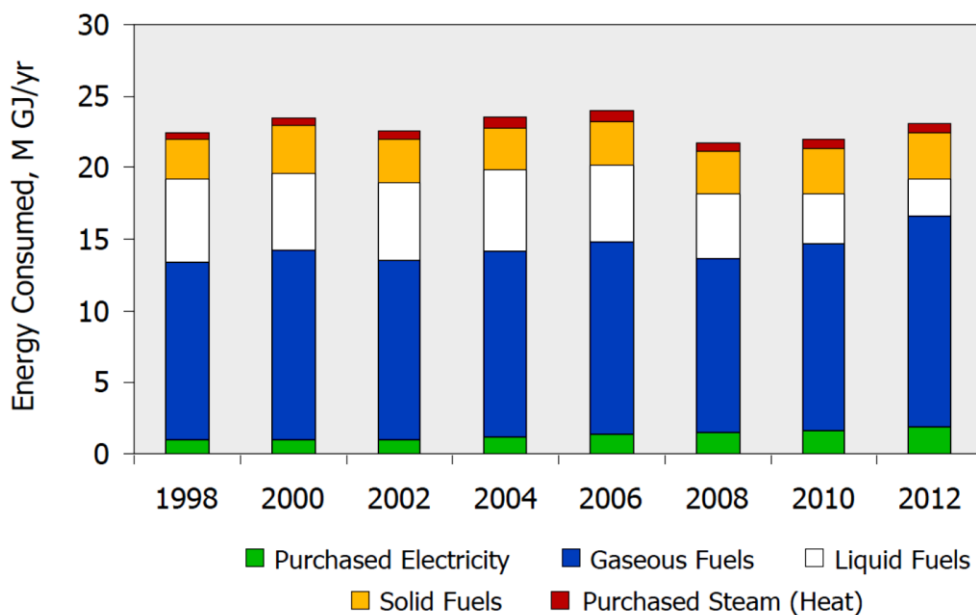
Figure 2.3.24: Refinery energy consumed per refinery, EU-28, 1998-2012
Source: Solomon Associates (2014).

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[71] Refinery-produced fuel is priced to reflect market values.

Figure 2.3.24 provides a breakdown of energy expenses for different types of fuel: heat (steam), electricity, natural/fuel gas, liquid and solid fuels. The main observation here is that the consumption of gaseous fuels has increased at the expense of liquid fuels which are also subjected to more air pollutant emissions regulation.

As the gaseous fuels and electricity constitute the largest and growing part of the EU refineries' energy consumption, we further examine the price dynamics for these two energy sources. Figure 2.3.25 presents a comparison of the end-user prices for gas and electricity in the EU and the US over recent years. It can be observed that, starting from 2006, the gas prices in the US have been consistently lower than those in the EU and the electricity prices have been lower in the US for even longer than that. Furthermore, the relative difference in price level and, thus, the US' energy price advantage have been growing.

The weight of energy costs in the total expenditures structure of European refineries appears to be have increased in the past decade, accompanied by the increased energy price advantage of the refineries in the US
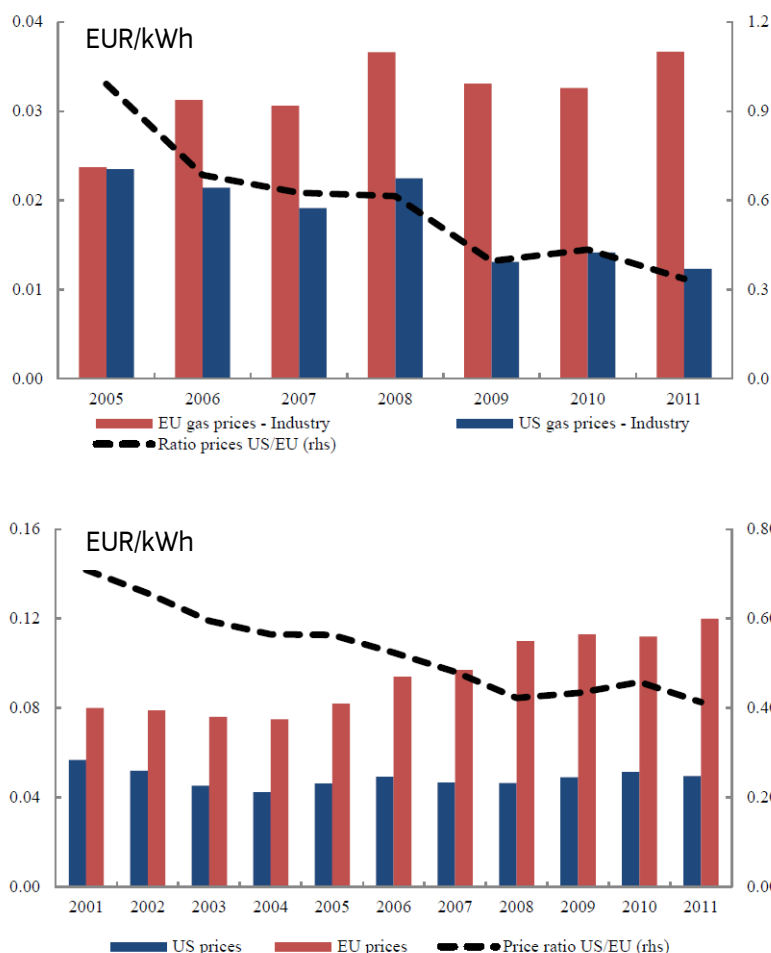
Figure 2.3.25: Evolution of end-user gas (above) and electricity (below) prices in the EU and the US
Source: IEA.

Therefore, observing the growing share of gas and electricity in the refineries' energy consumption mix, the stable level of total energy consumed, and the tendency for increasing energy intensity

with the growing complexity of refineries (discussed below), one can talk about the increasing pressure on the industry's profitability due to increasing total energy costs.

Growing complexity is accompanied by an increase in energy use per tonne of processed crude and other inputs

Following the logic of growing complexity and sophistication, one could expect that the energy intensity of refineries would grow with their complexity as more and deeper processing units require more energy to further process the residual fuels coming from distillation. A closer look at the data in Figure 2.3.26 supports this statement. With growing complexity, the refineries tend to use more energy per tonne of processed crude.

The energy use per tonne of processed crude appears to be stronger (positively) associated with the refineries complexity than with the crude sulphur content or the crude gravity

Examining the figures on the energy use intensities in different complexity groups and their relationship with the API gravity (i.e. density) of processed crudes and their sulphur content, we observed above that, per tonne of processed crude, the corresponding energy use intensity grows with the growing complexity of refineries. At the same time it is not clearly evident that there is a link between the crude API gravity and the energy intensity. We only see that the most complex refineries (GOC C and D) tend to process the heaviest crudes, consuming more energy. Less complex refineries (hydroskimming and GOC A and B) process on average lighter crudes with increasing energy intensity as the complexity increases.
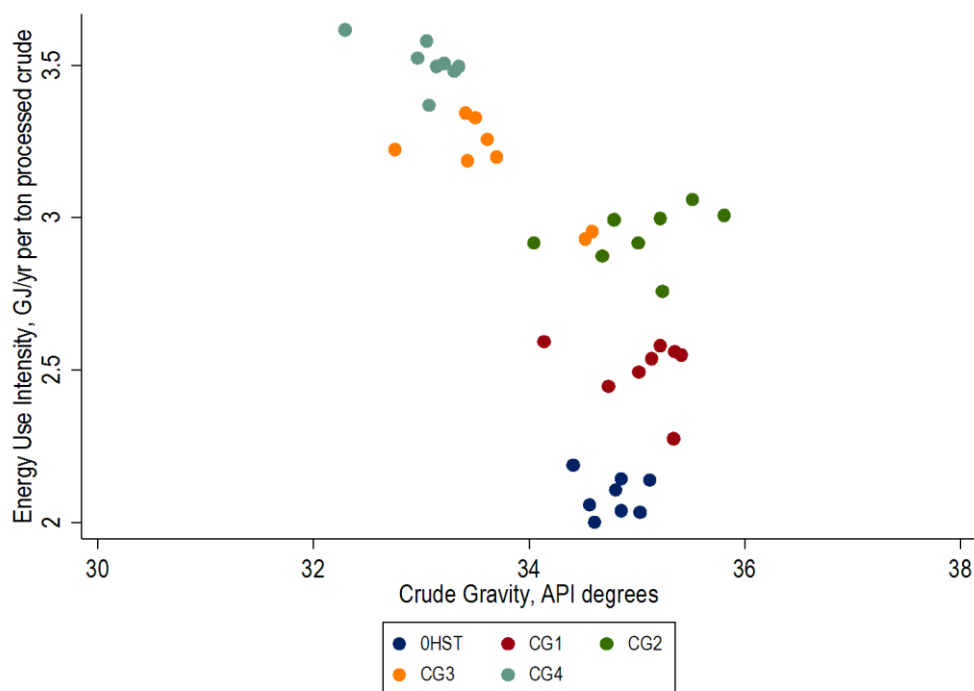
Figure 2.3.26: Average intensity of energy use and API gravity of processed crude at European refineries by complexity group (a dot in the graph corresponds to one annual average observation in the period 1998-2012). *Source: Solomon Associates (2014).*

Similarly, when looking at the relationship between the energy intensity per tonne of crude processed and the average sulphur content, the complexity groups GOC C and D appear to consume more energy processing sourer crude, but the other three less complex groups exhibit different energy intensities while still processing the crude with a similar sulphur content.
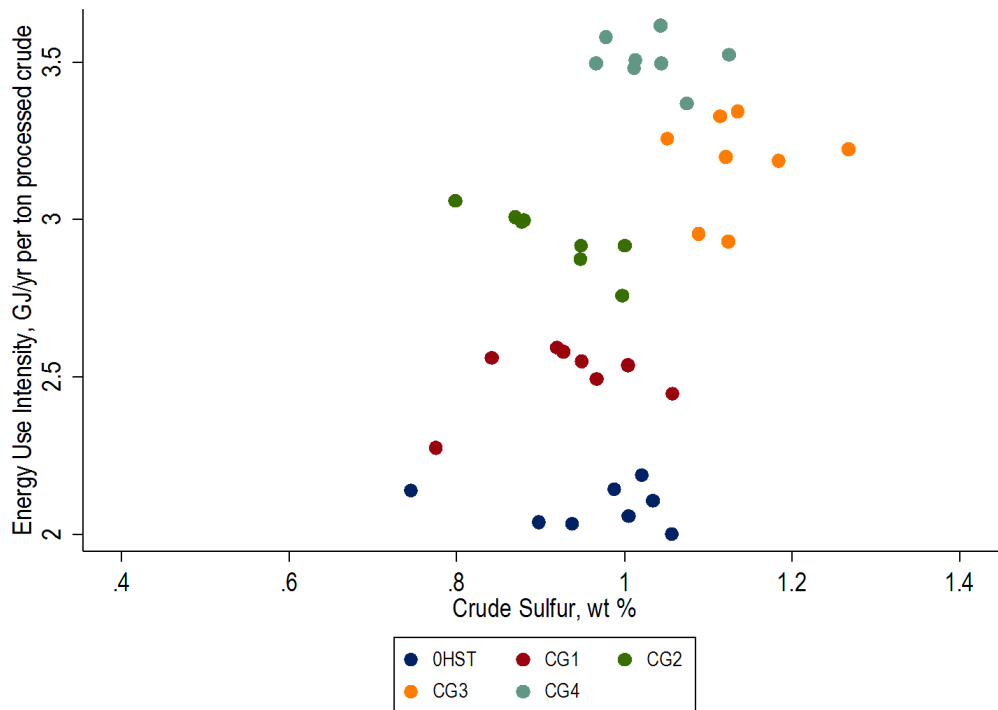
Figure 2.3.27: Average intensity of energy use and sulphur content of processed crude at European refineries by complexity group (a dot in the graph corresponds to one annual average observation in the period 1998-2012)
Source: Solomon Associates (2014).

The cluster analysis based on Solomon's *Fuels Study* data has revealed some consistent similarities and differences across the EU regions with respect to the combinations of different types of energy fuels used for refining activities. We analysed the emerging patterns in the way refineries use the main energy sources for their production (results shown in Table 2.3.5 and Table 2.3.6). These energy sources are:

- Gaseous Fuels (refinery fuel gas, natural gas, low calorific value gas, ethane, propane, and butane);
- Liquid fuels (naphtha/gasoline. Distillate fuels and residual fuels);
- Solid fuels (coal or marketable coke, calciner coke, coke burned, coke on FCC);
- Purchased Electricity;
- Purchased Steam (or Heat).

Table 2.3.5: Refinery region clustering by energy source use during 2000-2012

Source: Solomon Associates (2014).

Region	Pie chart
BAL – Denmark, Sweden, Finland, Lithuania	69.93%, 5.50%, 10.00%, 11.81%, 2.76%
GER – Germany FRA – France CEU – Austria, Czech Republic, Hungary, Poland, Slovakia MED – Italy, Greece SEE – Bulgaria, Romania, Croatia	52.10%, 23.99%, 12.80%, 7.59%, 3.51%
UKI – UK, Ireland BNX – Belgium, Netherlands	60.14%, 12.87%, 19.87%, 4.44%, 2.68%
IBE – Spain, Portugal	45.41%, 40.30%, 10.25%, 2.56%, 1.48%

Legend:
- Gaseous Fuels (fuel, natural and low calorific gas, ethane, propane, and butane)
- Liquid fuels (naphtha/gasoline. Distillate fuels and residual fuels)
- Solid fuels (coal or marketable coke, calciner coke, coke burned, coke on FCC)
- Purchased Electricity
- Purchased Steam (or Heat)

The extent of use and, therefore, the ease of access to gaseous and liquid fuels are the main distinguishing factors for clustering the regions according to their energy use

Looking at the results of the cluster analysis, we observe the emergence of four distinct patterns in energy use among refineries in different European regions. Refineries in Baltic states (Denmark,

Sweden, Finland and Lithuania) rely heavily on the use of gaseous fuels. At the other end of the spectrum, in Portugal and Spain we observe a very high proportion of liquid fuels as the main energy source for refineries.

In the UK, Ireland, Belgium and the Netherlands the balance of energy sources strongly favours gaseous fuels, but the countries in this cluster also show the highest share of purchased electricity in their energy balance. In a large cluster of regions in central and south-eastern Europe, and Germany, France, Italy and Greece, more than half of the energy sources mix consists of gaseous fuels with a large share of liquid fuels.

In general, in all clusters the share of gaseous fuels in the total net energy purchase balance exceeds or is close to 50 %. When considering the energy source mixes of refineries according to their complexity level (Table 2.3.6), the only emerging pattern comes from the fact that the more complex refineries (GOC types A, B, C, and D) use a considerable share of solid fuel, which is intuitive, as it mostly comes in the form of FCC coke.

Table 2.3.6: Refinery complexity group clustering by net energy sources use
Source: Solomon Associates (2014).

Hydroskimming and Thermal	1.89% 9.35% 27.56% 61.20%
+ Gasoil Conversion A, B, C, D	2.65% 5.95% 15.41% 20.30% 55.68%

- Gaseous Fuels (fuel, natural and low calorific gas, ethane, propane, and butane)
- Liquid fuels (naphtha/gasoline. Distillate fuels and residual fuels)
- Solid fuels (coal or marketable coke, calciner coke, coke burned, coke on FCC)
- Purchased Electricity
- Purchased Steam (or Heat)
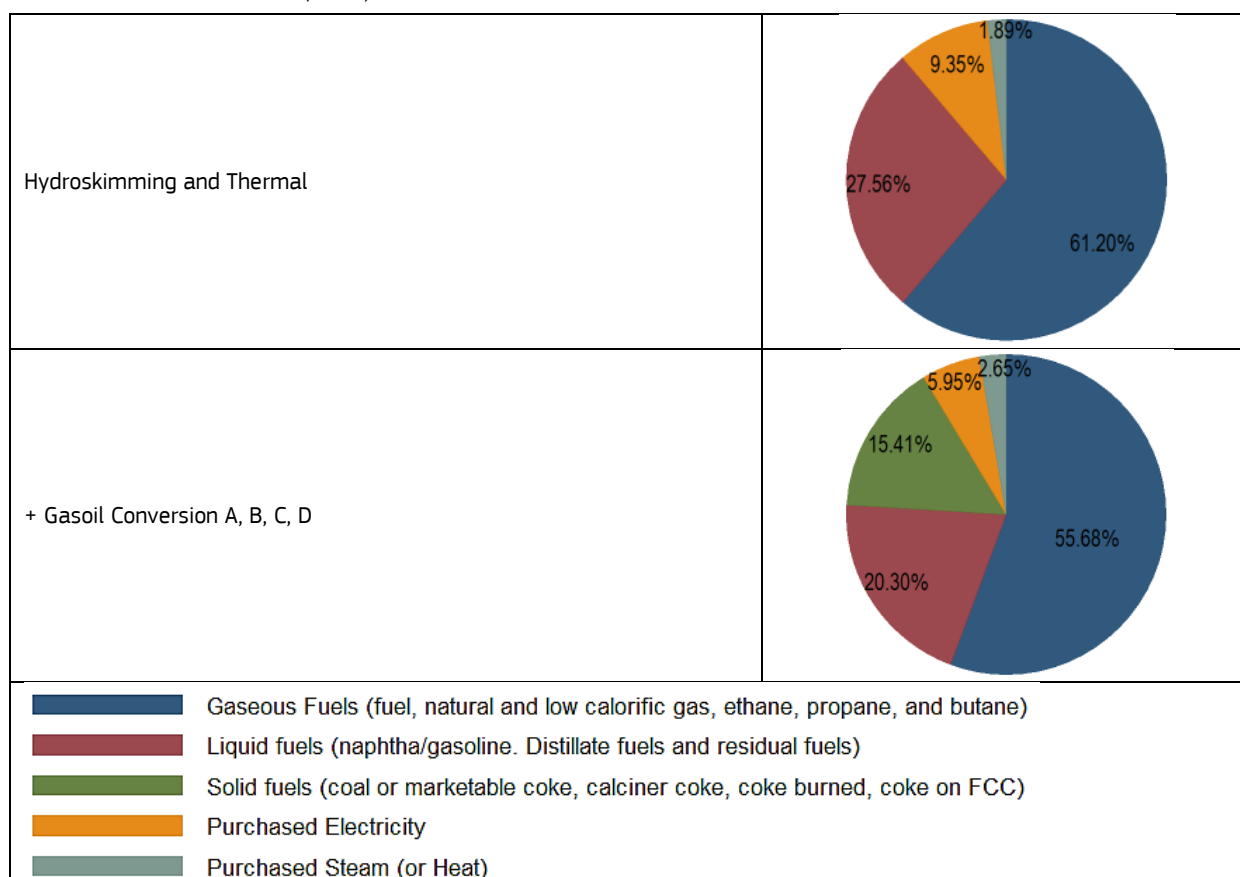
Fixed operating costs

As regards the fixed operating costs of the EU refineries, they have also been steadily increasing over the period in question. The important components in this category are turnaround ('T/A costs'),

which is the term used for the major maintenance shutdown occurring in a refinery once every four to six years[72], and personnel compensation.

On the other hand, within the 'Other fixed costs', an important role is played by such items as non-turnaround maintenance costs (excluding own company labour costs, but including materials, contract maintenance labour expenses, contract maintenance inspection expenses, contract maintenance material) and the non-turnaround maintenance materials. The increase in this type of costs was primarily driven by the growing prices of materials, parts and salaries.
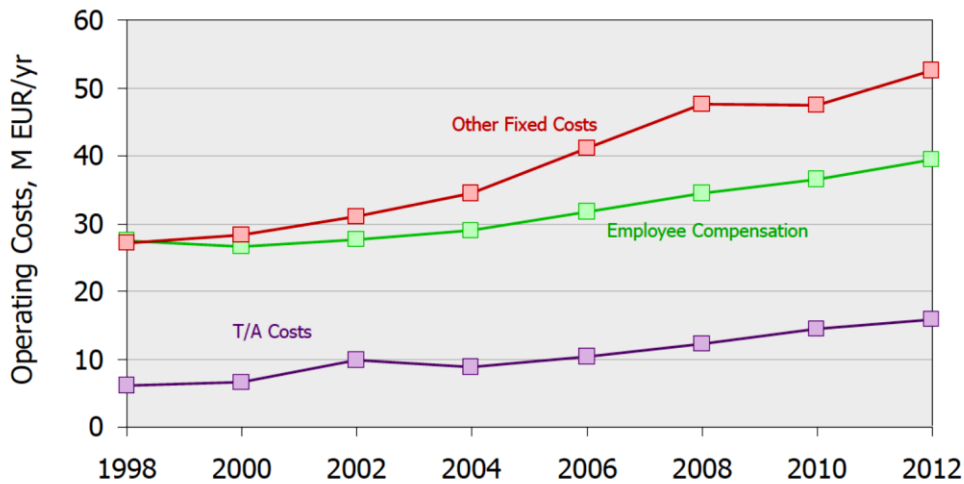
Figure 2.3.28: Fixed operating expenses, EU-28, 1998-2012
Source: Solomon Associates (2014).

In the global setting, the fixed operating costs of the EU refineries seem to be relatively higher than in several other world regions

Figure 2.3.29 and Figure 2.3.30 illustrate how the personnel and energy costs faced by the EU refining sector compare to the rest of the world (all the data is indexed relative to the EU-28 in 2000 = 100). The EU's energy costs are among the highest and definitely much higher than those of its main competitors: the US, Russia and the Middle East. We will discuss the EU's competitive positioning in this respect in the following section of the report.

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[72] T/A costs are annualised in the reporting to avoid spikes in operating costs in each T/A year.
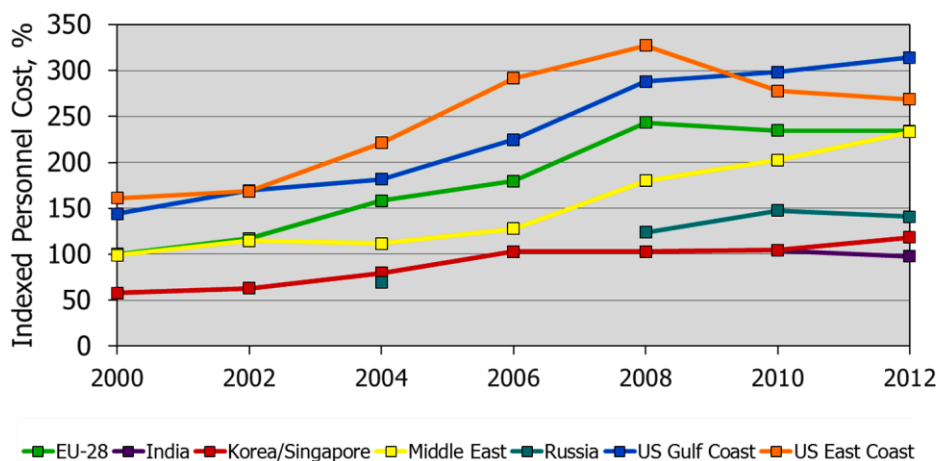
Figure 2.3.29: Indexed personnel costs of refineries in different world regions, 2000–2012
Source: Solomon Associates (2014).
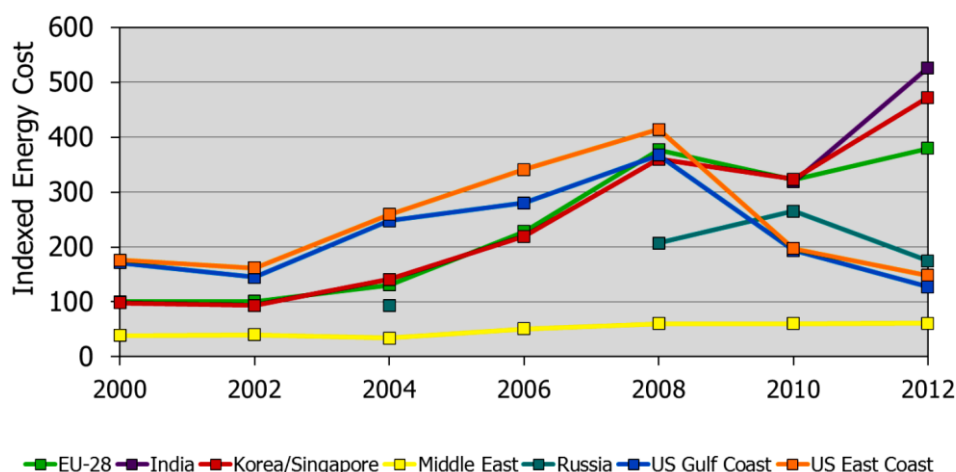
Figure 2.3.30: Indexed energy costs of refineries in different world regions, 2000–2012
Source: Solomon Associates (2014).

2.3.6. Margins and throughputs

The dynamics of the gross refining margins at EU refineries also did not show much change between 2008 and 2012, except for slightly higher volatility. The gross refining margins of hydroskimming remained negative for most of the period. The gross refining margins of cracking refineries were positive, usually falling in December and later recovering at the beginning of the year. Again, it is the more energy-demanding cracking technology that remains more competitive than the basic one.
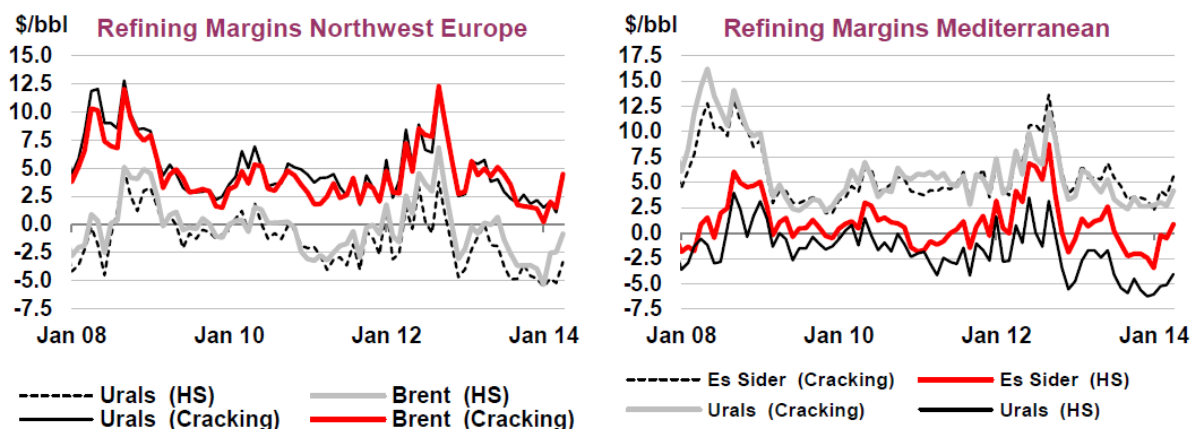
Figure 2.3.31: Evolution of European gross refining margins
Source: IEA.
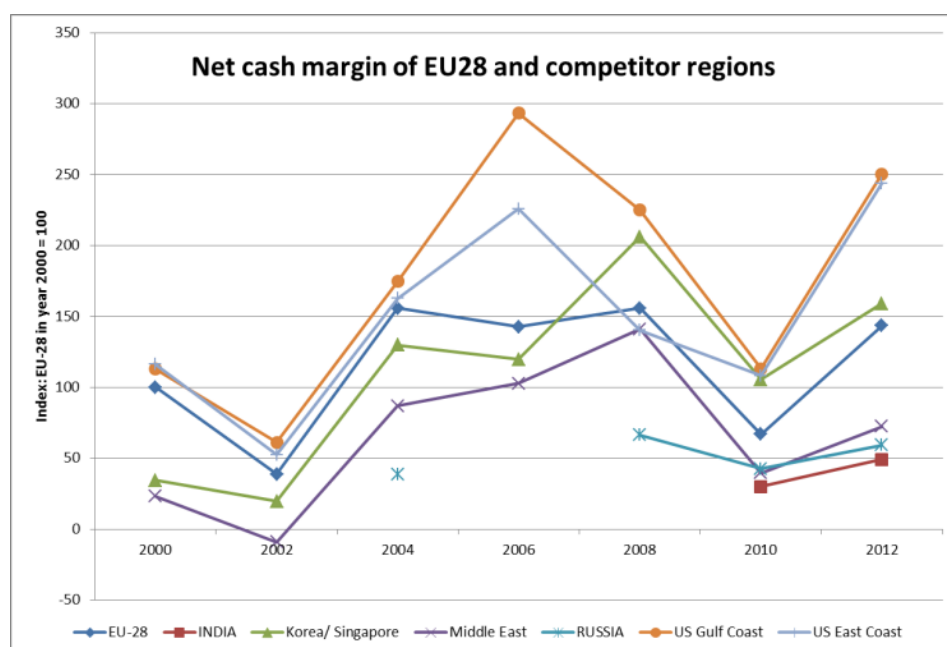
Figure 2.3.32: Evolution of net cash margins of European refineries
Source: Solomon Associates (2014).

The margins indicators for the EU refineries show positive general dynamics in the period between 2000 and 2012, but the EU appears to lag behind its main international competitors

The evolution of the net cash margins[73] in the EU-28 refining sector has been fairly volatile over the 2000-2012 period, ending about 50 % higher in 2012[74]. The dynamics of the US and the EU

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[73] Definition: Net Cash Margin = Gross Margin – Personnel Costs – Energy Costs – Other Operating Costs.

[74] These figures present the averages for the companies participating in the Solomon Associates survey. It is possible that the figures can be biased upwards because some companies could choose not to participate in the survey in their 'bad' years. Yet it is also rational to expect that such a bias would be consistently present in all regions, thus making it possible to make a meaningful comparison of the presented indices.

were rather similar in terms of increases and declines, but the US net margin in 2012 finished at much higher levels (150 % above the 2000 level). Compared to refining in other parts of the world, refining in the EU suffers from some of the highest operating costs, one component of which, energy costs, is also among the highest in the world. The further analyses in this report show that the net cash margins in recent years for EU refiners have been lower than for refiners in the US and South-East Asia mostly as a consequence of the high operating costs.

The downward tendencies in crude throughputs at EU refineries appear to persist against the backdrop of a continuously improving situation in the other world regions, e.g. the US
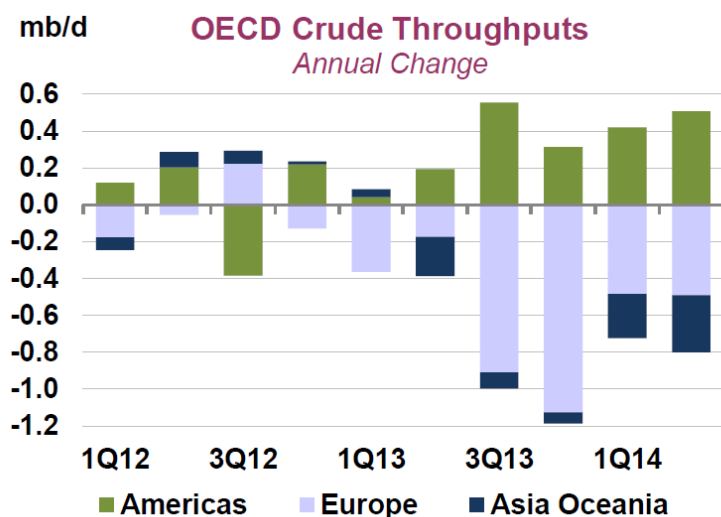
Figure 2.3.33: Most recent quarterly changes in the OECD crude throughputs
Source: IEA.

Based on the evidence examined above, we can conclude that the competitive position of the EU refinery industry has been under pressure in the last decade and shows signs of deterioration on several points (such as cost structure, trade imbalances, and capacity utilisation). The downward tendencies appear to persist, as can be seen from the declining crude throughputs registered in Europe in 9 out of the past 10 quarters (with the second quarter of 2014 the most recent one). At the same time the throughputs in some other parts of the world, for example in the US, have been growing.

The refining capacity in the EU remains substantially underutilised, also in comparison to competing regions

EU refinery utilizations, 2012-2013, [%]
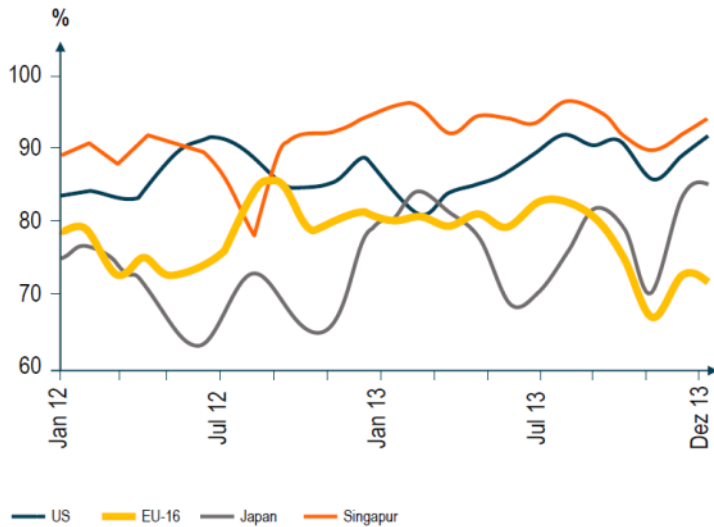
Figure 2.3.34: Refineries utilisation in the EU and competitor regions in 2012–2013
Source: Roland Berger.

It is also observed in Figure 2.3.34 that recently the EU refineries have been run with visibly lower utilisation rates than their counterparts in the US and Asia. There is, nonetheless, a difference between the situations in the EU and Asian regions. While in the EU the decreasing throughputs go together with the low utilisation rates, in Asia the decreasing throughputs take place against a backdrop of higher capacity utilisation than in Europe.
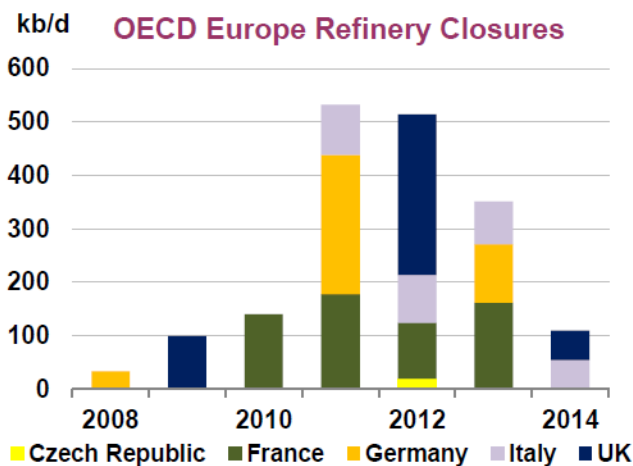
Figure 2.3.35: Closures of refining capacity in OECD Europe
Source: IEA (2014).

Despite the recent wave of refinery closures and capacity reductions, there is an indication that the process of refining capacity rationalisation will persist in the near future

In the period from 2007 to 2013, according to the IEA (2014), 13 refineries with a total capacity of 1.7 mbbl/d in the EU were shut down. In particular, the closed refining capacity in France amounted

to 585 kbbl/d, in Germany 400 kbbl/d, in UK 455 kbbl/d, and in Italy 320 kbbl/d. At the same time, at many other refineries the utilisation rate has decreased.

This gives us an indication that in the near future we are more likely to see further downsizing of the refining activities in Europe, while the expansion tendencies in other regions are likely to persist.

2.3.7. Recent developments in refined product markets

To identify the similarities in refining product mixes among EU regions, in the very wide spectrum of refinery products, we focus on the following set of main outputs:

- Gasoline Unleaded;
- Jet fuels and Kerosene;
- Diesel Transportation Fuel;
- Light Heating Oil/Light Gas Oil;
- Marine Diesel and Marine Bunker;
- Residual Fuel;
- Naphtha;
- Chemical Plant Feed;
- VGO;
- Refinery Produced Fuel (consumed and sold;
- All other outputs.

Marked trend towards the dieselisation of road transport and a greater demand for jet fuel against the backdrop of a declining general demand for fuels
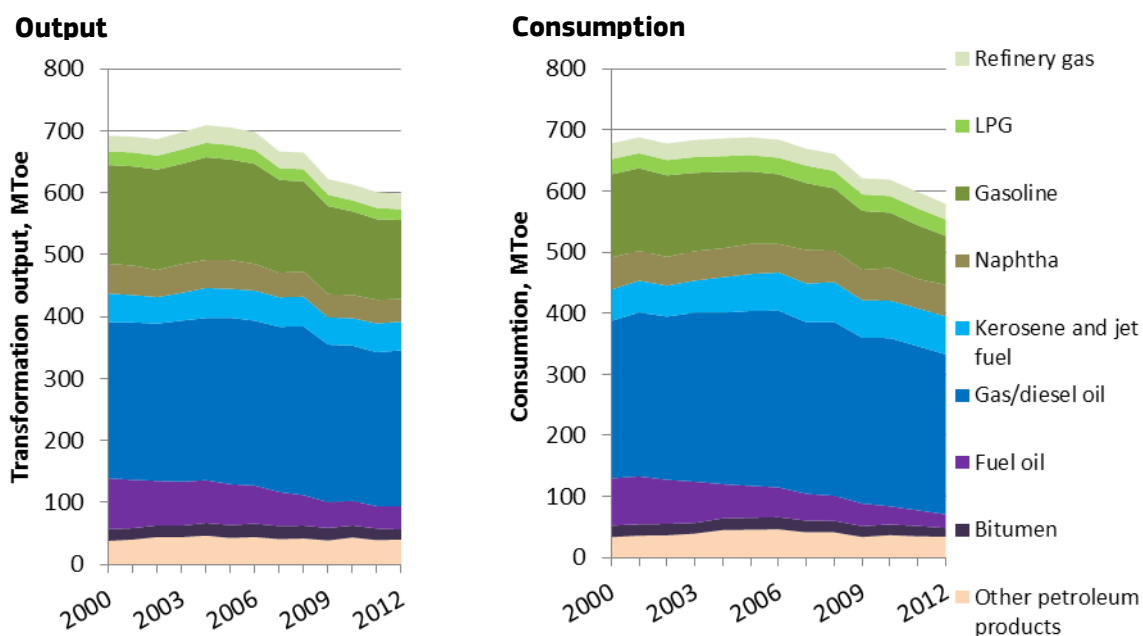
Figure 2.3.36: Transformation output from refineries and domestic consumption of refined petroleum products in the EU, 2000-2012 (MToe)
Source: IPTS on the basis of Eurostat database [nrg_102a].
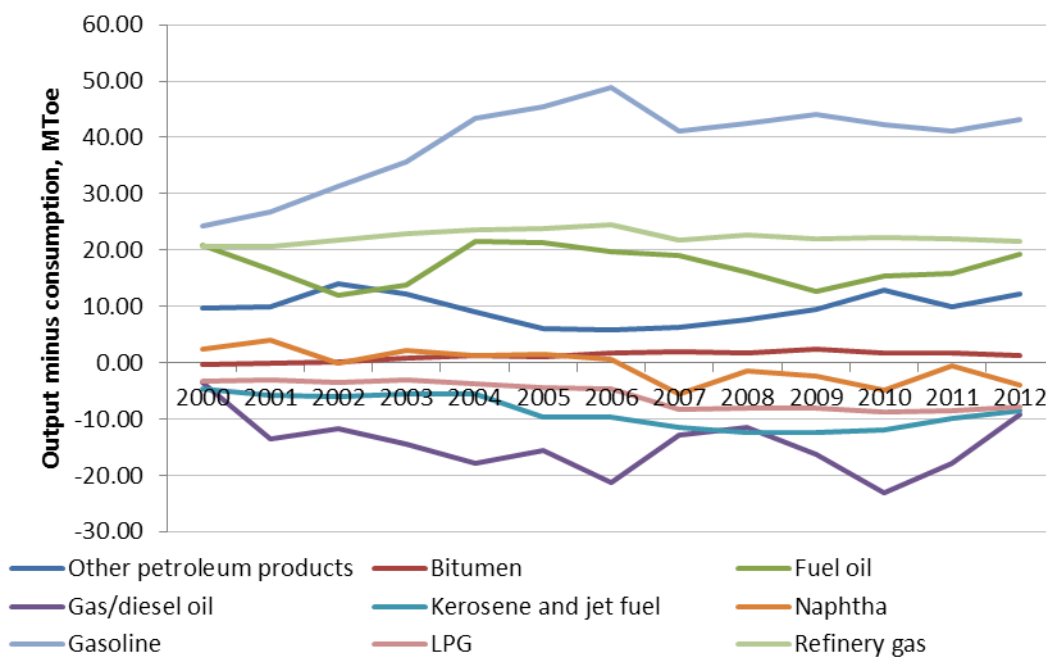
Figure 2.3.37. Difference between transformation output and domestic consumption of refined petroleum products in the EU, 2000–2012 (MToe)
Source: IPTS on the basis of Eurostat database [nrg_102a].

In recent years, one of the most important characteristics of global demand for petroleum products has been *dieselisation*[75], contributing both to the overall decline in demand and to a structural shift from gasoline to diesel as a motor fuel. In addition, in line with a significant increase in air transport activities, consumption of jet fuel and kerosene has been growing recently. The EU economy closely follows these general tendencies. The overall domestic consumption of oil products in the EU fell from 712 Mt/year (14.9 million barrels per day) in 2003 to 605 Mt/year (12.8 million barrels per day) in 2013. In 2003, the shares of light distillates (gasoline and naphtha) and middle distillates (jet fuel, kerosene, diesel, heating oil and gas oil) in total consumption were 25.6 % and 44.5 %, while in 2013 they shifted to 21.6 % and 52.7 %, respectively (BP, 2014).

Persistent imbalance between domestic production and consumption of gasoline and middle distillates

When comparing the dynamics of production with the structure of demand for different refined products in the period between 2000 and 2012 (Figure 2.3.36 and Figure 2.3.37), several distinctive mismatches in the product structure are observed, such as an excess domestic production of gasoline and fuel oil, and an insufficient domestic supply of gas/diesel oil and kerosene/jet fuel.

In recent years the total demand for the refining industry's products has been steadily declining, mostly due to the lower demand for gasoline and fuel oil. The overall production of refining products has declined as well, although at a slower pace and still preserving a strong imbalance between the production and consumption of gasoline. These tendencies to a large extent explain

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[75]Dieselisation is the increase in proportion of diesel-fuelled cars with respect to gasoline-fuelled cars. As diesel-fuelled cars are generally more energy-efficient than gasoline-fuelled ones, this change in addition contributes to lower overall transport fuel demand (IEA).

the current low utilisation rate of the EU refineries which, in turn, contributes to the pressure to close excess refining capacities.

The regional patterns in refining product mixes are not strongly visible. The differences between clusters are mostly driven by relative shares of gasoline and diesel fuel production

Table 2.3.7: Refinery region clustering by main refinery products (average during 2000-2012)
Source: Solomon Associates (2014).

BAL – Denmark, Sweden, Finland, Lithuania FRA – France GER – Germany UKI – UK, Ireland	12.88% 23.05% 5.98% 3.07% 7.20% 6.85% 2.53% 13.82% 24.62%
CEU – Austria, Czech Republic, Hungary, Poland, Slovakia IBE – Spain, Portugal MED – Italy, Greece SEE – Bulgaria, Romania, Croatia	13.78% 20.66% 6.76% 3.78% 4.03% 9.97% 3.07% 4.83% 33.12%
BNX – Belgium, Netherlands	14.87% 12.43% 5.61% 8.17% 7.24% 11.61% 22.40% 6.38% 11.29%

Legend:
- Gasoline Unleaded
- Jet fuels and Kerosene
- Diesel Transportation Fuel
- Light Heating Oil/Light Gas Oil
- Marine Diesel and Marine Bunker
- Residual Fuel
- Naphtha
- Refinery Produced Fuel (consumed and sold
- Al other outputs

In an attempt to identify the similarities in product slates among different European regions, we were able to distinguish three groups of geographical regions (see Table 2.3.7). Unlike in the case of crude input, the differences between these clusters are not that strongly visible. It appears that the relative shares of production of unleaded gasoline, transportation diesel fuel, jet fuel and kerosene, and the light heating oils are the main position by which different regional groups can be distinguished from one another.

The group of Baltic countries, the UK, Ireland, Germany and France can be characterised by a higher share of middle distillates (diesel, jet fuels and kerosene) in their product set together with a large share of produced gasoline. In south-east and central Europe, Spain, Portugal, Italy and Greece, we observe that diesel transportation fuel accounts for a very large share of output, mostly at the expense of light heating oil, which is also in rather low demand in this region. The shares of other products are similar to those observed in the previous group. Meanwhile, the Benelux refineries appear to produce much less gasoline and more naphtha in relative terms than the refineries in other regions. A larger share of naphtha production in this region is also related to the strong link of its refineries to petrochemical facilities (thus, naphtha is used as cracker feed rather than for producing gasoline). There is also a visibly higher share of marine fuels produced in Benelux.

In general, the cluster analysis has not detected statistically significant differences in the structure of product outputs among the refineries of the five different complexity types.

Expanding refinery conversion unit capacity to boost the production of middle distillates

This is reflected in the consolidated transformation output structure of the EU refineries (Figure 2.3.38). It can be clearly observed that gasoline constitutes a significant proportion of refining output, which decreased slightly in recent years (from 21.7 % of total transformation output in 2000 to 19.8 % in 2012), but more slowly than the rapidly declining gasoline demand. The other important refined products in terms of output are gas/diesel oil, fuel oil, kerosene/jet fuel, and naphtha. With the increasing demand for gas/diesel oil and kerosene/jet fuel, both products recently increased in terms of production volume (from 35.4 % to 40.2 % and from 6.3 % to 7.2 %, respectively). At the same time, the proportion of fuel oil decreased from 15.7 % to 11.8 %, reflecting the expanding capacity of conversion units such as cokers and hydrocrackers.
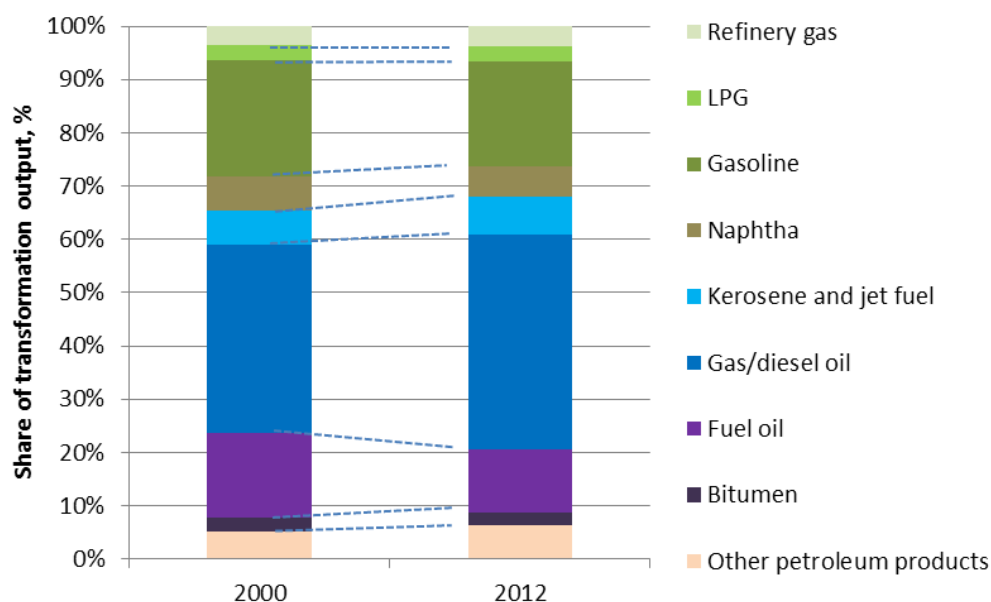
Figure 2.3.38: Structure of transformation output of the EU refineries, 2000 and 2012
Source: IPTS on the basis of Eurostat database [nrg_102a].

International trade is an important mechanism to correct for imbalances in the domestic production and consumption of refining products

The EU relies on international trade to correct for the above structural imbalances between domestic supply and demand for refined oil products – mainly, to compensate for its deficit in middle distillates and excess production of gasoline. As discussed earlier in the context of energy security, the EU is a net importer of several major oil products and a net exporter of others, such as gasoline and fuel oil (Figure 2.3.39).
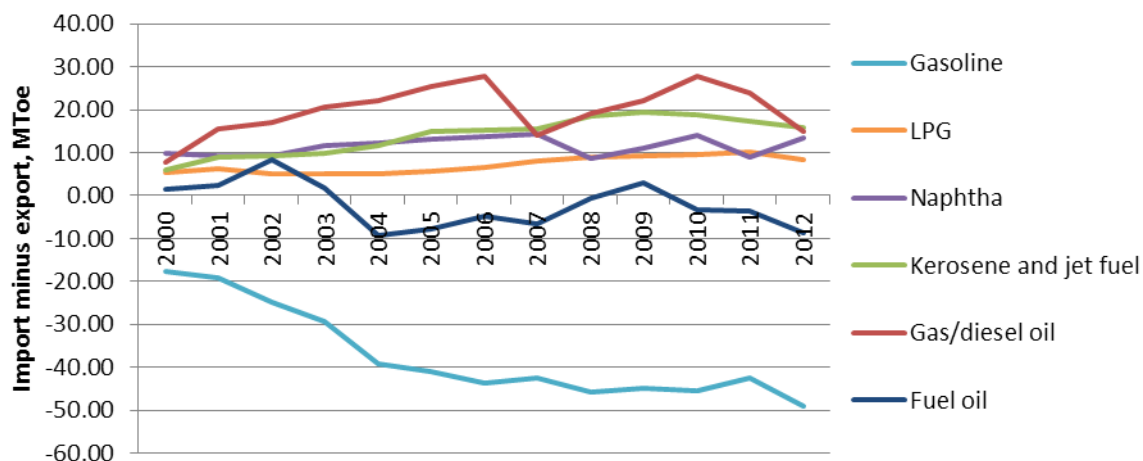
Figure 2.3.39: Net imports of selected refined petroleum products into the EU, 2000–2012 (MToe)
Source: IPTS on the basis of Eurostat database [nrg_102a].

This clearly means that the EU refining sector is strongly dependent upon international trade, and therefore upon demand and supply conditions in the other regional markets. The EU's principal external trade channels have not changed over recent years, with the exception of Asia recently emerging as a trade partner. Strong economic growth and the expansion of its refining industry has made Asia a source of imports for middle distillates and a destination for exports of heavy fuel oil. It is not, however, likely to become a destination for the EU's exports of gasoline, as in the near future Asian demand is expected to be met primarily by the regional supply (IHS, 2013). The main EU trading partner for gasoline exports has historically been the US, followed by the countries of Africa and the Middle East. European gas/diesel oil and kerosene/jet fuel imports primarily come from the FSU, the Middle East and the US.

There are doubts about the sustainability of external trade channels, in particular, trade in gasoline with the US to compensate for excess gasoline production in Europe

The reliability of the above external trade channels is coming into question in the short and medium term. Notably, the US domestic demand for gasoline is generally considered to have already reached its peak and is declining. The continued decrease in US gasoline consumption will be, among other factors, driven by increasingly stringent regulatory vehicle efficiency standards, biofuels, hybrid-electric and plug-in electric systems, and the increasing general fuel efficiency of the US car fleet. Indeed, the sales of vehicles using non-gasoline technologies in the US are predicted to grow by nearly 400 % from 2012 to 2040 (US EIA, 2014), although still at a relatively low absolute level.

At the same time, the recent political instability in some world regions, as discussed above, might threaten both the EU's external supplies of crude oil and its channels of refined product trade.

It is still the case (following the findings presented by the Commission in 2010[76]) that, in order to rebalance this trade deficit using its own production, the EU refining industry has to invest in restructuring its capacity to produce more middle distillates, and, at the same time, reduce gasoline production. The additional refinery units needed to produce the middle distillates are more energy-intensive, lead to extra CO_2 emissions, and are thus more costly and pushing the margins down.

2.3.8. Developments in international competition

From the discussion so far, it emerges that the EU is a large, mature and internationally established oil refining market. It accounts for around 15.5 % of the global oil refining capacity and, as of 2013, it is the second largest producer of refined products in the world after the US (BP, 2014).

GLOBAL REFINING CAPACITY
AS OF 2012
Source: PFC Energy

Region	%	kt/year
North America	23%	1.045.501
Europe	17%	843.394 kt/year of which EU + Norway + Swizerland = 792,961
Russia	9%	419.245
Latin America	7%	322.889
Africa	4%	161.654
Middle East	8%	379.283
Asia Pacific	32%	1.460.895
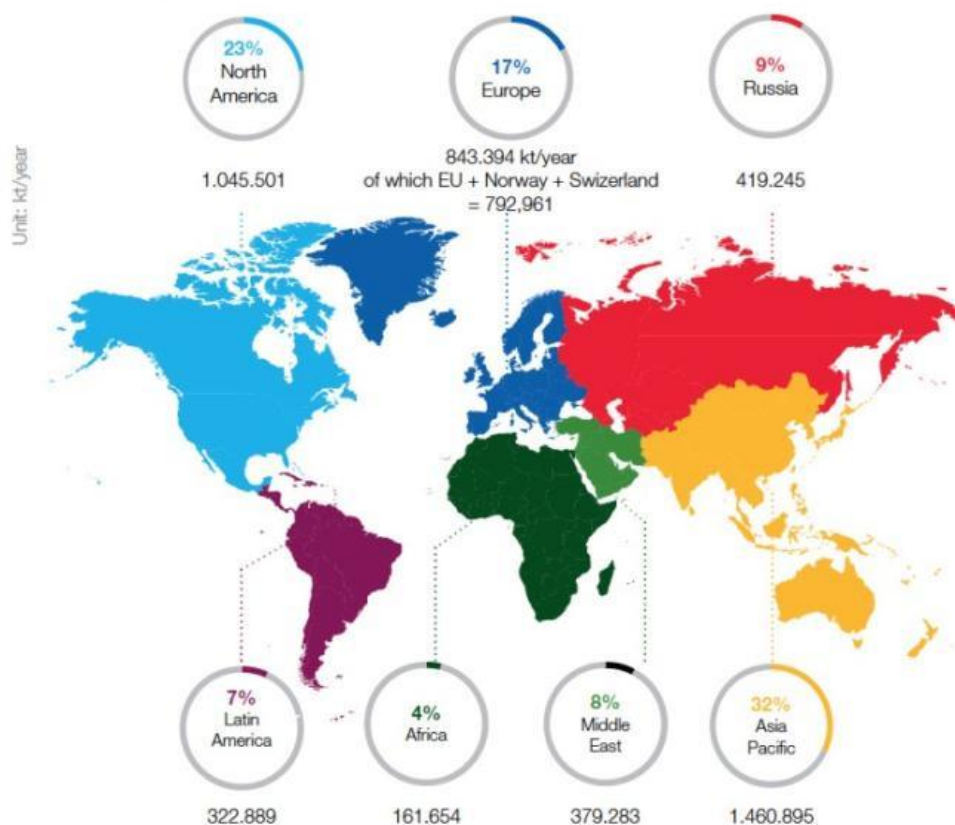
Figure 2.3.40: Map of the global refining capacity, 2012
Source: Europia (https://www.fuelseurope.eu/dataroom).

The global market for refining products is undergoing substantial transformation, where EU competitors are changing and building up their capacity at a fast pace

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[76] EC, 2010.

The international markets for refined products have been, however, recently undergoing significant changes. According to the BP Statistical Review of World Energy, the global refining capacity has grown by 12.8 % from 2003 to 2013, while the production of crude oil has only grown by 10.6 % over the same period. This means that competition in the global market for crude oil purchase and refined products trade has been tightening.

Indeed, while crude oil trading has traditionally been global and refined product markets were mostly local, crude oil is increasingly refined near the well and product trading is globalising (for example, international oil traders like Gunvor admit a shift in their core business from crude to product trade).

The refineries in the US, Russia, the Middle East, and South-East Asia are likely to expand their presence in the international markets for refined products

Greenfield investment in new refining capacity can, in the near future, be expected in the markets with significant demand growth (mainly in Asia) or which enjoy direct access to advantaged feedstocks (mainly in the Middle East). China alone, extending recent trends, might be expected to account for roughly 45 % of the incremental refining capacity, followed by the Middle East with nearly 25 %[77].

At the same time, India continues to build its refining capacity: Jamnagar refinery, belonging to India-based Reliance Industries Limited, houses the largest refining complex in the world with an aggregate refining capacity of 1.24 million barrels per day - around 8 % of the total EU capacity. It is one of the most complex refineries in the world with a Nelson complexity index of 14.

The same is relevant for North America, where the development of the US tight and shale oil and Canadian oil sands is displacing oil imports[78] and supporting the refinery throughput increases, allowing North America to become a net exporter of petroleum products. Also Russia, which has long been a large crude oil supplier, is currently investing in upgrading its Soviet era-built refining capacity and becoming a major refined products exporter[79]. These investments are both driven by government policy – notably export taxation – and developments in the Russian product market.

Competition in the European market from the Russian refining companies is felt more strongly by the central and southern European refineries, while refineries in other European regions are more exposed to competition from the US or the Middle East.

2.4. Concluding discussion

The EU oil refining sector constitutes a substantial part of the world's total refining capacity and accounts for a visible share of the manufacturing value added in Europe. It also contributes to

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[77] http://www.oxfordenergy.org/category/publications/oxford-energy-forum/

[78] There is still some controversy over whether oil production from shale formations is viable in the long term; for discussion, see e.g. http://belfercenter.ksg.harvard.edu/publication/23191/shale_oil_boom.html.

[79] After decades of being known for its inferior quality oil products, Russia emerged last year as a major producer and exporter of ultra-low-sulphur diesel (ULSD), the cleaner-burning motor fuel standard for European drivers (http://www.ft.com/intl/cms/s/0/17424454-f173-11e3-9fb0-0144feabdc0.html?siteedition=

intl#axzz3681flc8S).

employment, and demonstrates a substantial turnover. Refining products continue to play an important role in satisfying the energy demand in Europe and are an essential component of the EU's energy security. Furthermore, refined petroleum products are an important element of extra-EU trade, accounting for the majority of the EU energy exports and imports. It has been observed that in terms of the share of domestically produced refining products, the EU is not in the zone of high risk but appears to have become more imports-dependent during the last decade.

As discussed up to this point, we identified a number of factors and features of the EU's refining sector are potentially affecting its global competitive position. In this section we review the main findings of the above analysis.

Internal factors

Location

The overview shows that refining is a mature industry, fairly evenly distributed across the EU territory. In terms of geographic location, the proximity to crude sources and/or main crude transportation media determines the primary composition of EU refineries' crude diet. The effects of location on the product mix composition are weaker and the differences between regional clusters are mostly visible in relative shares of gasoline and diesel fuel production.

Refining Complexity and Types of Units

The average complexity of oil refineries in Europe has grown visibly since 2000. Throughout the observed time period the most complex refineries were located in Germany, Benelux, UK and Ireland, while the least complex ones were found in Iberia, central Europe and France.

Most complex refineries tend to specialise in the heaviest crudes, which could explain the fact that the strongest complexity growth was observed in the regions that have, on average, higher shares of heavier and sourer FSU crudes.

Regarding the specific types of refining units that are responsible for most changes in complexity, hydrotreating, hydrocracking, and coking units appear to be the main drivers of increasing complexity at European refineries. Also, hydrogen production capacities exhibited visible growth in order to satisfy the increased hydrotreating and hydrocracking needs.

Investments

In general, we observe a steady growth in all kinds of investments during the pre-crisis (before 2009) period in absolute volumes and per tonne of net raw material input and other feedstock processed. The share of regulatory/environment-related investments has been increasing against the backdrop of declining non-regulatory (profit improvement) capital investments in the aftermath of the economic crisis. The above results suggest that regulatory obligations allow refineries less flexibility in adjusting the regulatory/environmental capital investments compared to non-regulatory ones.

Energy Use

The energy use per tonne of processed crude and other inputs in different complexity groups remained stable over the past decade, although there is evidence of an increasing share of gaseous fuels in the total energy use mix.

The energy intensity of refining (GJ consumed per tonne of processed crude and other feedstock) appears to be more strongly associated with the complexity of the installed refining capacity (more complex – more energy-intensive) than with the characteristics of the processed crude, such as the sulphur content or the crude API gravity.

The weight of energy costs in the total expenditures structure of European refineries has steadily increased in the past decade. In particular, the price for natural gas has been substantially higher in the EU than in the US, to a large extent because of the latter's shale gas revolution.

Related to the above, the extent of use and, therefore, the ease of access to gaseous and liquid fuels are the main distinguishing factors for clustering of regions according to their energy use.

Operational Efficiency and Utilisation Rates

During the reviewed period we observe a clearly visible pattern of growth in both fixed and variable operating expenditures per tonne of net raw material input processed. In the global setting, the operating costs of the EU refineries seem to be relatively higher than those in several other world regions. The currently available data suggests that the likely explanation for this upward trend comes mainly from the changes in energy prices and personnel costs.

The gross margin indicators for refineries in all world regions show a positive trend in the period between 2000 and 2012, but with the EU lagging behind its main international competitors. The declining trends in crude throughputs of EU refineries are persisting against the backdrop of a continuously improving situation for refineries in the US.

Given the fact that the refining capacity in the EU remains substantially underutilised (also in comparison to the competing regions) we can expect that, despite the recent wave of refinery capacity reduction, the process of refining capacities closure will continue into the near future.

External factors

Crude Supply and Prices

The EU refinery sector works with a rather diversified stream of crude inputs with a wide range in API gravity and sulphur content. Still, among all types of crude, the relative shares of North Sea, FSU and Middle East crudes are the main components determining the crude diet of refineries and driving the changes in their configuration. In the past decade, the mix of crude inputs shifted towards heavier and more sour crudes (coming mostly from the FSU), although not in all EU refining regions.

There is particular uncertainty about the stability of the composition of the crude imports as a consequence of the unstable political situation in the main crude-producing regions. This problem is exacerbated by the continuing depletion of the domestic crude sources and growing oil prices.

Refinery Products Demand

The data shows a clear tendency for dieselisation of transport and greater demand for other middle distillate fuels due to the declining general demand for fuels. On the process side, the industry reacted by expanding capacity for conversion units to boost production of middle distillates, closing unprofitable (mostly less complex and 'gasoline-favouring') plants; but still the imbalance between domestic production and consumption of gasoline and middle distillates persists.

The international trade in refined products provides an important mechanism to correct for imbalances in the domestic production and consumption of refining products. Nonetheless, there are doubts about the sustainability of trade in gasoline with the US as a channel to compensate for excess gasoline production in Europe. Fuel exports will thus also be dependent on demand and supply conditions in the other regional markets. In terms of the share of other domestically produced refining products, the EU is not in the zone of high risk but appears to have become more imports-dependent during the last decade, especially for middle distillate products.

The declining demand for fuels in Europe together with the persisting low utilisation rate contribute to pressure towards further closure of excess refining capacity.

International Competition

The global market for refining products was undergoing substantial transformation, where the EU competitors are changing and building up their capacity at a fast pace.

A more detailed competitiveness analysis section of the report will formally examine the international competitiveness of the EU refining sector using a number of generally accepted indicators. This section deliberately avoided touching upon the additional costs of compliance with environmental regulations, which undoubtedly play an important role in the refining industry. These issues will be discussed in the following sections of the report.

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2.5. Annex

List of refineries

The following refineries are included within the scope of the EU Refining Sector Fitness Check.

Country	Refinery Name
Austria	Schwechat Refinery
Belgium	Total Antwerp Refinery
	ExxonMobil Antwerp Refinery
	Independent Belgian (BRC) Refinery Antwerp
Bulgaria	LUKOIL Neftochim Burgas
Croatia	Rijeka Refinery, Kostrena Urinj
	Sisak Refinery
Czech Republic	Litvinov Refinery
	Kralupy Refinery
Denmark	Kalundborg Refinery
	Fredericia Refinery
	Naantali Refinery
Finland	Porvoo Refinery
France	Provence Refinery La Mede
	Normandy Refinery Gonfreville
	Flandres Refinery Dunkerque
	Donges Refinery

Country	Refinery Name
	Feyzin Refinery
	Grandpuits Refinery
	Port Jerome-Gravenchon Refinery
	Fos-sur-Mer Refinery
	Reichstett Refinery
	Petit Couronne Refinery
	Berre L'étang Refinery
	Lavera
Germany	Schwedt Refinery
	Ingolstadt Refinery (ex Petroplus)
	Bayernoel Refinery
	Ruhr Oel Gelsenkirchen Refinery
	Mitteldeutschland Spergau Refinery (Leuna)
	Wilhelmshaven Refinery
	Rheinland Godorf/Wesseling Refinery
	Burghausen Refinery
	Emsland Lingen refinery (BP)
	Hamburg-Harburg Elbe (Shell)
	Holborn Europa Raffinerie Hamburg Harburg
	MIRO Oberrhein Karlsruhe
	Raffinerie Heide
Greece	Aspropyrgos Refinery
	Elefsina Refinery
	Thessaloniki Refinery
	Korinth Refinery
Hungary	MOL Dunai Szazhalombata Refinery
Ireland	Whitegate Refinery
Italy	Trecate Refinery
	Augusta Refinery
	Rome Refinery
	Falconara Marittima Ancona Refinery
	Mantova Refinery
	Lukoil, Impianti Priolo Sud/Nord Refinery
	Milazzo Refinery
	Sannazzaro Refinery
	Gela Refinery
	Taranto Refinery
	Livorno Refinery
	Porto Marghera Venice Refinery
	Cremona Refinery
	IPLOM Busalla Refinery
	Saras Sarroch

Country	Refinery Name
Lithuania	Mazeikiu Refinery
Netherlands	Shell Pernis Refinery
	Exxon Mobile Rotterdam-Botlek
	BP Rotterdam Refinery
	Kuwait Petroleum Europoort Rotterdam Refinery
	Vlissingen Refinery
Poland	Plock Refinery
	Gdansk Refinery
Portugal	Porto Refinery
	Sines Refinery
Romania	Arpechim Refinery Pitesti
	Petrobrazi Refinery Ploiesti
	Petromidia Constanta Refinery
	Petrotel Lukoil Refinery Ploiesti
Slovakia	Slovnaft Bratislava Refinery
Spain	Bilbao Refinery
	Puertollano Refinery
	Tarragona Repsol Refinery
	La Coruña Refinery
	Cartagena Refinery
	Tenerife Refinery
	La Rábida Refinery Huelva
	Gibraltar-San Roque Refinery
	Castellon Refinery
Sweden	Preem Gothenburg Refinery
	ST1 Gothenburg Refinery
	Lysekil Refinery
United Kingdom	Coryton Refinery
	Fawley Refinery
	Humber Refinery
	Lindsey Oil Refinery Humberside
	Teesside Refinery
	Stanlow Refinery
	Grangemouth Refinery
	Milford Haven Refinery
	Pembroke Refinery

Types of crude oil processed in the EU by region
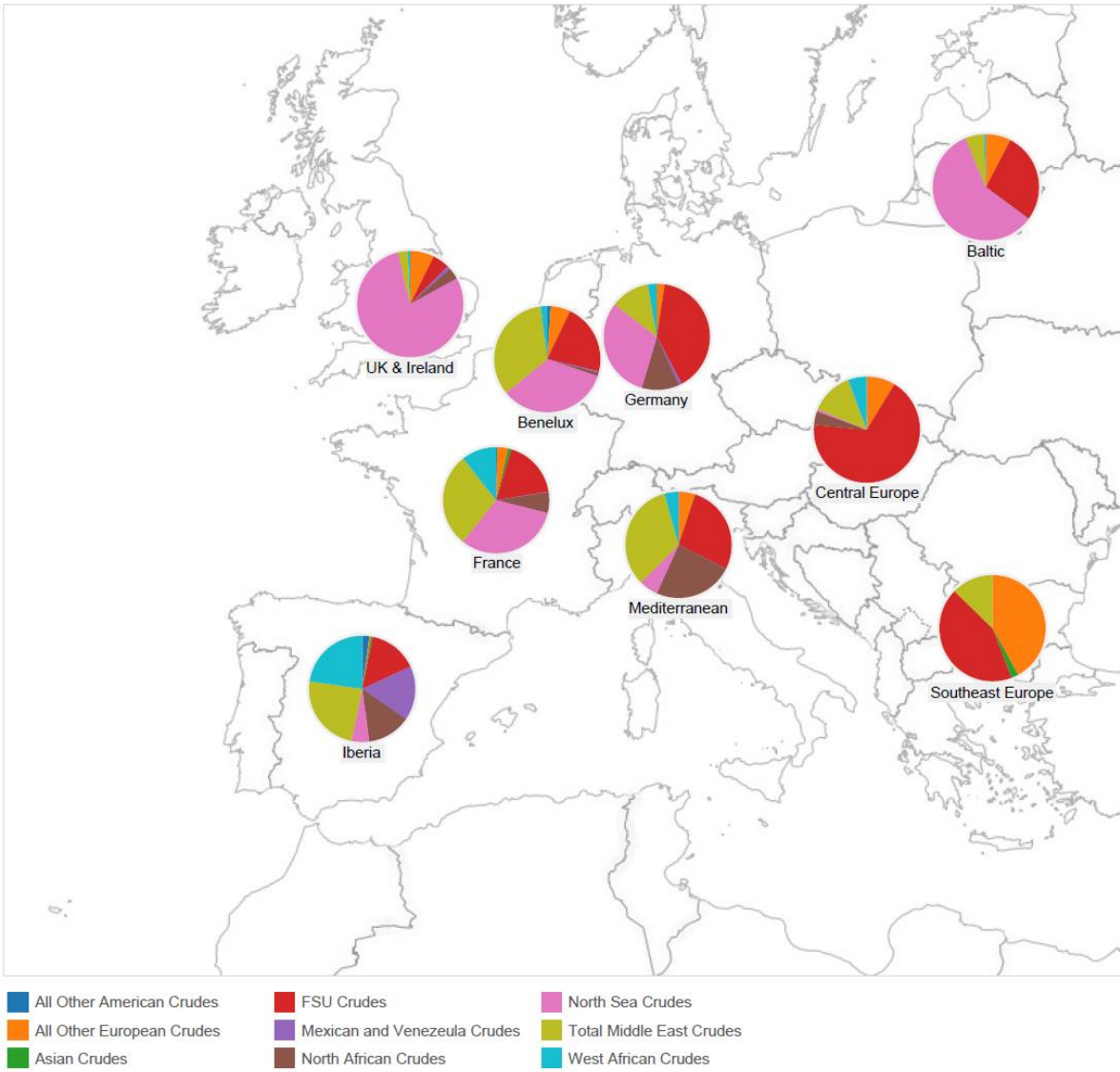
Figure 2.5.1: Crudes processed in the EU-28 in 2002
Source: Solomon Associates (2014).
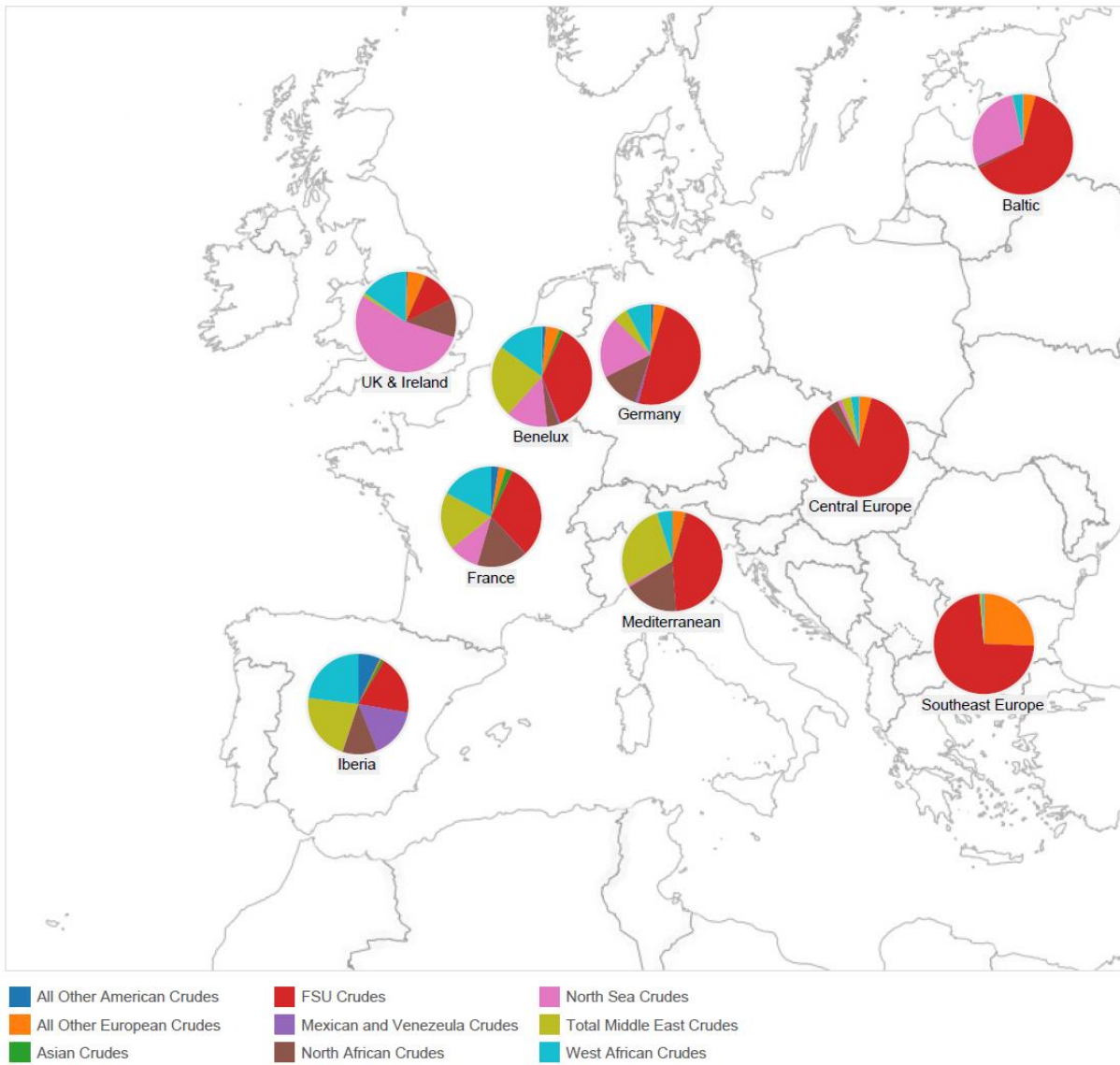
Figure 2.5.2: Crudes processed in the EU-28 in 2012
Source: Solomon Associates (2014).

Methodology of cluster analysis

The cluster analysis method applied in this study is a nearest neighbour hierarchical agglomerative linkage clustering[80]. The method proceeds by starting with the N observations as N separate groups, each of size one. Then the two closest observations (the ones with the shortest Euclidian distance) are merged into one group, producing N-1 total groups. The closest two groups are then merged so that there are N-2 total groups. This process continues until all the observations are merged into one large group, producing a hierarchy of groupings from one group to N groups.

The difference between the various hierarchical linkage methods depends on how they define 'closest' when comparing groups. In this analysis we used the average linkage clustering, where the closest two groups are determined by the average similarity between the observations of the two groups.

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[80] 'Hierarchical cluster analysis', Stata 13 Manual.

3. <u>Refinery-relevant EU legislation: review and economic impacts</u>

3.1. Renewable Energy Directive

We first review the objectives and measures of the Renewable Energy Directive (Section 3.1.1), assess its effectiveness in terms of its objectives (Section 3.1.2) and its impact on the EU refining sector (Section 3.1.3), and, finally, review the legislation's efficiency by means of putting benefits in perspective with costs (Section 3.1.4). The most important findings can be summarised as follows:

The Directive was successful in bringing the share of biofuels in transport from virtually zero in 2000 to 5.1 % in 2012. However, due to indirect land-use effects, the expected benefits in terms of GHG reductions could only be partially realised (during the time period considered here). A positive effect in terms of lower import dependence on oil and oil products can be affirmed, given that 82 % of EU biofuel is produced in the EU, with 64 % of the feedstock being of EU origin.

For EU refineries the most relevant implication of the Renewable Energy Directive is the potential reduction of EU demand for fossil-based fuels due to their substitution by biofuels. However, at the aggregate EU-wide level this was very likely *not* the case for biodiesel–which accounted for 80 % of all EU biofuels from 2000 to 2012–because at the aggregate level Europe has an overall shortage of diesel production capacity and is thus a net importer of diesel. EU diesel net imports have at all times exceeded its consumption of biodiesel.

Thus, the presence of biodiesel has partially softened the EU's dependence on diesel imports, and on energy imports in general, given that (in 2010) 60 % of the biodiesel consumed in the EU was produced from feedstock of EU origin. If the production of biodiesel had not been promoted by EU and Member State policies, and had EU biodiesel consumption remained at its year 2000 level, then year 2012 EU imports of fossil diesel would have had to be 74 % higher to fill the domestic supply gap, and 23 % higher cumulatively over 2000-2012.[81] The fact that a few EU-28 Member States like the Netherlands and Italy were net exporters of diesel does not invalidate this argument, given that they have neighbouring countries (France, Germany, Austria) which, cumulatively, are relatively larger net importers.

However, EU refineries are negatively impacted by the demand-reducing impact of biogasoline, as there is a surplus production of conventional gasoline at the EU level. If, hypothetically, biogasoline consumption had remained at its year 2000 level, then the EU demand for conventional gasoline in transport would have been 3.4 % higher in 2012, and 1.1 % higher cumulatively over 2000-2012. A model-based analysis by IHS suggests an associated impact on average EU refining margins between EUR 0.01 and EUR 0.20 per barrel of throughput during 2006 to 2012, and between EUR 0.01 and EUR 0.35 in 2012. Nevertheless, the overall drop in EU gasoline demand exceeded the policy-driven increase in biogasoline consumption by a factor of more than 10. Biogasoline is, consequently, only a minor cause of the current EU gasoline surplus.

EU biogasoline decreases demand but, as refining is a coupled production, the product yields of existing refineries cannot be easily shifted towards a 'max. diesel' mode. It can be done to some extent by shifting to heavier crudes and higher conversions (with the associated incremental costs), since a direct transformation of gasoline into diesel is not possible. As an alternative way of

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[81] Own calculation based on Eurostat (2014, 2014a) data.

adjusting to the increased gasoline surplus, the oil refining industry may restructure either by disinvesting gasoline units (FCC and reformers) or by shutting down whole refineries. But a reduction of EU overall refining capacity would also increase the EU's mid-distillate deficit and thus its dependence on third countries for such imports.

The modelling exercise within OURSE estimated the average effect (the forgone annual net earnings of the EU refineries) of a possible decrease in the utilisation rates of refineries because of demand drop due to the RED legislation at 3.65 euro cents per barrel of processed crude oil.

As a secondary impact, it would be expected that refineries' electricity costs have increased due to the EU-wide expansion of electricity from renewable sources, as mandated by the RED. However, lacking the required Member State-specific information on applicable electricity surcharges and relevant derogations, a quantitative estimate could not be provided here.

A final impact on the refining sector consists of additional expenditures associated with the blending, storage, and transportation of biofuels. According to industry data (Concawe 2014), these amounted to EUR 0.5 million annually per refinery during 2000-2012, and EUR 0.9 million annually during 2008-2012. In relative terms, both of these numbers correspond to about EUR 0.01 per barrel of refineries' throughput.

3.1.1. Objectives and measures

Directive 2009/28/EC 'on the promotion of the use of energy from renewable sources' came into force in June 2009, with Member State transposition required by December 2010. The Directive's scope encompasses the promotion of renewable energy use in various sectors, thus combining and extending the more specific predecessor directives (2001/77/EC covering the electricity sector and 2003/30/EC the transport sector), which it consolidated and replaced.

The overarching objective of the Directive is to contribute to the European Union's climate and energy '20-20-20' package. To achieve this target in a dynamically efficient manner, new – and in particular renewable – energy technologies have to be developed, which requires a stable and predictable investment environment. The Renewable Energy Directive prescribes a 20 % minimum share for renewables in EU-wide final energy consumption by 2020, as well as a specific 10 % target for renewable energy in transport (RES-T), where the latter has to be achieved in every Member State. The Directive obliges Member States to regularly present so-called National Renewable Action Plans (NREAP) in which the planned annual trajectory of the renewables' shares in three sectors – electricity, heating (including cooling), and transport – is outlined and monitored. The percentage share of renewables in transport is computed on the basis of their energy content and includes, inter alia, biofuels used for road and non-road transport[82], as well as renewable electricity used in transport.

The 10 % RES-T target represents a continuation of the 2010 biofuel target of 5.75 % (by energy content) already set by the predecessor directive 2003/30/EC 'on the promotion of the use of biofuels or other renewable fuels for transport'. This Directive also included an intermediate target of 2 % to be achieved by 31 December 2005. However, both targets represented non-binding reference values, which may be undercut by actual national targets if appropriately justified by the Member State.

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[82] A wide range of products are designated as biofuels, including bioethanol, biodiesel, hydrotreated vegetable oil, biogas, biomethanol, bio-ETBE, bio-MTBE, and others (2003/30 Art. 2).

Another piece of replaced predecessor legislation is 2001/77/EC 'on the promotion of electricity produced from renewable energy sources in the internal electricity market', with transposition by October 2003. It mandated an EU-wide increase from 13.9 % to 22 % by 2010 of electricity from renewable sources, with individual Member State targets ranging between 6 % and 78 %.

The benefits expected from these broad legislative packages include, inter alia, reduced GHG emissions (including compliance with the Kyoto Protocol), increased security and diversification of energy supply, enhanced energy efficiency, technological development and innovation, and a positive stimulus for employment and for regional development. Finally, a specific aim of the latest directive (2009/28) is to establish tighter criteria for the sustainability of biofuels, as the preceding regulation (2003/30) raised concerns over the negative impacts on food prices and land use.

In the present context of the EU oil refining sector, the Directive's most relevant aspect consists of its specific targets for the transport sector and the thereby implied substitution of petroleum-based fuels with fuels from renewable sources.[83] The focus of our analysis may be further restricted to biofuels, since the switch to renewable electricity for transport purposes, mainly concerning trains or tramways, does not directly impact the refining sector.[84] Moreover, since practically all biofuels are consumed by road transport, it is sufficient to concentrate on this type of final use.

A secondary impact of the Directive occurs through refineries' direct involvement in the supply of biofuels, for which they have to invest in blending, storage, and transport facilities.

3.1.2. Effectiveness of the legislation

Table 3.1.1 illustrates the increasing penetration of biofuels and renewables in transport for the EU. We assume that EU legislation was the main driver of the expansion, even though it cannot be ruled out that Member States would have pursued biofuel policies on their own if the EU had not adopted the Renewable Energy Directive. As can be observed, there was a steady increase in the EU-wide market penetration of biofuels from just 0.25 % in 2000 to 5.1 % in 2012.

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[83] Around 25 % of European energy consumption related to heating and cooling relies on heating oil (Pardo Garcia et al., 2012), thus representing an important market for the EU refining sector. Although there is no explicit EU target, Member States are also required to report on national policy measures aimed at increasing the share of renewables in this end use area. However, as the EU at the aggregate level has a production shortage of mid-distillates – including heating oil – there is no immediate threat of a crowding out of petroleum products from an increased use of biomass in heating (see discussion of biodiesel further below).

[84] Renewable electricity only accounts for a small share of renewable energy in transport; EU-27-wide it was below 10 % in 2010 (European Commission 2013b, Table 3). It may be considerably higher in some Member States with a very high renewable energy share in electricity, e.g. Austria.

Table 3.1.1: Biofuel shares in transport and RES-T, measured in energy content terms

Sources: European Commission (2007, p.15; 2013b, Fig.4), Ecofys (2012, p. 205), and EUROSTAT (2014; 2014a) database.

Note: The corresponding RES-T share for the EU-27 achieved in 2010 is 4.7 % (Ecofys 2012, p.205). Shares from Eurostat are relative to total fuel consumption for road transport purposes.[85]

Country	Biofuel share in 2000 [% energy]	National indicative 2005 biofuel target [% energy]	Biofuel share in 2005 [% energy], as per national reporting	National 2010 RES-T target [% energy]	Biofuel share in 2010 [% energy]	Biofuel share in 2012 [% energy]
Belgium	0,00	2,00	0,00	3,80	3,94	4,26
Bulgaria	0,00	na	na	1,20	0,56	3,32
Czech Republic	1,64	3,70	0,05	4,10	4,20	5,09
Denmark	0,00	0.10 [2006]	Na	1,00	0,74	6,50
Germany	0,41	2,00	3,75	7,25	5,75	5,79
Estonia	0,00	2,00	0,00	0,00	0,00	0,00
Ireland	0,00	0,06	0,05	3,00	2,92	2,98
Greece	0,00	0,70	na	1,75	1,91	2,99
Spain	0,27	2,00	0,44	6,00	4,75	8,25
France	0,76	2,00	0,97	6,50	5,75	6,43
Croatia	0,00	na	na	na	0,14	2,05
Italy	0,00	1,00	0,51	3,50	4,05	4,17
Cyprus	na	1,00	0,00	2,20	na	2,26
Latvia	0,00	2,00	0,33	4,00	2,70	2,57
Lithuania	0,00	2,00	0,72	4,00	3,21	4,31
Luxemburg	0,00	0,00	0,02	2,10	1,94	2,23
Hungary	0,00	0,60	0,07	3,75	4,41	3,81
Malta	0,00	0,30	0,52	2,80	0,00	2,74
Netherlands	0,00	2.00 [2006]	0,02	4,00	2,04	3,05
Austria	0,27	2,50	0,93	6,75	6,45	6,62
Poland	0,00	0,50	0,48	5,85	5,38	5,11
Portugal	0,00	2,00	0,00	5,00	5,07	5,16
Romania	0,00	na	na	5,75	2,55	4,51
Slovenia	0,00	0,65	0,35	2,70	2,60	2,74
Slovakia	0,00	2,00	na	4,10	4,55	4,51
Finland	0,00	0,10	na	6,00	3,61	6,88
Sweden	0,00	3,00	2,23	7,50	5,15	7,37
United Kingdom	0,00	0,19	0,18	2,70	2,98	2,37
EU	0.25[EU15]	1.4 [EU25]	1.0 [EU25]	4.95 [EU27]	4.4 [EU27]	5.1[EU27]

The evolution of biofuel consumption in the EU in absolute terms is shown in Figure 3.1.1. It shows the relatively small but steadily increasing amount of biofuels consumed in the EU, reaching almost

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[85] To derive the relative shares, EU rules allow the absolute contribution of some biofuels to be counted twice (e.g. from waste); however, these only accounted for 1.4 % of EU-consumed biofuels in 2010 (ECOFYS 2012, p.204).

15 million tons of oil equivalent in 2012. In terms of the split between biogasoline (consisting mostly of bioethanol) and biodiesel (mostly methyl esters, also called FAME), the data indicates a clear dominance of the latter, with an average share of 80.7 % over the 2000-2012 period (Eurostat 2014,2014a).[86]
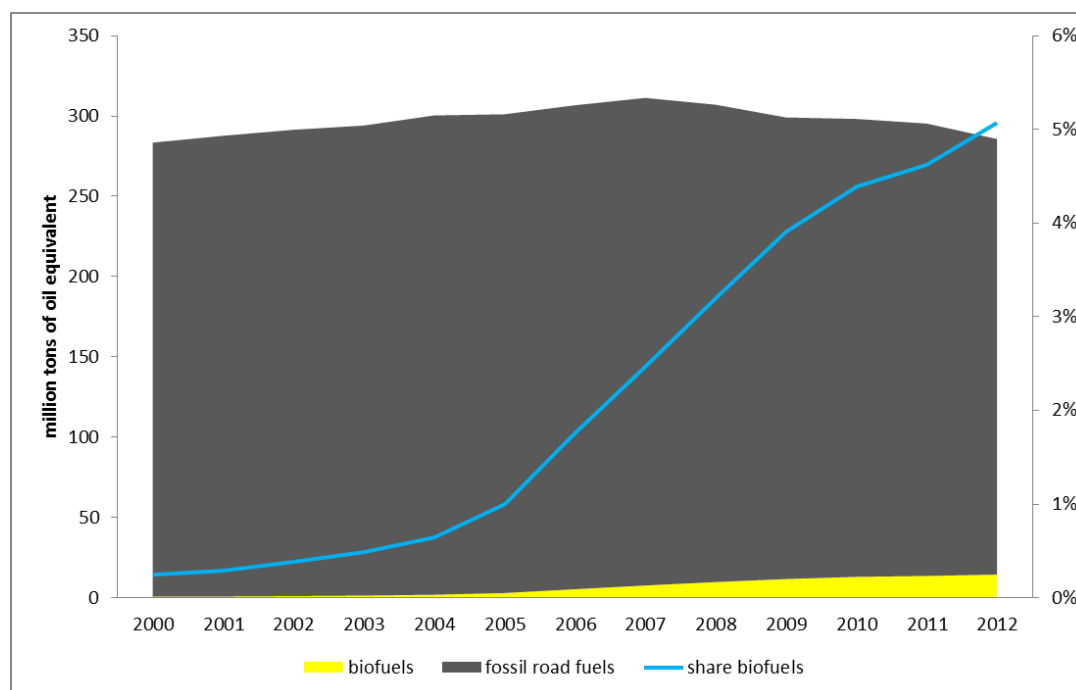
Figure 3.1.1: Time evolution of biofuel and conventional fossil fuel consumption in the EU-28, road transport only
Note: The relative percentage of biofuels is also shown, on the right axis. Data refers to energy content.
Source: Eurostat (2014,2014a).

In this figure, the biofuel market roughly follows that of conventional road fuels, where the share of diesel rose continuously and reached almost 70 % in 2012 (in energy terms, data from Eurostat 2014). For final consumption, the majority of biodiesel is blended with conventional diesel, mostly in concentrations of up to 7 % v/v, and sometimes up to 10 % (European Commission 2013b, p.12). In order to mitigate a potential increase in consumer prices due to the higher production costs of biofuels, EU Directive 2003/96 allowed Member States to apply tax reductions to such blended fuels.

The policy's effectiveness can be assessed by comparing the envisaged targets with the actually achieved shares of biofuels / renewable energy, as done in Table 3.1.1. It can be noted that about half of the Member States chose a lower 2005 biofuel target than the 2 % indicated by the Commission, resulting in an adjusted EU-wide target of only 1.4 %. However, even this lower target was not met, since the actual share in 2005 was 1 %. For 2010, the indicative biofuel target was 5.75 %, but again many Member States eventually adopted lower (some also higher) national

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[86] There is a slight difference between Eurostat (2014a) data and data from the European Commission (2013b, p.12), most likely due to the presence of the 'other liquid biofuels' category, for which the allocation in terms of diesel or gasoline is not clear.

targets, leading to an effective EU-wide target for all renewables in transport (not only biofuels) of 4.95 %, which–given an actual value of 4.7 %–was not quite achieved (Ecofys 2012, p.205).[87]

The presence of both indicative European and adjusted national targets points to an important caveat, namely that Directive 2003/30/EC did not set a legally binding target. Such a target was only defined later in 2009/28/EC, and only for the year 2020 (with an 'indicative' trajectory starting in 2011/12). Hence, the question arises as to what extent the observed increase in renewable energy and specifically in biofuel consumption during the 2000-2012 period can be ascribed to EU policy, and therefore whether it falls under the scope of the present fitness check. Here, we assume that EU policy was the decisive trigger for renewables expansion. Even though the first targets did not have a legally binding character, it became clear quite early on that eventually such targets would be adopted. For example, the binding 20 % target was already envisaged in the Commission's Energy Road Map (COM(2006) 848 final) drafted in 2006 and published in January 2007. Moreover, even if the responsibility between the EU and Member States cannot be fully disentangled, the observed biofuel expansion in any case remains a relevant factor when assessing the regulation-related economic constraints on the EU refining sector.

The practical implementation of the biofuel targets varied quite substantially at the Member State level, with a use of mandates, excise reductions, hybrid instruments, etc. (Ecofys 2012, p.139ff).[88] Overall, however, the share of biofuels continues to grow (see year 2012 data in Table 3.1.1) and it can be confirmed that the policy has been effective in bringing biofuels from a niche existence (see year 2000 data) to a significant market presence.

3.1.3. Impact on the EU refining sector

The Renewable Energy Directive legislation offers no apparent benefits to the petroleum refining industry. Although biofuels also need to be refined from underlying inputs, e.g. rapeseed or maize, refineries generally do not perceive this as an immediate business opportunity for conventional oxygen-containing biofuels because of the technically different processes it involves. However, with suitable investments in the required technologies (at the refineries capable of such investments)

> '[t]he potential to process renewable fuel sources within refineries to meet both reductions in GHG intensity and renewable fuel targets could provide some support to continued refinery operations' (Purvin & Gertz 2012, p.106).

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[87] In terms of the wider RES-T indicator, the EU-27 had an indicative target for 2010 of 5.15 % for RES-T (European Commission 2013a, p.3), corresponding to 16.2 Mtoe (European Commission 2013b, p.7), while the actual figure is estimated as 15 Mtoe (idem, p.7).

[88] The use of tax instruments might lead to inconsistencies with another policy, the Energy Taxation Directive 2003/96/EC, which prescribes minimum tax rates for different fuels, and overly punishes biofuels due to their relatively lower energy content (European Commission 2013b, p. 32).

One notable example is the Porto Marghera refinery in Italy, which over 2013 to 2015 has been converted into a 'green refinery' producing 0.3 million tons of high quality biodiesel ('green diesel') per year.[89] In fact, according to the Italian refiner ENI

> '[d]etailed technological studies and feasibility demonstrated that it is entirely possible to convert a traditional oil refinery into a bio-refinery with reasonable levels of investment'.[90]

For hydrogenation, co-processing, and to some extent advanced biofuels from non-edible biomass, production is more compatible with conventional refinery processes, but these products are not accepted overall in the EU as biofuels.

Biodiesel: no crowding out of EU domestic demand

To assess the economic impact of biofuel promotion on the competitiveness of EU petroleum refining, biodiesel and biogasoline need to be differentiated. Given the EU's position as a net importer of diesel, basic economic theory suggests that biodiesel would first replace these imports, before restraining the market opportunities of domestic refiners, which–given the European 'diesel deficit'– are likely to be operating at their capacity limit. Indeed, the industry association Europia (2010, p.9) affirms that

> 'The shift to diesel began 20 years ago and has contributed to excess gasoline production capacity and a shortage of diesel production in the EU despite refiner's efforts at boosting diesel yields' [implying that] 'The EU has significant excess gasoline production capacity and is unable to meet regional demand for diesel [..]'.

To satisfy the whole EU demand, additional diesel is imported from abroad, with local consumers ultimately paying for the additional transport costs. Because of these excess costs it would be expected that EU biodiesel would first reduce these imports, before diverting domestic diesel production.

More specifically, between 2005 and 2012[91] around 60 Mtoe of biodiesel were consumed in the EU, much less than the net imports of diesel/gasoil (including heating oil) of over 170 Mtoe during that same period (Eurostat 2014, 2014a). The situation for biodiesel is graphically summarised in Figure 3.1.2. Total EU diesel/gasoil production is slightly decreasing (red stacks), as is total consumption (the total height of the stacks), while diesel consumption for road transport is relatively stable. Due to its continuous increase, EU biodiesel production has now reached a similar magnitude as diesel/gasoil (including all end-use types) imports.

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[89] The Porto Maghera refinery of ENI had a capacity of 80 000 barrels per day. By means of an investment of approximately EUR 100 million it was converted into a biofuels refinery (while a greenfield bio-refinery would have cost EUR 600 million). The conversion is based on the reuse of the catalytic hydrodesulphurisation section. Having its main focus on high-quality biodiesel ('green' diesel) production, it also produces bio-naphtha and LPG, and possibly at a later stage will produce jet fuel. Different feedstocks can be used, though palm oil will be the main feedstock initially. Technically the refining is based on a two-stage process, first hydrodeoxygenation and later isomerisation. The resulting 'green diesel' has advantageous properties (high cetane number, no oxygen content) and can be used for blended biodiesel in concentrations of up to 30 % (source: ENI website: http://www.eni.com/en_IT/innovation-technology/technological-focus/green-refinery/green-refinery.shtml). For technical information on the refining process see http://www.eni.com/en_IT/attachments/innovazione-tecnologia/focus-tecnologico/green-refinery/Ecofining-ENG.pdf)

[90] http://www.eni.com/en_IT/innovation-technology/technological-focus/green-refinery/green-refinery.shtml

[91] Neglecting previous years because biofuel shares were below 1 % and the first policy targets referred to 2005.

Hence, one can conclude that the promotion of biodiesel has helped to partially reduce the EU's diesel deficit and its dependency on mid-distillate imports, rather than having reduced the demand for domestically produced conventional diesel. This assertion is backed by the fact that, in 2010, 83 % of the biodiesel consumed in the EU was also produced in the EU (Ecofys 2012, p.202)[92].
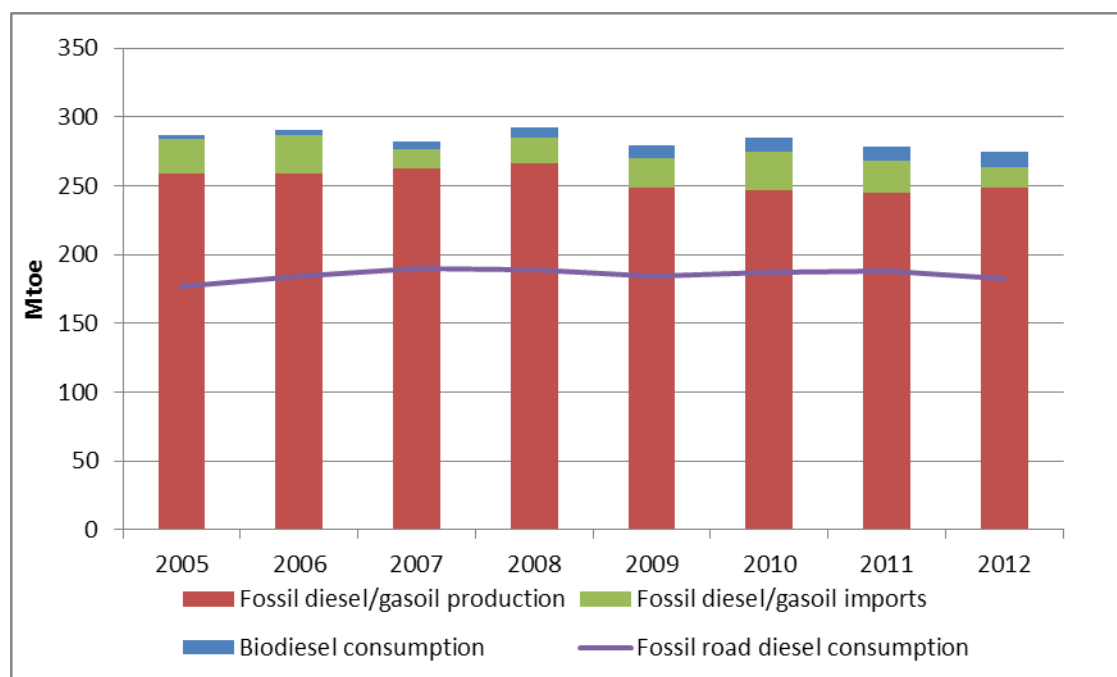
Figure 3.1.2: Evolution of EU consumption and production of conventional diesel/gasoil and biodiesel, for the years 2005 to 2012
Note: Imports and total domestic production refer to all types of final use (e.g. with heating oil), because data on use-specific diesel/gasoil imports is not available. However, the purple line indicates that 60 % to 70 % of all diesel is consumed for road transport.
Source: Eurostat (2014, 2014a).

However, an impact from biodiesel on the domestic demand level faced by EU refineries can only be expected once it has closed the EU's diesel deficit, i.e. the shortfall of domestic supply vis-à-vis domestic demand (Wood Mackenzie 2010, p.21). Basic economic theory posits that a lower demand for conventional diesel should–ceteris paribus–lead to a lower producer price. However, whether and to what extent this effect has occurred cannot be determined here.

Overall, one can conclude that the promotion of biodiesel has helped to reduce the EU's diesel deficit and its dependency on diesel imports, rather than having reduced the demand for domestically produced conventional diesel. In view of this, one study concludes that 'increasing use of biodiesel is not expected to result in significant worsening of EU refinery margins during the next decade and thus in incremental closures' (Wood Mackenzie 2010, p.23).

As one caveat, the previous reasoning is based on a simplified view of the EU as one singular 'frictionless' market, which is either an importer or an exporter of diesel. The reality does not correspond to this idealisation; for example, the Netherlands and Italy were in fact significant net exporters of diesel over 2000 to 2012 (Eurostat). However, this still does not invalidate the main argument, given that these countries have neighbours (France, Germany, Austria) which are

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[92] Naturally, the reduction in import dependency on diesel should not be viewed in isolation from the potential increase in imports of bio-feedstock whenever domestic supply of the latter is not sufficient.

relatively larger net importers. At the aggregate European level the supply shortage of diesel constitutes the dominant effect.

Another caveat concerns a product interdependence within the mid-distillate category: marketed biofuel blends like B7 require a higher share of fossil components from the kerosene pool than conventional diesel, due to the different physical properties of the FAME bio-component. As Europe has a production shortage not only of road-grade diesel, but also of jet fuels (the common types of which are largely based on kerosene), the increase of blended biodiesel fuels implies an exacerbation of the EU jet fuel import dependence.[93] Data from Eurostat (2014) shows that after lower volumes in the early 2000s, jet fuel net imports have indeed steadily grown and reached the level of EU diesel/gasoil net imports in 2012. Without further technical analysis it is not possible to quantify the additional demand for kerosene implied by the presence of blended biodiesel fuel. However, as long as one unit of blended biofuel requires less than one unit of kerosene–which is obviously the case–there is a net saving effect from biofuels on EU mid-distillate consumption and hence a reduction of the overall import dependence. Unless the case can be made that the EU import dependence on diesel/gasoil is of less importance than its dependence on jet fuel imports, the overall effect – although diminished – remains positive.

Biogasoline: crowding out of EU domestic demand

For biogasoline, the picture is different: over the 2000-2012 period the EU was a net exporter of gasoline, e.g. 49 Mtoe, or 38 % of production in 2012 (European Commission 2010, p.10; Eurostat 2014). The utilisation rates at and below 80 % observed for EU refineries in recent years (BP 2014) indicate the presence of excess domestic capacity for gasoline production. As a consequence, the policy-mandated market penetration of biogasoline is having a negative economic effect on EU refining and its competitiveness.

The situation is graphically illustrated in Figure 3.1.3. It shows how biogasoline has only very recently gained a noticeable presence. Moreover, it is clear that the main driver of the increased reliance on export markets for EU gasoline is the general decline of the EU domestic demand for gasoline, be it conventional or bio. In fact, from 2005 to 2012 the demand for road gasoline dropped by 33 Mtoe, which is considerably larger than the simultaneous 2.3 Mtoe increase in biogasoline. However, even if only as a second-order effect, the drop in demand for EU-produced conventional gasoline would have been alleviated by the 2.3 Mtoe if biogasoline had not been pushed into the market, with a corresponding positive effect expected for EU refineries' utilisation rates.

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[93] This point was raised in a written comment received from a Member State representative from the UK.
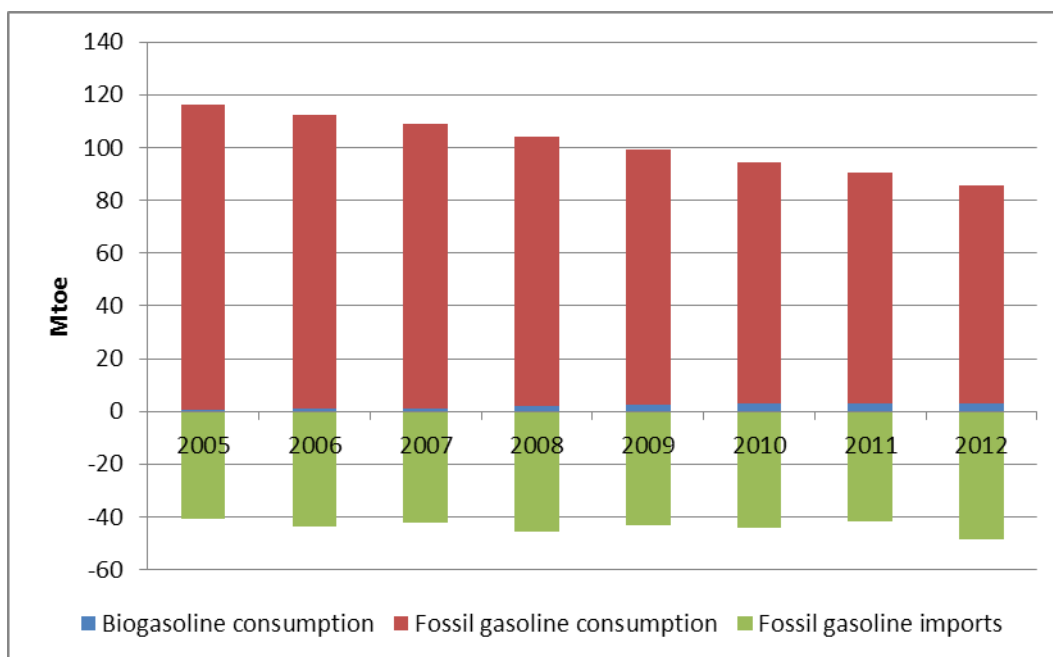
Figure 3.1.3: Evolution of EU consumption and production of gasoline and biogasoline, for the years 2005 to 2012

Note: Negative imports represent net exports.
Source: Eurostat (2014,2014a). [94]

At the cumulative level, the consumption over the years 2005-2012 of around 15 Mtoe of biogasoline replaced an equal amount of demand for conventional gasoline, the total consumption of which for road transport was 792 Mtoe, implying a relative share of 2 % for biogasoline (Eurostat 2014, 2014a). Due to the trend of overall falling gasoline consumption, this share has become higher in recent years, e.g. 3.5 % for 2012 (Eurostat).

Under the simplifying and extreme assumption that the current low EU utilisation rates are driven only by the gasoline market bottleneck, the absence of biogasoline would imply an increase of utilisation rates of the same order of magnitude. Correcting for the fact that typically between a quarter and a third of the total EU gasoline produced is exported, a back-of-the-envelope estimate suggests an increase by about two percentage points in 2012 if biogasoline had been absent. [95] This would represent a significant number in view of the typical inter-regional spreads observed for utilisation rates of around five to ten percentage points (BP 2014). If, as the other extreme, one assumes that the presence of biogasoline does not influence utilisation rates, but only shifts the sale of EU-produced gasoline from domestic to – assumingly less remunerative – export markets, there would be an impact on refinery margins depending on the corresponding price spread.

Based on estimated refinery throughput and margin data from IHS (2014), a scenario analysis was carried out to further quantify the implications of the above two opposing cases. To be precise, using the IHS refinery model, actual (estimated) refinery margins were compared with those of two hypothetical scenarios: (i) 'max' scenario, in which EU biogasoline consumption observed during 2000-2012 is eliminated and substituted by additional production from EU refineries, implying a

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[94] Since in the EU typically 99 % of all gasoline is consumed in road transport, no differentiation – as in the case for diesel – needs to be made between different end uses.

[95] Assuming that the bottleneck on refinery utilisation is the ability to allocate gasoline to the market, every tonne of mandated bio-ethanol forces a reduction in crude processing of about 5 tons (assuming 20 % yield share for gasoline).

concomitant increase of utilisation rates; (ii) 'min' scenario, in which historically observed EU biogasoline consumption is eliminated and replaced by EU gasoline that otherwise would have been exported, hence implying no change for EU utilisation rates. In these scenarios, any changes in the costs incurred by refineries for biofuel blending are not included.

As expected, both scenarios show an increase in EU refining margins, and 'max' scenario has the expected larger increase. More specifically, an average gain of EUR 0.20 (USD 0.25) per barrel of throughput during the years 2006 to 2012 is observed, with a maximum of EUR 0.35/bbl (USD 0.46/bbl) reached in 2012. Gasoline production per refinery is increased on average by 1 % a year, and by 1.5 % in 2012. In the 'min' scenario the hypothetical gain is much lower, with an average of EUR 0.01/bbl during 2006 to 2012, and a peak value of EUR 0.015/bbl (USD 0.02/bbl) in 2012. Given the caveats of the employed refining model (e.g. no general equilibrium effects, i.e. prices are fixed; refinery and price data often relies on estimates/assumptions) and the fact that the two scenarios were both deliberately chosen as extreme cases, these numbers should not be over-interpreted. But they should be seen as a confirmation of the significance of the biogasoline impact.

The modelling exercise within OURSE estimated the average effect (the forgone annual net earnings of the EU refineries) of a possible decrease in the utilisation rates of refineries because of demand drop due to the RED legislation at 3.65 euro cents per barrel of processed crude oil.

Hence, one can conclude that in the most recent years of the 2000-2012 period the presence of biogasoline has intensified the pressure on EU gasoline production and made it more reliant on export markets. A further decrease of EU refinery utilisation rates, so as to avoid excess gasoline production, would negatively affect its competitiveness. Importantly, this would also further exacerbate the already short EU supply of mid-distillates. This is the case because of the coupled production process characterising petroleum refining: given that the shares of different outputs are relatively fixed (at least in the short run), the reduction of one output inevitably leads to the reduction of all other outputs. At the aggregate level this means that if EU refineries shut down in order to reduce excess gasoline capacity, Europe's production of mid-distillates will also decrease and thus reinforce the import dependency for this product type.

In its 2010 'White Paper on EU Refining', the industry association Europia (2010) confirms the challenge arising from biogasoline:

> 'Due to the long investment cycle in refining, stable and predictable policy is required to make such investments possible. <u>Europe's existing gasoline overcapacity will be further impacted by policies to promote the use of biofuels in transport fuels</u>, which have been introduced in the EU and US. While the measures have contributed to reducing oil consumption in transport, the <u>increasing use of ethanol in gasoline in Europe and North America is aggravating the structural imbalance in the EU market for refined oil products</u>'. (Europia 2010, p.9) [underlining added]

Refineries' involvement in biofuel processing and blending

Even though the main economic impact on oil refining is the negative demand side effect, the mandatory presence of biofuels and the fact that they are typically marketed as a mix with conventional fuels means that refineries also become involved in their supply and supply logistics (e.g. IHS 2013, p.58). The available industry data includes two measures of such involvement: First, refineries increasingly acquired biofuels themselves in order to blend a final product or for reprocessing, e.g. bioethanol into bio-ETBE (the latter being an oxygenate used to improve the properties of gasoline). Second (and discussed further below), refineries invested in facilities for biofuel handling.

This first aspect is illustrated in Figure 3.1.4, showing that refineries' involvement in biodiesel blending in particular has strongly increased since 2005, highlighting once more the dominance of biodiesel versus biogasoline (bioethanol and bio-ETBE both belong in the latter category) in Europe. The magnitude of 130 000 tons of bio-components per refinery recorded in 2012 is comparatively small or even negligible, as it represents only 1.5 % of total inputs. However, the figures shown understate the real numbers to some extent. This is the case because the data collection was limited to those bio-components purchased by the refinery that were used for blending *within* the refinery, while in reality blending might also take place in dedicated facilities outside the refinery, particularly in the case of bioethanol.
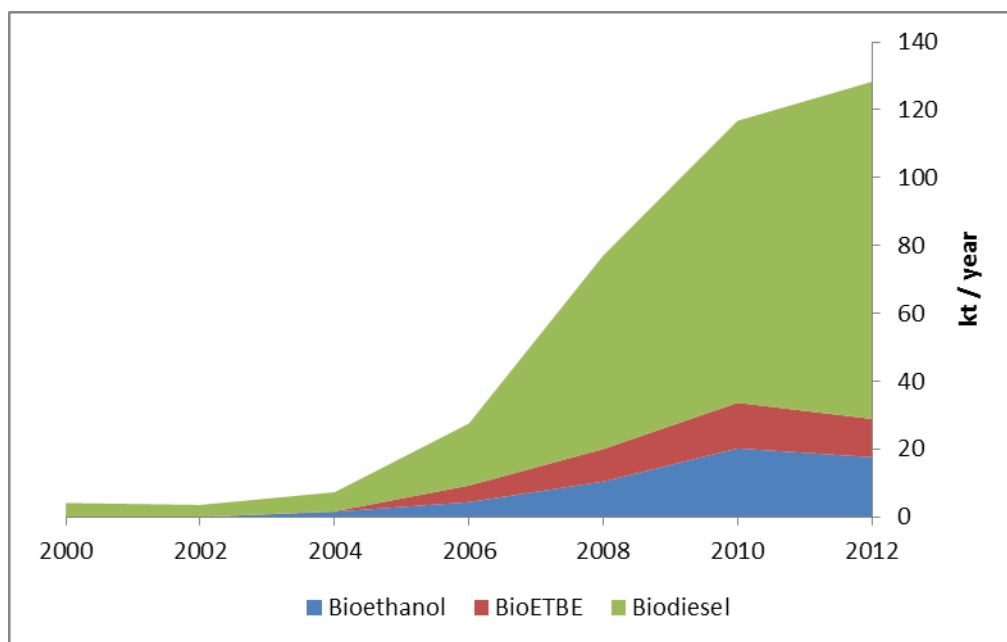
Figure 3.1.4: Annual average – per refinery – purchase of bio-components for processing (bioethanol for ETBE production) and blending of biofuels, in kt/year
Source: Solomon Associates (2014).

Apart from for the purpose of blending, EU refineries also purchased bioethanol for processing it into bio-ETBE, at a level of 1.5 kt in 2004 (earliest data), rising to 8.5 kt in 2010, and slightly lower thereafter. These numbers might be compared to the total ETBE production capacity, which on average was around 26 kt during 2008-12, and to the total ethanol (bio and conventional) input of around 22 kt during the same period (source: Solomon Associates (2014)).

Secondly, in order to gain access to the biofuel market, refineries also installed additional biofuel blending, storage, loading, discharging, and transportation facilities. Standard infrastructure used for conventional oil products might in fact not be suitable for biofuels, given their distinct properties, e.g. being hygroscopic or a potential source of bacterial contamination. The refinery survey (Concawe 2014) asked refineries to report the related capital expenditures, which are summarised in Figure 3.1.5.
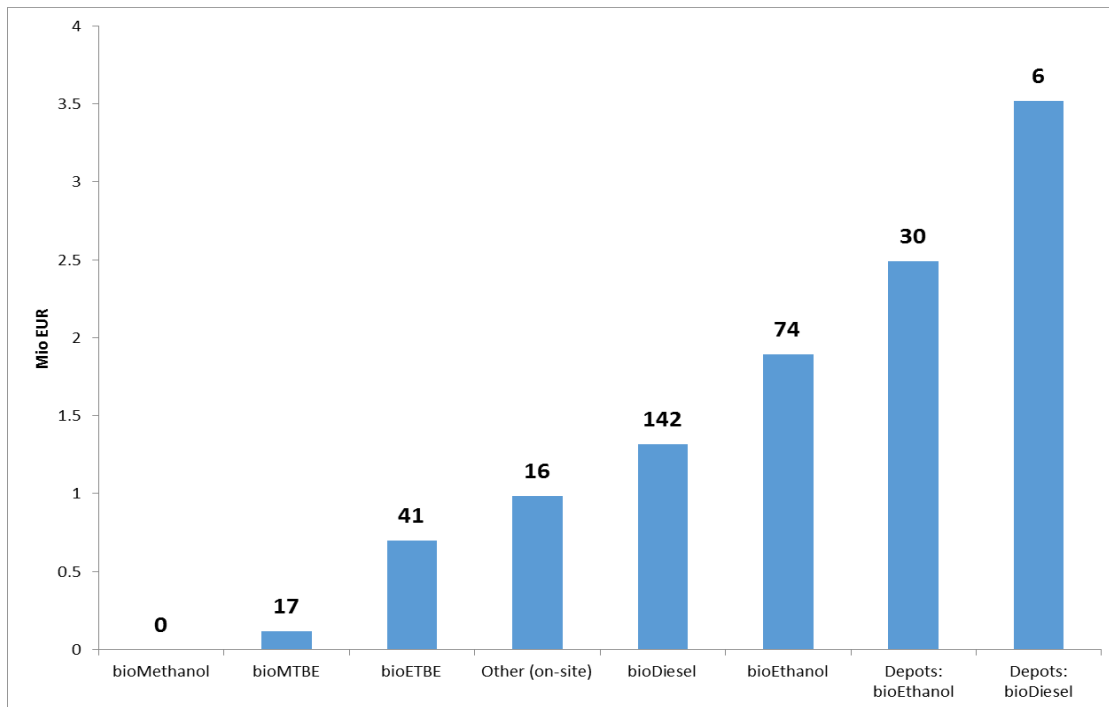
Figure 3.1.5: Average capital costs for additional storage capacity and other infrastructure at the refinery site and at external depot sites
Note: The numbers on top indicate the frequency, i.e. the total number of times such costs were reported by refineries during 2000-2012.
Source: Concawe (2014).

It can be observed that external depots constitute the most costly investment type, but have occurred much less frequently than investments in additional on-site storage capacities. In fact, the bulk of investments, roughly two thirds, went into biodiesel and bioethanol on-site capacities.

Overall, 326 investments of an average value of EUR 1.4 million have been reported by the sector, amounting to a total of EUR 469 million, or slightly above EUR 0.5 million on average annually per refinery that participated in the survey (67 refineries). Using throughput data from Solomon Associates (2014), this implies a cost of 0.9 euro cents per barrel of throughput. The time evolution of the sector's total biofuel-related capital expenditures is shown in Figure 3.1.6. The figure shows an increasing trend, with 63 % of all investments occurring in the five most recent years (2008-12), when the annual expenditures per refinery rose to nearly EUR 0.9 million, or 1.5 euro cents per barrel of throughput.

It should be acknowledged that individual investments can be much larger, e.g. the single highest reported investment was EUR 21.8 million in 2009 for bioethanol storage in the UK and Ireland region, and another very large EUR 15 million investment in biodiesel was reported in 2008 by a Baltic region refinery (Concawe 2014).
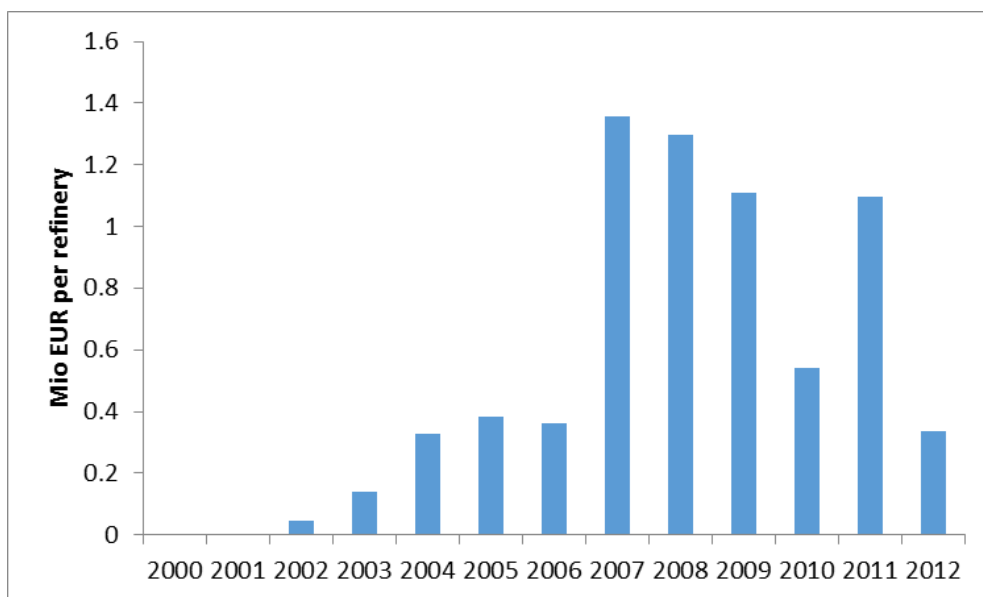
Figure 3.1.6: Annual capital expenditures related to biofuel storage capacity and other infrastructure at the refinery site and external depots (average total expenditures in EUR million per refinery, for the EU-28)
Source: Concawe (2014).

More generally, the degree of refineries' involvement in biofuel production might vary considerably across the EU, as suggested by the variance observed in the reported investments, which for example were EUR 123 million in the UK and Ireland region vs EUR 7 million in the Iberia region (cumulative over 2000-2012, source: Concawe (2014)). The available data does not allow us to determine which factors drive a refinery's involvement in biofuel production and distribution. In theory, various aspects are conceivable, e.g. particular local market conditions or the overall strategy of a vertically integrated company.

The resulting economic impact of the reported investment numbers depends on the possibility of cost pass-through. In fact, in a competitive market environment the policy instruments employed for biofuel support – blending mandates, excise tax reduction and direct subsidies – affect all product suppliers equally, from within or from outside the EU. This implies that the incremental costs of biofuel supply will eventually be borne by the consumers (or taxpayers, in the case of a subsidy instrument). In fact, IHS' UK refining sector study (2013, p.16 and p.184) assumes full cost pass-through in its estimate of the future costs of biofuel supply as mandated by the RED, and hence does not project an impact on refining margins (*idem*, p.173), but rather on refined product prices (*idem*, p.175). In line with this, it can be expected that the capital expenditures incurred by industry reported here – EUR 0.01 per barrel of throughput – will be recovered from the market.

Higher costs of electricity under the RED

For the average EU refinery, electricity accounted for about 20 % of its total energy consumption during 2000 to 2012, with a rising trend (Solomon Associates 2014). Clearly, the EU-wide mandatory introduction of electricity from renewable sources has led to an increase in overall electricity generation costs. The schemes by which the expansion of renewable electricity was financed differ from Member State to Member State, with feed-in tariffs and quota obligations as two prominent examples.

In cases where the incremental costs of renewable electricity were passed on to all final users, households and firms, refineries experienced an increase in the electricity price, which can be attributed to the RED. For example, in Germany the associated surcharge put on electricity

consumption grew steadily, becoming 3.6 euro cents/kWh in 2012.[96] However, Germany at the same time incorporated derogation rules for electricity-intensive companies and for companies producing electricity for their own consumption. Especially the latter will have allowed German refineries to avoid the surcharge for self-generated electricity, which represented 70 % of all electricity consumed in German refineries (Solomon Associates 2014).

In sum, without a detailed analysis of how the RED was implemented at the Member State level a conclusion with regard to its impact on refinery electricity costs is not possible. Since energy costs represented about 60 % of total refinery operating costs in recent years, the potential cost impact of a surcharge on electricity might be significant, even if electricity represents only 20 % of total energy consumption. For example, a hypothetical 10 % decrease in the costs only of purchased electricity (representing 8 % of total consumed energy) would translate into a reduction of total operating costs of EUR 0.02 per barrel of throughput for the average EU refinery during 2010 to 2012 (source: own computation based on Solomon Associates 2014).

Review of Member State refining sector studies

The studies by IHS (2013 p.158f.; 2014a, p.121f.) of the UK and Italian refining sectors, respectively, make a forward-looking assessment of the implications of the 10 % RES-T target for 2020, with annual cost estimates for the years 2013 to 2030, and, respectively, 2035. The UK study also briefly mentions the increasing substitution of gasoil and kerosene for domestic heating by renewables in Germany (IHS 2013, p.35) and in the UK and Ireland region (*idem*, p.43).

The Greek refinery sector study (Danchev and Maniatis 2014) identifies the presence of biofuels as one of three factors that increase the pressure on the EU gasoline surplus, the other two being US light tight oil and the improved fuel efficiency of cars (*idem*, p.14). It also discusses the impact of higher electricity prices, and mentions the 'Special Duty for Emissions Reduction' (ETMEAR) as one possible contributing factor (*idem*, p.21f.).

A study commissioned by France (Legrand et al., 2012) criticises the 'very ambitious' French biofuel policy for its content requirements and implementation rigidities, which are seen to be 'without equivalent in Europe' (*idem*, p.8). It also points to the fact that the use of biogasoline results in further deterioration of the EU gasoline surplus position (*idem*, p.29). Last but not least, it mentions that the differences across EU Member States in terms of regulatory biofuel specifications constitute a problem for European operators (*idem*, p.29).

Finally, the Irish study of the strategic value of oil refining (Purvin & Gertz 2012) discusses the impact of the RED and associated biofuel targets on future energy and oil product demand up to 2050 in Ireland and Northern Ireland (*idem*, p30ff.).

3.1.4. *Efficiency of the legislation*

This section discusses efficiency by putting the legislation's overall benefits into perspective with its costs and assessing whether the benefits are achieved at proportionate and affordable costs.[97] This analysis will mainly be based on reviews of existing studies. If relevant and possible, it also

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[96] https://www.netztransparenz.de/de/EEG-Umlage-2012.htm

[97] Official mandate of the Fitness Check, p.6: 'What are the costs and benefits associated with the implementation of the specific legislation? Can any costs be identified that are out of proportion with the benefits achieved?' (http://ec.europa.eu/smart-regulation/evaluation/docs/2014_refining_fc_mandate_final_en.pdf)

discusses regulatory gaps, inconsistencies, overlaps or evidence of excessive administrative burdens.

The Renewable Energy Directive has been analysed in Commission reports (European Commission 2007, 2009, 2011, 2013a, 2013b), in studies commissioned by the EC (Ecofys 2012, Wood Mackenzie 2010), as well as in joint Commission-industry studies (Lonza et al., 2011, Hamje et al., 2014). This section draws on these documents. Its scope is, however, limited to policies on renewable energy in the transport sector, as this constitutes the relevant issue for the refinery sector.[98]

Limited evidence is available on the policy's achieved implementation efficiency, i.e. on the question of whether the reported expansion of biofuels has been reached at the lowest possible cost (e.g. from an ex post perspective, subsidies might have been too high). In one approach, a study by Ecofys compares the marginal production costs of biofuels and their market remuneration (Ecofys 2012, p.139ff), arguing that if they are close to each other, the policy is efficient. Although compensation schemes and levels are quite variable across Member States, for the widely employed instrument of 'excise reduction' the authors come to the conclusion that there is no systematic overcompensation for biofuel producers (Ecofys 2012, p.143), i.e. the market remuneration seems to be consistent with an efficient policy implementation.

The overall costs–in terms of public financial support–of the EU biofuel policy have been estimated as between EUR 5.5 billion and EUR 6.9 billion for 2011, corresponding to a support of EUR 0.15-0.21/litre for biogasoline and EUR 0.32-0.39/litre for biodiesel (IISD 2013, 2013a).[99] However, there is uncertainty with regard to the appropriate estimation methodology, leading another study (Ecofys 2013) to question the validity of some of the approaches and results.[100] Without presenting a full calculation of its own, Ecofys' study estimates that the total public financial support (excluding R&D support) for biodiesel in 2011 was EUR 2.2 billion or EUR 0.15/litre, and hence 50 % to 60 % lower than the (revised) figure of EUR 4.6 billion to EUR 5.6 billion from IISD (2013a).

Depending on the implementation scheme, these costs are borne by the fuel consumers (e.g. in the case of mandated biofuel quotas) paying higher prices at the pump or by taxpayers (e.g. in the case of tax exemptions for biofuels). We lack data on the observed price mark-ups for biofuels and biofuel blends in EU Member States, but according to the analysis in IISD (2013, p.43ff.), which estimates 'additional costs to motorists', the implied excess costs might be in the order of billions of euros for the year 2013. Again, the reanalysis by Ecofys (2013) raised doubts about the chosen methodology in IISD (2013), arguing that this type of cost is part of the 'market support' costs. Their own estimate of the higher costs to consumers due to the presence of biodiesel is EUR 603 million in 2011, and this sum was already included in the total public finance support of EUR 2.2 billion cited before.

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[98] There could be an indirect link between renewable electricity and refineries if a higher renewable share leads to higher electricity prices and if electricity constitutes a significant energy input of a refinery. Apart from very few exceptional cases, this does not seem to be the case.

[99] Whether this level of financial support corresponds to the real gap in production costs of conventional fuels and biofuels cannot be answered straightforwardly, as the production costs of the former are dominated by highly volatile crude oil prices and those of the latter depend on equally volatile commodity prices (and vary widely across different types of biofuels). For example, IEA estimates expect a minimum Brent price of around USD 100/bbl for biofuels to become competitive (IEA 2008, p.66).

[100] One computation error made by the IISD in an earlier (2013) study was corrected in IISD (2013a). However, the critique of Ecofys (2013) also concerned other aspects.

The societal benefits from biofuel promotion are a widely and controversially discussed topic (e.g. de Gorter and Just 2010; Khanna and Chen 2013). Generally, greenhouse gas savings and security of energy supply are perceived as the two main quantifiable benefits. A potential third, but so far less researched and less established, benefit occurs if lower EU demand leads to a decrease in the international crude oil price and hence in EU import costs (Laborde 2011, p.57). Finally, employment figures for the biofuel sector point to further potential benefits: studies and approaches vary, with one estimate of 3630 direct jobs at EU biofuel production facilities in 2011 (IISD 2013, p.3), while the inclusion of all indirect and induced jobs leads to numbers like 220 000 (European Commission 2013b, p.26) or 122 000 (IISD 2013, p.3), referring, respectively, to the years 2010 and 2011. However, the overall benefit would need to be judged by the net effect on total EU employment to draw a definite conclusion.

Benefits related to climate change

Regarding greenhouse gas savings, Member States reported that between 22.6 and 25.5 Mt CO_2eq were saved in the year 2010 due to the use of biofuels, 14 Mt CO_2eq in 2007, and 9.7 Mt CO_2eq in 2006. The numbers represent 1–3 % of the around 900 Mt CO_2 emissions from road transport in 2009 (EEA 2012). As a more intuitive measure, biofuels are estimated to generate between 53 % and 60 % less greenhouse gas emissions than a comparable amount of conventional fossil fuels (European Commission 2013b; European Commission 2009, p.7).

However, these numbers do not include additional emissions from indirect land-use changes or agricultural intensification, which are associated with biofuel feedstock production. Once included, they are expected to lead to a significant reduction of the estimated emission savings (European Commission 2013a, p.12).[101] For example, a UK impact assessment (UK DfT 2014, p.23) finds a net *negative* GHG saving effect from biofuels for the years 2008/09, due to the dominance of crop-based feedstock during this early stage of biofuel policy. Later on positive net GHG savings were achieved–up to 2.1 Mt CO_2eq/year–because of, inter alia, 'double certification of waste-derived biofuels, sustainability criteria and a duty incentive for used cooking oil derived biodiesel' (*idem*, p.1).

A back-of-the-envelope computation allows us to put the GHG reduction into perspective: with CO_2 intensities of 2.7 kg/litre for diesel and 2.3 kg/litre for gasoline, and an assumption on the social costs of carbon of EUR 15/t CO_2, a carbon-neutral fuel substitute would generate a climate benefit of EUR 0.04 (2.7*15/1000) and EUR 0.03/litre, respectively (for assumed social costs of carbon of EUR 5/t CO_2 the value would be one third of this, and for social costs of carbon of EUR 30/t CO_2 the value would double).[102] For the first-generation biofuels used in the past, a more realistic (and likely still optimistic) estimate would be that a 50 % GHG reduction was achieved, implying a climate benefit of about 2 euro cents/litre.[103]

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[101] However, past legislation considered here (up to 2012) does not include all production-related greenhouse gas emissions for fossil fuels either. These 'well-to-wheel' emissions are discussed, for example, by http://iet.jrc.ec.europa.eu/about-jec/jec-well-wheels-analyses-wtw

[102] According to a report by the US Government Interagency Working Group on the Social Cost of Carbon (2010), mean estimates for the social costs of carbon are USD 35/t CO_2, USD 21/t CO_2, or USD 5/t CO_2, depending on whether the discount rate is taken to be 2.5 %, 3 %, or 5 %, respectively. A meta-study by Tol (2010) based on 211 estimates finds a mean value of USD 28/t CO_2, with a median of USD 4/t CO_2. For more details, see the review section in Pycroft et al. (2011).

[103] Note that the expected climate benefit of biofuels constitutes one rationale (but there might be others) for a regulatory discrimination vis-à-vis fossil transport fuels, e.g. by means of a biofuel subsidy. The computation/estimation

This implies that only a small fraction of the estimated past financial support for biofuels can be explained by its emission savings benefit. In fact, in the hypothetical case that all of the financial support was aimed at this objective, the expenditure of EUR 5.5 billion in 2010 (lower end number from IISD (2013a)), together with an assumed 23 Mt of CO_2eq saved, would imply average abatement costs of EUR 240/tonne of CO_2eq. Even with only the EUR 2.8 billion of budgetary support reported in Ecofys (2013), this number would remain at EUR 122/tonne of CO_2eq.

Such high abatement costs are not a new finding, given an earlier Commission report's statement that 'Biofuels are an expensive way of reducing greenhouse gas emissions' (COM(2005) 628 final). However, one should take into account that there are only a few available abatement options in the transport sector.

Benefits related to decreased energy import dependence

For the second main expected benefit of biofuels, the EU's security of energy supply, the positive effect in terms of a reduced crude oil and oil product import dependency is obvious, given the fact that the majority of biofuels consumed in the EU were produced in the EU (82 % in 2010) and stem from EU feedstocks (64 % in 2010).[104] Moreover, with Argentina, Brazil, and the US as the most important outside suppliers of biofuels, a diversification of the EU's supplier countries is also achieved (European Commission 2013b, p.13ff).[105]

To further quantify this effect, one needs to estimate the benefits of reduced oil imports (reduced exposure to oil price spikes, improved terms of trade, etc.). In a published study, Hedenus et al. (2010), using a numerical model of the oil market and the cost of oil supply disruption, estimated them to be EUR 9-22 per barrel of replaced crude oil, or 6-14 euro cents per litre of gasoline (or any other product refined from crude oil) for the EU-25.[106] Based only on these numbers, and on the assumption that there is no risk of disruption associated with biofuel and biofuel feedstock imports, the reduction of the EU's import dependency would therefore constitute the main benefit of biofuel promotion.

However, in view of the uncertainty related to the potential costs of import dependency, a conservative approach would be to simply compute the biofuel's mitigating impact on the EU's stocking obligations for crude oil and oil products, and the implied cost saving. Since Europe has no strategic import dependency for biofuels (64 % of the feedstock from within the EU in 2010, and suppliers are diversified), there would be no need to have strategic reserves as for oil and oil products (just as there are no strategic coal reserves). Assuming a unit of biofuels displaces an equivalent amount of crude imports, computed by applying a factor of 1.065 as per 2009/119/EC,

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of this climate benefit does not depend on the production costs or market prices observed for biofuels and/or conventional transport fuels.

[104] For the origin of biodiesel feedstock, the EU's share is 60 %, with rapeseed as the largest single source, followed by recycled vegetable oil (RVO). For biogasoline, the EU's share is 79 %, with sugar beet as the largest single source, followed by wheat (European Commission 2013b, p.15).

[105] If, as we argue, EU biodiesel consumption displaces diesel imports, then the benefit of biodiesel promotion consists of a net reduction of these oil product imports. For biogasoline, the situation is less simple: higher EU consumption could either lead to higher exports of fossil gasoline, or to lower EU fossil gasoline production, or both. The second effect will be dominating if, as we assume, the gasoline market is the main driver of low EU utilisation rates. However, biogasoline would in any case lead to a lower EU net dependency on oil, even if nominally crude oil imports did not change.

[106] The study employs a model for calculating the effect on the expected economic costs of oil disruptions of energy policies and the monopsony power gain. A noteworthy result is that 'it is found that substituting pellets for oil in households and using imported sugar cane ethanol are cost-efficient policies if greenhouse gas benefits are included. Domestically produced wheat ethanol is not found to be cost-efficient even if both the expected cost of oil disruption and greenhouse gas benefits are included'.

and noting that 90 days of imports plus a 10 % safety addition must be held, the resulting stock reduction becomes 0.29 units of crude per unit of biofuel replacement.[107] The storage costs have been estimated as USD 7-10 per barrel (IEA 2013), implying EUR 3.2-4.5 euro cents per litre. Therefore, by potentially decreasing the EU import dependency on oil product imports and allowing for reduced compulsory stockholding obligation, the increased use of biofuels could lead to saving of roughly EUR 0.01 per litre.

Benefits with regard to lower crude oil import price

A potential third, but so far less researched and less established, benefit occurs if lower EU demand leads to a decrease in the international crude oil price and hence in EU import costs (Laborde 2011, p.57). This theoretical effect is expected because in as much as biofuels substitute refined oil products, the EU's demand for crude oil imports will be reduced. Following basic economics, in a competitive crude oil market a drop in demand will lead to a drop in the price of crude oil and hence a reduction of the EU's total costs for importing it (in technical terms, an improvement of the EU's terms of trade). The existence and strength of this effect will depend on a number of factors, including on whether oil suppliers will indeed act competitively (and not strategically), or on whether the price drop will not be neutralised by additional demand from non-EU regions. Given that the year 2012 level of EU biofuel consumption of 14.6 Mtoe represents only about 0.35 % of global oil consumption (Eurostat 2014a, BP 2014), the effect might be very small. However, the potential savings for the EU could still be substantial, as the EU imports crude oil for typically USD 200-400 billion per year.[108]

Criticism with regard to policy implementation

In terms of the policy's wider impacts and coherence, the promotion of biofuels in Europe has been accompanied by discussions regarding its potential counterproductive effects. The main negative impacts discussed consist of increased and unsustainable land use, biodiversity loss, and water, air and soil stress.

Moreover, although no direct quantitative evidence is available for now, it is generally believed that the increased demand for biofuel feedstock has contributed to the expansion of cropping areas and to soil degradation from intensification (Ecofys 2012, p.282ff). Some studies have used numerical models to estimate the extent to which EU biofuel policy leads to additional land use (e.g. Ecofys 2012, p.238; Laborde 2011, p.11).

On top of these negative environmental impacts, there are also concerns about the negative social impacts associated with EU biofuel consumption, namely increases in food prices and a weakening of land-use rights. Agricultural land used for biofuel production competes with land used for food production and hence–given limited land availability–growing demand for biofuels might lead to higher opportunity costs of food production and eventually higher food prices. These concerns were fuelled by two spikes in global food prices occurring in 2007/08 and 2010/11. However, modelling-based analysis suggests that EU biofuel usage only had a marginal impact on global food prices, between 1-2 % for bioethanol and 4 % for biodiesel (the latter mostly affecting non-food items) (European Commission 2013b, p.22-23).

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[108] Source: G Energy website on EU crude oil imports, see http://ec.europa.eu/energy/en/statistics/eu-crude-oil-imports.

Clearly, these environmental and socio-economic impacts bear consequences in terms of the policy's efficiency. First, with regard to its main environmental objectives: some biofuels might not provide any net greenhouse gas savings once land-use effects are taken into account, and in addition risk harming natural resources like water, soil, and biodiversity. Hence, there is a potential contradiction with the EU's policy goal of safeguarding the environment and mitigating climate change. Second, with regard to the 'fuel vs food' conflict, i.e. the potential food price increase due to competition with biofuel feedstock production. If proven true, it would constitute a contradiction of the EU's wider international development objectives.

However, after these problems were identified, the Commission engaged in a discussion on how to improve legislation, leading to stricter greenhouse gas reduction rules and sustainability criteria in Directive 2009/28 than in the preceding 2003/30, and further modifications proposed in a 2012 document (European Commission 2012). As a means to support a transition from first-generation (i.e. based on sugar, starch, vegetable oil) to second-generation or advanced (based on agricultural waste, cellulosic, etc.) biofuels, these reforms envisage, inter alia, restricting the use of food crops for biofuel production, incentivising biofuel feedstocks that do not lead to land-use expansion, and including indirect land-use change emissions in the reporting of greenhouse gas savings.

Finally, if the share of biogasoline on EU fuel markets consistently increases, further policy contradictions might arise. When—so as to avoid excess gasoline production—refineries' utilisation further diminishes and leads to a reduction of diesel output, the EU's current reliance on diesel imports would further increase, undermining the security of supply. Second, with higher consumption levels of biogasoline, a need for its increased import might eventually arise, which would put the few currently important suppliers of ethanol, like Brazil, in a strategic position (Wood Mackenzie 2010, p.23). Third, as a means to avoid excess gasoline production, EU refineries might try to shift their product portfolio further towards diesel, which would imply reduced energy efficiency (and thus reduced economic efficiency) and higher CO_2 emissions (Lonza et al., 2011, p.42).

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3.2. Energy Taxation Directive

Some of the main conclusions derived from the analysis of this chapter focusing on the effectiveness and efficiency of the Energy Taxation Directive (ETD) in relation to its own objectives and those of the EU refining industry are the following:

- The ETD's main objective of reducing divergent tax rates across the EU countries was largely achieved by 2010 in the case of gasoline and diesel oil used as propellants, as measured by the reduction observed in cross-country excise tax variability. Thus, the ETD has played a positive role in improving the functioning of the internal market by reducing distortions of competition between Member States due to their divergent gasoline and diesel tax rates.

- Given that the overwhelming majority of the excise duties for heating gasoil (business and non-business use), heavy fuel oil (heating business and non-business use), and LPG used for motor fuels were relatively stable over the 2002-2013 period, they contributed much less to the narrowing of the differences between these taxes across the EU countries than those of gasoline and diesel oil.

- Concerns were raised, in particular in the European Commission proposal for a revision of the ETD in 2011 (see EC COM(2011) 169/3), about the effectiveness of the ETD in relation to its other two objectives of encouraging more efficient use of energy and improving the functioning of the internal market by reducing distortions in competition between mineral oils and other energy products. Such concerns are related to the fact that the current minimum tax rates are based on the volume of energy products, and as such they do not reflect the CO_2 emissions or the energy content of these products.

- Regarding the ETD's impact on the refining sector, we find a negligible reduction in total EU demand for gasoline and diesel. Relative to the observed EU-27 consumption, the average demand reductions for the 2004-2008 period are estimated to be 0.17 % for gasoline and 0.10 % for diesel, while those for the 2009-2013 period are 0.27 % and 0.32 %, respectively.

- The gasoline and diesel tax levels of, respectively, 17 and 16 Member States, representing 85-88 % and 77-78 % of the total EU-27 gasoline and diesel markets, were not affected by the ETD, because their tax levels were already higher than the minimum ETD levels before these minimum excise rates were adopted.

- Up to 11 Member States (from Bulgaria, Cyprus, Czech Republic, Estonia, Spain, Greece, Lithuania, Luxembourg, Latvia, Malta, Poland and Romania) were found to be affected by the ETD's minimum tax levels for gasoline and diesel excise duties. The assessed average Member States-level demand reductions for gasoline and diesel account for up to only 3.3 % and 2.2 %, respectively. The largest reduction of 4.4 % is obtained for Bulgaria in the case of gasoline consumption during the 2009-2013 period.

- At the EU level, we did not find any discernible impact of the ETD in terms of the European consumption switch from gasoline to diesel. However, for seven Member States (Bulgaria, Czech Republic, Lithuania, Latvia, Malta, Poland and Romania) the ETD seems to have only marginally contributed to their diesel to gasoline demand switch, given that their diesel to gasoline demand ratios in the counterfactual environment without the ETD were assessed to decrease, on average over the two periods, by 0.63 % to 2.07 %.

3.2.1. Objectives and measures

Council Directive 2003/96/EC of 27 October 2003 is the key piece of relevant legislation aimed at restructuring the Community framework for the taxation of energy products and electricity. The Directive entered into force on 1 January 2004 and replaced Council Directive 1992/81/EEC on the harmonisation of the structures of excise duties on mineral oils and Council Directive 1992/82/EEC on the approximation of the rates of excise duties on mineral oils.

Historically, Council Directive 1992/82/EEC introduced for the first time a minimum level of taxation for refined oil products in EU Member States.[109] In view of the 2004 EU enlargement process, two amendments – Council Directives 2004/74/EC and 2004/75/EC – were adopted on 29 April 2004 that aimed at facilitating the transition arrangements for the new EU members.[110] They set a general transition period up to 1 January 2007 and included additional derogations and exemptions.[111] Besides the legislative acts mentioned, the *Protocol concerning the conditions and arrangements for admission of the Republic of Bulgaria and Romania to the European Union* (OJ L 157, 21.6.2005, Annexes VI and VII) includes specific provisions on the adoption of the EU minimum tax levels on energy products for Bulgaria and Romania.

The main **objectives** of the Energy Taxation Directive (ETD, referring to Council Directive 2003/96/EC) were the following:

- improve the functioning of the internal market by reducing distortions of competition between Member States due to then existing divergent tax rates across the EU countries;
- improve the functioning of the internal market by reducing distortions of competition between mineral oils and other energy products that have not been subject to Community tax legislation up to 2003;
- encourage more efficient use of energy so as to reduce dependency on imported energy and to cut greenhouse gas emissions; and
- authorise Member States to grant tax incentives to businesses undertaking specific measures in reducing their emissions.

Energy products and electricity are taxed only when they are used as motor or heating fuel, but the ETD does not apply when they are used as raw materials or for the purposes of chemical reduction or in electrolytic and metallurgical processes, as well as mineralogical processes. Based on this principle, the ETD sets minimum rates of taxation for motor fuel, motor fuel for industrial or commercial use, heating fuel and electricity. The ETD specifies *industrial and commercial uses* as (i) agricultural, horticultural or piscicultural works, and forestry, (ii) stationary motors, (iii) plant and

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[109] Directive 1992/82/EEC (Article 2) provides a list of mineral oils covered, which include leaded and unleaded petrol, gas oil, heavy fuel oil, liquid petroleum gas, methane and kerosene. Without prejudice to given exemptions, the adopted minimal tax rates were applicable from 1 January 1993. In comparison to this Directive, Council Directive 2003/96/EC widened the product coverage to all energy products, including mineral oils, coal, coke, lignite, bitumen and products derived from them, natural gas, and electricity.

[110] In order to smoothly align the existing energy taxation in the new Member States with the overall EU practise, the first amendment of the ETD facilitates the application of temporary exemptions or reductions in the levels of taxation for the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovenia and Slovakia, while the second amendment facilitates similar mechanisms for Cyprus. Both amendments entered into force on 1 May 2004.

[111] For setting the fiscal framework of energy and refined oil products, Council Directive 1995/60/EC111 of 27 November 1995 on fiscal marking for gas oil and kerosene, and Commission Decisions 2006/428/EC and 2001/574/EC are also relevant legal documents.

machinery used in construction, civil engineering and public works, and (iv) vehicles intended for use off the public roadway. Thus, the *levels of taxation*[112] applied by all Member States shall not be lower than the minimum rates set in the ETD.[113]

The main **measures** of the ETD that are directly relevant for the EU refining sector include setting *minimum* levels of taxation on energy products that all Member States have to abide by, considering also the exemptions and transitional periods provided to certain EU countries. All these minimum taxation levels as set in Council Directives 92/82/EEC and 2003/96/EC with their corresponding effective dates are summarised in Table 3.2.1. In the next section, references to this table will often be made to compare the EU minimum taxation levels to the actual levels observed across Member States. For now, it is worth noting that Table 3.2.1 shows that all the listed petroleum products have similar minimum taxation levels across the last two implementation dates (but different across product dimension) as set in the ETD, except for gas oil and kerosene used for motor fuels. For the last refined products, the minimum levels of taxation are required to increase further by 9.3 % compared to their 2004 levels.

Member States are allowed to apply *differentiated rates of taxation*, provided that these rates comply with the minimum levels of taxation prescribed by the ETD and are compatible with EU law, in cases when the differentiated rates are directly linked to product quality or depend on quantitative consumption levels for electricity and energy products used for heating purposes, and in cases when used for local public passenger transport (including taxis), waste collection, armed forces and public administration, disabled people, ambulances, and for between business and non-business uses.

The ETD includes an extensive list of *exemptions* or *permitted reductions* in taxation rates. Among other purposes/uses, Member States may apply total or partial exemptions or reductions in the level of taxation of:

- energy products used in pilot projects with the aim of technological development of more environmentally friendly products or in relation to fuels from renewable sources;
- biofuels;
- forms of energy which are of solar, wind, tidal or geothermal origin, or from biomass or waste;
- energy products and electricity used for the carriage of goods and passengers by rail, metro, tram and trolley bus; and
- natural gas and LPG used as propellants.

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[112] The 'level of taxation' is defined as the total charge levied in respect of all indirect taxes (except VAT) calculated directly or indirectly on the quantity of energy products and electricity at the time of release for consumption (Council Directive 2003/96/EC, Article 4).

[113] It should be noted that the European Commission on 13 April 2011 presented its new proposal to overhaul the existing rules on the taxation of energy products with the aim of restructuring the way energy products are taxed (see EC COM(2011) 169/3). In particular, it was proposed that the existing energy taxes be split into two components – CO_2 emissions component and energy component – that, taken together, would determine the overall rate at which a product is taxed. The reasoning is to promote energy efficiency and consumption of more environmentally friendly products and to avoid distortions of competition in the single market. According to the proposal, the new minimum tax rates had to be reached by 2018. However, the European Parliament on 18 April 2012 did not fully support the proposal, and in particular the proposed alignment of motor fuel taxation was rejected.

Table 3.2.1: Minimum levels of taxation applicable to relevant energy products
Source: Council Directive 92/82/EEC and Council Directive 2003/96/EC.

Energy product	Effective date		
	1 Jan 1993[114]	1 Jan 2004	1 Jan 2010
Leaded petrol/gasoline (EUR/1000 litres)	337	421	421
Unleaded petrol/gasoline (EUR/1000 litres)	287	359	359
Gas oil (EUR/1000 litres)			
-- Used for motor fuels	245	302	330
-- Used for industrial and commercial purposes	18	21	21
-- Used as heating fuel	18[115]	21[116]	21
Heavy fuel oil (EUR/1000 kg)	13	15	15
Kerosene (EUR/1000 litres)			
-- Used for motor fuels	245	302	330
-- Used for industrial and commercial purposes	18	21	21
-- Used as heating fuel	0	0	0
LPG (EUR/1000 kg)			
-- Used for motor fuels	100	125	125
-- Used for industrial and commercial purposes	36	41	41
-- Used as heating fuel	0	0	0
Natural gas (EUR per GJ gross calorific value)			
-- Used for motor fuels		2.6	2.6
-- Used for industrial and commercial purposes		0.3	0.3
-- Used as heating fuel		0	0

Energy products are exempt from taxation if used for the purposes of (i) air navigation other than in private pleasure-flying and (ii) navigation within EU waters, including fishing, other than private pleasure craft, and electricity produced on board a craft. Member States may limit the scope of these two mandatory exemptions to international and intra-EU transport. Thus, Member States may apply a lower level of taxation than the relevant minimum set by the ETD for all air or sea transport within an EU country or between two EU countries that have signed a relevant bilateral agreement.

For some Member States, the ETD defined *transitional periods* during which they were required to gradually reduce the gap between their rates and the new minimum rates of taxation. However, when the difference between the national rate and the minimum rate did not exceed 3 % of the minimum rate, the EU country could wait until the end of the period to adjust its national level. In Table 3.2.2 we summarise the transitional periods of selected EU countries for unleaded gasoline and diesel oil, which will be used in our analysis in the next section.

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[114] Exemptions applied for Luxembourg over the period of 1 January 1993 to 31 December 1994 that set lower minimal rates of 292 and 242 ECU/1000 litres, respectively, for leaded and unleaded petrol. Similarly, in the case of gas oil used for motor fuels, exemptions applied for Luxembourg and Greece for the period of 1 January 1993 to 31 December 1994 that set a lower minimal rate of 195 ECU/1000 litres.

[115] This rate applies on heating gas oil. Member States that did not apply excise duty on heating gas oil on 1 January 1991 were authorised to apply a zero tax rate, provided that they have levied a monitoring charge of EUR 5 per 1000 litres from 1 January 1993. The charge was raised to EUR 10 per 1000 litres from 1 January 1995.

[116] Member States, which on 1 January 2003 were authorised to apply a monitoring charge for heating gasoil, may continue to apply a reduced rate of EUR 10 per 1000 litres for that product (Article 9.2).

Table 3.2.2: Transitional periods' taxation rates for selected countries: unleaded gasoline and diesel oil (EUR)

	1 May 2004	1 Jan 2007	1 Jan 2008	1 Jan 2009	1 Jan 2010	1 Jan 2011	1 Jan 2012	1 Jan 2013
Unleaded gasoline used as a propellant								
EU minimum	359	359	359	359	359	359	359	359
CY, EE, MT	287	287	287	287	359	359	359	359
LT, LV	287	287	323	323	323	359	359	359
PL	287	287	287	359	359	359	359	359
BG, RO			323	323	323	359	359	359
Diesel / Gas oil used as a propellant								
EU minimum	302	302	302	302	330	330	330	330
EL	245	245	245	245	302	302	330	330
ES	245	302	302	302	302	302	330	330
LU	245	245	245	302	302	302	330	330
EE, MT	245	245	245	245	330	330	330	330
CY	245	245	302	302	330	330	330	330
LT, LV	245	245	274	274	274	302	302	330
PL	245	245	274	274	302	302	330	330
BG			274	274	302	302	302	330
RO			274	274	274	302	302	330

Besides EU-wide minimum levels of taxation, the reduced taxation levels over the given transitional periods are reported in Table 3.2.2, where the figures refer to the newly set minimum tax rates to be implemented by the Member State concerned. For example, to abide by the diesel oil minimum taxation requirements, Lithuania (LT) and Latvia (LV) were given a transitional period of the following nature: the level of taxation on gas oil used as a propellant was not allowed to be less than EUR 245 per 1000 litres from 1 May 2004, no less than EUR 274 per 1000 litres from 1 January 2008, no less than EUR 302 per 1000 litres from 1 January 2011, and had to reach the EU-wide minimum level of EUR 330 per 1000 litres starting from 1 January 2013.

Taxation of leaded gasoline is not discussed in this study as this fuel was largely phased out of the EU market before 2000. The only agreed transitional period to adjust the tax level of leaded gasoline was in the case of Malta, which was allowed to adopt the common EU minimum level of EUR 421 per 1000 litres by 1 January 2010 and EUR 337 per 1000 litres was set as the corresponding lower bound as from 1 May 2004.

3.2.2. Effectiveness of the legislation

Of the four objectives of the ETD discussed in the previous section, the most important and also straightforward to measure is the first objective on reducing divergent tax rates across the EU countries with the aim of improving the functioning of the internal market. To see whether this objective has been achieved, we simply look at the actual excise duties by Member State, and analyse the overall variations of the corresponding national taxation levels. In general, *excise duties* are indirect taxes on the consumption/use of certain products and, unlike the value added tax (VAT), are specific taxes expressed as a monetary amount per quantity of the product. All EU countries apply excise duties to all energy products (and alcoholic beverages and manufactured tobacco products), and the obtained revenue accrues entirely to the Member States. The applied national excise duties have to respect the ETD's minimum taxation level requirements or relevant exemptions.

Using the excise duty rates data available from the DG Taxation and Customs Union of the European Commission[117], the actual excise duties for unleaded gasoline and gas oil used as a propellant (diesel oil) by Member State over the period from 2002 to 2013 are reported, respectively, in Table 3.2.3 and Table 3.2.4.[118] Along with these national excise duties, the second rows of the tables also show the relevant ETD minimum taxation levels. Jumping ahead, the highlighted figures indicate the actual national taxation levels that were *lower* than the corresponding EU-wide minimum levels, and this information will be used in the analysis of the ETD impact in the next section. Although from these tables we observe that gasoline and diesel excise duties in the highlighted Member States were easily achieving their EU-wide minimum levels, it is not at all obvious that the ETD's objective of the overall convergence of taxation at the EU level has been achieved as well. For example, if it was the case that in other Member States national tax rates were actually (disproportionately) increasing, then one would end up with further divergence of tax rates across the EU countries instead of (relative) convergence. To see whether national tax rates' variability has increased or decreased over time, we use the *relative standard deviation* (RSD) indicator, which is defined as:

$$\text{RSD} = \frac{\text{Standard deviation}}{\text{Mean}} \times 100\,\% \,.$$

That is to say, RSD quantifies the variability as a percentage of the mean. We prefer to use RSD to a simple variance (or standard deviation) indicator, because (1) the variability is expressed relative to (or is quantified in the context of) the mean and (2) it is a dimensionless indicator which makes comparison of dispersions of different variables meaningful.[119] Below, such a comparison will be made between the variability of excise duties and that of final prices. Such an indicator also makes comparisons of the variability of excise duties across different refining products meaningful, which will also be (briefly) discussed below.

The data in Table 3.2.3 and Table 3.2.4 are used to compute the RSDs of unleaded gasoline and diesel oil excise duties for all EU members. The developments of the obtained RSDs are illustrated in Figure 3.2.1, which focuses on the time period from 2004 onwards, because the ETD was particularly relevant starting from the 2004 EU enlargement period. In addition, there was much less tax rates divergence, in particular that of gasoline excise duties, between the EU-15 countries compared to the overall tax variability of the EU-25 and the EU-27. Since this observation is common knowledge, the overall taxation differences of the EU-15 vs the EU-27 will not be discussed further.

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[117] The EC DG Taxation and Customs Union excise rate data per Member State and energy product is available from http://ec.europa.eu/taxation_customs/taxation/excise_duties/energy_products/rates/index_en.htm. An alternative source is the Oil Bulletin of the European Commission (Market Observatory & Statistics, DG Energy), which is also used in our analysis. The advantage of the first source is that it provides richer details of the excise rates according to products' qualities (e.g. fuel sulphur content). However, it should be noted that the final results remain largely the same irrespective of the choice of the excise rate data source.

[118] In general, as part of the REFIT study, the focus here is only on the 2002-2012 period. However, we add 2013 data in the tables because BG, LT and RO complied by the EU-wide diesel taxation minimum in 2013 in accordance with their transitional periods.

[119] In probability theory and statistics, RSD is also defined as the absolute value of the coefficient of variation, (often) expressed in percentage term.

Table 3.2.3: Observed unleaded gasoline excise duties (EUR/1000 litres)

Source: Excise duty rate data of the European Commission, DG Taxation and Customs Union.
Note: Highlighted cells indicate national taxation levels that are less than the relevant EU-wide minimum levels.

MS	Specifics (if provided)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	EU minimum	287		359									
AT	<=10 mg/kg	407	407	417	417	417	447	442	442	442	482	482	482
AT	>10 mg/kg			432	432	432	462	475	475	475	515	515	515
BE	<98 oct	494	499	508	592	592	592	597	614	614	614	614	614
BE	<98 oct bio							555	571				
BE	>=98 oct low sulphur		499	508	592	592	592	597	614	614	614	614	614
BE	>=98 oct high sulphur		508	522	607	607	607	612	629	629	629	629	629
BG				254	253	271	322	350	350	350	363	363	363
CY				299	304	305	303	299	299	359	359	359	429
CZ				340	374	400	419	430	483	505	526	516	512
DE	>10 mg/kg	639	670	670	670	670	670	670	670	670	670	670	670
DE	<=10 mg/kg	624	655	655	655	655	655	655	655	655	655	655	655
DK		539	539	539	509	508	538	547	557	567	576	587	592
EE				337	288	288	288	359	398	423	423	423	423
EL	<=96,5 oct.I.O	296	296	296	296	313	331	350	410	670	670	670	670
EL	>96,5 oct.I.O	316	316	316	316	327	338	349	410	670	670	670	670
EL	unleaded substitute gasoline					342	347	352	410	670	670	670	670
ES	<97 oct.I.O	396	396	396	396	396	396	396	425	425	425	425	425
ES	>=97 oct.I.O	427	427	427	427	427	427	427	456	456	456	456	456
FI							588	588	627	627	627	627	650	650
FI	norm	567	597	597	614								
FI	envm friend	559	588	588	588								
FR	<95 oct.	571	586	589	589	589	607	607	607	607	607	607	607
FR	unleaded substitute gasoline	621	637	640	640	640	640	640	640	640	640	640	640
HU				408			407		451	444	438	419	432
HU	<=10 mg/kg			440	420	413							
HU	>10 mg/kg			460	454	446							
HU	>=4.4 % bioethanol, S<=10 mg/kg						376	412					
HU	<4.4 % bioethanol, S<=10 mg/kg							431					
HU	>=4.4 % bioethanol, S>10 mg/kg							443					
HU	<4.4 % bioethanol, S>10 mg/kg							463					
IE									509	543	576	588	588
IE	ordin unleaded	401	401	443	443	443	443	443					
IE	high-oct	506	506	548	548	548	548	548					
IT		542	542	542	564	564	564	564	564	564	613	704	728
LT				287	287	287	287	323	434	434	434	434	434
LU		372	372	442	442	442							
LU	>10 mg/kg						465	465	465	465	465	465	465
LU	<=10 mg/kg						462	462	462	462	462	462	462
LV				288	288	276	300	324	379	380	407	408	415
MT				310	310	474	474	404	459	459	469	469	489
NL		609	631	659	668	668	679	689	701	714	718	730	747
PL				320	377	356	416	437	488				
PL	CN 27101145, CN 27101149									391	422	380	406
PL	CN 27101131, CN 27101141									451	487	438	444
PT		479	507	523	523	558	583	583	583	583	583	584	585
RO				267	327	327	327	327	336	348	360	360	360
SE	Class1a	475	349	356	375	366	371	398	393	374	413	428	460
SE	Class1b	475	491	527	549	536	542	575	568	540	597	617	664
SE	Class2	478	520	531	553	539	545	579	571	543	600	620	668
SI				362	366	360	400	359	462	485	417	502	566
SK				376	387	398	415	458	515	515			
SK	<3.3 % bio										551	551	551
SK	>=3.3 % bio										515	515	515
UK								722	684	628	668	674	674
UK	ordin unleaded	791	778	734	726	738	760						
UK	ultra low sulphur gasoline	742	730	668	682	682	713						
UK	sulphur free			689	682	682	713						
UK	aviation gasoline					407	425	431	422	421	421	439	439

Table 3.2.4: Observed diesel oil (gas oil used as a propellant) excise duties (EUR/1000 litres)

Source: Excise duty rate data of the European Commission, DG Taxation and Customs Union.
Note: Highlighted cells indicate national taxation levels that are less than the relevant EU-wide minimum levels.

MS	Specifics (if provided)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	EU minimum	245		302						330			
AT		282	282										
AT	<=10 mg/kg			302	302								
AT	>10 mg/kg			317	317								
AT	>= 66 bio & s<=10 mg/kg					297	347	347	347	347	397	397	397
AT	otherwise					325	375	375	375	375	425	425	425
BE		290	290										
BE	>=50 mg/kg			326	383	342	346	333					
BE	<50 mg/kg			315	368	327	331	318					
BE	>10 mg/kg								368	408	448	443	443
BE	<=10 mg/kg norm								353	393	433	428	428
BE	<=10 mg/kg bio						317	302	335				
BG				203	202	220	274	307	307	307	314	322	330
CY				245	248	250	248	245	245	330	330	330	400
CZ				312	315	336	352	361	406	431	448	440	437
DE	>10 mg/kg	455	486	486	486	486	486	486	486	486	486	486	486
DE	<=10 mg/kg	440	470	470	470	470	470	470	470	470	470	470	470
DK				406	405	404	364	365	380	386	393	444	443
DK	norm	405	406										
DK	light	392	392										
DK	low sulphur	368	368										
EE				245	245	245	245	330	370	393	393	393	393
EL		245	245	245	245	260	276	293	302	412	412	412	330
ES		294	294	294	294	294	302	302	331	331	331	331	331
FI											364	470	470
FI	norm	329	346	346	346	346	346	391	391	391			
FI	low sulphur	304	319	319	319	319	319	364	364	364			
FR		374	389	417	417	417	428	428	428	428	428	428	428
HU				335					375	360	355	386	398
HU	<=10 mg/kg				345	339	309						
HU	>10 mg/kg				365	359	327						
HU	>=4.4 % biodiesel, S<=10 mg/kg							338					
HU	<4.4 % bioethanol, S<=10 mg/kg							354					
HU	>=4.4 % bioethanol, S>10 mg/kg							370					
HU	<4.4 % bioethanol, S>10 mg/kg							385					
IE				368	368				409	449	466	479	479
IE	>50 mg/kg	354	379										
IE	<=50 mg/kg	302	327			368	368	368					
IT		403	403	403	413	413	423	423	423	423	472	593	617
LT				245	245	245	245	274	330	274	302	302	330
LU	>10 mg/kg		268	253			293	305	305	313	323	333	338
LU	<=10 mg/kg	253	253	268	265	278	290	302	302	310	320	330	335
LV				245	246	236	256	274	330	330	330	330	336
MT				246	245	332	332	332	352	352	382	382	402
NL				360									
NL	normal	340	337										
NL	low sulphur	326	323										
NL	<=10 mg/kg				365	365	371	406	413	421	424	431	440
NL	>10 mg/kg				375	375	381	417	424	432	434	442	451
PL									339	302	327	330	355
PL	<=10 mg/kg			222	261	290	288	303					
PL	>10 mg/kg & <= 50 mg/kg			233	273	303	301	316					
PL	>50 mg/kg			250	291	324	321	338					
PT		272	300	308	308	339	364	364	364	364	364	366	368
RO				190	260	260	260	275	284	293	303	316	330
SE	Class 1	321	349	367	404	394	399	452	446	425	493	509	573
SE	Class 2	345	375	393	431	420	425	480	473	451	521	539	605
SE	Class 3	376	410	428	466	455	460	494	488	465	536	554	621
SI				307	305	303	323	302	433	427	351	382	446
SK				351	362	373	388	427	481	368			
SK	<5.3 % bio										386	386	386
SK	>=5.3 % bio										368	368	368
UK								722	684	628	668	674	674
UK	norm	839	826	779	771	782	807						
UK	ULSD	742	730	668	682	693	713						
UK	sulphur free diesel			689	682	693	713						
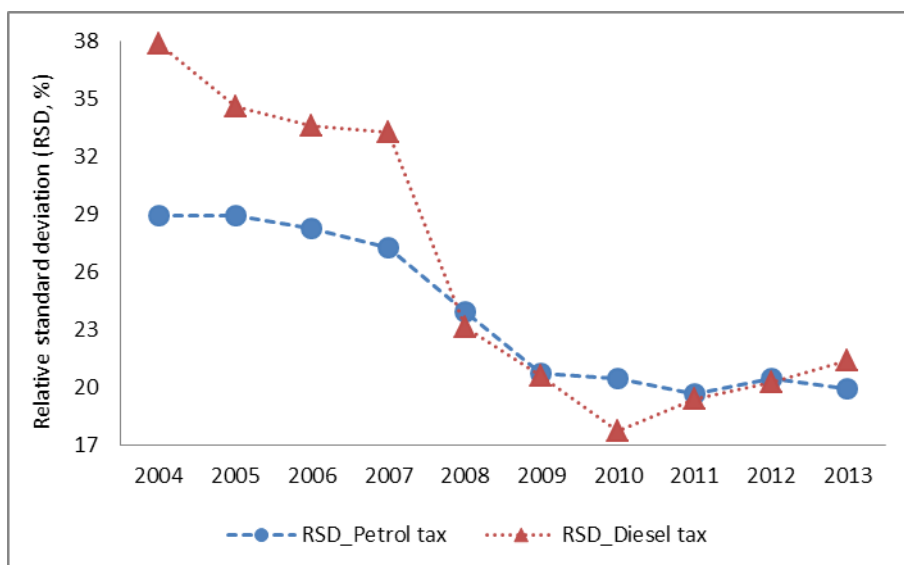
Figure 3.2.1: Relative standard deviations (RSDs) of EU-27 excise duties for gasoline and diesel oil
Source: Own calculations based on the EC DG TAXUD excise rates data.

It is obvious from Figure 3.2.1 that over the 2004-2013 period a *relatively strong convergence* of the levels of excise duties of gasoline and diesel oil across all the EU countries was achieved. Indeed, compared to 2004, the RSD of gasoline excise duties decreased by 31.2 % in 2013, while the corresponding number for diesel tax rates RSD reduction is 43.5 %.[120] The second important observation that can be drawn from Figure 3.2.1 is the fact that the reductions in tax rates took place continuously over the considered period up to the year 2010. This essentially implies that the Member States affected by the ETD requirements made efficient use of the transitional periods provided to them (the details of which will be discussed in the next section). All in all, we conclude that the objective of the ETD to reduce divergent tax rates across the EU countries was largely achieved by 2010 in the case of excise duties of gasoline and gas oil used as a propellant.

For reducing distortions of competition between Member States, it is (the variability of) consumer or final prices of fuels that are important. Therefore, the next legitimate question is whether the observed tax rates convergence also led to gasoline and diesel final price convergence as well.[121] To answer this question we use consumer price data for unleaded gasoline (Euro-super 95) and automotive diesel oil available for the EU-27 from the Oil Bulletin of the European Commission (Market Observatory & Statistics, DG Energy). Figure 3.2.2 presents the obtained RSDs of these final prices. Thus, Figure 3.2.2 also gives evidence of the convergence of consumer prices of gasoline and automotive diesel oil. Compared to 2004, in 2013 the extent of variability of gasoline and diesel consumer prices across the EU-27 countries – as measured by the RSD indicator – had

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[120] Compared to 2004, the reductions of the sample standard deviations for gasoline and diesel in 2013 are 19.2 % and 29.7 %, respectively. The observed larger reductions in RSDs are explained by the fact that over the considered period the EU averages of gasoline and diesel excise rates increased, respectively, by 17.5 % and 24.3 %. Similarly, the relevant reductions in the range statistics (i.e. maximum – minimum) are found to be equal to 19.3 % and 41.5 % for gasoline and diesel, respectively.

[121] However, it is evident that prices cannot converge absolutely across the EU countries as long as there exist differences in other factors that are also determinants of fuel prices, such as, for example, supply and demand structure, income levels, etc.

decreased by 44.1 % and 49.9 %, respectively.[122] These price reductions are, respectively, 1.41 and 1.15 factors larger than those of gasoline and diesel excise duties' variability reported above.
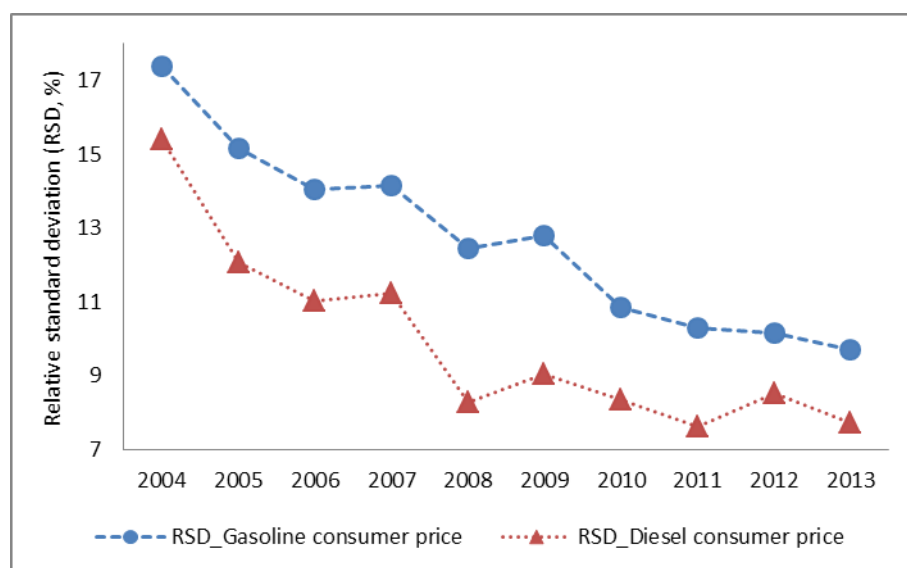
Figure 3.2.2: Relative standard deviations (RSDs) of EU-27 consumer prices for gasoline and diesel oil
Source: Own calculations based on the Oil Bulletin data (EC, Market observatory & Statistics, DG Energy).

It will be shown in the next section that the shares of excise duties in consumer prices of gasoline and diesel oil are, on average, significant, where the corresponding EU-wide average proportions exceed or are close to 50 %. Thus, as will be also shown econometrically below, it is evident that convergence in tax rates contributed to the convergence of final prices of gasoline and diesel across all Member States. Also given that these fuels are at the core of the well-known problem of gasoline and diesel demand-supply mismatch in Europe, we believe that the ETD was *effective* in the sense that it has played a positive role in improving the functioning of the internal market by reducing distortions of competition between Member States which existed due to their divergent gasoline and diesel tax rates.

For completeness purposes, the excise rates of heating gasoil for business use, heating gasoil for non-business use, heavy fuel oil for heating business use, heavy fuel oil for heating non-business use, and liquefied petroleum gas (LPG) used as a propellant are also reported, respectively, in Table 3.2.11, Table 3.2.12, Table 3.2.13, Table 3.2.14 and Table 3.2.15 in the appendix. One can easily observe from these tables that the overwhelming majority of the reported excise rates were (relatively) constant over the entire 2002-2013 period. This implies that, compared to gasoline and diesel taxes, these other five types of excise duties should have contributed (much) less to the narrowing of the overall variations of the corresponding tax rates across the EU countries. Indeed, the following *reductions* in RSDs in 2013 compared to 2004 were found: heating gasoil for business use – 9.1 %; heating gasoil for non-business use – 6.2 %; heavy fuel oil for business use – 10.3 %; heavy fuel oil for non-business use – 10.0 %; and LPG used as a propellant – 2.2 %. On the other hand, from the Oil Bulletin price data we found that over the same 2004-2013 period the RSDs as a measure of variability of consumer prices across EU-27 countries of heating oil, heavy fuel oil (low sulphur) and LPG decreased, respectively, by 45.8 %, 42.2 % and 38.3 %. Therefore, the rather slow convergence of the relevant excise duties should also have played a positive role in this process of convergence of Member States' final prices.

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[122] The corresponding reductions in standard deviations of consumer prices of gasoline and diesel are respectively 12.1 % and 13.1 %, while the respective reductions in their range values are 26.5 % and 30.5 %.

Table 3.2.5**: LSDV regression results**

Note: Robust t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Tax_bus and Tax_nonbus indicate that the RSDs of heating gasoil and heavy fuel oil are based on the relevant excise data for business use and non-business use, respectively.

VARIABLES	(1) RSD_price	(2) RSD_price	(3) RSD_price	(4) RSD_price
RSD_tax_nonbus	0.33***		0.096***	
	(3.09)		(2.78)	
RSD_tax_bus		0.21**		0.096***
		(2.60)		(2.78)
Gasoline*Tax_nonbus			0.46***	
			(4.64)	
Diesel*Tax_nonbus			0.29***	
			(4.03)	
Heatingoil*Tax_nonbus			0.45***	
			(6.19)	
Fueloil*Tax_nonbus			0.59**	
			(2.21)	
Gasoline*Tax_bus				0.46***
				(4.64)
Diesel*Tax_bus				0.29***
				(4.03)
Heatingoil*Tax_bus				0.17
				(0.29)
Fueloil*Tax_bus				0.20
				(0.90)
Gasoline	13.6***	8.58**	-7.38**	-7.38**
	(3.47)	(2.55)	(-2.06)	(-2.06)
Diesel	10.4***	5.89*	-6.49**	-6.49**
	(2.93)	(1.87)	(-2.05)	(-2.05)
Heatingoil	4.35	8.18**	-30.8***	-4.37
	(1.11)	(2.66)	(-4.25)	(-0.084)
Fueloil	-6.46	3.73	-77.1*	-17.3
	(-0.62)	(0.48)	(-1.88)	(-0.51)
Constant	-8.56	-0.75	6.84**	6.84**
	(-1.34)	(-0.14)	(2.43)	(2.43)
Observations	60	60	60	60
R-squared	0.831	0.787	0.865	0.797
F	40.2	27.8	67.6	32.7

To provide additional formal insights, we run a least squares dummy variable (LSDV) regression (i.e. fixed effect model) of the RSDs of final prices on the RSDs of excise duties and the interaction terms of the last with fuel type dummies. The results are summarised in Table 3.2.5. The first two regression results, where interaction terms are not included, confirm that in general a decrease in the RSDs of excise duties resulted in a decrease in the RSDs of final fuel prices (i.e. the corresponding coefficients are positive and statistically different from zero). By adding the interaction terms of fuel types with the excise tax RSDs, we are able to confirm that indeed changes in the RSDs of gasoline and diesel had a larger (both in terms of size and statistical significance) positive impact on the RSDs of final prices (of gasoline and diesel) than the other types of fuel. When the tax RSDs variable include the RSDs of heating gasoil and heavy fuel oil for non-business use, the impact of these two fuels is also singled out. This is not, however, the case with the RSDs of heating gasoil and fuel oil for business use. Finally, the interaction term corresponding to LPG (i.e. 0.096) is also statistically significant from zero, but in terms of economic size it is much smaller than those for gasoline and diesel. All in all, the results in Table 3.2.5 confirm our earlier conclusions on the contributions of the fuel types' excise duties harmonisation across Member States on the relevant final price convergence. The degree of these impacts can also be partly explained by the extent to which the energy carrier can be bought in one Member State and used in another. For example, such cross-border movement (trade) is feasible with

respect to gasoline and diesel, especially diesel given that trucks can be equipped with tanks with volumes of up to 3 m³ which are used for international transport purposes. However, heating oil, for example, is filled in a stationary tank, and thus large differences in tax and prices between neighbouring countries may trigger smuggling but not regular cross-border trade. This is reflected by the large variations of heating oil taxation across Member States.

The other two objectives of the ETD, which we now only briefly discuss here, were: (a) encourage *more efficient use of energy* so as to reduce dependency on imported energy and to cut greenhouse gas emissions, and (b) improve the functioning of the internal market by *reducing distortions of competition between mineral oils and other energy products* that were not subject to Community tax legislation up to 2003. Concerns were raised regarding the effectiveness of the ETD with regard to these objectives. As already mentioned in footnote 5, in 2011 the European Commission presented a new proposal with the aim of restructuring the way energy products are taxed (see EC COM(2011) 169/3). The main concern of this proposal was that the current minimum tax rates are based on the *volume* of energy products, and as such they do not reflect the CO_2 emissions or the energy content of these products, possibly 'leading to *inefficient energy use* and *distortions in the internal market*' (EC COM(2011) 168/3, p. 5, emphasis added, which are directly related to the emphasised statements in the beginning of this paragraph). Some of the implications of disregarding fuels' CO_2 emissions and energy content were shown to be the following. Although diesel currently has a lower minimum tax level than gasoline, according to the proposal mentioned, diesel needs to be taxed more because it has a higher energy content and also generates more CO_2 emissions per litre than gasoline. Similarly, the current ETD promotes the use of coal as heating fuel as its current minimum tax level is lower than that of gas oil and natural gas. However, coal is a CO_2-intensive energy source. In the same vein, renewables are, in principle, taxed at the same rate as conventional fuels. For example, it has been found that E85 – an energy product consisting of 85 % ethanol and 15 % gasoline – is taxed much more heavily than gasoline, though it has a lower energy content and generates less CO_2 emissions than gasoline.

Without entering into details (the interested reader is referred to the relevant documents), as a solution the proposal for a revision of the ETD suggested that the existing energy taxes needed to be split into two parts – CO_2 emissions component and energy content component – which taken together would determine the overall rate at which the energy product is taxed.[123] The discussions on the proposal did not result in unanimous agreement by all Member States. A similar situation also occurred with regard to the first proposal of the European Commission for an energy tax in 1992.[124] In general, such an outcome should not be considered surprising, since taxation is a very sensitive issue for Member States given that 'tax sovereignty is considered a fundamental part of national sovereignty, as evidenced by the fact that, to date, all Commission proposals on taxation need to be unanimously agreed by the Member States'[125] (van Eijndthoven, 2011, p. 283).

3.2.3.   Impact on the EU refining sector

In general, it is obvious that anything having a cost-push or demand-pull energy product(s) impact is of immediate relevance for the refining sector, since the market (demand) size of petroleum

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[123] It should be noted that the proposal was based on existing EU legislation setting the energy content and the CO_2 emissions of products, namely Commission Decision 2007/585/EC and Directive 2006/32/EC.

[124] Proposal for a Council Directive introducing a Tax on Carbon Dioxide Emissions and Energy, COM(92) 226 final, 30 June 1992.

[125] See Article 113 of the Treaty on the Functioning of the European Union (TFEU) for indirect taxation, and Article 115 TFEU for direct taxation.

products is an important determinant of the performance of the refining industry. Below we evaluate the likely impact of raising EU-wide minimum rates of taxation on consumer (final) prices of the relevant petroleum products and subsequently translate these into the appropriate products' demand quantity reductions. Thus, the potential decrease in the market size of refined products can be considered the most relevant ETD impact on the EU refineries, on the analysis of which this section concentrates.

It is clear that an increase in taxes raises consumer prices as producers pass on the additional tax-related costs, to the maximum extent possible, to consumers. An increase in prices is expected to affect the demand for petroleum products in two ways. The first type of impact is related to *own price effect*, which states that a higher *own price* of a refined product, other things being equal, implies a lower quantity demanded for the product in question. The second type of impact has to do with inter-fuel substitution or *cross price effect* and reflects changes in demand due to changes in the prices of substitute products. For example, the need for private transportation can be fulfilled either by using a gasoline-driven car or a diesel-driven car. Apart from prices, there are other relevant factors such as car characteristics that influence consumers' decisions. For example, if a diesel-driven car is more efficient in terms of fuel use cost per kilometres travelled than a gasoline-driven car, then in the medium or long term consumers are likely to adjust their behaviour by switching to diesel-driven cars (or in general to more fuel-efficient vehicles). Thus, unlike *short-run demand elasticities*, the reaction of consumers to price changes and associated factors like fuel efficiency, in the long run are captured by the *long-run demand elasticities*, and the last usually indicate greater sensitivity of demand to changes in fuel prices.[126,127]

Figure 3.2.3 presents EU-wide weighted averages of consumer prices inclusive of duties and taxes of six petroleum products. These were obtained from the Oil Bulletin price data of the European Commission, where in averaging we used the consumption (demand) of refined products of Member States as corresponding weights per year. The most important information to be taken from Figure 3.2.3 is that during the 2002-2012 time period: (a) gasoline was always more expensive, on average in the EU, than diesel oil with a rather *stable gap*, and (b) in general, an upward trend was observed for all petroleum products' consumer prices. Not surprisingly, low- and high-sulphur residual fuel oil show the lowest prices, while heating oil and LPG used for motor fuels take intermediate positions in this ranking along the entire period.

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[126] For the US, Parry et al. (2007) surveys relevant studies and concludes that 'around 20–60 percent of the [long-run] gasoline demand elasticity appears to reflect changes in VMT [vehicle mile travelled], while the other 40–80 percent reflects long-run changes in average fleet fuel economy, as manufacturers incorporate fuel-saving technologies into new vehicles and consumers buy smaller vehicles' (pp. 385-386). However, American and European consumers appear to react differently to changes in fuel prices. For example, using 2002-2007 monthly data, Klier and Linn (2013) find that fuel prices have a positive effect on average fuel economy in Europe, but the relevant elasticity is more than twice as large in the US than in Europe. They conclude that their 'results suggest that, in recent years, rising oil prices have had a small effect on new vehicle fuel economy in Europe' (p. 281).

[127] The short-run and long-run elasticities are derived from the so-called static and dynamic demand equations, respectively. While static equations include only non-lagged explanatory variables (e.g. prices), the dynamic equations include both non-lagged and lagged explanatory variables. For further details, see e.g. Dahl (2012).
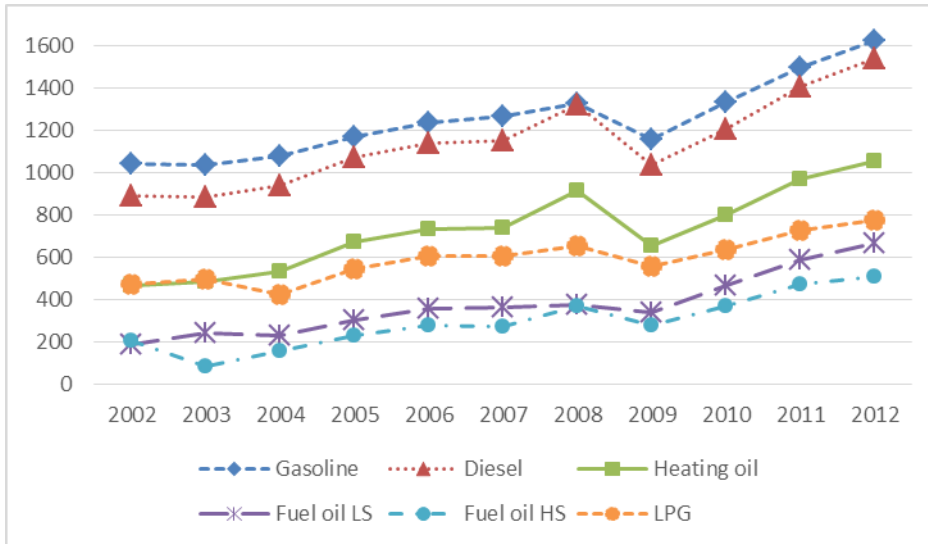
Figure 3.2.3: Refined products prices with taxes: EU consumption-weighted average
Note: These derivations are based on weekly data of petroleum products prices available from the Oil Bulletin of the European Commission. Gasoline, Diesel, Heating oil, Fuel oil LS, Fuel oil HS and LPG refer, respectively, to premium unleaded gasoline, automotive diesel oil, heating gasoil, residual fuel oil with up to 1 % sulphur content, residual fuel oil with more than 1 % sulphur content, and LPG used for motor fuels. All units are EUR per 1000 litres, except for residual fuel oil, where the price is expressed in EUR per tonne.

The only exception with respect to the above-mentioned second point (b) is observed for the price changes of all refined products from 2008 to 2009. Generally, time trends of all prices very much follow that of the crude oil price, which is arguably the most important determinant of refined products' *prices without taxes*. To roughly account for this, all consumer prices of petroleum products were first normalised with respect to their respective prices in the year 2002. Such normalisation has also been implemented on prices of North Sea crude oil, obtained from the International Energy Agency (IEA) data. Figure 3.2.4 illustrates the ratios of the obtained normalised EU average consumer prices of refined products to the normalised price of the North Sea crude oil.
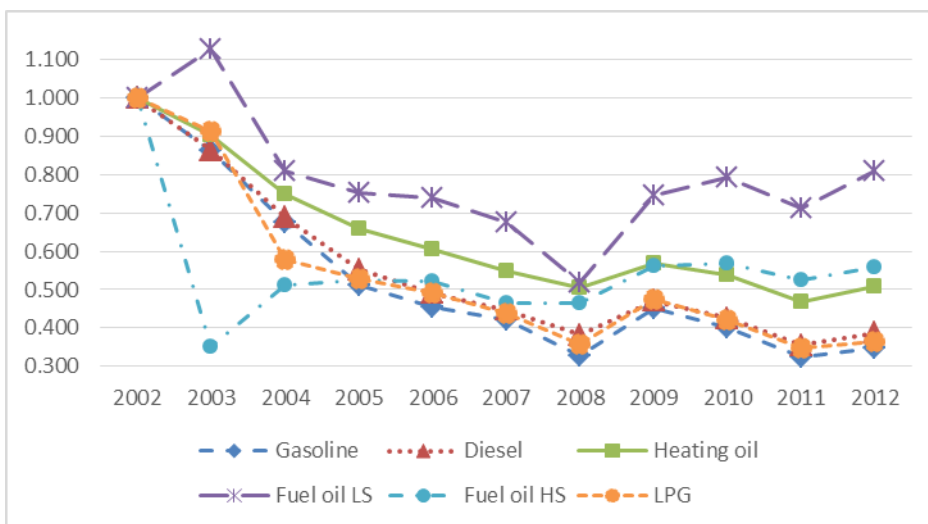
Figure 3.2.4: Ratio of normalised EU average consumer prices to normalised North Sea crude price
Note: Division by the first figure of the relevant series gives the normalised prices of the refined products and of crude oil.

The upward trend of prices observed in Figure 3.2.3 is now completely absent from Figure 3.2.4, implying that increasing crude oil prices were the main factor for the observed increase in EU average prices of petroleum products. Note that the 2008-2009 downward jumps in refined products prices observed in Figure 3.2.3 now reverse their trend in Figure 3.2.4, implying that crude prices decreased more than final fuel prices. Any upward jumps in Figure 3.2.4 within the 2004 to 2012 period – covering the two effective dates of the ETD and Member States-specific transitional periods (see Table 3.2.1 and Table 3.2.2) – *could be related* to the EU-wide possible impact of the ETD. The most vivid upward trends in the normalised ratios include the 2008-2009 trends for all petroleum products and the 2003-2004 upward jump for high-sulphur residual fuel oil. At this stage it is not possible to state that these upward jumps (and possibly also downward jumps that are compensated by other effects) are caused by an increase in minimum taxation levels in some EU members, because there are many more factors that could have affected these trends.

Next we consider the relative contributions of excise duties to consumer prices of petroleum products. Using the same source and similar to the EU consumer price averages, the proportions of excise duties in final or consumer prices (i.e. prices including taxes) were computed at the high (mainly weekly) frequency level, averaged for each year and Member State, and finally the EU-wide weighted averages of excise duties shares in final prices were obtained using the reported refined products consumption figures as weights. In the Oil Bulletin except for low- and high-sulphur residual fuel oil prices, all other prices inclusive of duties and taxes include VAT. Some Member States also report other indirect taxes apart from excise duties, which differ largely across Member States, but these data are not explicitly available.[128] Thus, for each petroleum product, the contribution of excise duties to its final price is quantified as {Excise duty}/{Price without taxes + Excise duty}. As long as other indirect taxes are small (which is largely valid), this will give us the almost exact value of the share of excise duties in consumer prices.[129] The EU-wide fuel consumption-weighted averages of these proportions are given in Figure 3.2.5.

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[128] For example, in its recent Methodological notes for Oil Bulletin, Belgium clarifies that 'Ex-tax prices include other indirect taxes and duties, such as strategic stockholding fees (APETRA), soil remediation for motor fuels (BOFAS), social fund (for heating fuels), FAPETRO (quality control of the petroleum products). These amount to approx. 2 % of the final consumer price'.

[129] Note that for calculating excise duty shares in final prices it is not important whether VAT is explicitly accounted for or not. With VAT included, the *real* contribution of excise duties to final price would be calculated from {(Excise duty)*(1+VAT rate)} /{(Price before taxes + Excise duty + Other indirect taxes)*(1+VAT rate)}, which boils down to {Excise duty} /{Price before taxes + Excise duty + Other indirect taxes}.
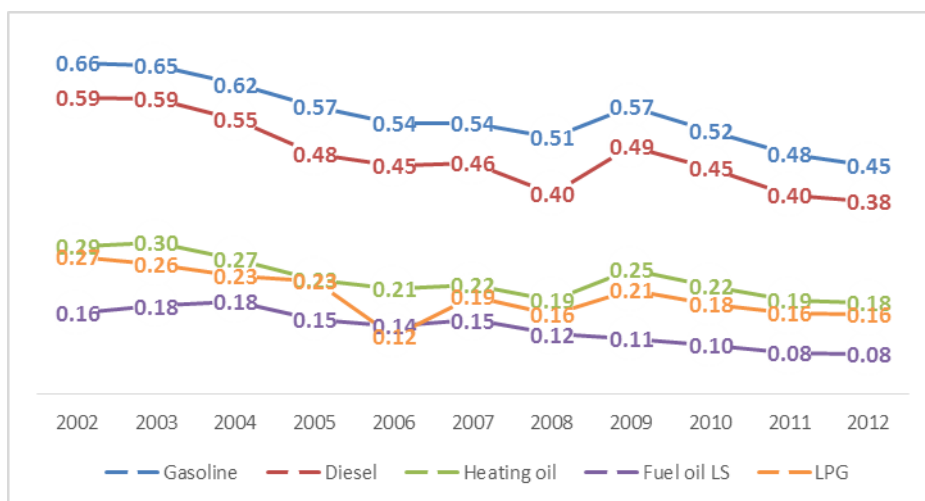
Figure 3.2.5: EU-wide weighted average share of excise duties in final price
Source: Own calculations based on the Oil Bulletin data (EC, Market observatory & Statistics, DG Energy).

It follows from Figure 3.2.5 that, on average in the EU, excise duties make up a considerable part of the final prices of gasoline and diesel oil, though a decreasing trend in both these proportions is observed. Thus, over the considered period, on average, excise duties make up 45–66 % of the gasoline final price, while for diesel oil these shares range between 38 % and 59 %. On average, excise duties contribute from 12 % to 30 % to the level of the EU average consumer prices of heating oil and LPG used for motor fuels. The lowest overall contribution of excise duties among the categories considered is observed for residual fuel oil.

However, these overall average shares hide a lot of heterogeneity among Member States.[130] As an example, Figure 3.2.6 presents country-specific annual average contributions of excise duties to gasoline consumer prices, which shows that the range of differences is indeed quite large. The UK, Germany, France, the Netherlands and Finland consistently show the largest shares of excise duties in their final gasoline prices (the corresponding simple averages over the 2002-2012 period are, respectively, 0.62, 0.60, 0.58, 0.58, and 0.57). On the other hand, the bottom five countries with the smallest contributions of excise duties to gasoline consumer prices are Bulgaria, Latvia, Malta, Romania, and Cyprus with respective average excise shares of 0.40, 0.39, 0.39, 0.38, and 0.37 (these are averages over the 2004-2012 or 2008-2012 period, depending on the country's EU membership status or data availability).

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[130] The same is true with respect to the EU consumption-weighted averages of consumer prices presented in Figure 3.2.3. For the sake of simplicity, the country-specific consumer prices are not presented here.
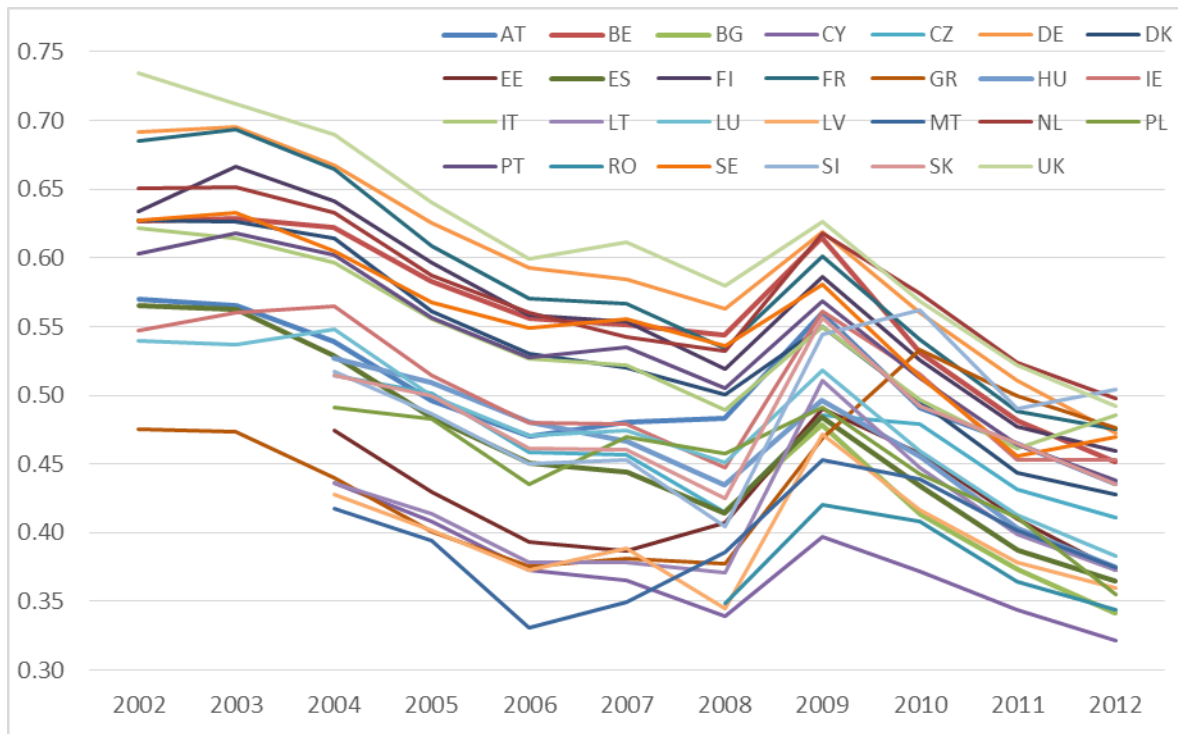
Figure 3.2.6: Excise contributions to final gasoline prices per EU-27 country
Source: Own calculations based on the Oil Bulletin data (EC, Market observatory & Statistics, DG Energy).

Similar results can be observed for diesel oil excise duties shares. Thus, these outcomes have, at least, two important implications: (i) an equal percentage tax change for all products will have a much larger impact on consumer prices and hence demand for gasoline and diesel than those of the other fuel categories considered, and (ii) if it turns out that the ETD mainly affected countries with small (or large) shares of excise contributions to final fuel prices and small (or large) – in terms of domestic fuel consumption – economies, then the overall impact at the EU level will also be negligible (or large).

Now we turn to the question of which Member States were affected by the ETD. These are directly observed from the reported excise rate tables (i.e. Table 3.2.3, Table 3.2.4, Table 3.2.11, Table 3.2.12, Table 3.2.13, Table 3.2.14 and Table 3.2.15) and are the Member States with highlighted figures indicating that the relevant actual national taxation levels are *lower* than the corresponding EU-wide minimum levels. Starting with gasoline and diesel excise rates, it can be seen from Table 3.2.3 and Table 3.2.4 that at certain stages during the considered 2002–2013 period:

(a) 10 Member States, namely, Bulgaria (BG), Cyprus (CY), Czech Republic (CZ), Estonia (EE), Greece (EL), Lithuania (LT), Latvia (LV), Malta (MT), Poland (PL) and Romania (RO), had unleaded gasoline excise duties below the EU-wide minimum of EUR 359 per 1000 litres; and

(b) 11 Member States, namely, the 10 EU countries already mentioned excluding the Czech Republic, plus Spain (ES) and Luxembourg (LU), had national diesel excise duties below the relevant EU-wide minimum levels of EUR 302 per 1000 litres and/or EUR 330 per 1000 litres.

Looking at the list of the EU countries given in Table 3.2.2, it is not surprising to find that all the Member States mentioned were given transitional periods in order to smoothly adapt their national taxation to the appropriate EU minimum levels. For example, in the case of gasoline excise duty, Bulgaria and Romania had a transitional period that required them to have a minimum gasoline taxation of EUR 323 per 1000 litres (less than the EU-wide minimum of EUR 359 per 1000 litres)

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as of 2008, while the ultimate aim of the ETD, i.e. the minimum of EUR 359 per 1000 litres, had to be implemented from 2011. This is exactly what we observe in Table 3.2.3. For example, Bulgaria had an actual gasoline excise duty of EUR 350 per 1000 litres (above the relevant transitional minimum level of EUR 323 per 1000 litres, but below the ultimate target of EUR 359 per 1000 litres) from 2008 to 2010, which increased to EUR 363 per 1000 litres from 2011 onwards bypassing the EU minimum level.

Very similar observations can be made with regard to the national diesel excise duties reported in Table 3.2.4. Without going into the country-specific details, the highlighted countries were again given the possibility of gradually reaching the EU-wide diesel oil taxation targets which match the Member State-specific transitional periods reported in Table 3.2.2.

Turning our focus to the excise duties of the other fuels reported in Table 3.2.11, Table 3.2.12, Table 3.2.13, Table 3.2.14 and Table 3.2.15, it can be concluded that the reported actual excise duties for all the Member States were always equal to or greater than the relevant ETD minimum taxation levels or were consistent with the provided exemptions (e.g. see footnote 8). In this study we do not analyse the taxation rates of gas oil used for industrial and commercial purposes or those of kerosene. All in all, based on the analysis so far, we may conclude that the ETD minimum taxation levels of heating gasoil (business and non-business use), heavy fuel oil (business and non-business use) and LPG used for motor fuels had zero or a negligible impact on the price and demand for these refined products at the EU level, and thus on the performance of the EU refining sector as well. To summarise, this conclusion is based on the following grounds:

- (very) few countries that were affected by the ETD had actual excise duties (many in accordance with provided exemptions on reduced rates[131]) that were largely constant over the covered period (see e.g. Table 3.2.11, Table 3.2.12, Table 3.2.13, Table 3.2.14 and Table 3.2.15 in the appendix);
- our EU-wide general finding that the proportions of excise duties in the final prices of the fuels mentioned were much lower than those for gasoline and diesel (see Figure 3.2.5), which is largely the case for the affected Member States; and
- the affected Member States tend to be small economies and/or the difference between the observed excise duty and the relevant EU minimum tax of the affected Member States is generally negligible.

Table 3.2.6: Observed and estimated counterfactual demands of the affected Member States
Note: World Energy Statistics database of the International Energy Agency is the source of the observed demand figures. Aff_EU refers to the 10 or 11 affected EU countries depending on whether the fuel under consideration is gasoline or diesel.

	Observed demand with ETD (1)		Estimated reductions due to ETD (2)		Estimated demands without ETD (1)+(2)		Observed demand with ETD (1)		Estimated reductions due to ETD (2)		Estimated demands without ETD (1)+(2)	
	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010
	Gasoline (kt)						Diesel oil (kt)					
Bulgaria	545	582	11.9	25.9	557	608	1317	1406	9.6	22.7	1327	1429
Cyprus	303	390	0.4	5.9	303	396	346	329	0.5	8.3	347	337
Czech Republic	2057	1770	14.1	10.1	2071	1780						
Estonia	296	275	1.9	6.6	298	282	348	388	1.9	12.1	350	400

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[131] For example, Luxembourg in the case of heating gasoil applies, according to the granted tax reduction (Article 9.2 of the ETD), a reduced rate of EUR 10 per 1000 litres over the entire 2004-2013 period. See also footnotes 6-8.

Greece	3918	3705	36.3	55.4	3954	3760	2055	2392	23.5	79.9	2079	2472
Spain							23216	22060	39.7	250.8	23256	22311
Lithuania	339	279	1.7	9.7	341	289	684	857	0.7	6.7	685	864
Luxembourg							1794	1731	19.0	41.2	1813	1772
Latvia	344	288	1.7	10.4	346	298	522	646	0.6	6.9	523	653
Malta	69	73	1.3	1.6	70	75	37	99	0.2	1.0	37	100
Poland	3958	3960	82.7	77.8	4041	4038	5356	9303	50.3	108.8	5406	9412
Romania	1705	1358	34.2	33.5	1739	1391	2130	2827	25.5	46.4	2156	2873
Total Aff_EU	13534	12680	186	237	13720	12917	37805	42038	172	585	37977	42623
Total EU-27	110012	87286	186	237	110198	87523	173356	183225	172	585	173528	183810
Aff_EU in EU-27	12 %	15 %	100 %	100 %	12 %	15 %	22 %	23 %	100 %	100 %	22 %	23 %

Therefore, from this point onwards we only focus on the impact of changes in minimum tax rates of gasoline and diesel oil on the demand for these fuels. There are potentially many methods that can be useful for the purpose of this assessment, including using various large-scale complex modelling approaches. We adopt a straightforward approach, all the details of which are presented in Appendix A.1. It should be noted that, given the approach chosen, our method is conservative in the sense of resulting in maximal impacts, i.e. the demand impacts can be considered as upper bound estimates (see Appendix A.1 for details). The estimates of the percentage changes in final prices and demand quantities are reported in this appendix, and here we only present the final outcomes. The estimates of gasoline and diesel demand reductions and totals per affected Member State in the counterfactual scenario without the ETD are reported in Table 3.2.6, which also includes the demand levels observed for the years 2005 and 2010 from the International Energy Agency data.

The very first observation to be made from Table 3.2.6 is that the affected Member States represent only 12-15 % of the total EU gasoline market and 22-23 % of the total EU diesel oil market (see the last row). Or alternatively, the gasoline and diesel excise duties of, respectively, 17 and 16 Member States, representing 85-88 % and 77-78 % of the total EU-27 gasoline and diesel markets, were not affected by the ETD because their tax levels were already higher than the relevant minimum ETD levels before the later excise rates were adopted.

Next we find that the total estimated demand *reductions* due to the ETD of the affected Member States are insignificant and make up only 1.4 % and 1.9 %, respectively, of *their* 2005 and 2010 total observed gasoline demand, while the respective numbers for diesel demand reductions are 0.5 % and 1.4 % (these and the follow-up figures in this paragraph can be easily derived from Table 3.2.6). At the EU-27 level, the relevant average demand reductions for 2005 are 0.17 % for gasoline and 0.10 % for diesel, while those for 2010 are 0.27 % and 0.32 %, respectively. Thus, the ETD impact in terms of demand reduction at the overall EU level is found to be negligible. At the individual affected Member State level, the *average* reductions account for up to only 3.3 % and 2.2 % in the case of gasoline demand and diesel demand, respectively. The largest reduction (4.4 %) is obtained for Bulgaria for gasoline consumption during the second period.

In Table 3.2.7 we also present the diesel to gasoline (D/G) ratios of the observed demands with the ETD impact and of the estimated counterfactual demands without the ETD. The last two columns report the percentage differences of the estimated and observed D/G ratios for all 12 affected EU countries. We find that without the ETD in place, on average over both periods, these ratios would have been *lower* in seven Member States (Bulgaria, Czech Republic, Lithuania, Latvia, Malta, Poland and Romania), implying that these countries would have consumed less diesel and more gasoline. But this impact is only *marginal* since the D/G ratios differences are quite small and range only from -0.63 % to -2.07 %.

Table 3.2.7: Diesel to gasoline demand ratios with and without the ETD
Source: Own calculation.

Note: D/G stands for the ratio of diesel demand to gasoline demand.

	D/G ratios of observed demands with ETD		D/G ratios of estimated demands without ETD		Difference between the estimated and observed D/G ratios (%)		
	2005	2010	2005	2010	2005	2010	Average
Bulgaria	2.417	2.416	2.382	2.350	-1.43 %	-2.71 %	-2.07 %
Cyprus	1.142	0.844	1.142	0.852	0.00 %	0.97 %	0.49 %
Czech Republic	1.569	1.865	1.559	1.854	-0.68 %	-0.57 %	-0.63 %
Estonia	1.176	1.411	1.175	1.421	-0.09 %	0.69 %	0.30 %
Greece	0.525	0.646	0.526	0.657	0.22 %	1.82 %	1.02 %
Spain	3.193	4.147	3.199	4.195	0.17 %	1.14 %	0.65 %
Lithuania	2.018	3.072	2.010	2.992	-0.39 %	-2.60 %	-1.49 %
Luxembourg	3.581	4.946	3.619	5.063	1.06 %	2.38 %	1.72 %
Latvia	1.517	2.243	1.512	2.188	-0.39 %	-2.45 %	-1.42 %
Malta	0.536	1.356	0.529	1.341	-1.26 %	-1.12 %	-1.19 %
Poland	1.353	2.349	1.338	2.331	-1.13 %	-0.78 %	-0.95 %
Romania	1.249	2.082	1.239	2.065	-0.79 %	-0.81 %	-0.80 %
Total EU-12	1.926	2.471	1.917	2.471	-0.45 %	0.00 %	-0.23 %
Total EU-27	1.576	2.099	1.575	2.100	-0.07 %	0.05 %	-0.01 %

The total *EU-27-wide* D/G ratios would have decreased in 2005 by only 0.07 %, but would have increased in 2010 by 0.05 % in the counterfactual environment without the ETD. Thus, we may conclude that, at the EU level, we did not find any *discernible* impact of the ETD in terms of the switch from gasoline consumption to diesel consumption. Of course, by setting only minimum rates and giving a tax advantage to diesel, the ETD does not prevent such a switch. Table 3.2.17 in the appendix presents the percentage differences between the *actual* gasoline tax to diesel tax (GT/DT) ratios and the ETD GT/DT ratios for all Member States. Indeed, the table shows that almost all Member States cross the 'bounds' of the ETD GT/DT ratios, often by a significant amount (with the exception of the UK, Greece and Sweden). Thus, it can be argued that the ETD cannot be blamed for the far bigger *actual* tax advantage given to diesel by the majority of Member States; there should be some other factors that explain this favourable treatment of diesel by Member States.

The above results are consistent with Miravete et al. (2014), who argue that the successful diffusion of diesel engines was due to the lenient European vehicle emissions policy, in particular, due to less stringent nitrogen oxide emissions standards compared to those of the US. They find that this emission policy both fostered customer adoption of diesel vehicles and favoured domestic car manufacturers serving as a 'non-tariff trade barrier equivalent to a 37 % import tariff that cut imports in half' (p. 1). The authors also show that 'while the favourable tax treatment of diesel fuel in Europe does encourage sales of diesel vehicles, its overall effect, less than 5 % of the market, is significantly smaller than any of the evaluated emissions policies' (p. 4).

3.2.4. Efficiency of the legislation

Efficiency in the framework of this study is understood as putting *benefits* into perspective with *costs* and, if possible, assessing whether the benefits are achieved at proportionate and affordable costs. In general, it is a rather complicated task to assess the cost-benefit efficiency of the ETD. Thus, below, we provide a general discussion of the benefits and (potential) costs associated with the ETD.

The first and most important benefit of excise duties is that that they accrue entirely to Member States, and thus contribute to their fiscal revenues, which can be spent as Member States wish. In particular, the additional tax-related income due to the ETD could be used to reduce the tax burden on labour (also referred to as a 'growth-friendly tax shift') and/or to stimulate environmentally benign activities, including incentivising green investments, and green research and development.[132] Also, these additional revenues could be used to mitigate the distributional impact of related policies on household incomes by compensating the lower income group of the population.

The question therefore is how big these revenues in total tax receipts per Member State are. Using the extensive database on revenues by individual taxes per Member State from the European Commission's DG Taxation and Customs Union[133], we computed the shares of total revenues from excise duties on mineral oils into *total tax receipts* for each EU country for the period from 1995 to 2012. These proportions are reported in Table 3.2.18 in the appendix. Total tax receipts include taxes on production and imports, current taxes on income, wealth, etc. and capital taxes. The excise tax revenues covered exclude revenues from excise duties on electricity, natural gas and solid fuels, with the exception of Slovenia which reports revenues from mineral oils and gas together.

To get a macro-picture of these annual data, we divide the entire 1995-2012 period into two sub-periods: 1995-2003 and 2004-2012. Figure 3.2.7 illustrates the average contributions of excise duties on mineral oils to total tax receipts over these two sub-periods per Member State. The columns in the chart are ordered according to the size of these tax-related average contributions in the second sub-period. It is observed that the eastern European countries obtain from 9 % to 12 % of their total tax income from excise duties on mineral oils. Also, Portugal collected a similar proportion of tax earnings from this source, with average shares of excise duties income in total tax receipts of 9.5 % and 8.2 % in 1995-2003 and 2004-2012, respectively. The lowest contributions, of less than 3 %, are consistent for all years observed for the Netherlands and Denmark. But it should be noted that these countries (and all other Member States) also benefit from excise duties on gas and electricity. For example, the Dutch revenues from excise duties on natural gas consistently exceed those on mineral oils.

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[132] In fact, the 1997 proposal of the Commission for a Community framework for the taxation of all competing sources of energy, including minimum tax levels, already encouraged Member States to stimulate these activities. The proposal aimed at improving the functioning of the Internal Market and ensuring greater respect for the environment, while at the same time combating unemployment by allowing Member States to compensate increased revenues from energy taxation by lower taxation of labour (see IP/97/211).

[133] These data are available from the European Commission's DG Taxation and Customs Union website at http://ec.europa.eu/taxation_customs/taxation/gen_info/economic_analysis/tax_structures/article_5985_en.htm .
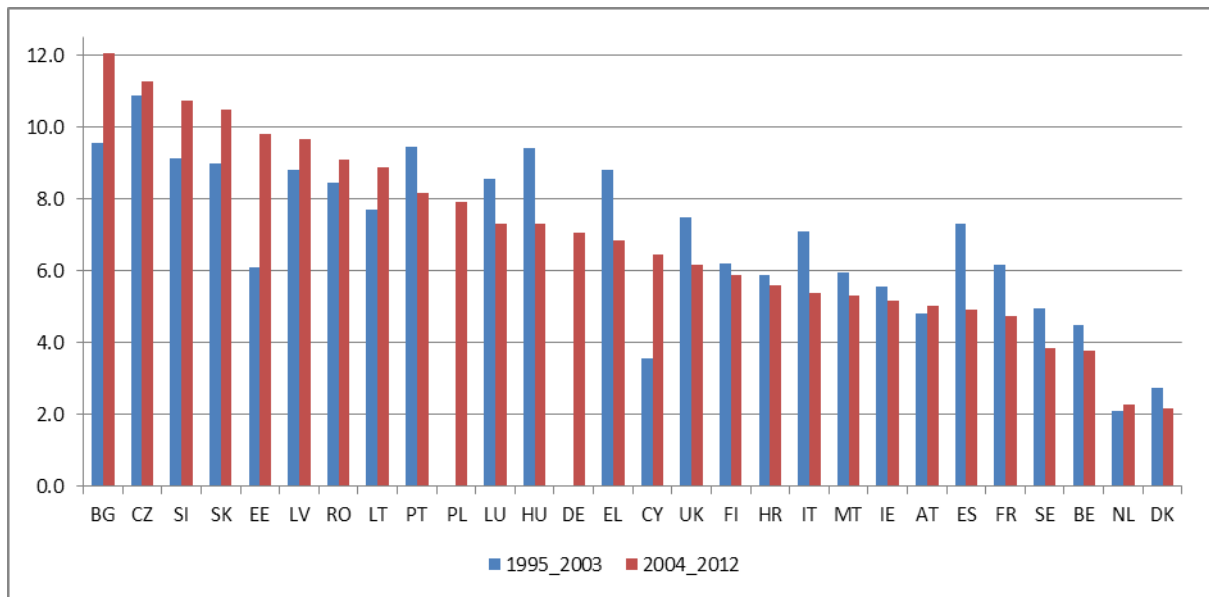
Figure 3.2.7: Revenues from excise duties on mineral oils in total tax receipts (%)
Note: Based on the revenue by individual tax data of the European Commission's DG Taxation and Customs Union.

Note from Figure 3.2.7 that the Member States found to be affected by the ETD (Bulgaria, Cyprus, Czech Republic, Estonia, Spain, Greece, Lithuania, Luxembourg, Latvia, Malta, Poland and Romania) are among the EU countries with the largest contributions of income from excise duties to their total tax receipts. It is not surprising that for many of these countries the size of these contributions increased over time, since they had to increase the relevant taxes. All in all, it could be concluded that the (extra) revenues of excise duties on energy products (due to the ETD) are indeed important sources of tax receipts for many Member States.

The second benefit of excise duties is that 'the high levels of fuel taxation in Member States can be considered as the main absorber of oil price shocks' (Dersalle, 2002). That is, large changes in fuel prices before taxes, e.g. due to crude oil price shocks, will be smoothed out by excise duties at the level of final prices, especially in Member States where the proportion of excise duties in the fuel consumer price is high. For example, Dersalle (2002) points out that an average 86 % increase in the net fuel price translates into only 32 % and 18 % increases in fuel prices at the pump in Spain and the UK, respectively. On the other hand, a 35 % decrease in the price before taxes leads to 15 % and 8 % decreases in final fuel prices, respectively, in Spain and the UK. This price shock–absorbing capacity differs, nonetheless, across Member States and also depends on the current level of oil prices. Still, it can be concluded that the ETD ensures that the imposed excise duties absorb large (unexpected) variations in the prices before taxes of the energy products, given that the ETD sets minimum levels for these taxes.

Coming back to the impact of the ETD when the related extra income is spent on various purposes, it should be noted that, depending on the exact mechanism(s) for using these earnings, there can be both benefits and *costs*. For example, one would expect a positive impact on employment (i.e. job creation) if the additional revenue from energy products' taxation is used to reduce employers' social security contributions (such a scenario in modelling is called 'budget neutrality'). This would further boost the domestic production of various sectors of the economy, resulting in higher GDP growth, for example. In addition, such a reduction of labour costs is expected to limit the price increase due to an increase in energy tax. Thus, real wages would also be positively affected, which would then result in higher private consumption and hence a positive impact on welfare.

However, these benefits will not be realised if no specific 'recycling' strategy of the revenues is imposed, because then higher domestic and export prices due to higher costs of energy taxation result in reduced demand both in domestic and foreign markets. These effects and the implied consequences of reduced demand are the *costs* of taxation policies, such as the ETD.[134]

In a transport modelling setting, the increase in fuel prices due to an increase in taxes reduces the demand for private transport, while increasing demand for public transport. The associated cost for consumers is then longer travelling time, if public transport is more time-consuming. In the TREMOVE model, Dersalle (2002) indicates three components in quantifying the costs to society of the related policies. These are consumer surplus for passenger and freight transport, net changes in tax revenues, and Marginal Cost of Public Fund (MCPF). MCPF is the proportion of an increase in transport taxes that is *not* used to reduce labour taxes, which implies a reduction in real wages and implicitly an increase in labour tax, causing an efficiency loss.

Given the above detailed description of the benefits and costs potentially incurred due to the ETD at the global level, we refrain from making any definitive conclusion(s) regarding the efficiency of the ETD and do not make any claims on whether the incurred costs are justified by the obtained benefits. This is because it is extremely difficult to quantify all these benefits and costs, partly also because there is no information on the exact uses of the extra revenues due to the ETD by Member States. Obviously, modelling could help, but then it would give the efficiency outcome that holds only under the environment of the modelling assumptions which in most cases would not entirely reflect the real situation.

Kohlhaas et al. (2004) seems to be the only study that assessed the impact of the ETD (Council Directive 2003/96/EC of 27 October 2003) using the GTAP-E computable general equilibrium model. They find, for example, that in eastern European accession countries (XAC, which excludes the Czech Republic, Hungary and Poland which are modelled individually) the overall price of petroleum products increases by 8.8 % and the total demand for energy goods decreases by 5.63 %. These results are generally consistent with our findings reported in Table 3.2.9 and Table 3.2.10, although these two studies are not entirely comparable because Kohlhaas et al. (2004) also model tax changes for coal, gas and electricity. In terms of macroeconomic effects, the study furthermore finds a negative impact on the XAC's real GDP, which is reduced by 0.18 %. On the other hand, the ETD was assessed to lead to the reduction of XAC's CO_2 emissions by 2.99 %.

Another finding of the study mentioned that is relevant here is their analysis of implied international trade effects. They use the so-called revealed comparative advantage (RCA) indicator which is defined as the export to import ratio for a sector divided by the overall export to import ratio. Hence, a positive (or negative) change in the RCA value of an industry indicates an improvement (or deterioration) of the comparative advantage position of the sector in question. Kohlhaas et al. (2004) find that the European refining sector *on average improves* its comparative advantage position in foreign trade as the reported RCAs show an average increase of 0.65 in value, with positive RCAs seen only for XAC countries, the Czech Republic and Poland (the corresponding RCA changes are 4.2, 2.8 and 1.0). The explanation for this outcome is that, due to higher energy taxes, the output of the petroleum products sector decreases, which also implies less

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[134] All these mechanisms are accounted for in Kouvaritakis et al. (2005) which assesses the impact of the proposal for a revision of the ETD using the GEM-E3 computable general equilibrium model. Besides the budget neutrality scenario, they also run another scenario where revenues are used to decrease the public deficit such that the EU current account is kept constant relative to GDP. The positive impact of such a setting is the alleviation of the financial constraints of private economic agents and the reduction of the interest rate. The latter will have a positive impact on investment and consumption. However, the study finds that this positive impact is rather small and 'does not allow compensating for the price effect on the domestic and export market, making this policy more costly' (p. 32).

use of intermediate inputs. In particular, the effect on imports is assessed to be larger than on exports, which thus results in a higher RCA for the industry.

The OURSE modelling chapter of the REFIT study, assesses the impact of reduced demand due to the ETD (together with Renewable Energy Directive) on the costs and international competitiveness of the EU refining sector. It has been assessed that the net forgone earnings (forgone profits) due to the ETD were roughly EUR 0.22 (in constant 2008 prices) per barrel of processed crude per year over the 2000-2010 period. This impact has been found to be much lower (eight times lower) than that of the Renewable Energy Directive (RED) which also results in a lower demand for conventional fuels. On the benefit side for the EU, it was found that, in the counterfactual situation without the RED and ETD in place, European imports of diesel oil (from Russia) would have increased, on average over the 2000-2010 period, by 1-6.3 %, with an upper bound of 8.9 %. Thus, a reduction in the diesel imports dependency of the EU (from Russia) can be considered the most noticeable EU-wide benefit derived from the RED and ETD if one focuses on the trade dependency issues. Here again, the contribution of the ETD alone is much lower and makes up roughly only 11 % of the total impact.

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3.2.5. Annex

A.1. Estimation of gasoline and diesel demand reductions due to the ETD

It is obvious that there will never be *real* fuel consumption figures on the impact of the ETD available and there will always be uncertainties in their estimates. With this in mind, we adopt the following straightforward and conservative (in the sense of providing maximum impact estimates) approach. Let us denote *prices before taxes* (net prices) in period 1 as p_1, excise duties in periods 0 and 1, respectively, as t_0 and t_1, and other indirect taxes in period 1 as n_1. Then, the *actual consumer price* in period 1 is $(p_1 + t_1 + n_1) \times (1 + \tau)$, where τ is the corresponding VAT rate. However, in a hypothetical scenario without changes (increase) in excise duties, the *counterfactual consumer price* in period 1 would be equal to $(p_1 + t_0 + n_1) \times (1 + \tau)$, where only excise duty is from period 0. Thus, relative to the actual consumer price in period 1, in the counterfactual environment without the ETD in place, the reduction in final fuel prices due to lower tax levels, assuming *full pass-through*[135]- the <u>first conservative assumption</u> of our approach, is equal to:

$$\Delta p\,\% = \frac{(p_1 + t_0 + n_1) \times (1 + \tau) - (p_1 + t_1 + n_1) \times (1 + \tau)}{(p_1 + t_1 + n_1) \times (1 + \tau)} \times 100\,\%$$

$$= \frac{(t_0 - t_1) \times (1 + \tau)}{(p_1 + t_1 + n_1) \times (1 + \tau)} \times 100\,\%. \tag{2.1}$$

Note first that in considering the changes in final fuel price in Eq. (2.1) only the excise duty component of prices including duties and taxes is changed, thus the derived change is only due to changes in excise duties, while the corresponding prices before taxes and indirect taxes are kept at their end-period levels. This approach is most reasonable for ex post analysis which allows the *available* information on the net and indirect taxes to be used. Second, given that the Oil Bulletin data already provides data on consumer prices (which also includes VAT), to implement Eq. (2.1) we need to adjust the obtained changes in excise tax levels by accounting for VAT rates. For the sake of completeness, the observed average gasoline and diesel consumer prices and VAT rates of the affected Member States are reported in Table 3.2.16 in the appendix.

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[135] There are many papers that confirm or use this assumption for gasoline and diesel oil markets. For example, Marion and Muehlegger (2011) conclude that they 'find that under most circumstances, gasoline and diesel taxes are fully passed on to consumers' (p. 1203). See also Li et al. (2014). Although these studies refer to the US gasoline and diesel oil markets, we adopt this assumption because we adopt a conservative approach as full pass-through assumption results in larger changes in demands (in absolute values) compared to the incomplete pass-through case.

The estimated reductions of excise duties in the counterfactual environment without the ETD (i.e. $t_0 - t_1$) are reported in Table 3.2.8, which were computed using the assumption that in the hypothetical environment without the ETD all affected Member States keep their 2004 excise duties unchanged over the entire period. Here we make the <u>second conservative assumption</u> regarding the choice of tax levels without the ETD for Bulgaria and Romania: although these two countries joined the EU in 2007, we still keep their 2004 excise duties as taxes representing the environment without the ETD for the entire 2004-2013 period. One could have chosen their 2006 or 2007 taxes instead, which are higher than the corresponding 2004 taxes, on average, by 15 % to 23 %. Thus, the estimated impact on Bulgaria and Romania will be higher than if their later taxes had been used as their counterfactual excise duties. It should be noted that for three affected countries (Greece, Luxembourg and Poland) which report more than one excise duty value for gasoline or diesel depending on the product specifications, we take the simple average of the reported values to represent the country's gasoline or diesel tax.

To further explain how the figures in Table 3.2.8 were derived, consider for example the case of gasoline tax for Latvia (LV). Without the ETD we assume that the gasoline excise duty in Latvia, i.e. t_0, would remain at its 2004 level of EUR 288 per 1000 litres over the entire 2004-2012 period. In computing the difference $t_0 - t_1$ then actual values of excise duties are used for t_1 *unless* the actual tax is higher than the EU-wide minimum. In the latter case, we use the EU-wide minimum tax level instead of the higher actual tax, because there is no reason to justify that Member States increased their tax level *beyond* the relevant EU-wide minimum due to the ETD. Thus, in the case of gasoline tax in Latvia from 2009 onwards the value of t_1 was kept at its EU minimum level of EUR 359 per 1000 litres. Hence, for 2007 we obtain $t_0 - t_1 = 287.65 - 300.29 \approx -13$ (note that the numbers in the reported excise duties tables are all rounded to the nearest integer), while for 2010 the tax reduction would be $t_0 - t_1 = 287.65 - 359 \approx -71$ (and *not* $287.65 - 379.78 \approx -92$, where 379.78 is the actual gasoline tax in 2010, see Table 3.2.3)

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Table 3.2.8: Estimated reductions in excise duties without the ETD

Source: Own calculations using data in Table 3.2.3 and Table 3.2.4. The reported tax changes exclude VAT.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Gasoline (EUR per 1000 litres)										
BG	0	0	-17	-68	-96	-96	-96	-105	-105	-105
CY	0	-5	-6	-4	0	0	-60	-60	-60	-60
CZ	0	-19	-19	-19	-19	-19	-19	-19	-19	-19
EE	0	0	0	0	-71	-71	-71	-71	-71	-71
EL	0	0	-21	-33	-44	-53	-53	-53	-53	-53
LT	0	0	0	0	-36	-72	-72	-72	-72	-72
LV	0	0	0	-13	-36	-71	-71	-71	-71	-71
MT	0	0	-49	-49	-49	-49	-49	-49	-49	-49
PL	0	-39	-36	-39	-39	-39	-39	-39	-39	-39
RO	0	-60	-60	-60	-60	-69	-81	-92	-92	-92
Diesel (EUR per 1000 litres)										
BG	0	0	-17	-71	-99	-99	-104	-112	-119	-127
CY	0	-4	-5	-3	0	0	-85	-85	-85	-85
EE	0	0	0	0	-57	-57	-85	-85	-85	-85
EL	0	0	-15	-31	-48	-57	-85	-85	-85	-85
ES	0	0	0	-8	-8	-8	-36	-36	-36	-36
LT	0	0	0	0	-29	-57	-29	-57	-57	-85
LU	0	-5	-18	-31	-42	-42	-51	-61	-70	-70
LV	0	-1	0	-11	-29	-57	-85	-85	-85	-85
MT	0	0	-56	-56	-56	-56	-84	-84	-84	-84
PL	0	-40	-67	-67	-67	-67	-67	-92	-95	-95
RO	0	-70	-70	-70	-85	-94	-103	-113	-126	-140

Using the tax change figures from Table 3.2.8 and the actual average consumer prices and VAT rates from Table 3.2.16, the reductions in final prices in the counterfactual scenario without the ETD were estimated according to Eq. (2.1). These are reported in Table 3.2.10. To further analyse the impact on demand, we divided the 2004-2013 period into two sub-periods: 2004-2008 and 2009-2013. These (roughly) correspond to the two modelling periods of 2005 and 2010 in the OURSE global refining model, which assesses the impact of the obtained demand reductions on the EU refining sector (e.g. in terms of costs, capacity utilisation rate, etc.). In this overview chapter, however, the focus is only on the ETD impact in terms of changes in final prices and demand for gasoline and diesel. The average changes in consumer prices over the two sub-periods are reported in the last two columns of Table 3.2.9. Note that since the ETD impact in 2004 is zero for all the affected Member States, we adopted a conservative approach and estimated the price changes for the first period as averages over 2005-2008, rather than 2004-2008 (which is our third conservative assumption), which will also give higher price impact estimates.

Table 3.2.9: Estimated reductions in final prices for gasoline and diesel without the ETD

Source: Own calculations according to Eq. (2.1) using tax change figures in Table 3.2.8, and price and VAT data in Table 3.2.16.

	Annual change in prices (%)										Average price change (%)	
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2005–2008	2009–2013
	Gasoline consumer price change (%)											
BG	0	0.0	-2.2	-8.6	-11.3	-13.1	-11.3	-10.8	-9.8	-9.6	-5.5	-10.9
CY	0	-0.6	-0.7	-0.5	0.0	0.1	-6.6	-5.7	-5.3	-5.1	-0.4	-4.5
CZ	0	-2.4	-2.2	-2.1	-1.8	-2.2	-1.8	-1.6	-1.6	-1.7	-2.1	-1.8
EE	0	0.0	0.0	0.0	-8.0	-9.3	-7.7	-6.9	-6.3	-6.5	-2.0	-7.4
EL	0	0.0	-2.6	-3.8	-4.7	-6.3	-4.5	-3.9	-3.7	-3.9	-2.8	-4.5
LT	0	0.0	0.0	0.0	-4.1	-8.4	-7.4	-6.6	-6.2	-6.3	-1.0	-7.0
LV	0	0.0	0.0	-1.6	-4.1	-9.0	-7.9	-6.8	-6.1	-6.4	-1.4	-7.3
MT	0	0.0	-5.2	-5.5	-5.0	-5.1	-4.8	-4.2	-3.9	-3.9	-3.9	-4.4
PL	0	-4.7	-4.3	-4.2	-3.8	-4.9	-4.2	-3.8	-3.5	-3.6	-4.3	-4.0
RO	0	-7.9	-7.9	-7.5	-7.0	-9.7	-9.4	-9.3	-9.0	-8.9	-7.6	-9.3
	Diesel consumer price change (%)											
BG	0	0.0	-2.3	-9.2	-10.9	-14.3	-12.8	-11.4	-11.2	-11.4	-5.6	-12.2
CY	0	-0.5	-0.6	-0.4	0.0	0.0	-9.8	-7.8	-7.4	-7.2	-0.4	-6.4
EE	0	0.0	0.0	0.0	-5.8	-7.5	-9.2	-8.0	-7.4	-7.7	-1.4	-8.0
EL	0	0.0	-1.9	-3.8	-4.7	-7.0	-8.3	-7.1	-6.8	-7.5	-2.6	-7.3
ES	0	0.0	0.0	-1.0	-0.8	-1.0	-4.0	-3.4	-3.2	-3.2	-0.4	-3.0
LT	0	0.0	0.0	0.0	-3.1	-7.6	-3.5	-5.6	-5.2	-7.8	-0.8	-5.9
LU	0	-0.7	-2.2	-3.9	-4.3	-5.6	-6.0	-6.0	-6.3	-6.6	-2.8	-6.1
LV	0	-0.2	0.0	-1.5	-3.2	-7.6	-9.7	-8.2	-7.5	-7.9	-1.2	-8.2
MT	0	0.0	-6.7	-7.0	-5.8	-6.9	-9.5	-7.7	-7.2	-7.2	-4.9	-7.7
PL	0	-5.3	-8.3	-8.3	-6.7	-9.8	-7.7	-9.3	-8.6	-9.0	-7.2	-8.9
RO	0	-9.2	-9.1	-9.0	-9.2	-13.4	-12.4	-11.3	-11.8	-13.1	-9.1	-12.4

Two observations can be made from Table 3.2.9. First, changes in the consumer prices of gasoline and diesel are higher in the second period than in the first period for all listed Member States, except for the Czech Republic and Poland in case of gasoline price. Thus, for these EU countries the main 'burden' for complying with the ETD requirements had to be shouldered over the second period. Second, comparing the changes in final prices of gasoline vs those of diesel oil, we find that these changes are, on average, larger (in absolute value) for diesel than for gasoline (the respective average values for diesel and gasoline for the second period are −7.8 % and −6.1 %). Thus, with the ETD in place, on average in the affected Member States, diesel became relatively more expensive than gasoline compared to their pre-ETD prices. This is, of course, due to the higher average gap between the actual pre-ETD taxation of diesel of the affected Member States and the relevant ETD minimum levels than that for gasoline. A similar conclusion holds for each Member State, except for Estonia, Greece and Latvia in the first period, and Lithuania in both periods.

Though we observe that for the affected Member States in many cases, in particular in the second period, the estimated reductions in final prices in the counterfactual environment without the ETD were larger for diesel than for gasoline, we still *cannot* conclude that the ETD counteracted the switch of European consumers from gasoline to diesel consumption. The reason is that these price changes still need to be translated into the changes in quantity demanded, which depend on (a) price elasticities of demand, and (b) the size of the observed demands with the impact of the ETD in place.

To convert the estimated final price changes reported in Table 3.2.9 into the changes in demand quantities, the estimates of *intermediate- or long-run*[136] gasoline and diesel price elasticities of transport fuel demand reported in an extensive study by Dahl (2012) are used. It should be mentioned that Dahl (2012) presents two estimates of gasoline demand price elasticities, one set of which takes into account the impact of the introduction of turbo-charged fuel injection diesel engines in Europe causing a switch from gasoline use to diesel consumption. In particular, the author 'increased gasoline demand price elasticities by 50 % for all those countries that have seen a strong switch towards diesel fuel with gasoline consumption decreasing' (Dahl, 2012, p. 7). We again take a conservative approach, and thus use the *higher* reported gasoline demand price elasticities – our <u>fourth conservative assumption</u> – that are supposed to explicitly account for the European fuel consumption switch from gasoline to diesel. Our derived estimates of the percentage increase in demand for gasoline and diesel in the counterfactual environment without the ETD are reported in Table 3.2.10.

Table 3.2.10: Percentage increase in gasoline and diesel demand without the ETD
Source: Own calculations. The estimates of intermediate- or long-run price elasticities of demand are taken from Dahl (2012).

	Gasoline price elasticity	Gasoline demand change (%)		Diesel price elasticity	Diesel demand change (%)	
		2004–2008	2009–2013		2004–2008	2009–2013
Bulgaria	-0.39	2.15	4.26	-0.13	0.73	1.59
Cyprus	-0.33	0.15	1.50	-0.38	0.15	2.45
Czech Republic	-0.32	0.68	0.57	-0.38		
Estonia	-0.32	0.64	2.35	-0.38	0.55	3.02
Greece	-0.33	0.92	1.47	-0.44	1.13	3.23
Spain	-0.36			-0.38	0.17	1.12
Lithuania	-0.48	0.49	3.35	-0.13	0.11	0.77
Luxembourg	-0.50			-0.38	1.05	2.32
Latvia	-0.48	0.69	3.48	-0.13	0.15	1.06
Malta	-0.48	1.89	2.11	-0.13	0.63	1.00
Poland	-0.48	2.05	1.93	-0.13	0.93	1.16
Romania	-0.26	1.97	2.41	-0.13	1.19	1.61

In order to obtain the final estimates of likely demand reduction (in kilotonnes) due to the ETD requirements, the demand change percentages reported in Table 3.2.10 were used in conjunction with the 2005 and 2010 *observed* demand quantities (using the World Energy Statistics database of the International Energy Agency) of the affected Member States as follows:

$$\text{Demand reduction due to the ETD} = \frac{\delta}{1-\delta} \times (\text{Observed demand with the ETD}), \qquad (2.2)$$

where δ indicates the demand reduction proportions (not percentages) reported in Table 3.2.10. The reasoning behind using Eq. (2.2) is that it is assumed that:

$$\text{Observed demand with the ETD} = (1-\delta) \times (\text{Unknown demand without the ETD}),$$

$$\text{Demand reduction due to the ETD} = \delta \times (\text{Unknown demand without the ETD}).$$

---

[136] Elasticity estimates from static models typically fall between the short-run and long-run estimates obtained from dynamic models (see e.g. Brons et al., 2008), hence they are also labelled intermediate-run. 'However, more recent work suggests that in time series estimates, if the variables in the model are non-stationary unit roots, but are co-integrated, the elasticities from static models should be interpreted as long-run' (Dahl, 2012, p. 3). The elasticities estimates of Dahl (2012) used in this study are based on static models.

The final estimates of demand *reductions* due to the ETD requirements are reported in Table 3.2.6.

Here we make our <u>fifth and final conservative assumption</u> by using the observed demand figures in (2.2) to estimate the demand reduction and not accounting for *reduced excise rates,* even if they are below the relevant ETD minimum levels or set to zero. If we had taken them into account, the impact on demand would have been *lower* than we have reported in Table 3.2.6. The point is that to estimate the reduction in fuel demand due to the ETD then the factor $\delta/(1-\delta)$ in (2.2) should have been multiplied *not* by the observed demand quantities (as we do in this study), but by lower quantities than these observed demand figures because the reduced rates are essentially exemptions. And that is why some parts of the fuel demand on which reduced rates are applied should not be affected by the ETD EU-wide minimum excise levels. But this bias is small given that the size of fuels with reduced rates is tiny in their overall fuel type demand.

We note that this approach is (even more) conservative since without considering the supply-side effect of the price changes, and hence demand changes, estimates may be somewhat overestimated. On the other hand, it should also be noted that if one allows for the price impacts passing through different sectors of the economy using economy-wide models, our estimates *could* also be undervalued. But in more complex economy-wide modelling there are many counteracting effects which partly compensate each other. In any case, given that the affected countries are mostly small economies, such a bias, if it exists, is mostly likely to be negligible at the EU level.

Table 3.2.11: Actual heating gasoil (business use) excise duties (EUR/1000 litres)

Source: Excise duty rate data of the European Commission, DG Taxation and Customs Union.
Note: Highlighted cells indicate national taxation levels that are below the relevant EU-wide minimum levels. For Slovakia, the biodiesel content levels are 5.3 % and 5.4 % for 2012 and 2013, respectively.

MS	Specifics (if provided)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	EU minimum	18		21									
AT		282	282	98	98	98	98						
AT	<=10 mg/kg								98	98	98	98	98
AT	>10 mg/kg							128	128	128	128	128	128
BE		19	19										
BE	>50			18	18	18	18	18					
BE	<=50			17	17	17	17	17					
BE	>10								18	18	18	18	18
BE	<=10								17	17	17	17	17
BG				203	202	220	26	26	307	26	26	26	26
CY				245	196	197	196	125	125	125	125	125	125
CZ				312	315	336	352	361	406	431	448	440	437
DE			61	53	53	53	53	45					
DE	>50								60	60	61	61	61
DE	<=50								45	45	46	46	46
DK		281	282	406	405	364	280	285	290	330	335	342	395
EE				27	44	44	44	61	67	111	111	111	111
EL		245	245			260	276	293	302	412	412	412	330
ES		80	85	85	85	85	85	85	85	85	85	85	85
FI		67	71	71	71	71	71	87	87	87	161	161	163
FR		41	55	57	57	57	57	57	57	57	57	57	57
HU				335	345	339	309	338	375	360	355	386	398
IE		47	47	47	47	47	47	47	47	89	89	102	102
IT		121	121	403	403	403	403	403	403	403	403	403	403
LT				21	21	21	21	21	21	21	21	21	21
LU	RDC	19	19	10	10	10	10	10	10	10	10	10	10
LV				21	21	20	22	21	21	56	56	56	57
LV	>= 5 % bio									21	21	21	22
MT				246	245	332	332	332	352	352	382	382	402
NL			47	47	47	47	47	77	248	253	255	259	440
PL				43	53	59	59	62	69	55	59	53	57
PT		272	300	90	90	91	137	176	176	176	251	292	330
RO				190	260	260	260	275	284	293	303	316	330
SE		257	318	367	370	361	366	397	391	62	124	128	138
SI				63	53	53	54	54	95	118	87	123	126
SK				165	362	175	182	200	226	226			
SK	<5.4 % bio										386	386	386
SK	>=5.4 % bio										368	368	368
UK		51	67	94	76	95	113	139	132	121	131	130	130

Table 3.2.12: Actual heating gasoil (non-business use) excise duties (EUR/1000 litres)

Source: Excise duty rate data of the European Commission, DG Taxation and Customs Union.
Note: Highlighted cells indicate national taxation levels that are below the relevant EU-wide minimum levels. For Slovakia, the biodiesel content levels are 5.3 % and 5.4 % for 2012 and 2013, respectively.

MS	Specifics (if provided)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	EU minimum	18	21										
AT		69	69	98	98	98	98						
AT	<=10 mg/kg							98	98	98	98	98	98
AT	>10 mg/kg							128	128	128	128	128	128
BE		5	5										
BE	>50			18	18	18	18	18					
BE	<=50			17	17	17	17	17					
BE	>10								18	18	18	18	18
BE	<=10								17	17	17	17	17
BG				203	202	220	26	26	307	26	26	26	26
CY				245	196	197	196	125	125	125	125	125	125
CZ				312	315	336	352	361	406	431	448	440	437
DE			61	61	61	61	61	61					
DE	>50								76	76	76	76	76
DE	<=50								61	61	61	61	61
DK		281	282	406	405	364	280	285	290	330	335	342	395
EE				27	44	44	44	61	67	111	111	111	111
EL		123	18	245	245	260	276	293	302	412	412	412	330
ES		80	85	85	85	85	85	85	85	85	85	85	85
FI		67	71	71	71	71	71	87	87	87	161	161	163
FR		41	55	57	57	57	57	57	57	57	57	57	57
HU				335	345	339	309	338	375	360	355	386	398
IE		47	47	47	47	47	47	47	47	89	89	102	102
IT		403	403	403	403	403	403	403	403	403	403	403	403
LT				21	21	21	21	21	21	21	21	21	21
LU	RDC	5	5	10	10	10	10	10	10	10	10	10	10
LV				21	21	20	22	21	21	56	56	56	57
LV	>= 5 % bio									21	21	21	22
MT				246	245	97	97	97	97	97	142	142	162
NL		47	47	47	47	47	47	77	248	253	255	259	440
PL				43	53	59	59	62	69	55	59	53	57
PT		34	88	90	90	91	137	176	176	176	251	292	330
RO				190	260	260	260	275	284	293	303	316	330
SE		257	318	367	370	361	366	397	391	373	414	428	461
SI				63	53	53	54	54	95	118	87	123	126
SK				165	362	175	182	200	226	226			
SK	<5.2 % bio										386	386	386
SK	>=5.2 % bio										368	368	368
UK		51	67	94	76	95	113	139	132	121	131	130	130

Table 3.2.13: Actual heavy fuel oil (heating business use) excise duties (EUR/t)

Source: Excise duty rate data of the European Commission, DG Taxation and Customs Union.
Note: Highlighted cells indicate national taxation levels that are below the relevant EU-wide minimum levels. The UK's excise rates for 2003 to 2007 are expressed per 1000 litres.

MS	Specifics (if provided)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	EU minimum	13		15									
AT		36	36	60	60	60	60	60	60	60	60	60	60
BE			13	15	15	15	15	15	15	15	15	15	15
BE	<=1 % sulphur	7											
BE	> 1 % sulphur	19											
BG				13	13	13	15	15	15	26	26	26	26
CY				15	15	15	15	15	15	15	15	15	15
CZ				15	15	16	17	17	19	19	19	19	19
DE		18	25	25	25	25	25	25	25	25	25	25	25
DK		320	320	320	320	320	319	325	331	379	386	393	454
EE				13	15	15	15	15	15	15	15	15	15
EL		19	19	--	19	19	19	19	19	19	38	38	38
ES		14	14	14	14	14	15	15	15	15	15	15	15
FI		57	60	60	60	60	60	67	67	67	188	188	192
FR				19	19	19	19	19	19	19	19	19	19
FR	>2 % sulphur	23	23										
FR	<2 % sulphur	17	17										
HU	<=1 % sulphur			15	16	16	14	16	16	16	16	15	15
HU	>1 % sulphur			158	162	160	145	159	166	148	146	136	140
HU				402	414	407	371	406	422	429	424	394	407
IE		13	13	14	15	15	15	15	15	61	61	78	78
IT		128	128	128	128								
IT	>1 % sulphur					64	64	64	64	64	64	64	64
IT	<1 % sulphur					31	31	31	31	31	31	31	31
LT				15	15	15	15	15	15	15	15	15	15
LU			13	13	15	15	15	15	15	15	15	15	15
LU	<=1 % sulphur	6											
LU	>1 % sulphur	19											
LV				15	15	14	16	16	16	16	16	16	16
MT				14	14	14	15	15	15	15	30	30	32
NL		16	16	33	33	33	33	33	33	34	34	34	35
PL				13	14	15	15	16	18	15	16	15	16
PT				15	15	15	15	15	15	15	15	16	16
PT	>1 % sulphur	12	28										
PT	<=1 % sulphur	27	13										
RO				0	7	10	13	14	14	15	15	15	15
SE		271	334	386	390	380	379	418	412	65	131	135	146
SI				48	55	55	55	55	55	55	55	55	61
SK				19	20	21	21	24	27	27	27	112	112
UK		44	61	89	70	89	108	135	128	117	125	124	124

Table 3.2.14: Actual heavy fuel oil (heating non‑business use) excise duties (EUR/t)

Source: Excise duty rate data of the European Commission, DG Taxation and Customs Union.
Note: Highlighted cells indicate national taxation levels that are below the relevant EU‑wide minimum levels. The UK's excise rates for 2003 to 2007 are expressed per 1000 litres.

MS	Specifics (if provided)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	EU minimum	13		15									
AT		36	36	60	60	60	60	60	60	60	60	60	60
BE			13	15	15	15	15	15	15	15	15	15	15
BE	<=1 % sulphur	7											
BE	> 1 % sulphur	19											
BG				13	13	13	15	15	15	26	26	26	26
CY				15	15	15	15	15	15	15	15	15	15
CZ				15	15	16	17	17	19	19	19	19	19
DE		18	25	25	25	25	25	25	25	25	25	25	25
DK		320	320	320	320	320	319	325	331	379	386	393	454
EE				13	15	15	15	15	15	15	15	15	15
EL		19	19	19	19	19	19	19	19	19	38	38	38
ES		14	14	14	14	14	15	15	15	15	15	15	15
FI		57	60	60	60	60	60	67	67	67	188	188	192
FR				19	19	19	19	19	19	19	19	19	19
FR	>2 % sulphur	23	23										
FR	<2 % sulphur	17	17										
HU	<=1 % sulphur			15	16	16	14	16	16	16	16	15	15
HU	>1 % sulphur			158	162	160	145	159	166	148	146	136	140
HU				402	414	407	371	406	422	429	424	394	407
IE		13	13	14	15	15	15	15	15	61	61	78	78
IT		128	128	128	128								
IT	>1 % sulphur					64		128	128	128	128	128	128
IT	<1 % sulphur						64	64	64	64	64	64	64
LT				15	15	15	15	15	15	15	15	15	15
LU			13	13	15	15	15	15	15	15	15	15	15
LU	<=1 % sulphur	6											
LU	>1 % sulphur	19											
LV				15	15	14	16	16	16	16	16	16	16
MT				14	14	14	15	15	15	15	30	30	32
NL		16	16	33	33	33	33	33	33	34	34	34	35
PL				13	14	15	15	16	18	15	16	15	16
PT				15	15	15	15	15	15	15	15	16	16
PT	>1 % sulphur	12	28										
PT	<=1 % sulphur	27	13										
RO				0	7	10	13	14	15	15	15	15	15
SE		271	334	386	390	380	379	418	412	393	436	450	486
SI				48	55	55	55	55	55	55	55	55	61
SK				19	20	21	21	24	27	27	27	112	112
UK		44	61	89	70	89	108	135	128	117	125	124	124

Table 3.2.15: Actual LPG used as a propellant excise duties (EUR/t)
Source: Excise duty rate data of the European Commission, DG Taxation and Customs Union.
Note: Highlighted cells indicate national taxation levels that are below the relevant EU-wide minimum levels. Ireland's excise rates for 2002 to 2004 are expressed per 1000 litres

MS	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
EU minimum	100		125									
AT	261	261	261	261	261	261	261	261	261	261	261	261
BE	0	0	0	0	0	0	0	0	0	0	0	0
BG			175	174	174	174	174	174	174	174	174	174
CY			125	127	127	127	125	125	125	125	125	125
CZ			123	124	133	139	143	160	155	161	158	158
DE	153	161	180	180	180	180	180	180	180	180	180	180
DK	468	469	469	468	466	467	475	483	489	497	507	507
EE			100	100	100	100	125	125	125	125	125	125
EL	100	100	-	100	100	125	125	125	125	200	200	200
ES	795	125	125	125	125	57	57	57	57	57	57	57
FI	0	0	0	0	0	0	0	0	0	0	0	0
FR	100	100	108	108	108	108	108	108	108	108	108	108
HU			189	195	191	174	191	198	177	175	163	163
IE	105	105	105	125	125	125	125	125	88	88	176	176
IT	285	285	285	285	285	228	228	228	228	228	268	268
LT			125	125	125	125	125	304	304	304	304	304
LU	102	102	102	102	102	102	102	102	102	102	102	102
LV			128	127	119	125	124	127	127	127	127	127
MT												
NL	104	79	96	96	96	96	124	126	154	155	168	168
PL			138	183	204	203	214	240	192	208	188	188
PT	100	100	100	102	104	107	109	109	110	125	128	128
RO			100	128	128	128	128	128	128	128	128	128
SE	133	145	148	150	146	148	172	170	164	241	249	249
SI			137	134	134	134	134	125	125	125	125	125
SK			189	195	201	209	230	259	259	182	182	182
UK	146	143	185	130	132	180	236	313	335	364	368	368

Table 3.2.16: Average gasoline and diesel final prices, and VAT rates of the affected Member States

Source: Oil Bulletin of the European Commission (Market observatory & Statistics, DG Energy).
Note: As the 2004-2007 consumer prices for Bulgaria and Romania were not available in the data source, they were forecasted based on the relevant price development structure of Hungary.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Gasoline consumer prices (EUR per 1000 litres)												
BG			856	910	909	954	1022	882	1019	1168	1278	1318
CY			793	859	937	951	1035	882	1039	1213	1318	1377
CZ			858	954	1047	1064	1232	1032	1255	1407	1463	1396
EE			695	798	867	880	1050	925	1110	1238	1361	1311
EL			803	892	978	1012	1128	996	1430	1667	1750	1693
LT			780	829	902	902	1039	1022	1176	1319	1412	1376
LV			611	811	878	913	1032	958	1086	1279	1409	1351
MT			801	936	1100	1041	1153	1125	1195	1381	1484	1466
PL			847	997	1019	1114	1246	956	1135	1243	1364	1307
RO			858	912	911	956	1024	845	1064	1229	1274	1278
Diesel consumer prices (EUR per 1000 litres)												
BG			801	899	904	923	1094	835	978	1175	1273	1334
CY			732	836	900	905	1093	832	1004	1252	1351	1407
EE			662	803	871	866	1153	908	1104	1265	1372	1320
EL	624	643	723	886	960	981	1223	966	1243	1471	1535	1392
ES	688	696	759	899	959	969	1151	913	1075	1267	1366	1359
LT			721	824	888	878	1102	889	1017	1235	1331	1323
LU	632	639	697	842	918	933	1117	848	987	1170	1264	1217
LV			572	802	872	899	1103	917	1064	1271	1372	1309
MT			665	875	986	949	1140	961	1044	1297	1372	1378
PL			724	919	985	995	1227	842	1060	1219	1357	1305
RO			806	904	909	929	1100	834	1032	1236	1320	1323
VAT (%)												
BG			20	20	20	20	20	20	20	20	20	20
CY			15	15	15	15	15	15	15	15	17	18
CZ			22	19	19	19	19	19	20	20	20	21
EE			18	18	18	18	18	20	20	20	20	20
EL	18	18	18	19	19	19	19	19	21	23	23	23
ES	16	16	16	16	16	16	16	16	18	18	21	21
LT			18	18	18	18	18	19	21	21	21	21
LU	15	15	15	15	15	15	15	15	15	15	15	15
LV			18	18	18	18	18	21	21	22	21	21
MT			18	18	18	18	18	18	18	18	18	18
PL			22	22	22	22	22	22	22	23	23	23
RO			19	19	19	19	19	19	24	24	24	24

Table 3.2.17: Differences between the actual and ETD gasoline tax to diesel tax (GT/DT) ratios (%)
Source: Own computations based on the relevant DG TAXUD data.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
AT	23.2	23.2	15.4	15.4	14.8	5.9	6.8	6.8	16.7	11.5	11.5	11.5
BE	45.3	47.7	34.6	33.8	50.3	51.6	56.3	45.0	42.0	29.1	30.7	30.7
BG			5.4	5.4	3.7	-0.9	-4.0	-4.0	4.9	6.1	3.6	1.2
CY			2.8	2.8	2.8	2.8	2.5	2.5	0.0	0.0	0.0	-1.4
CZ			-8.4	0.1	0.1	0.1	0.1	0.1	7.8	7.8	7.8	7.8
DE	20.5	18.2	16.5	16.5	16.5	16.5	16.5	16.5	27.3	27.3	27.3	27.3
DK	18.4	18.4	11.9	5.8	5.8	24.2	26.3	23.3	34.9	34.9	21.7	22.8
EE			15.7	-1.4	-1.4	-1.4	-8.5	-9.5	-1.1	-1.1	-1.1	-1.1
EL	6.6	6.6	5.1	5.1	5.9	3.2	0.6	14.2	49.5	49.5	49.5	86.6
ES	19.5	19.5	17.7	17.7	17.7	14.6	14.6	11.9	22.3	22.3	22.3	22.3
FI	52.0	51.9	49.7	51.9	48.6	48.6	39.8	39.8	52.8	58.3	27.3	27.3
FR	36.2	34.2	24.0	24.0	24.0	22.4	22.4	22.4	33.7	33.7	33.7	33.7
HU			9.5	3.5	3.5	3.5	1.6	1.3	13.3	13.3	-0.2	-0.2
IE	18.1	9.8	13.2	13.2	13.2	13.2	13.2	4.6	11.2	13.7	12.8	12.8
IT	14.7	14.7	13.0	14.9	14.9	12.2	12.2	12.2	22.6	19.4	9.1	8.4
LT			-1.4	-1.5	-1.5	-1.5	-0.9	10.7	45.6	32.2	32.2	20.9
LU	25.6	22.0	42.8	40.2	33.8	33.7	28.4	28.4	36.7	32.4	28.4	26.5
LV			-1.1	-1.5	-1.5	-1.2	-0.6	-3.3	5.7	13.5	13.5	13.5
MT			6.2	6.1	20.0	20.0	2.3	9.7	19.8	12.8	12.8	11.8
NL	56.2	63.1	54.0	51.9	51.9	51.9	40.9	40.9	53.9	53.9	53.9	53.9
PL			14.8	15.4	-2.1	15.4	15.2	21.2	28.1	27.7	14.0	10.2
PT	50.4	44.5	42.6	42.6	38.3	34.6	34.6	34.6	47.0	47.0	46.6	46.4
RO			18.2	5.9	5.9	5.9	0.3	-0.5	9.1	9.3	4.6	0.0
SE	16.9	2.4	0.0	-4.4	-4.4	-4.5	-8.5	-8.5	-0.2	-4.5	-4.5	-8.4
SI			-0.8	0.8	0.0	4.1	0.0	-10.3	4.3	9.2	21.0	16.6
SK			-10.1	-10.1	-10.3	-10.1	-9.8	-10.1	28.5	29.8	29.8	29.8
UK	-17.3	-17.3	-17.6	-17.6	-27.0	-26.2	-32.9	-32.0	-23.2	-25.1	-24.1	-24.1

Table 3.2.18: The share of revenues from excise duties on mineral oils in total tax receipts

Source: Based on the revenue by individual tax data of the European Commission, DG Taxation and Customs Union.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
AT	5.3	4.9	4.7	4.6	4.7	4.6	4.5	4.8	5.1	5.4	5.3	5.0	4.9	4.8	5.0	4.9	5.1	4.8
BE	4.8	4.9	4.8	4.6	4.5	4.3	4.2	4.2	4.2	4.2	4.0	3.7	3.7	3.5	3.8	3.8	3.8	3.5
BG	7.8	4.6	6.7	9.4	10.7	12.0	11.4	10.9	12.5	12.5	12.1	11.2	11.7	12.0	12.4	12.4	12.5	11.8
CY	2.6	2.8	2.6	2.6	2.6	3.0	4.1	4.1	7.7	8.1	7.0	6.3	5.2	4.9	5.9	6.6	7.1	6.9
CZ	10.6	10.7	10.4	10.6	11.0	11.0	11.6	11.0	11.1	11.3	11.8	11.6	11.1	11.2	11.6	11.6	11.0	10.4
DE											8.2	7.7	6.8	6.7	7.1	7.1	6.7	6.3
DK	2.7	2.8	2.7	2.7	2.8	2.7	2.8	2.7	2.7	2.6	2.3	2.2	2.2	2.2	2.3	2.0	2.1	1.9
EE	2.3	4.6	5.2	7.0	6.3	6.2	8.2	7.5	7.6	8.9	9.4	8.7	8.6	9.0	10.6	11.4	10.9	10.8
EL	12.5	12.6	11.0	9.3	7.9	6.5	6.8	6.3	6.5	6.3	6.0	5.6	5.8	5.5	6.0	8.8	8.9	9.0
ES	8.3	8.2	7.8	7.7	7.5	7.0	6.8	6.4	6.2	5.7	5.1	4.6	4.4	4.9	5.4	5.0	4.8	4.3
FI	6.6	6.2	6.8	6.4	6.5	5.5	5.9	5.9	6.0	6.0	5.7	5.6	5.2	5.5	5.9	5.9	6.6	6.6
FR	7.2	7.0	6.7	6.3	6.0	5.8	5.3	5.5	5.6	5.4	5.1	4.9	4.7	4.5	4.9	4.7	4.4	4.1
HR								6.0	5.7	5.4	5.0	4.7	4.1	3.6	4.1	8.9	7.6	7.0
HU	10.1	9.2	9.7	11.3	10.5	9.0	8.6	8.5	8.0	6.9	7.9	7.9	7.1	6.9	7.1	7.5	7.6	6.8
IE	6.1	6.0	6.0	6.0	5.8	5.2	4.7	5.2	5.0	5.2	4.9	4.4	4.4	5.0	6.0	6.0	5.6	5.1
IT	8.8	8.1	7.6	7.1	7.2	6.3	6.2	6.2	6.2	6.0	5.8	5.5	5.0	5.1	5.1	5.1	5.1	5.9
LT	5.3	5.7	5.6	7.5	9.3	8.2	9.0	9.3	9.6	8.9	8.3	7.6	7.5	7.1	10.6	10.5	9.8	9.6
LU	9.3	9.0	8.7	8.6	8.3	8.0	8.3	8.3	8.7	9.4	8.7	8.0	7.1	6.9	6.6	6.4	6.5	6.4
LV	4.8	7.7	8.4	11.6	9.6	9.4	8.5	9.2	10.1	10.8	10.8	9.2	7.9	8.0	11.3	10.5	9.7	8.8
MT	4.1	4.3	6.0	8.3	7.4	6.4	6.5	5.6	5.0	4.8	4.7	4.7	6.1	5.2	5.2	5.4	5.8	5.7
NL	2.2	2.1	2.2	2.3	2.1	2.1	1.9	2.0	2.2	2.2	2.0	2.1	2.1	2.2	2.4	2.5	2.6	2.6
PL													8.0	7.6	8.3	7.9	7.8	8.1
PT	11.6	11.0	10.2	10.4	9.2	6.7	7.9	8.9	9.3	9.4	8.8	8.3	8.1	7.7	8.6	8.1	7.3	7.2
RO	5.3	5.1	6.7	10.0	15.3	12.6	5.6	5.7	9.7	10.5	9.9	9.0	8.6	7.5	9.1	9.8	8.7	8.7
SE	5.4	5.6	5.2	5.1	4.6	4.4	4.7	4.9	4.8	4.5	4.2	3.8	3.8	3.7	3.9	3.8	3.5	3.4
SI					5.2	9.4	10.8	10.5	9.8	9.7	9.2	9.0	9.1	9.5	12.7	12.7	11.9	13.1
SK	8.3	8.0	8.2	7.8	8.3	9.9	9.1	10.3	11.2	12.2	11.4	11.3	10.3	10.3	10.3	9.9	9.5	9.2
UK	7.3	7.6	7.7	8.0	8.0	7.7	7.1	7.1	6.9	6.8	6.4	5.9	5.9	5.6	6.6	6.4	6.0	5.9

3.3. EU Emissions Trading System

This section reviews the legislation on the EU Emissions Trading System (EU ETS) since its inception in 2005 and analyses its key implications for the EU oil refining sector in the 2005-2012 period (Phases 1 and 2 of the ETS). Our main conclusions can be summarised as follows:

- At the oil refining sector level, the average greenhouse gas emission levels per refinery stayed relatively stable between 2006 and 2012, while an increase in the average complexity of refineries was observed. This suggests that emission levels were influenced by some offsetting factors, such as energy consumption management and fuel switching by refineries, which is further supported by additional data.
- We cannot precisely conclude on the extent to which the EU ETS contributed to preventing potential growth in emissions, given the multiplicity of factors at play and difficulties with constructing a suitable baseline scenario. The available assessments and empirical data indicate that during the first two phases of the EU ETS, improvements in carbon emission performance were achieved due to improved energy efficiency and fuel switching. These were driven by production cost optimisation where the carbon emission-related cost played a relatively minor role during that period.
- On the basis of statistical data analysis, we conclude that, on the one hand, carbon emission abatement scope and options differed between the EU regions and were determined by region-specific factors, and on the other hand, that across all the EU regions the emission performance of refineries was strongly linked to refining complexity.
- The refining sector incurred indirect costs through the ETS-induced increase in the prices of key inputs, most importantly, electricity. The magnitude of such costs could differ between the EU regions; however, a cost increase of this type can be estimated as an insignificant part of refineries' operating expenditures overall, as discussed below. Potentially, certain refineries producing excess electricity could derive benefits from higher electricity prices by selling internally produced electricity to the grid when allowances for emissions related to electricity production were distributed to the sector free of charge – notably, such refineries only constitute a minority of the sector.
- Empirical analysis of the EU refineries' emission trading positions during the first two phases of the ETS shows that, in total, allowances allocated to the sector overall exceeded its total verified emissions in both phases. At the same time, we observe that in both trading periods slightly more than a quarter of the installations in the refining sector were short of emission allowances. Table 3.3.1, Table 3.3.2 and Table 3.3.3 summarise the estimated costs and benefits related to carbon trading for the oil refining sector.
- Statistical analysis of the emission trading data, matched with the characteristics of respective refineries, suggests that while operational characteristics and emission levels of refineries played a role in determining resulting emission trading positions, the 'shortage' of emission allowances was also a result of the initial allocation of allowances. This suggests that the approach to emission allowance allocation by national regulatory authorities is an important consideration for the analysis of the two initial phases of the ETS.
- The immediate impact of the EU ETS on refinery margins depended on the sector's ability to pass the associated costs on to fuel consumers. Based on the available estimates, below we conclude that the EU refineries had the possibility, at least in the short term, to pass the ETS-associated costs on to final consumers (however, to a different extents in different markets,

depending on various factors such as market structure and degree of exposure to international trade). Overall, the available empirical evidence is not conclusive with respect to the degree of ETS-related costs pass-through was actually exercised.

- Overall, we conclude that, during its first two phases, the EU ETS was not associated with significant costs for the oil refining sector as a whole; rather, the EU refineries were on average able to receive additional income due to the surplus of emission allowances. The limited impact of carbon trading on emission abatement investments was to a certain extent explained by the rather 'generous' overall allocation of allowances in the first two phases, together with the lower than expected levels of economic activity and resulting low prices of carbon.

Table 3.3.1: Emission balances of refineries – sector level
Source: Own elaboration on the basis of EUTL and Thomson Reuters Point Carbon data.

	Allocated allowances [million EUA]	Verified emissions [million EUA]	Surplus allowances			
				Theoretical value for the sector per year [million EUR]		
			%	EUA EUR 5	EUA EUR 30	Average EUA price[137]
1st period (2005-2007)	472.3	445.0	6.1 %	45.5	273	122.8
2nd period (2008-2012)	746.9	694.1	7.6 %	52.8	316.8	150

Table 3.3.2. Estimated opportunity costs of refineries – sector level (with assumed pass-through rate of 50 %)
Source: Own elaboration on the basis of EUTL and Thomson Reuters Point Carbon data.

	Verified emissions [million EUA]	Estimated opportunity costs for the sector (with *assumed* pass-through rate of 50 %[138]) [billion EUR]		
		EUA EUR 5	EUA EUR 30	Average EUA price
1st period (2005-2007)	445.0	0.37	2.23	1.00
2nd period (2008-2012)	694.1	0.35	2.08	0.99

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[137] Calculated on the basis of average EU Allowance Unit (EUA) prices of EUR 13.5 in the 1st trading period and EUR 14.2 in the 2nd trading period, obtained from Thomson Reuters Point Carbon data.

[138] Estimate based on the reviewed empirical literature.

Table 3.3.3. Emission balances of refineries – breakdown into 'SHORT' and 'LONG' refineries

Source: Own elaboration on the basis of EUTL and Thomson Reuters Point Carbon data.

	'SHORT' refineries [% of overall]	Average theoretical cost of additional permits per 'SHORT' refinery per year [million EUR]			'LONG' refineries [% of overall]	Average theoretical value of excess permits per 'LONG' refinery per year [million EUR]		
		EUA EUR 5	EUA EUR 30	Average EUA price		EUA EUR 5	EUA EUR 30	Average EUA price
1st period (2005-2007)	27.2 %	0.54	3.23	1.46	72.8 %	0.79	4.74	2.1
2nd period (2008-2012)	28.3 %	0.48	2.91	1.37	71.7 %	1.08	6.48	3.07

3.3.1. Objectives and measures

Council Directive 2003/87/EC of 13 October 2003, which entered into force on 25 October 2003, together with its subsequent amendments, established the scheme for greenhouse gas (GHG) emission[139] trading within the Community. Its first amendment by Directive 2004/101/EC entered into force on 25 June 2009 and permitted installations to convert and use their CERs[140] received from Kyoto instruments such as the joint implementation (JI) and clean development mechanism (CDM) against their carbon budget. The second amendment through Directive 2008/101/EC expanded the coverage of the EU emissions trading system (ETS) to aviation activities. The third amendment through Directive 2009/29/EC introduced additional improvements and expanded the scope of the EU ETS. The revised Directive has become a part of the EU 2020 climate and energy package agreed in December 2008.

The primary objective of the EU ETS is to ensure a cost-effective compliance with internal as well as international commitments for reductions of CO_2 and other greenhouse gas (GHG) emissions. Notably, the EU had committed to reduce its GHG emissions by 8 % within 2008-2012 relative to the emission levels of 1990 within the Kyoto protocol. Beyond this, the need for a longer term strategic GHG emission reduction of up to 70 % relative to the emission levels in 1990 has been acknowledged[141]. The adopted emission trading framework also contributes to providing further market incentives for investments in low-carbon technologies, while preserving the integrity of the internal market and avoiding distortions to competition.

The key principle of the emission trading scheme is to impose an obligation to surrender allowances to cover the previous year's reported GHG emissions from defined emission-generating activities (listed in Annex I to Directive 2003/87/EC), unless the installation is temporarily excluded from the ETS. Emission allowances are freely tradable on the exchange markets. Since its inception, the EU ETS fully covered the energy-intensive industries such as power stations and other

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[139] Strictly speaking, Directive 2003/87/EC covers the emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Annex II). However, Annex I only covered CO_2 emissions from installations; other GHGs could be added via a comitology process at a later date but were not included until 2013.

[140] The abbreviation CERs stands for the 'certified emission reductions', referring to the greenhouse gas emission reduction credits issued by means of the complementary flexible instrument introduced by the Kyoto Protocol – the Clean development mechanism (CDM).

[141] See paragraph (2) of Directive 2003/87/EC.

combustion plants, oil refineries, coke ovens, iron and steel plants and factories making cement, glass, lime, bricks, ceramics, pulp, paper and board.

To ensure compliance with the system, businesses must monitor and report their EU ETS emissions for each calendar year; their emission reports need to be verified by an accredited auditor. They must surrender enough allowances to cover their total emissions by 30 April of the following year – these surrendered allowances are then cancelled and cannot be used again. The accurate accounting of all allowances issued is facilitated by a single EU registry.

The initial Phase I, planned as a test phase, was launched in January 2005 with a duration of three years (2005–2007). During the first phase, Member States (MS) were given the authority to decide upon the total quantity of allowances[142] through the adopted National Allocation Plans[143]. At least 95 % of allowances were handed out to installations free of charge[144]. The penalty for non-compliance was set at EUR 40 per tonne. The MS had the authority to establish a reserve for emission allowances for the new entrants. Phase II followed with a duration of five years (2008–2012). The legally set minimum amount of allowances to be distributed for free fell slightly to around 90 %. The penalty for non-compliance increased to EUR 100 per tonne. Several MS (Austria, Czech Republic, Germany, Lithuania, the Netherlands, and the UK) organised CO_2 emission allowance auctions. Notably, during the first two phases of the EU ETS all emission allowances distributed to the installations within the refining sector were free of charge.

The EU ETS, as it stands now, operates in the 28 EU Member States as well as Iceland, Liechtenstein and Norway, applying to GHG emissions from more than 11 000 installations in the power generation industry and the manufacturing industry and covering around 45 % of the EU's GHG emissions[145].

3.3.2. Effectiveness of the legislation

Given its scope and ambition, the EU ETS is undoubtedly one of the most important environmental policies ever implemented. Not surprisingly, it triggered an extensive amount of theoretical and empirical literature assessing its performance (see, among others, Ellerman and Buchner 2007, Ellerman and Buchner 2008, Anderson and Di Maria 2011, Calel and Dechezleprêtre 2012).

The key obstacle in such evaluations is missing information on the counterfactual scenario – in particular, the 'business as usual' emission performance of the affected installations in the absence of the carbon cost. As the latter is unobservable, the studies can only draw on available estimates. Moreover, most researchers point out significant uncertainties regarding the attribution of any observed deviations from the baseline scenario to the impact of emission trading, given the multitude of other factors affecting the emission performance of the EU industry during the first two phases of the ETS (including, importantly, the economic recession). Therefore, assessing the attributable investment effects of the EU ETS has proven to be a major challenge, leading most investigators to apply either econometric estimation techniques or qualitative approaches through surveys on managerial decision-making.

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[142] See Directive 2003/87/EC, Article 11.1.

[143] Adoptions of the National Allocation Plans were subject to notification to the Commission and to the other Member States (see Directive 2003/87/EC, Article 9.1).

[144] See Directive 2003/87/EC, Article 10.

[145] Factsheet by the European Commission, available at: http://ec.europa.eu/clima/publications/docs/factsheet_ets_en.pdf.

On this basis, most of the studies we reviewed reach the conclusion that, while the overall cap set for CO_2 emissions during the first two phases was met, the impact of the EU ETS in terms of driving emission reduction was rather limited. In an extensive survey of the relevant empirical literature, Laing et al. (2013) report attributable emission savings in the range of 40-80 Mt CO_2/year (annual average) during the pre-financial crisis period (2005-2007), while in the post-crisis period they evaluate them as insignificant (however, admitting that in the second phase of the ETS, assessments were strongly complicated by the impact of recession). Among the key conclusions, Laing et al. report the insufficient effectiveness of the first two phases of the ETS in providing incentives for investment in abatement technologies. On the other hand, the paper suggests that the EU ETS had possibly contributed to deterring major carbon-intensive investments.

At the same time, it is important to keep in mind the wider objectives of the ETS when assessing the effectiveness of the system in the first years of its implementation. In this sense, the ETS was admittedly successful in implementing its goals during the first two phases, namely raising awareness and developing a general culture of the 'polluter pays' emission control (EC, 2008). In this respect, Laing et al. (2013) highlight that although the EU ETS had not stimulated emission abatement investment on a large scale, it proved to be instrumental in 'moving the discussion of carbon into the boardroom' and became an important factor in business decision-making. Importantly, in the initial years of its existence it had already established an effective infrastructure for carbon emissions trading[146]. Moreover, the first two phases of the ETS undoubtedly provided a valuable learning experience, whereby some identified drawbacks (such as certain inefficiencies in the emission allowances allocation procedures) are addressed in the current, third phase.

Our findings regarding the oil refining sector, discussed below, are generally in line with these conclusions.

3.3.3. Impact on the EU oil refining sector

At the plant level, the decision to invest in abating emissions is determined by the relation between the market price of emission allowances and the company's marginal abatement costs. Naturally, a firm will only have an incentive to invest in emission reduction as long as the purchase price of an additional allowance exceeds the cost of reducing an additional unit of emissions. The central question with respect to the impact of the EU ETS on the oil refining industry is thus whether, in the period concerned, the sector faced costs of emission allowances high enough to induce any significant changes in its investment and/or operating behaviour.

One needs to take into account that emission allowances, even if allocated for free, are associated with 'opportunity' costs for their holders. *Opportunity cost* is defined as the value of the best foregone alternative once another alternative is chosen. With respect to emission allowances, opportunity costs refer to the possibility of earning positive profits through selling the unused emission permits in exchange markets. By covering its incremental emissions through surrendering emission rights, a company will always face opportunity costs associated with not selling these rights. Therefore, abatement investment decisions will be influenced, among others, by the value of the CO_2 allowances a company can sell if it has a surplus of emission allowances. In this sense, opportunity costs create an additional mechanism for stimulating emission abatement even if emission allowances are distributed free of charge.

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[146] Since the establishment of the EU ETS, volumes of carbon trading rose steeply and exceeded 100 million allowances traded on a monthly basis in 2007. In 2006, the EU ETS already accounted for around 81 % of the global carbon market in terms of value and 67 % in terms of volume (EC, 2008, p. 13).

The average per-refinery level of GHG emissions in the sample of EU refineries that reported data to Solomon Associates in the period from 2006 to 2012 remained relatively stable – at 1531 kt/year (in CO_2 equivalents) per refinery in 2006 and 1520 kt/year (in CO_2 equivalents) per refinery in 2012 (Solomon Associates, 2014)[147]. As discussed above, the information on the 'business as usual' emissions of refineries, in particular hypothetical emission levels without having implemented the EU ETS, is crucial for concluding the extent to which the ETS was instrumental in reducing or preventing the growth of emission levels for each particular refinery. While some estimates of the 'business as usual' emissions can be collected directly from the Member States' National Allocation Plans, we do not consider it feasible to construct a comprehensive reference scenario at the refinery level. As mentioned above, even if estimating the counterfactual was possible, disentangling the impacts of the ETS from a set of the other factors potentially affecting refineries' emission levels can be a major challenge.

To provide additional insights into the issue, below we investigate some driving factors behind the carbon emission levels of oil refineries and the emission abatement options available to them. We discuss additional incentives to improve the CO_2 emission performance of the EU refineries potentially generated by the EU ETS. We subsequently look at the prices of purchased inputs as an indirect channel adding to the costs of emission abatement and the purchase of additional emission allowances. As the short-term impact of the ETS on refineries' margins depended on the extent to which the ETS-related costs were passed on along the value chain, this is another important aspect we touch upon. Subsequently, we provide an empirical overview of the EU refineries' trading positions in the emission markets in 2005-2012 and discuss the overall allocation and emission trading dynamics of the sector in this period. We consider the operational characteristics of refineries and the approaches to initial free allocations of emission allowances as the factors jointly determining the resulting emission trading positions. Finally, we conclude on the overall extent to which the ETS impacted the EU refineries during the period in question.

Factors affecting the levels of CO_2 emissions in refineries

To understand the emission abatement possibilities in the oil refining sector, below we consider the most important determinants of refinery plants' GHG emission levels.

Energy generation is the main source of air emissions in refineries. Typically, more than 60 % of refinery air emissions are related to the energy generation in various internal processes (JRC, 2013). Energy is required by the combustion systems and process units, whereby the processes with the greatest throughput dominate in energy consumption. Atmospheric distillation and, to a lesser extent, vacuum distillation units represent together 35–40 % of the total process energy consumed in a refinery. Energy consumption is also largely related to sulphur removal from refinery feedstock – on average, another 20–25 % of energy is spent in hydrotreating (JRC, 2013). Drawing on the data from Solomon Associates (2014), we observe significant heterogeneity in the reported average energy use in GJ/year and the associated imputed CO_2 emissions[148] across the refineries in different EU regions (Figure 3.3.1). The average emissions relative to the throughput of refineries varied across the EU regions in the range from around 160 tonnes of CO_2 per thousand

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[147] Note that changes in the average emission levels can reflect both the overall emission dynamics and changes in the sample composition.

[148] 'Imputed CO_2 emissions' are calculated from the fuels consumed to supply the net energy requirements of a refinery, including the emissions associated with external production of purchased electricity and heat but excluding emissions associated with production of exported electricity, as well as estimated CO_2 in any flare losses and any CO_2 emissions resulting from hydrogen production at the refinery.

tonnes of net raw material input in Baltic region, Benelux and France to around 280 tonnes of CO_2 per thousand tonnes of net raw material input in south-eastern Europe in 2012.

Figure 3.3.1. Average energy consumed vs imputed CO_2 emissions of refineries in different regions, 2000–2012
Source: Own elaboration on the basis of Solomon Associates (2014).

Product slate. Importantly, the energy and emission levels of oil refining processes are determined by the final product specifications to be achieved. In general, lighter product refining requires more processing (such as secondary conversion and/or treatment) and therefore result in higher CO_2 emissions. Incremental CO_2 emissions are estimated to be positively correlated in a non-linear way with the target sulphur levels (e.g. Reinaud, 2005, p. 27). In this sense, legislative requirements for cleaner fuels, in particular with respect to their sulphur content, can be, to a different extent, associated with additional energy consumption and higher CO_2 emissions in refineries.

Refining complexity. As we discussed in the refining sector overview (Chapter 2), increasing the complexity of refineries, while providing a set of advantages in terms of flexibility and improved product slate, is typically associated with higher energy consumption (due to the use of highly energy-intensive secondary conversion processes, as discussed above). Indeed, drawing on the data from Solomon Associates (2014), we clearly observe that more complex refineries on average consumed more energy in GJ/year, and, as a consequence, were characterised by higher emission levels (Figure 3.3.2).

Figure 3.3.2. Average energy consumed vs imputed CO₂ emissions of refineries in different complexity groups[149], 2000–2012
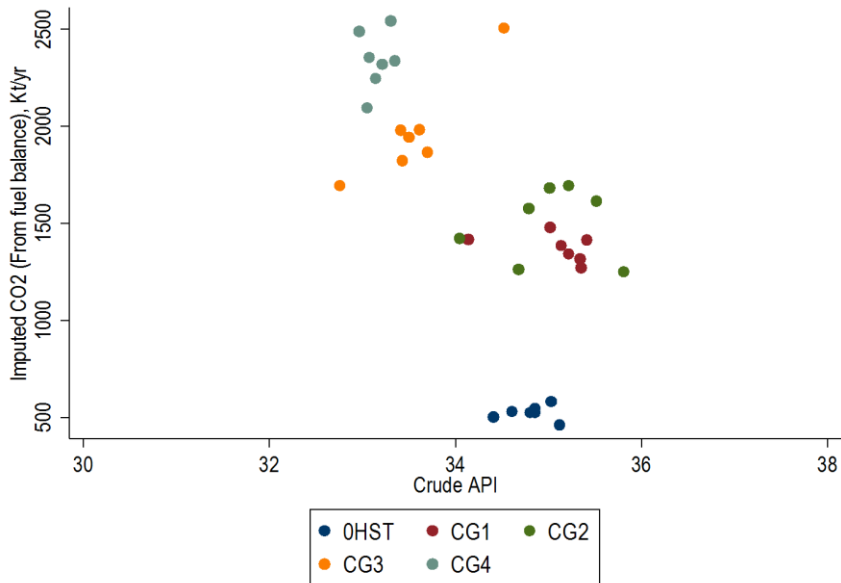
Source: Own elaboration on the basis of Solomon Associates (2014).

Energy sources. The emissions profile of a refinery is to a large extent determined by the composition of the fuel mix used at different stages of crude oil processing. In particular, gaseous fuels are associated with the lowest levels of CO_2 emissions (per GJ of energy), followed by liquid and solid fuels (solid fuels consumed are generally produced internally in the refinery). Analysis of the sample of European refineries, conducted on the basis of Solomon Associates (2014) database and presented in the refining overview (Chapter 2), has revealed that over the 2000–2012 period gaseous fuel was the major resource for refinery energy production across the EU regions, with its largest share in the plants' energy mix in the Baltic region and the smallest in the Iberian Peninsula. The next most important energy sources were liquid fuels, followed by solid fuels. This suggests that, in recent years, the EU refineries were predominantly using less carbon-intensive energy sources.

Crude oil diet. As we discussed in the refining sector overview (Chapter 2), refineries often have access to a comparatively limited range of crude oil types. The characteristics of the crude oil have impacts on refinery processes and emission levels – namely, the processing of heavier and sourer crudes is associated with higher energy intensity and emissions. When plotting Solomon Associates (2014) data for crude oil characteristics and the CO_2 emission levels of different complexity groups, we observe that more complex refineries tend to process heavier and sourer crudes, and on average emit higher amounts of CO_2 (Figure 3.3.3 and Figure 3.3.4).

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[149] See Chapter 2 for the definition of the complexity groups in Solomon Associates (2014) database.

Figure 3.3.3. Imputed CO$_2$ emissions vs average crude API gravity of refineries in different complexity groups, 2000–2012
Source: Own elaboration on the basis of Solomon Associates (2014).
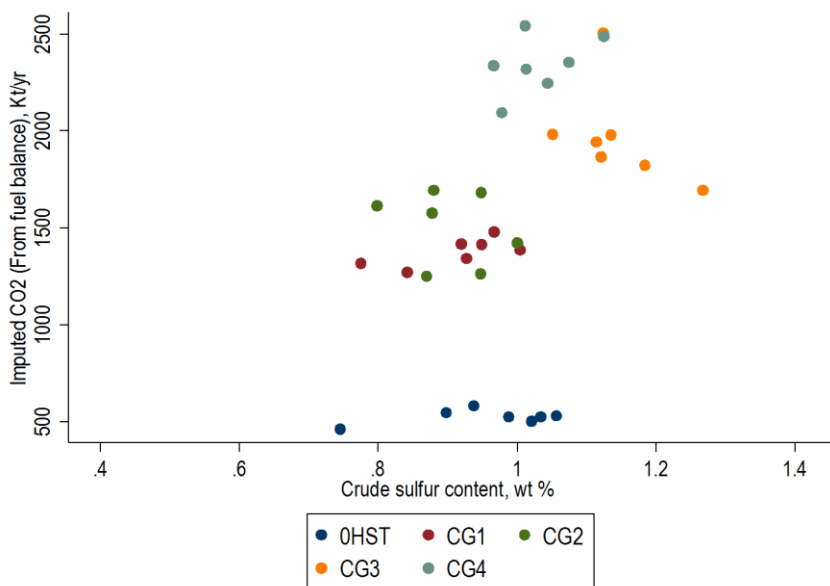
Figure 3.3.4. Imputed CO$_2$ emissions vs average crude sulphur content of refineries in different complexity groups, 2000–2012
Source: Own elaboration on the basis of Solomon Associates (2014).

On the basis of statistical analysis of the data available in Solomon Associates (2014) for the 2000–2012 period, we can thus conclude that (i) capacity for secondary conversion, i.e. refining complexity, was strongly associated with CO$_2$ emission levels: on average more complex refineries consumed more energy in GJ/year and accordingly were characterised by higher CO$_2$ emissions (Figure 3.3.2); (ii) in addition, more complex refineries on average processed crude oil with a lower

API gravity and higher sulphur content, with associated greater emission levels (see Figure 3.3.3 and Figure 3.3.4); (iii) apart from the influence of complexity, there is significant heterogeneity in the average refineries' energy use across the EU regions (Figure 3.3.1), which can be attributed to the interplay of region-specific factors. These findings suggest, on the one hand, that emission abatement scope and options could differ significantly between the EU regions, i.e. determined by local factors, and on the other hand, that higher refining complexity (generally linked to a lighter, lower-sulphur product slate, which might be necessitated by compliance with legislative requirements) was associated with greater CO_2 emission levels of refineries across all the EU regions.

Emission reduction options available to refineries

As specified in JRC (2013), abatement technologies directed at CO_2 – in particular, CCS (Carbon Capture and Storage) – are not currently available at the relevant scale. While CO_2 separation techniques exist, the storage and recycling of CO_2 are problematic. Therefore, reduction of CO_2 emissions can mainly be realised through improving the emission performance of internal refining processes. In view of the factors outlined above, emission reduction options potentially available to refineries include:

- energy consumption management (e.g. improving heat exchange between refinery streams; integration of refinery processes to avoid intermediate cooling of components; recovery of waste gases and their use as fuels; use of the heat content of flue-gases; the highest possible recovery of energy from fuel combustion (JRC, 2013));
- fuel source switching (with gaseous fuels accounting for less emissions per GJ than liquid and solid fuels);
- potential changes in the crude oil diet, where this option is technically feasible.

While a number of abatement opportunities can be identified, they can only be effective to a limited extent within the current technological reality, due to the inherent energy intensity of oil refining processes (as well as the limited variety of crude sources available). Notably, as discussed in Chapter 2, the EU oil refineries are predominantly mature; therefore, switching to low-energy and low-carbon technologies could be relatively more burdensome for them as opposed to introducing such technologies in newly built refineries.

As discussed above, the average level of CO_2 emissions per refinery in the Solomon Associates (2014) sample remained relatively stable over 2006-2012. Together with the growing average complexity of the participating refineries (the complexity measured by the Solomon Index for Refinery Complexity increased on average from 8.1 in 2006 to 9.0 in 2012), which in line with the above discussion would imply higher CO_2 emissions, this suggests that refineries generally improved their emission performance over that period. Indeed, the average energy intensity of the participating refineries, measured by the Solomon Energy Intensity Index™ [150], decreased from 100 in 2006 to 95 in 2012, meaning that they became more energy-efficient. While the average CO_2 emissions measured per tonne of throughput remained at roughly the same level over 2006-2012 (around 200 tonnes per thousand tonnes of net raw material input), the energy consumption per tonne of throughput grew over the same period (from 2711 GJ per thousand tonnes in 2006 to 2757 GJ per thousand tonnes in 2012), suggesting that refineries also switched to less carbon-intensive sources of energy. Overall, this implies that, in absolute terms, the sample refineries on

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[150] Re-indexed to total EU-28 2000 population = 100.

the whole became less GHG emission-intensive. In the absence of a suitable baseline scenario, it is not feasible to precisely conclude on the extent to which this effect could be attributed to the ETS. It can be argued, however, that the attribution could be only partial given the multitude of factors affecting the EU refineries during the period in question.
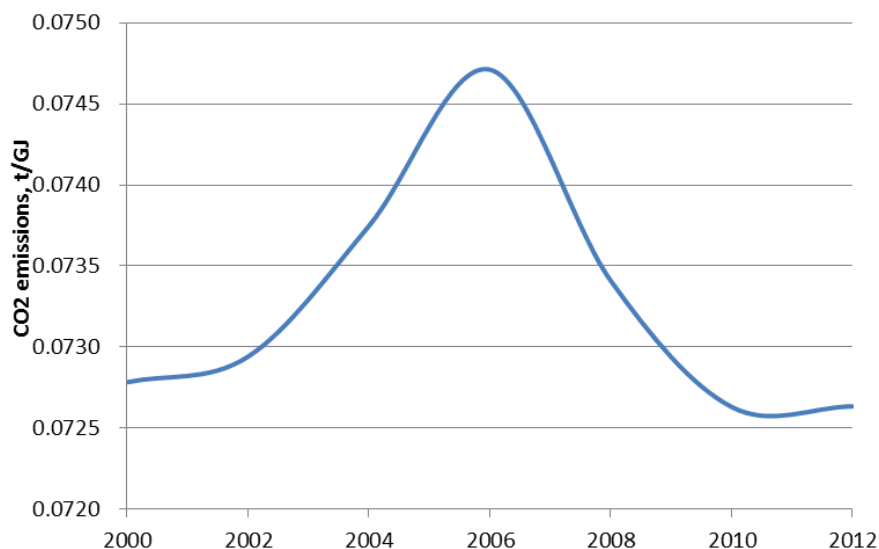
Figure 3.3.5. Average CO_2 emissions intensity of the EU refineries' energy consumption (imputed t CO_2 per GJ energy consumed), 2000-2012
Source: Own elaboration on the basis of Solomon Associates (2014).

As we discuss in the respective chapters of the report, energy constitutes a very important part of the operating costs in the EU refineries, with energy prices playing a crucial role in refiners' operational decisions. They are very interested in increasing the energy efficiency of their processes and, as confirmed by the data from Concawe (2012) and Solomon Associates (2014), already widely implement available measures aimed at optimising energy consumption[151]. It can be argued that any additional effort on top of the energy-saving and less carbon-intensive technologies already implemented would be made by refineries for cost-minimising reasons, unless considered excessively expensive or impractical at the moment.

One could estimate the incremental incentives for increasing energy efficiency in refineries, potentially generated by the EU ETS, through the observed 'carbon emission intensity' of energy consumed in the EU refineries. Figure 3.3.5 illustrates a simplified relationship between the average imputed CO_2 emissions and the average consumption of energy by refineries participating in the Solomon Associates survey over the 2000-2012 period. On this basis, assuming a carbon content of energy, for example, of 0.074 tonnes of CO_2 per GJ of energy, and a range of allowance prices from EUR 5 to EUR 30, the incremental cost of CO_2 for an average refinery in the Solomon Associates (2014) database can be estimated to be in the range of EUR 0.37 to EUR 2.22 per GJ of energy consumed. Comparing this to the average cost of energy consumed by the sample refineries, which according to the Solomon Associates (2014) database was between EUR 5.9 and

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[151] According to Concawe (2012), the share of cogeneration in electricity generation in the EU refineries has risen from 76 % to 92 % over the 1992-2010 period. Data from Solomon Associates shows that high-efficiency electricity production, including cogeneration, in the EU refining sector has been steadily growing and increased from 201.1 MWh/yr on average per refinery in 1998 to 361.4 MWh/yr in 2012.

EUR 9.3 per GJ of energy over 2006, 2008, 2010 and 2012, the ETS-related increase in the cost of energy appears negligible.

In addition, analysing the evolution of the 'carbon intensity' of the energy consumed by refineries in the Solomon Associates (2014) sample (Figure 3.3.5), we observe that it slightly increased up to 2006 (by around 2.7 % from 2000 to 2006) and started to slightly decrease afterwards (by around 2.8 % from 2006 to 2012). This implies that, in addition to energy-saving measures, refineries were also to a certain extent switching to less CO_2-intensive sources of energy. Arguably, this effect could be partially attributed to the EU ETS, while it can be explained to a large extent by the interplay of several other factors, such as economic reasons (with relative prices of different energy sources playing an important role) and fuel switching due to the environmental regulation other than emissions trading (as discussed in more detail in the relevant chapters of this report). While further empirical analysis with a view to breaking down the effect of each of these factors would be useful, we do not attempt it within this report due to the lack of pertinent refinery-level data.

The available assessments – as discussed above – in general confirm that during the first two phases of the EU ETS, the affected industries did not consider emissions trading a significant factor affecting the investments in emission abatement technologies. This could suggest that they generally considered incremental emission reduction to be relatively costly in comparison with the current and expected market prices of CO_2. As discussed below, this could be a result of the total allocation of certificates quite significantly exceeding actual emissions over the first years of the EU ETS, which resulted in a fall in CO_2 prices and an overall limited impact on investment incentives.

ETS-related increases of electricity costs

In addition to the direct costs of abatement activities or purchasing additional emission allowances, in the 2005-2012 period the refining sector could incur indirect emissions trading costs through the increased prices of key inputs, importantly electricity. For instance, Sijm et al. (2006) estimate that at a CO_2 price of EUR 20/t, the ETS-induced increases in the wholesale electricity prices in Germany and the Netherlands could range from EUR 3 to EUR 18/MWh, depending on the carbon intensity of a power installation. Naturally, the degree to which electricity prices may have increased due to the costs of carbon trading depended on the ability of the power sector to pass these costs on to consumers, which Sijm et al. (2006) estimate to be between 60 % and 100 %[152].

Notably, the majority of EU refineries are net importers of electricity (Concawe, 2012). As discussed in more detail in Chapter 2, the share of externally purchased energy (mainly natural gas and electricity) in the operating costs of the EU refineries in the Solomon Associates (2014) sample developed on average from 6.5 % in 2000 to 18.2 % in 2012, displacing own produced energy, although still only constituting a relatively minor part of total refineries' operating expenditures. On average, purchased electricity constituted 30.6 % of the total electricity consumption of refineries in 2000 and 38.7 % in 2012.

Regionally, during 2000-2012 the share of externally purchased electricity in the total electricity consumption of refineries differed quite substantially (Figure 3.3.6). While electricity purchased from the grid on average constituted a relatively marginal share in some regions (e.g. Iberia, the UK

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[152] For more detail, see Sijm et al. (2005) on the distinction between the add-on and work-on rates in power price transmission, and how different electricity market features determine the reference pricing, as well as the time delay to account for external shocks such as changes in prices of emission allowances.

and Ireland), in other regions quite large shares were observed (e.g. Baltic states and south-eastern Europe). Iberian refineries produced almost all of their own electricity during the period, although in the second half of the period the share of their own-produced electricity slightly declined. The degree of indirect impact on refineries of electricity price increases could thus differ across the EU regions.
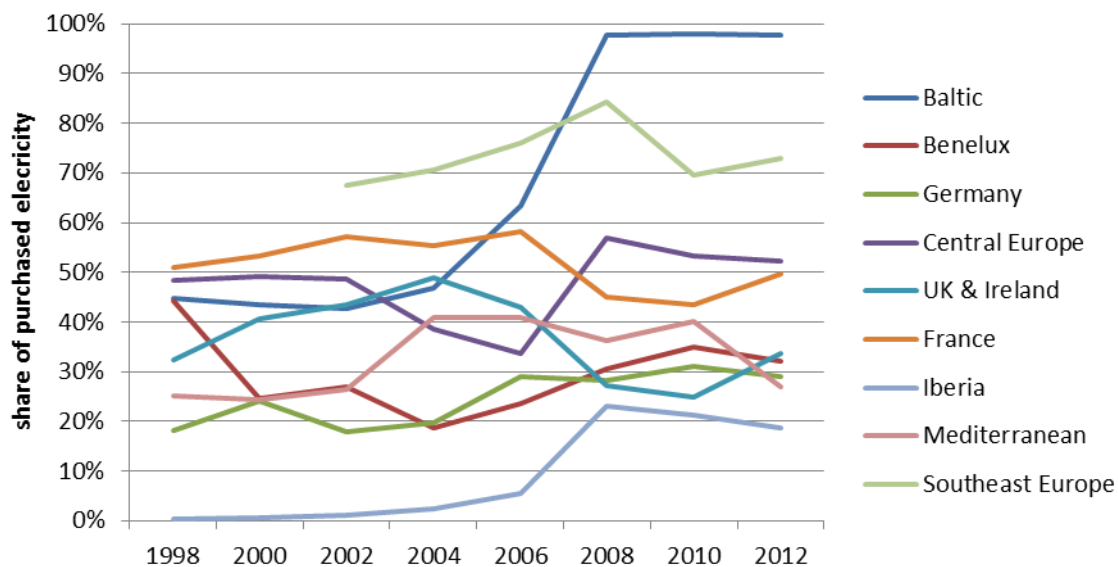
Figure 3.3.6. Share of purchased electricity in total electricity consumption of refineries (%)
Source: Own elaboration on the basis of Solomon Associates (2014).

On the basis of the Solomon Associates (2014) data, we observe a visible increase in the unit costs of electricity purchased by the EU refineries after 2004 (Figure 3.3.7, Figure 3.3.1). At the same time, it is apparent from the graph that this increase closely follows the upward trend for the other main sources of energy used by refineries. Furthermore, the unit costs of other energy sources have grown faster than that of purchased electricity. Therefore, the growth observed in electricity costs after 2004 is likely to be explained to a large extent by a set of wider economic conditions (including, importantly, utility markets liberalisation in this period) and can be only marginally attributed to the effect of emissions trading, which in turn indicates that the attributable impact of the EU ETS on the electricity prices faced by refineries in 2005-2012 was insignificant.
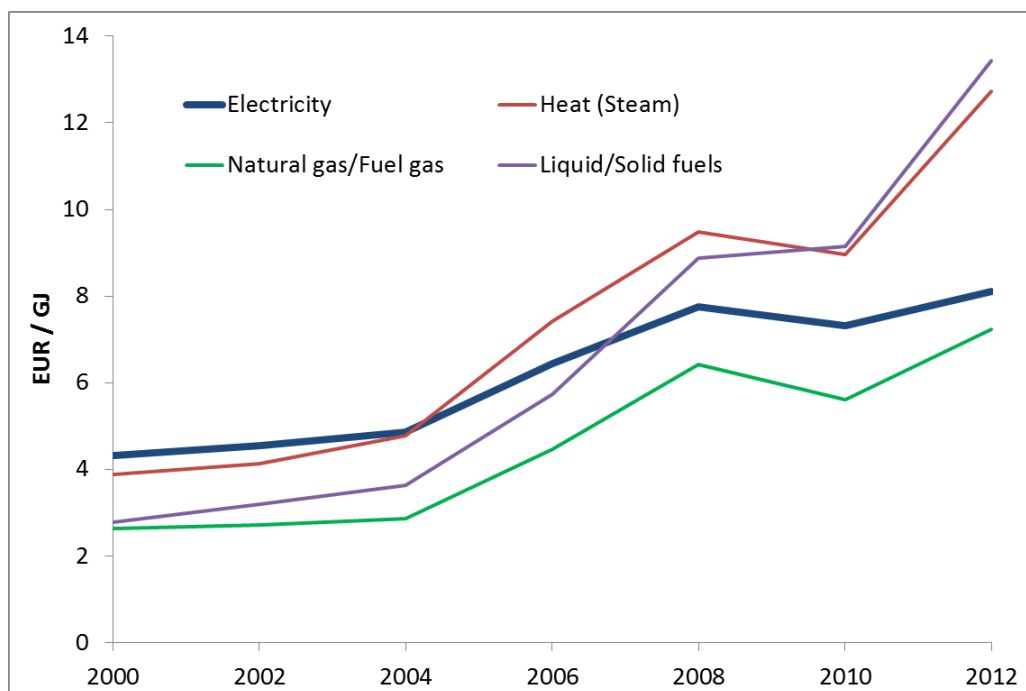
Figure 3.3.7. Average unit costs of energy purchased by refineries by source, 2000–2012
Source: Own elaboration on the basis of Solomon Associates (2014).

Overall, we can conclude that, during the period in question, the EU refineries could face indirect costs as a result of increased electricity prices due to the ETS; these costs can on average be estimated as a minor share of the operating expenditures of the EU refineries (as discussed above, the attributable impact of the ETS on electricity prices faced by refineries was insignificant; in addition, purchased electricity did not on average constitute a significant share of OpEx). However, the effect could differ in magnitude between the individual refineries and the EU regions. Alternatively, a minority of the EU refineries were net producers of electricity (in the relevant period only four refineries according to Concawe (2012)) and could derive benefits from higher electricity prices by selling own-produced and not internally consumed electricity to the grid. However, such benefits were likely limited by the growing prices of inputs for electricity production (crude oil and natural gas).

Below we look at the refineries' emission trading positions during the first two phases of the EU ETS in order to provide an insight into the potential costs or benefits associated with emissions trading. We do not, however, interpret these trading positions as an indication of the overall ETS-induced costs or benefits of refineries – instead, they should be considered in the context of all the relevant cost-benefit channels discussed in this chapter.

Emission trade balances of refineries

The EU Allowance Unit (EUA) price has become an additional cost element for refineries since the introduction of the EU ETS in 2005. From the start of the trading, the EUA price continuously increased up to around EUR 30. However, trading in 2006 and 2007 was characterised by an overall excess supply of allowances, which brought the EUA price essentially down to zero. The market revived again in early 2008, reaching its peak at slightly below EUR 30, and then continued to fluctuate between EUR 10 and EUR 15. In 2011, the EUA price started to decline towards EUR 5 and remained relatively stable between EUR 5 and EUR 10 in 2012 (Figure 3.3.8).
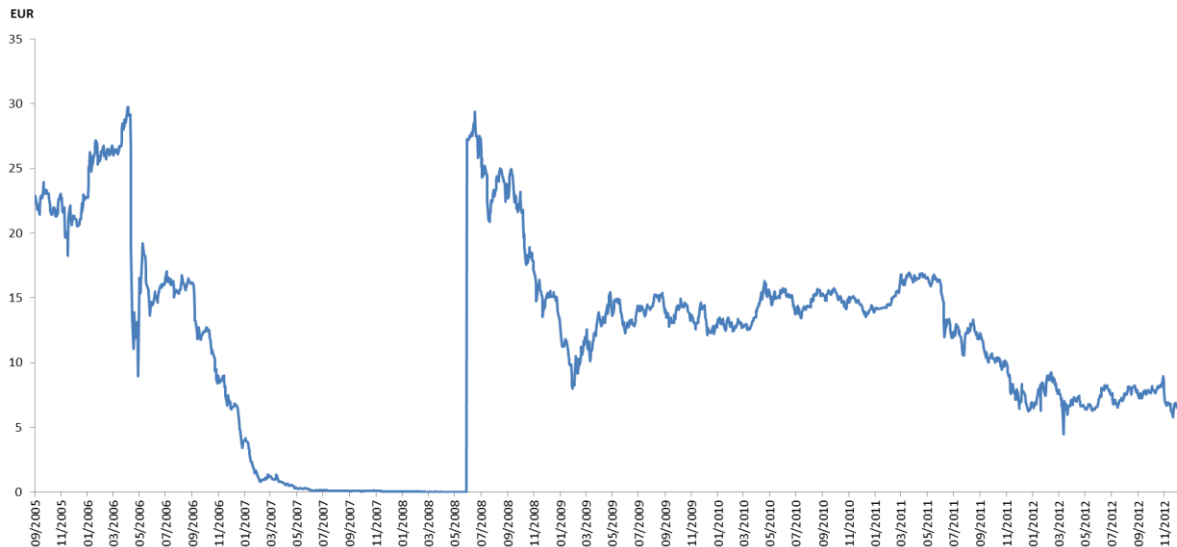
Figure 3.3.8. EUA spot prices in 2005-2012
Source: Thomson Reuters Point Carbon data.

We draw on the information available in the European Union Transaction Log (EUTL)[153] to reconstruct the refineries' emission trading positions in 2005-2012. As discussed above, emission allowances for both the first and second trading periods were distributed to the installations within the refining sector free of charge. Decisions on the distribution of emission allowances among the installations were taken by the Member States by means of the National Allocation Plans (NAPs). It was the responsibility of the Member States to propose an initial distribution of their share in the overall EU emission allowances among the participating installations.

The refining sector received a total of 472.3 million emission allowances[154] during the first three-year trading period, followed by 746.9 million emission allowances over the second five-year trading period (Table 3.3.4). Notably, while the number refers to the EU refining sector according to the EUTL classification, there is a certain divergence between the installations covered within the oil refining sector in the EUTL and the definition of a refinery used in the survey by Solomon Associates (2014). Two reasons for this discrepancy are: (i) some accounts included in the EUTL as mineral oil refining installations are not in fact refineries according to the definition used by Solomon Associates; (ii) there are some refineries that are included in the EUTL under the activity 'combustion of fuel' and 'other activity' (for further discussion on this issue see e.g. Ecofys (2009)). It is not our intention to adopt any specific definition of the oil refining sector in this chapter. After referring to the total amounts of allowances distributed within the refining sector as they are reported in the EUTL (codes 21.0 and 21.2), our further analysis will focus only on the refineries covered in Solomon Associates (2014).

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[153] All installations regulated under the EU ETS have an account in their respective national registries recording their allocated emission allowances and verified emission levels. The data from the national level are further transferred to the European registry – European Union transaction log (EUTL).

[154] One emission allowance (EUA) covers 1 tonne of CO_2 equivalent emissions.

Table 3.3.4: EU emission allowance allocations and verified emissions of the oil refining sector (Mt CO$_2$ equivalent)
Source: EUTL.

Year	Allowances [Million EUA]		Verified emissions [Million EUA]	
	1st period	2nd period	1st period	2nd period
2005	157.2		148.8	
2006	156.3		147.3	
2007	158.8		149.0	
2008		146.3		148.6
2009		146.4		140.0
2010		150.8		137.8
2011		150.3		136.3
2012		153.1		131.4
Total	472.3	746.9	445.0	694.1

According to the EUTL, the total CO$_2$ emissions from the refining sector within the EU-25/27 reached 148.8 Mt CO$_2$ in 2005 and 131.4 Mt CO$_2$ in 2012. The total allowances allocated to the installations exceeded their total verified emissions by around 6.1 % in the first phase and around 7.6 % in the second phase. In relative terms, the amount of allowances allocated to the refining sector in excess of its verified emissions appears moderate: overall, according to the EUTL, allocations to the ETS industrial sectors were above their verified emissions by 9.75 % and 32.5 % during the first and second trading periods, respectively. Based on the reported figures, a permit price range of EUR 5 to EUR 30 would imply a potential additional income for the sector between EUR 136.5 million and EUR 819 million and between EUR 264 million and EUR 1.58 billion during the first and second trading periods, respectively. On average, this translates into a potential surplus at the level of the sector of around EUR 123 million and EUR 150 million per year in the first and second trading phases, respectively. Naturally, this implies that excess permits could be sold at the assumed prices, while in reality they were determined by the market prices of CO$_2$ at each particular point in time. Additionally, emission allowances could either be sold by the companies or serve as insurance for the future; importantly, while banking of permits was allowed in the transition from the second to the third phase of the ETS, it was not possible between the first and second phases.

Notably, while allocation above the amount of verified emissions has been generally interpreted as a total 'over-allocation' of emission allowances, the notion of 'over-allocation' needs to be applied with a certain degree of caution. First, while the sector as a whole may demonstrate a positive difference between the allocated amounts and observed emissions, the picture can be different at the level of individual refineries. Second, even for a specific refinery, the observed 'over-allocation' could be a result of the efforts to reduce emissions generated in the current or past periods (in anticipation of the regulation), and therefore can only be identified with respect to the correct reference scenario, as discussed above.

Figure 3.3.9. Share of excess/shortage of emission allowances over the plant's allocation
Note: Each data point corresponds to a refinery in the sample of 92 refineries (Annex I) ordered by the degree of 'over-allocation'.
Source: Own elaboration on the basis of the EUTL. Closed/reduced capacity refineries in the 2nd phase shown according to the data provided by Concawe (Annex III).

Figure 3.3.9 illustrates the distribution of short and long positions of installations in the oil refining sector according to the EUTL in both trading periods. On the basis of this data, one observes that around 27.2 % and 28.3 % of the installations were short of emission allowances during the first and second trading periods, respectively. For the subsample of 'short' refineries, this corresponds to an average shortfall of around 323 000 and 480 000 tonnes of CO_2 equivalents per refinery in the first and second trading periods, respectively. On the other side of the distribution, over 70 % of the refineries were holding an excess of emission allowances over their verified emissions in both trading periods. The average 'long' position of these refineries reached around 474 000 and 1.08 million tonnes of CO_2 equivalents per refinery in the first and second trading periods, respectively. We observe that around 30 % of the allocation in excess of the verified emissions of 'long' refineries was concentrated in the right tail of the distribution (in the 10 'longest' refineries). Among these, around half were closed or idled after 2009 (Teesside and Coryton refineries in the UK, Reichstett and Berre L'étang refineries in France, and Wilhelmshaven refinery in Germany[155]), and some were characterised by unusually low utilisation rates (for example, 33 % at Mazeikiu refinery in Lithuania in 2007[156]), which might explain some extreme cases of 'over-allocation'.

To ensure compliance, refineries with short positions, i.e. those from the lower end of the graph in Figure 3.3.9, were obliged to purchase the required amount of emission allowances on the market. One can estimate the average potential costs to a refinery buying additional emission allowances as the average excess emissions of 'short' refineries multiplied by the per unit price. Accordingly, the potential costs of emissions in excess of the allocated amounts could reach from EUR 1.62 million to EUR 9.69 million (assuming EUA prices of EUR 5 to EUR 30, respectively) and on average EUR 4.36 million during the first trading period (i.e. distributed over three years). In the second phase, the costs would increase to EUR 2.42–14.55 million and on average to

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[155] According to the information provided by Concawe.

[156] Estimated data from the IHS (2014) database.

EUR 6.82 million (distributed over five years). For comparison, in terms of throughput[157] the costs incurred by refineries that were 'short' of emission allowances constituted, respectively, from 0.3 euro cents to 1.8 euro cents per barrel (with EUA prices of EUR 5 and EUR 30) and on average 0.81 euro cents per barrel in the first phase, and from 0.4 euro cents to 2.3 euro cents per barrel (with EUA prices of EUR 5 and EUR 30) and on average 1.14 euro cents per barrel in the second phase. In other words, the slightly more than 25 % of all sample refineries with a 'short' allocation had an excess cost of around EUR 1.4 million, or 1.02 euro cents per barrel, on average per year. Correspondingly, at the level of the whole sector the average level of such a potential cost is much lower.

The emission trading positions of refineries are an outcome of the interplay of multiple factors. Notably, they are a result of initial allocations of allowances and the actual verified emissions of refineries, and can therefore be affected by both. As discussed above, the structural characteristics of refineries (such as their size and capacity for secondary conversion) could play an important role in determining their emission levels. In order to understand whether there are any consistent patterns in the role of size and complexity of refineries for the dynamics of emission balances, we conducted a statistical analysis of the EUTL data, matched with IHS (2014) information on the capacity and complexity of the respective refineries. This analysis aimed to clarify whether the size and complexity of refineries, as well as their emission levels, were statistically significant in affecting their emission trading positions. For this, we statistically compared the average size, complexity and emission levels (T-test on equality of means) of two groups of refineries: the ones with 'long' emission trading positions and the ones with 'short' positions.

The results reveal (see Annex II for the formal test results), consistent with our expectations, that in both trading periods refineries with higher emission levels (per unit of capacity) were on average significantly more likely to need to purchase additional emission allowances. The test on the average complexity, expressed with the Nelson complexity index, on the other hand, did not demonstrate statistically significant results. With respect to the size of refineries, the results were significant and showed that, rather counterintuitively, on average smaller refineries were more likely to be short of allowances in both periods[158]. One of the explanations for this could be that these refineries were allocated less allowances in the first place. This highlights the fact that both the operational characteristics of refineries and the initial allocation of allowances indeed played a role in the resulting emission balances. Approaches to emission permits allocation by national regulatory authorities, which we consider in more detail below, could therefore be an important factor in the emissions trading positions of refineries.

As discussed above, emission allowances were distributed to the installations free of charge in both trading periods of the EU ETS. Decisions on the specific allocation of emission allowances were taken by Member States through the National Allocation Plans (NAPs) and assessed by the European Commission for compliance with the general rules laid down in Annex III to Directive 2003/87/EC. In the framework of these overall guiding principles, it was the responsibility of national authorities to propose a method of distribution of their share of the overall EU emission allowances among the participating installations in a non-distortive way.

In order to provide some intuition behind the resulting market positions of the EU Member States in the first two phases of the EU ETS, we investigated in more detail the allocation procedures used in

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[157] Estimated throughput data from the IHS (2014) database.

[158] This finding differs from the conclusions reached in certain other studies. For example, Keppler at al. (2010) find that, in overall terms, small installations are biased to long and big installations to short positions.

the MS where the refineries with resulting 'net short'[159] positions were located. As outlined above, we identified 25 and 26 refineries with a lower allocation of emission allowances than their verified emissions in the first and second trading periods, respectively. During the first trading period, the 'short' refineries were located in 10 of the MS (AT, FI, DE, EL, IT, ES, SE, RO, PL and UK), and during the second trading period – in 12 MS (AT, CZ, DK, FI, FR, DE, EL, IT, NL, SE, HU and PL)[160]. This, in particular, indicates that installations within the refining sector on average faced relatively higher costs of emission trading in the above MS than the rest of the EU in the respective periods.

According to the NAPs of these MS, the numbers of permits allocated to the refining sector were – following the general guidelines of the Directive – typically based on the levels of emissions observed in several preceding years. These numbers were subsequently adjusted to reflect the MS' obligations under the Kyoto Protocol, as well as the sector's technical abatement potential, expected economic conditions and estimated degree of exposure to international competition (as an indication of ability to pass on the associated costs). The rules generally incorporated special treatment of new entrants in the scheme, compensation for unavoidable increases in emissions due to legislative requirements, rewards for 'early action', use of clean and energy-efficient technologies, as well as penalties for specific cases of underperformance. The NAPs were subject to public consultations, including feedback from the industry.

As a result, the number of allowances allocated with respect to the 'business as usual' emissions differed between MS and participating sectors. The NAPs we reviewed, for example, acknowledged the significant contribution of the energy generation sector (notably, the refining sector was generally treated as part of the energy sector) to the overall GHG emissions, its high emission reduction potential and in some cases the relatively low exposure to international competition, i.e. a relatively high estimated ability to pass the costs on to final consumers. Comparing the information obtained from the NAPs with the relevant data in the EUTL, we conclude that, in addition to the characteristics and levels of activity of refineries, the observed 'short' positions could be a result of several factors, including: (i) estimation of the technological potential of the refining sector (as part of the energy sector) to reduce emissions as relatively high (e.g. in Austria[161]); (ii) evaluation of the sector's ability to pass the costs on as significant (e.g. in Italy[162]); (iii) unanticipated increases in the amount of emissions due to increases in capacity (e.g. in Finland[163] and Greece[164]); (iv) actual

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[159] The 'net short' position corresponds to the overall negative emission trade balance over the whole trading period.

[160] Note that in some cases the assessment might be biased due to data issues, for example, when the data on allocated allowances does not reflect all the installations comprising a refinery, while the data on verified emissions refers to the full refinery or its larger part.

[161] The agreement on the sector-specific contribution to climate protection largely determined the distribution of emission allowances. During the 1st trading period, the climate contribution of the energy and the refining industry sectors in Austria was 7.7 % and 2.85 % relative to the BaU scenario, respectively (see AT-NAP-01(2004)). During the 2nd trading period, the contribution of the energy sector was set to 28.9 % relative to the BaU emissions; the refining sector as a part of the energy sector was expected to contribute 13 % (AT-NAP-02(2007)).

[162] The refining sector in Italy was short of emission allowances in particular due to on average 27.6 % reduction of the emission allowances distributed during the 2nd trading period with respect to the 1st period. The Italian NAP for the 2nd trading phase indicates that the decision to decrease the emission allowances to the refining sector was based, among others, on a higher potential for emissions reduction, a lower exposure to international competition, and on a higher ability of the sector to pass on the additional costs to final customers, see IT_NAP_02(2006), page 8.

[163] The data (EUTL and IHS (2014)) indicate that an increase in emissions was potentially due to the addition of the residue hydrocracking facility in the Porvoo refinery in 2006.

[164] The data (EUTL and IHS (2014)) indicate increases in the crude distillation capacity in the Aghii Theodori and Aspropyrgos refineries and in the vacuum distillation capacity in the Elefsis refinery, as well as in the hydrotreating capacity expansion in the Thessaloniki refinery.

emissions fluctuating around the projected emissions due to the economic activity of the sector (e.g. in the UK).

Costs pass-through to final consumers

The immediate impact of the EU ETS on refineries' margins, among others, depended on the sector's ability to pass these costs on to fuel consumers. Such a pass-through would be desired within the system as a mechanism for distributing the costs of pollution along the value chain and inducing shifts in final consumption towards less carbon-intensive fuels. In reality, the pass-through rates differ from market to market and depend on different factors such as market structure, demand features and product-specific characteristics. While refined oil products are typically characterised by relatively inelastic demand, their high international mobility and substantial product uniformity can constrain the extent of cost pass-through when the incremental costs are not equally incurred by market participants. Namely, the pass-through may be limited both through the potential loss of exports and through displacement of domestic production by imports from the countries with less stringent environmental regulations.

The literature empirically addressing the issue of carbon cost pass-through rates in the oil refining sector is relatively scarce. While several studies we reviewed are conclusive with respect to the positive pass-through in the markets they investigated, (i) they typically look at a relatively short time period and at specific individual markets, therefore, the results should be generalised with caution, and (ii) the reported magnitude of pass-through rates varies within a significant range depending on the data and method used. From the methodological point of view, one may distinguish between the input cost approach, where various cost components are regressed on the output price and the significance of the CO_2 parameter is being observed, and the markets methods, where common patterns in price movements between markets with and without carbon policies are analysed.

For instance, De Bruyn et al. (2010) use econometric methods stemming from the concept of co-integration and market integration to develop a standardised estimation procedure which is applied to a range of selected products, including refined oil products. The results of the econometric analysis for most products demonstrate a significant influence of the EUA prices on the European product prices in the period between 2005 and 2008. Overall, De Bruyn et al. (2010) conclude that for the refined oil products 'full cost-pass-through rates are likely'[165]. Alexeeva-Talebi (2011), employing econometric ex post co-integration analysis for the price data covering 14 MS, found the pass-through rate to be 'rather likely' 100 % for gasoline during Phase I of the EU ETS. Finally, Oberndorfer et al. (2010) carried out an empirical analysis of the UK refinery sector using the input cost method (autoregressive distributed lag model) and found the pass-through rate in Phase I of the EU ETS to be around 50 % for diesel and 75 % for gasoline. On the other hand, Ecorys (2013) conjectures that the pass-through of costs in the oil refining industry is limited given that the industry is active in a global market.

Based on the available estimates, we conclude that on the whole the EU refineries had the possibility to pass the ETS-associated costs on to final consumers. However, the degree of such pass-through could differ between markets depending on various factors such as market structure and exposure to international trade. Overall, the empirical evidence available is not conclusive with respect to the degree of ETS-related costs pass-through actually exercised.

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[165] Due to the structure of the model chosen in De Bruyn et al. (2010) (non-inclusion of certain potentially significant explanatory variables to avoid endogeneity issues, potentially resulting in omitted variable bias), the magnitude of the pass-through rate could be overestimated.

Arguably, given that pass-through was possible, it could be so for all the associated costs, including the opportunity costs of emission allowances surrendered. For example, based on the data on verified emissions presented in Table 3.3.4 (which can be used for calculating opportunity costs given that they needed to be covered with emission allowances) and assuming a cost pass-through rate of 50 % based on the reviewed empirical literature, the theoretically possible additional income related to the opportunity costs of emission permits passed on could be estimated as EUR 1.1 billion to EUR 6.7 billion (with the assumed EUA prices of EUR 5 to EUR 30) and on average EUR 3 billion in the first period of the ETS, and EUR 1.7 billion to EUR 10.4 billion (with the EUA prices of EUR 5 to EUR 30) and on average EUR 4.9 billion in the second period. Naturally, the availability and amount of such potential income varied at the refinery level, which could only be assessed through refinery-specific market transactions data.

It needs to be noted that, in the short term, increases in consumer prices, potentially resulting from the ETS-related cost pass-through, could be advantageous for refineries not subject to regulation under the EU ETS (non-EU competitors of the EU refineries) and therefore not facing the costs of carbon emissions, while, in the long run, significant increases in product prices due to the cost pass-through by the EU refiners could eventually lead to a decrease in their market shares in favour of their international competitors.

Overall impact

As discussed above, a large body of empirical literature attempts to assess the effectiveness of the EU ETS, including its impact on companies' investment behaviour. Such assessments are complicated by the lack of detailed firm-level investment data, identification of the correct baseline scenario, as well as disentangling the impact of the ETS from a large number of other factors potentially affecting refineries' investment behaviour. The available research is mainly based, on the one hand, on surveys questioning the policy impacts on managerial decision making and, on the other hand, applying econometric techniques to empirical data to attempt to isolate the impacts of the ETS from the other factors. In a survey of such empirical literature, Laing et al. (2013) conclude that 'over-allocation' and the economic recession were the factors that significantly reduced the direct impact of the EU ETS on emission abatement investments in the first years of its existence[166]. We are not, on the other hand, aware of any empirical studies providing conclusions on the emission abatement effects of the EU ETS specifically in the refining sector.

Our discussions with industry representatives (Concawe) in general confirm that, during the first two phases of the EU ETS, compliance with the ETS was not a significant factor driving investment in carbon emission abatement technologies in refineries during the 2005-2012 period. Refineries mainly focused on cost optimisation, for example through improving their energy efficiency, and covered excess emissions through carbon trading as opposed to investing in emission abatement technologies (potentially because rather low carbon prices during most of the period did not render such investments economically attractive). As follows from the above discussion, this can be attributed to the overall allocation of allowances significantly in excess of verified emissions due to various factors over the first years of the ETS. According to Lacombe (2008), interviews with the managers of selected European refining companies also revealed that the first phase of the EU ETS had a very limited economic impact on their firms. On the other hand, the ETS has admittedly been successful in bringing the carbon emissions considerations into corporate decision-making. It reportedly contributed to emission reduction incentives to a certain extent through a combination of raising awareness, rigorous monitoring and a positive carbon price (see e.g. Laing et al., 2013).

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[166] The majority of studies focus on Phase 1 (2005-2007) data.

While the ETS was associated with certain costs for refineries – in the form of potential emission abatement costs, purchasing allowances to cover excess emissions and opportunity costs of surrendering emission certificates, as well as indirect costs through increased prices of inputs – the evidence available suggests that these costs were on average not sizeable in comparison to the companies' operating expenditures and that they could to a certain extent be passed on to final consumer prices. In addition, the emission trading balances of the EU refineries demonstrate that overall, the sector benefitted from a moderately higher amount of free emission allowances than its actual verified emissions in both initial phases of the ETS[167].

3.3.4. Efficiency of the legislation

While the costs borne by society as a result of GHG emissions are admittedly significant, there is an on-going debate on how to monetise, or even correctly estimate, the total costs of atmospheric pollution due to CO_2. A report published by the European Environmental Agency (EEA, 2011) highlights the variety of approaches used for quantifying the social cost of carbon (SCC) and the associated uncertainties. Namely, a very wide range of values is available in the present literature, where the assumed SCC varies between USD 4 and USD 95 per tonne of CO_2 (EEA, 2011).

Another recent assessment by the European Environmental Agency (EEA, 2014) quantifies the damage to health and the environment resulting from a number of pollutants emitted by industrial facilities in the EU, including CO_2. The report uses a range of values applied in the EU ETS carbon price forecasts performed for the European Commission to support the proposal for a 2030 climate and energy policy framework. As a result, the minimum value of EUR 9.50 and the maximum value of EUR 38.10 per tonne of CO_2 (in 2005 prices) are adopted. The aggregated damage costs of CO_2 emissions from all industrial facilities in the EU are thus estimated as EUR 18–73 billion at 2005 prices in 2012. Applying the same ranges of CO_2-related damage costs to the data on the verified emissions of the EU refining sector (Table 3.3.4), the aggregate social costs of CO_2 emissions related to the refining sector in the 2005-2012 period can be estimated to be in the range of EUR 10.8-43.4 billion in 2005 prices, or on average EUR 1.4-5.4 billion at 2005 prices per year.

These social costs can be seen in the context of the societal and economic role of the industry. In 2011, EU refining had total revenues of EUR 7.3 billion (IHS (2014)). According to Solomon Associates (2014), the participating refineries in 2011 employed around 40 000 workers and paid approximately EUR 3 billion in wages. Furthermore, the total employment effect of the EU refineries (taking into account the Input-Output relationships of EU refining with other sectors, see Refining Overview Chapter) is estimated at 160 000 workers.

In economic theory, emission trading schemes are commonly acknowledged as an economically efficient mechanism for emission control. They do so through assigning property rights and creating the corresponding markets for emissions permits, thereby steering the incentives of potential polluters and making it attractive for them to implement emission-reducing technologies. Hence such schemes allow for 'internalising' the negative 'externalities' of production activities, harmful emissions, which would otherwise be borne by society. The actual emission reduction target is set by the total amount of emission allowances supplied to the market and/or distributed among the installations by the regulatory authority. Emission trading then ensures that the desired

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[167] In a forward-looking assessment, McKinsey and Ecofys (2006) conclude under a set of assumptions that, on average, the EU ETS was likely to have a neutral to positive effect on refinery margins. Moreover, they suggest that refineries could benefit from CO_2 emissions trading if 95 % of the CO_2 costs were covered by free allowances and at least a quarter of the cost increase could be passed on to customers. However, the study acknowledges that, at significantly lower levels of free allowances (i.e. below 80 %), refinery margins might come under pressure.

amount of abatement takes place in the most cost-efficient way, with the maximum abatement occurring in the sectors and installations where the marginal costs of emission reduction are the lowest (in contrast, for example, to taxation of excess emissions, where the optimal distribution of costs is the responsibility of the regulator). It is, however, equally important to ensure that the emissions trading system is operational and functions without distortions.

An impact assessment, accompanying the proposal for the current Emissions Trading Directive, concludes that 'experience gathered during the first years of its operation suggests that there is potential to reinforce economic efficiency of the system' (SEC(2008)). Among the inefficiencies identified are lack of a level playing field in the allocation of allowances between the EU ETS operators (due, for example, to heterogeneous definitions and allocation methods used by Member States); generally overoptimistic emission projections by Member States for the purpose of allowance allocation; potential undue benefits resulting from the pass-through of opportunity costs from firms to final prices when no cash costs were actually incurred; as well as the long and cumbersome procedures of National Allocation Plans' approval (SEC(2008)). These are being addressed in the third phase of the EU ETS, notably, through more centralised allocation rules. A number of empirical studies reach similar conclusions regarding the national allocation procedures: for example, using the example of the cement sector, Sartor et al. (2014) show that Phase 2 National Allocation Plans (NAPs) led to a significant degree of unexplained heterogeneity in the levels of allowances allocated to different installations. The study attributes this, among others, to the high degree of discretion exercised by Member States in the allocation process.

As regards the administrative costs of the ETS, they are presumably mostly borne by the public sector and related to the registration of rights, monitoring and enforcement. The administrative burden on the industry, consisting, for example, of monitoring emissions, auditing, emission trading and ensuring overall legal compliance, can be considered marginal for large installations such as the majority of oil refineries, although they could turn out to be more significant for smaller installations, especially those operating at low profitability.

The general efficiency considerations, outlined above, are equally relevant for the oil refining sector. Over the first two phases of the ETS, one of the important issues with respect to its efficiency was admittedly the process of emission allowance allocation, whereby the divergent criteria applied by Member States could lead to a non-level playing field within the sector. However, while certain differences could indeed be identified, our assessment based on the National Allocation Plans did not reveal significant divergences in the allocation of allowances leading to an unjustified burden on the sector at the national level. Where a number of individual refineries were obliged to purchase additional emission allowances as a result of their verified emissions exceeding initial allocations, this was either due to unanticipated sector- or refinery-specific developments or a conscious emission reduction effort by national authorities.

The current, third phase with a duration of eight years was initiated in January 2013 and brought important changes to the functioning of the EU ETS. In view of these changes, the impact of emission trading on the oil refining sector would need to be reassessed in the third and later phases. Some qualitative considerations in this respect (beyond 2012) are presented in a separate subsection in this report. Any formal analysis of the resulting impact on the sector, however, goes beyond the scope of this study.

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3.3.5. Annex

Results of a two-sample T-test for equality of means between 'short' and 'long' refineries under the assumption of not equal variances (presented in subsection 'Emission trade balances of refineries')

PERIOD 1

```
. ttest Nelson if period==1, by( position) une

Two-sample t test with unequal variances
-------------------------------------------------------------------------------
   Group |    Obs       Mean    Std. Err.   Std. Dev.   [95 % Conf. Interval]
---------+---------------------------------------------------------------------
    long |    186    7.709751    .1746094    2.381355    7.365269    8.054233
   short |     69    7.756439    .2124023    1.764346    7.332597    8.180281
---------+---------------------------------------------------------------------
combined |    255    7.722384    .1395252    2.228039    7.447611    7.997158
---------+---------------------------------------------------------------------
    diff |           -.046688    .2749604               -.5896187    .4962427
-------------------------------------------------------------------------------
    diff = mean(long) - mean(short)                          t =  -0.1698
Ho: diff = 0                     Satterthwaite's degrees of freedom =  163.515

   Ha: diff < 0                  Ha: diff != 0                   Ha: diff > 0
 Pr(T < t) = 0.4327         Pr(|T| > |t|) = 0.8654          Pr(T > t) = 0.5673

. ttest Crudecap if period==1, by( position) une

Two-sample t test with unequal variances
-------------------------------------------------------------------------------
   Group |    Obs       Mean    Std. Err.   Std. Dev.   [95 % Conf. Interval]
---------+---------------------------------------------------------------------
    long |    186    166.9731    6.778969    92.45281    153.599     180.3471
```

```
    short |      69    144.8813    8.780292    72.93458    127.3605    162.4021
---------+--------------------------------------------------------------------
 combined |     255    160.9953    5.511616    88.01346     150.141    171.8496
---------+--------------------------------------------------------------------
     diff |             22.09176     11.0927                .1773822    44.00614
---------+--------------------------------------------------------------------
     diff = mean(long) - mean(short)                              t =   1.9916
 Ho: diff = 0                     Satterthwaite's degrees of freedom =  153.219

    Ha: diff < 0                 Ha: diff != 0                  Ha: diff > 0
 Pr(T < t) = 0.9759        Pr(|T| > |t|) = 0.0482         Pr(T > t) = 0.0241
```

Long refineries appeared to have on average larger crude capacity than the short ones in period 1

. ttest **Emissions** if period==1, by(position) une

Two-sample t test with unequal variances
```
---------+--------------------------------------------------------------------
    Group |     Obs        Mean    Std. Err.   Std. Dev.   [95 % Conf. Interval]
---------+--------------------------------------------------------------------
     long |     197     1442831    76215.62     1069737     1292523     1593139
    short |      72     1616690      169127     1435090     1279460     1953919
---------+--------------------------------------------------------------------
 combined |     269     1489365    71844.02     1178329     1347915     1630816
---------+--------------------------------------------------------------------
     diff |            -173858.9    185506.8               -541843.4    194125.5
---------+--------------------------------------------------------------------
     diff = mean(long) - mean(short)                              t =  -0.9372
 Ho: diff = 0                     Satterthwaite's degrees of freedom =  101.252

    Ha: diff < 0                 Ha: diff != 0                  Ha: diff > 0
 Pr(T < t) = 0.1754        Pr(|T| > |t|) = 0.3509         Pr(T > t) = 0.8246
```

. ttest **EmmIntensity** if period==1, by(position) une

Two-sample t test with unequal variances
```
---------+--------------------------------------------------------------------
    Group |     Obs        Mean    Std. Err.   Std. Dev.   [95 % Conf. Interval]
---------+--------------------------------------------------------------------
     long |     182    8558.842    335.2268    4522.457    7897.387    9220.297
    short |      69    9935.536    591.4356    4912.833    8755.344    11115.73
---------+--------------------------------------------------------------------
 combined |     251    8937.295    294.3828      4663.9    8357.509    9517.082
---------+--------------------------------------------------------------------
     diff |            -1376.694    679.8332               -2723.403   -29.98486
---------+--------------------------------------------------------------------
     diff = mean(long) - mean(short)                              t =  -2.0250
 Ho: diff = 0                     Satterthwaite's degrees of freedom =  114.279

    Ha: diff < 0                 Ha: diff != 0                  Ha: diff > 0
 Pr(T < t) = 0.0226        Pr(|T| > |t|) = 0.0452         Pr(T > t) = 0.9774
```

Long refineries appeared to have on average lower emissions intensity (per unit of crude capacity) than the short ones in period 1

PERIOD 2

. ttest **Nelson** if period==2, by(position) une

Two-sample t test with unequal variances
```
---------+--------------------------------------------------------------------
    Group |     Obs        Mean    Std. Err.   Std. Dev.   [95 % Conf. Interval]
---------+--------------------------------------------------------------------
     long |     303    7.937921    .1346475    2.343796    7.672955    8.202887
    short |     109    8.288889    .1849516    1.930951    7.922283    8.655496
```

```
---------+--------------------------------------------------------------------
combined |     412    8.030774    .1106061     2.24506     7.81335    8.248199
---------+--------------------------------------------------------------------
    diff |              -.3509683    .2287729               -.8017295    .099793
---------+--------------------------------------------------------------------
    diff = mean(long) - mean(short)                              t =  -1.5341
Ho: diff = 0                       Satterthwaite's degrees of freedom =   229.74

    Ha: diff < 0                    Ha: diff != 0                   Ha: diff > 0
 Pr(T < t) = 0.0632          Pr(|T| > |t|) = 0.1264          Pr(T > t) = 0.9368
```

. ttest **Crudecap** if period==2, by(position) une

Two-sample t test with unequal variances
```
---------+--------------------------------------------------------------------
   Group |    Obs        Mean    Std. Err.    Std. Dev.   [95 % Conf. Interval]
---------+--------------------------------------------------------------------
    long |    303    165.7797    4.943768    86.05564    156.0511    175.5083
   short |    109    148.5761     6.70034     69.9536    135.2949    161.8574
---------+--------------------------------------------------------------------
combined |    412    161.2283    4.058186    82.37218    153.2509    169.2057
---------+--------------------------------------------------------------------
    diff |              17.20356    8.326787                .7981079     33.609
---------+--------------------------------------------------------------------
    diff = mean(long) - mean(short)                              t =   2.0660
Ho: diff = 0                       Satterthwaite's degrees of freedom =   232.914

    Ha: diff < 0                    Ha: diff != 0                   Ha: diff > 0
 Pr(T < t) = 0.9800          Pr(|T| > |t|) = 0.0399          Pr(T > t) = 0.0200
```

Long refineries appeared to have on average larger crude capacity than short in period 2

. ttest **Emissions** if period==2, by(position) une

Two-sample t test with unequal variances
```
---------+--------------------------------------------------------------------
   Group |    Obs        Mean    Std. Err.    Std. Dev.   [95 % Conf. Interval]
---------+--------------------------------------------------------------------
    long |    328     1277792    51742.69      937100     1176001     1379582
   short |    130     1574426    121779.6     1388501     1333482     1815369
---------+--------------------------------------------------------------------
combined |    458     1361989     50983.5     1091095     1261798     1462180
---------+--------------------------------------------------------------------
    diff |             -296633.7    132316.2               -557748.9   -35518.37
---------+--------------------------------------------------------------------
    diff = mean(long) - mean(short)                              t =  -2.2419
Ho: diff = 0                       Satterthwaite's degrees of freedom =   177.499

    Ha: diff < 0                    Ha: diff != 0                   Ha: diff > 0
 Pr(T < t) = 0.0131          Pr(|T| > |t|) = 0.0262          Pr(T > t) = 0.9869
```

Long refineries appeared to have on average smaller emissions (in absolute volume) than short in period 2

. ttest EmmIntensity if period==2, by(position) une

Two-sample t test with unequal variances
```
---------+--------------------------------------------------------------------
   Group |    Obs        Mean    Std. Err.    Std. Dev.   [95 % Conf. Interval]
---------+--------------------------------------------------------------------
    long |    303    7994.242    223.1646    3884.602    7555.087    8433.396
   short |    109    10049.85    537.5066    5611.734    8984.414    11115.28
---------+--------------------------------------------------------------------
combined |    412    8538.079    221.3563    4493.043    8102.947     8973.21
```

```
---------+-------------------------------------------------------------------
    diff |          -2055.604    581.9929              -3205.765   -905.4425
---------------------------------------------------------------------------
    diff = mean(long) - mean(short)                              t =  -3.5320
Ho: diff = 0                       Satterthwaite's degrees of freedom =  146.882

    Ha: diff < 0                  Ha: diff != 0                  Ha: diff > 0
 Pr(T < t) = 0.0003          Pr(|T| > |t|) = 0.0006          Pr(T > t) = 0.9997
```

Long refineries appeared to have on average lower emissions intensity (per unit of crude capacity) than the short ones in period 2

List of refinery closures and capacity reductions, 2009-2014, Concawe

2009/10

Teesside Refinery (UK)	117 kb/d
Flandres Refinery Dunkerque (FR)	156 kb/d

2011

Cremona (IT)	96 kb/d
Reichstett Refinery (FR)	85 kb/d
Wilhelmshaven Refinery (D)	260 kb/d
Arpechim Refinery Pitesti (RO)	65 kb/d

2012

Berre L'étang Refinery (FR)	80 kb/d
Hamburg-Harburg Elbe (D)	108 kb/d
Rome (IT)	92 kb/d
Coryton (UK)	172 kb/d

2013

Petit Couronne (F)	141 kb/d
Porto Marghera Venice (I) (conversion to biofuel refinery)	80 kb/d

2014

Mantova (IT)	57 kb/d

3.4. Fuel Quality Legislation

The legislation on fuel quality regulates the specification of petrol/gasoline, diesel, gas oils and inland heavy fuel oil in terms of their content of sulphur, metallic additives, biofuel components, etc. The package of legislation on fuel quality in this review consists of the following documents: (1) Directives jointly referred to as the Fuel Quality Directive (FQD), dealing with gasoline, diesel and gas oil fuels' quality: Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009, Directive 2003/17/EC of the European Parliament and of the Council of 3 March 2003, and (2) Directives jointly referred to as the Sulphur in Liquid Fuels Directive (SLFD), dealing with other fuels used for heating and marine propulsion: Council Directive 1999/32/EC of 26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels, Directive 1998/70/EC of the European Parliament and of the Council of 13 October 1998, and Council Directive 1993/12/EEC of 23 March 1993 relating to the sulphur content of certain liquid fuels.

The main findings of our analysis are the following:

- The continuous decline in average sulphur content in road fuels in the EU-27 countries provides evidence that road fuel quality improved. This is expected to impact on exhaust emissions. In particular, it shows how the two most important thresholds were met, namely the 50 ppm threshold for diesel and gasoline fuels in 2005, and the 10 ppm threshold in 2009, showing that the sector is on track in complying with the objectives of the legislation.
- The effects of the fuel quality legislation in terms of the GHG emissions are less straightforward. In general, meeting the stricter fuel quality standards involves more processing capacity and more severe modes of operation for the existing units. Almost all of these changes go together with more energy use (assuming no other energy efficiency-improving measures are undertaken) and, hence, carbon dioxide emissions.
- Regarding the economic impact on the sector of measures for meeting fuel quality requirements, a look at the declared investment costs for fuel specifications compliance during 2000-2012 for the EU-28 provided by Solomon Associates (2014) gives an estimate of the average annual capital investment costs:
    - o meeting specifications for all clean fuels: EUR 8.5 million per refinery per year or EUR 0.14 per barrel of throughput.;
    - o meeting the gasoline specifications: EUR 3.4 million per refinery per year or EUR 0.06 per barrel of throughput;
    - o meeting the corresponding diesel and gasoil specifications: EUR 4.9 million per refinery per year or EUR 0.08 per barrel of throughput.
- Our estimate of the total increase in annual operating costs attributable to additional fuel quality-related efforts over the 2000-2012 period amounts to EUR 8.9 million per refinery per year or EUR 0.15 per barrel of throughput.
- It was observed that the majority of the energy costs increase (regardless whether it is fuel quality-related or not) in EU-28 refineries most likely comes from growing energy prices.
- The economic impact is to a great extent associated with the Directive's limits on the sulphur content of fuels. Other provisions of the Fuel Quality Legislation did not result in tangible economic impacts during 2000-2012:
    - o investments for meeting vapour pressure requirements occurred before 2000;
    - o reducing the content of polycyclic aromatic hydrocarbons takes place in parallel with hydrodesulphurisation, hence results in negligible additional costs;

- lead-based additives to gasoline were phased out before 2000;
- the use of methylcyclopentadienyl manganese tricarbonyl (MMT) in European countries was avoided as a result of a consensus among users and producers;
- there is no reliable way to provide an estimate of the additional costs related to FAME regulation incurred within the main refineries' operations.

- The estimates of the monetary benefits associated with decreasing the SO_2 emissions amounts to EUR 196.8 million per average EU-28 refinery during 2001-2011. It should be pointed out that for the above estimates we used the lower limit of the monetary benefits from avoided SO_2 emissions estimated by the EEA. The assessment based on the higher limit estimate would result in the total benefits being three times higher.

- The total additional costs incurred by the refineries during the same period are estimated at EUR 202 million per refinery (EUR 103 million in investment costs and EUR 98 million in operating costs).

- Based on the available information we did not detect any other visible contradictions or non-productive redundancies in prescribed fuel quality specifications, norms and limits.

- In relation to priorities in other pieces of legislation for decreasing CO_2 emissions, it should be noted that, given the current state of technology, improving fuel quality requires more extensive and intensive processing, which is more energy-intensive and, holding all other parameters equal, leads to additional GHG emissions.

3.4.1. Objectives and measures

In general, the fuel quality legislation is intended to ensure a single market in the fuels covered by setting the minimum specifications based on environmental and health grounds.

The key specific objective of the reviewed directives (presented in Table 3.4.1) related to the quality of liquid fuels is to reduce the emissions of harmful air pollutants linked to fuel combustion and their adverse environmental and health implications. The legislation on fuel quality regulates the specifications of petrol/gasoline, diesel, gas oils (used for road and non-road mobile machinery as well as heating and industrial oils) and inland heavy fuel oil in terms of its content of sulphur, metallic additives, biofuel components, etc.

Table 3.4.1: Fuel Quality-related legislation in the scope of this assessment

Directive 2009/30/EC of the European Parliament and of the Council of 23.04.2009	
Amending:	Directive 98/70/EC as regards the specification of petrol/gasoline, diesel and gas-oil and introducing a mechanism to monitor and reduce GHG emissions
Repealing:	Directive 93/12/EEC
Entry into the force:	25.6.2009
Transposition by MS:	31.12.2010
Directive 2003/17/EC of the European Parliament and of the Council of 03.03.2003	
Amending:	Directive 98/70/EC relating to the quality of petrol/gasoline and diesel fuels
Entry into the force:	22.03.2003
Transposition by MS:	30.06.2003
Council directive 1999/32/EC of 26.04.1999 relating to a reduction in the sulphur content of certain liquid fuels	
Amending:	Directive 93/12/EEC
Entry into the force:	11.05.1999
Transposition by MS:	01.07.2000
Directive 1998/70/EC of the European Parliament and of the Council of 13.10.1998 relating to the quality of petrol/gasoline and diesel fuels	
Amending:	Directive 1993/12/EEC
Entry into the force:	28.12.1998
Transposition by MS:	01.07.1999 and 01.01.2000

Council Directive 1993/12/EEC of 23.3.1993 relating to the sulphur content of certain liquid fuels	
Entry into the force:	date of notification
End of validity:	24.06.2009
Transposition by MS:	30.09.1994

The measures adopted and implemented during the time period from 2000 to 2012 include in particular reduction of the sulphur content of fuels[168], and lower aromatics content in the fuels.

The policy mix developed by the reviewed directives on fuel quality consists of a combination of technical performance standards for fuel and a complex reporting mechanism. Technical specifications are introduced as maximum/minimum limits on selected elements (fuel components) and are specifically defined for each type of fuel (e.g. petrol/gasoline, diesel and gas oil and heavy fuel oil, as shown in Table 3.4.2). Note that the legislation on fuel quality classifies fuels according to their use and only covers fuels used by road and non-road mobile machinery, agricultural and forestry tractors and recreational crafts.

In this analysis we distinguish several fuel product groups, which correspond to the following generalised definitions:

- Gasoline (petrol) refers to any volatile mineral oil intended for the operation of internal combustion positive-ignition engines for the propulsion of vehicles.
- Diesel fuel means gas oil fuel used for self-propelling vehicles.
- Gas oil means any petroleum product within the category of middle distillates intended for use as fuel in general and as fuel in compression ignition engines in general and by non-road mobile machinery, including inland waterway vessels, agricultural and forestry tractors, and recreational craft.
- Heavy fuel oil is any petroleum-derived heavy liquid fuel, other than gas oil, and excluding marine fuels.

The legislation sets various environmental specifications for each of the fuels, i.e. gasoline, diesel, gas oil and (inland) heavy fuel oil, in the form of the minimum or maximum permitted levels. Legislation Annexes I and III include limit values for gasoline and Annex II for diesel. Numerous derogations apply to accommodate specific, e.g. geographic-[169] and weather-related[170], aspects (presented in detail in Table 3.4.7 – Table 3.4.11 in Annex).

Among the key fuel quality requirements, we can mention the following:

- A maximum oxygen content of 2.7 % and a maximum ethanol content of 5 % were allowed until 2013 accompanied by the provision of appropriate information to consumers (Directive 2009/30/EC Article 3.3).

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[168] On the international level, sulphur emissions are covered by the UN-ECE Convention. See paragraph (7) Directive 1999/32/EC.

[169] This typically refers to the outermost EU regions, which means France with regard to the French overseas departments, Portugal with regard to the Azores and Madeira and Spain with regard to the Canary Islands, see Article 2 paragraph 4 Directive 98/70/EC as amended by Directive 2003/17/EC of 3.3.2003.

[170] The summer period is defined as from 1 May until 30 September and for MS with Arctic conditions from 1 June until 31 August. See Directive 98/70/EC Annex I.

- Different limits for Reid vapour pressure and maximum distillation point apply to the MS with low ambient summer temperatures i.e. regions where the average temperature for the majority of their territory is below 12 °C for at least two of the three months of June, July and August[171].
- The presence of the metallic additive methylcyclopentadienyl manganese tricarbonyl (MMT) in fuel was limited to 6 mg per litre from 1 January 2011 and to 2 mg from 1 January 2014.
- Provisions regarding the limits for sulphur content in diesel fuels and gas oils for use by non-road mobile machinery and agricultural and forestry tractors are summarised in Table 3.4.2.

Table 3.4.2: Integrated timeline of fuel specification norms
Source: JRC (2013).

Refinery product	Unit	Product specification Before 2000	2000	2005	2009
Gasoline					
Sulphur	ppm	500 max.	150 max.	50 max.	10 max
Lead	g/l	0.15	0.005 max	10 max	10 max
Aromatics	% v/v	none	42 max.	35 max.	35 max.
Olefins	% v/v	none	18 max.	18 max.	18 max.
Aromatics	% v/v		42 max	35 max	35 max
Benzene	% v/v	5 max.	1.0 max.	1.0 max.	1.0 max.
Evaporation at 100 °C (summer)	%	65/70 max.	46 min.	46 min.	46 min.
Evaporation at 150 °C (winter)	%	none	75 min.	75 min.	75 min.
RVP, summer	kPa	80	60 max.	60 max.	60 max.
Oxygen	%	2.5 max.	2.7 max.	2.7 max.	3.7
Methanol	% v/v		3	3	3
Ethanol	% v/v		5	5	10
Iso-propyl alcohol	% v/v		10	10	12
Ter-butyl alcohol	% v/v		7	7	15
Iso-butyl alcohol	% v/v		10	10	15
Ethers >C_4	% v/v		15	15	22
Other oxygenates	% v/v		10	10	15
Diesel					
Sulphur	ppm	500 max.	350 max.	50 max.	10 max
Cetane number		49 min.	51 min.	51 min.	51 min.
Density @ 15°C	kg/m³	860 max.	845 max.	845 max.	845 max.
Distillation 95 % (v/v)	°C	370 max.	360 max.	360 max.	360 max.
Polycyclic Aromatics	% m/m	none	11 max.	11 max.	8 max.
FAME - EN 14078	% v/v	none	none	none	7 max.
Heating gas oil					2008
Sulphur	% m/m				0.1 max
Inland heavy fuel oil				2003	
Sulphur	% m/m			1	

It should be noted that the Fuel Quality Legislation represents a whole system of requirements and standards, and contains regulations that mostly have technological implications for the refining industry and also include those that have an economic impact in both refining and other sectors of the European economy (such as transport, energy generation, etc.). In the analysis below we focus on the fuel quality norms with visible economic and social effects, such as: sulphur content requirements and the limits on substances affecting the health of the general public.

3.4.2. Effectiveness of the legislation

The EEA data on the average sulphur content in fuels in the EU-27 countries in Figure 3.4.1 provides empirical evidence that, starting from 2000, the improving fuel quality should have gradually resulted in improving air quality. In particular, it shows how the two most important thresholds were met, namely the 50 ppm threshold for diesel and gasoline fuels in 2005, and the 10 ppm threshold in 2009. Thus, in terms of complying with the formal constraints, the fuel quality legislation appears to be on track in terms of inducing the fuel producers to meet its product specifications regarding the sulphur content.
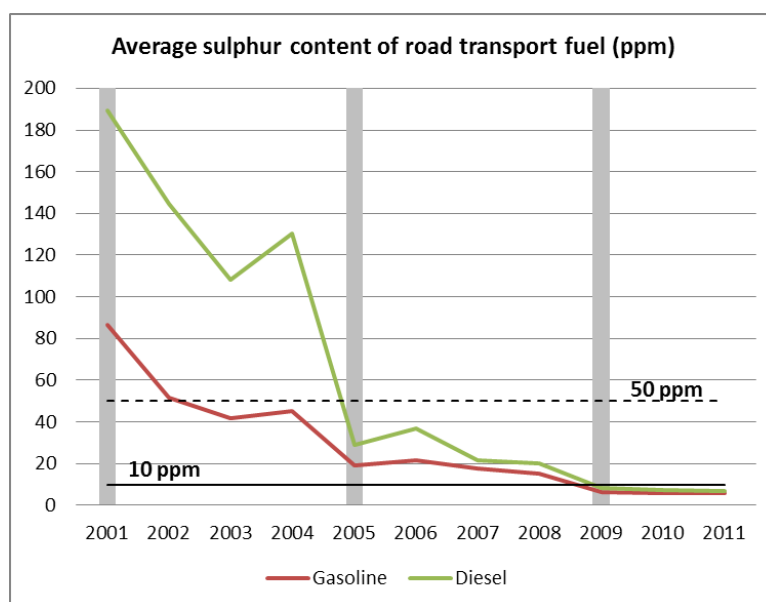
Figure 3.4.1: Time series of the average ppm of sulphur in fuels in the EU-27 countries
Source: EEA[172].

In general, reduction of the sulphur content implies the reduction of both the SO_2 and particulate matter emissions produced by transport in Europe. The EEA (2014) study provides an assessment of the SO_2 emissions' contribution to damages caused by air pollution. Below, in the section on the legislation's efficiency, we provide our assessment of the general societal benefits from avoided SO_2 emissions as a result of improved fuel quality, departing form the EEA (2014) estimates of the damages per tonne of emitted SO_2.

Furthermore, higher quality road fuels allow the reduction of particulate matter emissions from the older (pre-2005) vehicles without retrofitting them with additional scrubbers or filters. This effect is especially relevant to the impact of fuel quality standards on the medium and heavy-duty fleet.

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[172] EEA (2013), 'Use of cleaner and alternative fuels', CSI 037/TERM 031 – Assessment published Dec 2013.

Regarding the more recent and more advanced vehicles, the impact on this class of vehicles is smaller but still present.

A particular benefit of the fuel quality legislation for the industry comes in the form of harmonised rules regarding the refining products at EU level. The creation of an internal market with harmonised rules can be seen as beneficial to EU industries because each Member State has to adopt similar requirements on the quality of fuels, making it easier in terms of logistics for EU refineries to supply products all across the EU[173] and creating a level playing field.

The effects of the fuel quality legislation in terms of the GHG emissions are less straightforward. Meeting the stricter fuel quality standards will be discussed below and it will be shown that this will involve more processing capacity (such as hydrotreating) and more severe modes of operation for the existing units (hydrotreating and hydrocracking). Almost all of these changes go together with increased energy use and, thus, increased CO_2 emissions, either to support deeper processing of feedstock, or for production of the extra hydrogen needed for hydrotreating operations.

Between 1992 and 2010, EU refiners improved the energy efficiency of their operations by an estimated 10 % (Concawe (2012). Yet, the data provided by Solomon Associates (2014) in Figure 3.4.13 in the Annex shows that the energy use intensity per tonne of processed crude at European refineries remained fairly constant for most of 2000-2012 across different complexity groups.
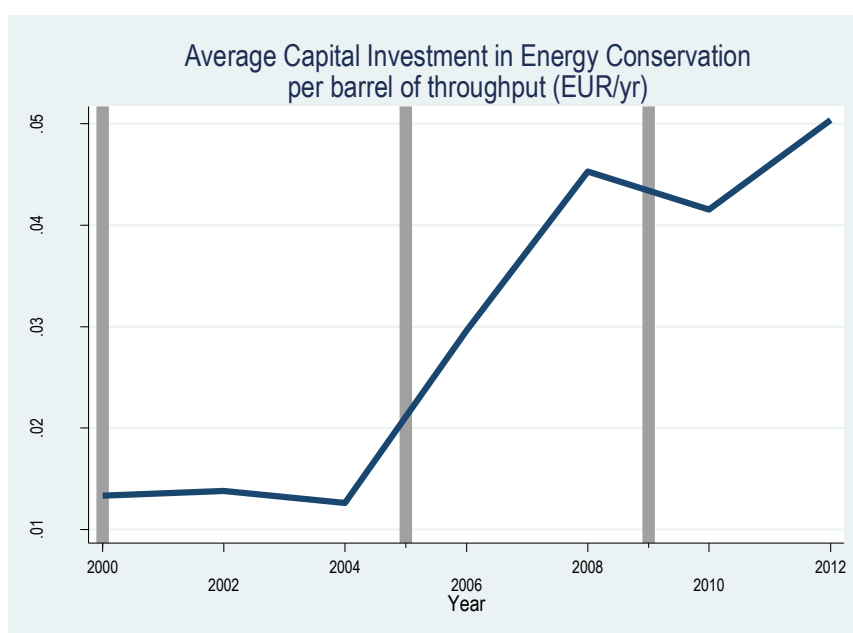
Figure 3.4.2: Energy efficiency-related capital investment in the EU-28
Source: Solomon Associates (2014).

The additional energy consumption and the corresponding CO_2 emissions associated with meeting the fuel quality standards depend on the new target sulphur standard (10 ppm during 2000-2012) and the prior sulphur standard (350-50 ppm). The analysis in the following sections shows that

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[173] European Commission (2007), 'Impact Assessment of Proposal for amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil that may be placed on the market and introducing a mechanism to monitor and reduce greenhouse gas emissions from the use of road transport fuels and amending Council Directive 99/32/EC to remove the elements setting the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC', SEC(2007) 56

increasing and improving refineries' capacities with a view to meeting fuel quality requirements has indeed resulted in a visible increase in energy use even taking into account the fact that refineries have a natural incentive to improve their energy efficiency as a cost-minimising strategy.

In general, refineries' capital investments in energy efficiency in the EU-28 have been growing visibly (Figure 3.4.2). This indicates that refineries continuously make efforts to improve the energy efficiency of their operations regardless of their configuration. Thus, at the individual refinery level, the net effect of the fuel quality legislation on GHG emission depends on the relative sizes of the GHG emission increase as a result of more energy use for desulphurisation and the emission-decreasing effects of the energy efficiency-promoting measures. The size of such counteractive effects appears to be comparable given the fact that the indicators of increasing investment in energy efficiency go together with fairly constant energy use.

It should be noted that the actions for implementing the measures designed exclusively to reduce the life cycle GHG (article 7a of the FQD) emissions have not yet been put in place and remain beyond the scope of this assessment.

3.4.3. Impact on the EU refining sector

One of the key indicators within the data provided by Solomon Associates (2014) is the average annual capital investment in 'New Process Unit/Modifications for Clean Fuels'. These include all capital expenditures in a given year for new process units or modifications to the fuel refinery configuration to produce more environmentally acceptable fuels mandated by government regulations[174]. The following investments are presented separately:

- to meet gasoline specifications;
- to meet diesel/gasoil specifications (diesel/gasoil category includes projects that affect transportation fuels only);
- to meet other specifications (such as the 'clean' heating oil projects that are included in the 'Other' category of the Solomon Associates (2014) dataset, along with any other fuel specifications for kerosene, jet fuel, residual fuel oil, including marine bunkers, and LPG).

Observing the timeline of sulphur requirements (shown in Table 3.4.2) imposed by different directives, three dates can be identified as affecting the main 'thresholds' in fuel quality requirements: the years 2000, 2005, and 2009.

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[174] If a project applied to more than one type of fuel, the costs are allocated by the appropriate volumes affected. These costs also include any applicable replacement or modification of a unit if the cost exceeds 50 % of the total replacement cost or the project increases capacity more than 40 % for that unit.
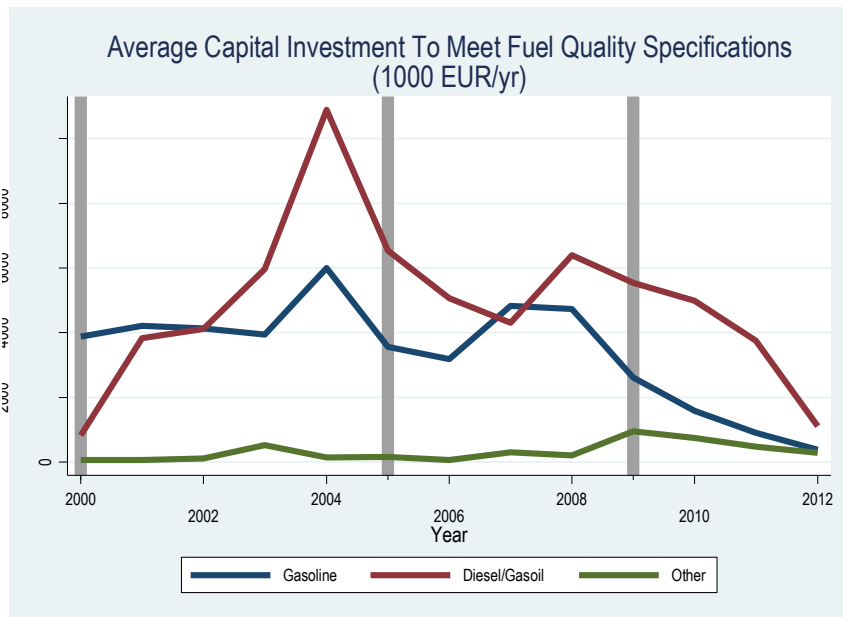
Figure 3.4.3: Average capital investment in the EU-28 per barrel of input to meet fuel specifications
Source: Solomon Associates (2014).

The biennial data on capital investments related to clean fuels during 2000-2012 from Solomon Associates (2014) covers two of these dates: 2005 and 2009 and clearly indicates that the refineries' investments peaked right before 2005 and 2009 (as shown in Figure 3.4.3 above and Figure 3.4.12 in the Annex). This can be reasonably explained by an assumption that refineries tend to concentrate their investment efforts right before the period when new regulations come into force (before 2005 and 2009 in this case). One could argue that the onset of the economic crisis in 2008 contributed to the decline in regulation-related investments after 2009, but this does not provide an explanation for the similar situation in 2005, therefore we still argue that the observed dynamics of average capital investments to meet fuel quality specifications are likely to follow the timing of regulation.
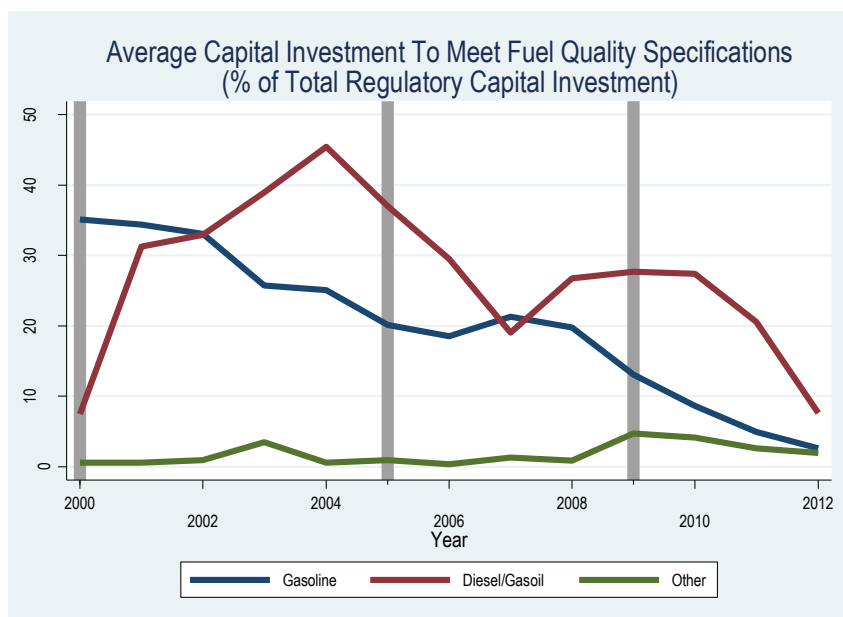
Figure 3.4.4: Share of capital investment in the EU-28 to meet fuel specifications within total regulation-related capital investments
Source: Solomon Associates (2014).

When looking at the share of fuel quality-related capital investment in the total refineries' regulation-related expenditures in Figure 3.4.4, we observe that for most of the 2000-2012 period the total fuel quality-related investments constituted an important part (more than 50 %) of the total investments marked by the refineries as regulation-related in the Solomon Associates (2014) data.

The above observations give us some confidence to state that the peaks in the refineries' regulation related investments are related to the corresponding steps in the tightening of the fuel quality requirements and can be considered as reflecting the main capital investment costs of compliance with the fuel quality regulation.
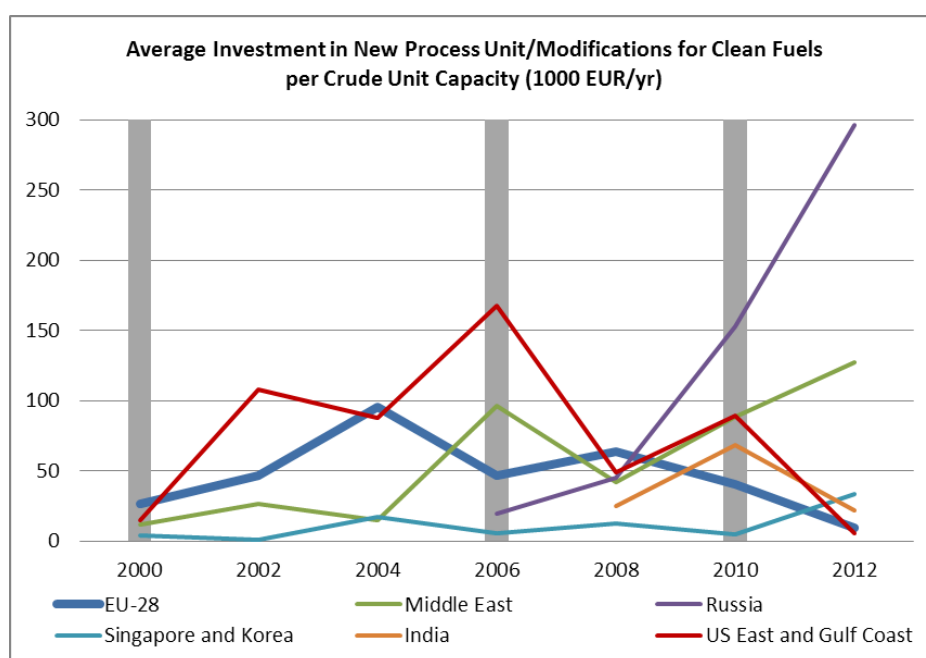
Figure 3.4.5: Average fuel quality-related capital investments in Europe and other competitor regions
Source: Solomon Associates (2014a).

Comparing the time evolution of the fuel quality-related capital investments in Europe to the comparable peer group averages from the Solomon Associates (2014a) investment data, we can see that the regulatory capital investment intensity in clean fuels in other parts of the world also shows similar increase/decrease patterns, although with a time lag of one to two years. It is also the case that in the most recent period (after 2009) the per-refinery averages in most peer regions were consistently higher than those in Europe. In the period 2000-2012 and in absolute terms, the fuel quality-related investments in the USA were substantially higher or very close to those in the EU-28.

Another way to compare the size of the fuel quality-related investments between Europe and the competitor regions is to consider the capital investment intensity in terms of the volume of sulphur removed from the refining products. Figure 3.4.6 presents the average fuel quality-related capital investment expressed per tonne of sulphur removed from the produced gasoline and diesel volumes. These estimates used the regulated sulphur content norms for gasoline and diesel for a given year in different regions (provided by IHS (2014)) and the production volumes reported in Solomon Associates (2014a).
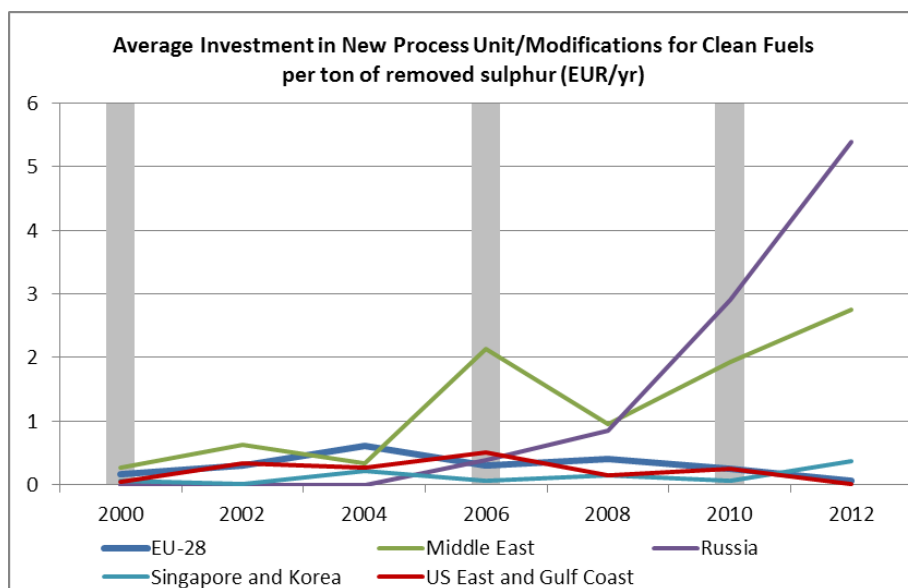
Figure 3.4.6: Average fuel quality-related capital investments in Europe and other competitor regions per tonne of removed sulphur
Source: Solomon Associates (2014a).

In relative terms per tonne of removed sulphur, the estimated investment intensities were the highest in Russia and the Middle East after 2006. The EU-28 refineries had, on average, higher fuel quality-related investment intensities than those in the US competitor regions, although the observed difference is not very large.

Meeting sulphur content requirements

In general, the option of processing sweeter crudes as a means of decreasing the sulphur content in products is rather straightforward. A study by Concawe (2008) investigated the possible effects of increasing the share of sweet crude in the crude diet in terms of decreasing the sulphur content in produced fuels. It estimates that increasing the share of sweet crude (North Sea) by 10 percentage points in 2020 would result in a decrease of approximately 0.22 percentage points in the sulphur content of the average EU refining crude input mix (from 1.12 % to 0.90 % sulphur).

Although a straightforward way to respond to stricter specifications, increasing the share of sweet crude is problematic in light of the recent tendencies towards decreasing availability of light crudes. Taking into account this tendency, refineries have become gradually more complex in order to be able to process increasingly heavier crudes, thereby transforming low-value residues into high-value distillates. Furthermore, the sweet crudes are more expensive than the other types, which in fact results in a situation whereby a refinery can avoid capital investments in desulphurisation while paying a premium for sweeter crudes. It replaces capital expenditure with higher crude costs and can therefore reduce the profitability of refineries. It would also tend to make refineries less flexible and more dependent on a declining resource for light crudes (Concawe 2008).

A crude substitution strategy can work in short term, but does not provide a long-term sustainable response to changing fuel specifications, especially when maximum sulphur content requirements decreased to the level of 50 to 10 ppm. At such levels, changing the crude inputs is no longer sufficient to achieve the adequate decreases in product sulphur content. According to the survey of Concawe (2006), 98 % of the participating refineries had, by 2006, sulphur contents in their road diesel products below 50 ppm and 40 % already below 10 ppm. Therefore, we do not consider

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switching to low-sulphur crude a viable stand-alone producers' strategy for meeting the fuel quality goals, although it may still be part of a portfolio of measures.

At the current stage of technological development, refineries are capable of producing gasoline and diesel fuels with the required low sulphur content using advanced versions of several mainstream refining processes. These advanced processes were developed in response to the stricter fuel quality standards being adopted from the beginning of 1990s (ICCT (2012)).

The sole purpose of desulphurisation processes (see Table 3.4.3 for details) is to achieve the sulphur concentrations needed to meet the imposed standards and in some cases ensure the reliable operation of equipment (mostly to prevent catalyst poisoning). In general, all processes are required to ensure low-sulphur fuel production, and in most instances, they are sufficient for that purpose and can reach the necessary content limits.

Table 3.4.3: Primary refining processes that contribute to decreasing sulphur content in fuels
Source: ICCT (2012).

Process	Process Type	Primary purpose	Reduce sulphur in	
			Gasoline	Diesel
Hydrocracking	Conversion	Yield Improvement	X	X
FCC Feed Hydrotreating	Treating	Yield Improvement	X	X
FCC Naphtha Hydrotreating	Treating	Sulphur Control	X	
Other Naphtha Hydrotreating	Treating	Sulphur Control	X	
Distillate Hydrotreating	Treating	Sulphur Control		X

Some yield improvement processes (such as FCC feed hydrotreating and hydrocracking) are used to increase the refinery yield of light products when converting heavy crude fractions to sweeter streams. They contribute to decreasing the sulphur content, but this is not their primary purpose. Therefore, investments are made in these processes primarily with the goal of improving the product revenues/margins. According to ICCT (2012), these processes contribute to meeting the fuel quality standards, but are not required for doing so, and, in general, these processes alone are not sufficient to reach the sulphur content goals. On the other hand, hydrocracker streams are especially useful blendstocks for ultra-low sulphur diesel production, because they are almost completely free of sulphur and aromatics. Therefore, in the analysis we consider two compositions of the fuel quality-related capacities: one including hydrotreating and hydrogen production together with hydrocracking operations and one including hydrotreating and hydrogen production only.

In most instances, when facing stricter sulphur content specifications, only sulphur control investments are required to upgrade a refinery without any parallel increase in product volume. It should be noted that sulphur control expansion also requires an adequate increase in hydrogen production, refinery energy supply, sulphur recovery capacity, and, to a certain extent, capacity for oil movement and storage.

Installed refining capacity (t/yr) Evolution 2000-2012
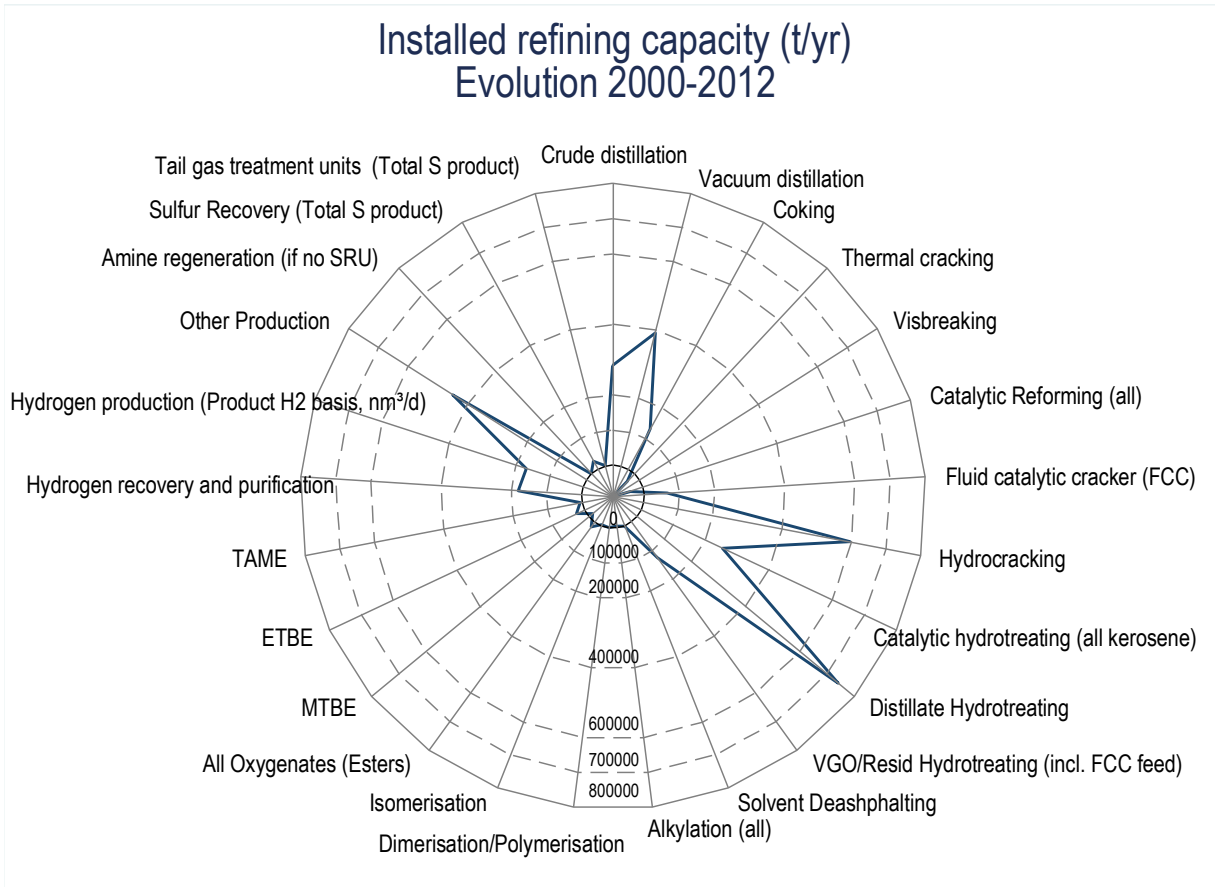
Figure 3.4.7: The average 2000–2012 changes in the installed refining capacity units in the EU-28
Source: Solomon Associates (2014).

Looking at the changes in installed refinery capacities during 2000–2012 in Figure 3.4.7, it is clear that, apart from expansion of crude and vacuum distillation, the highest growth has been registered in hydrocracking, different types of hydrotreating capacities and in production and recovery of hydrogen. All these types of refining processes grew steadily over the 2000–2012 period (as shown in Figure 3.4.8) and are to a large extent linked to sulphur control and fuel quality-related yield improvements.
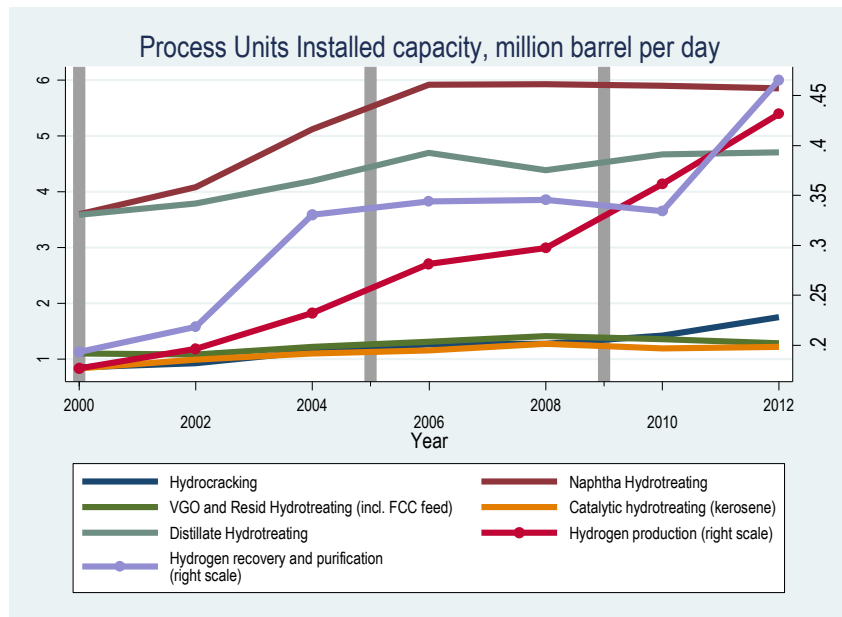
Figure 3.4.8: Evolution of installed capacities related to meeting the fuel quality specifications (<= left axis, => right axis)
Source: Solomon Associates (2014).

Capital Investment Costs

A direct look at the declared investment costs for fuel specifications compliance during 2000-2012 provided by Solomon Associates (2014) (in Figure 3.4.3) gives us an estimate of the average annual capital investment costs:

- meeting specifications for all clean fuels: EUR 110 million per refinery in total or EUR 8.5 million per refinery per year;
- meeting the gasoline specifications: EUR 44 million per refinery in total or EUR 3.4 million per refinery per year;
- meeting the corresponding diesel and gasoil specifications: EUR 63.3 million per refinery in total or EUR 4.9 million per refinery per year.
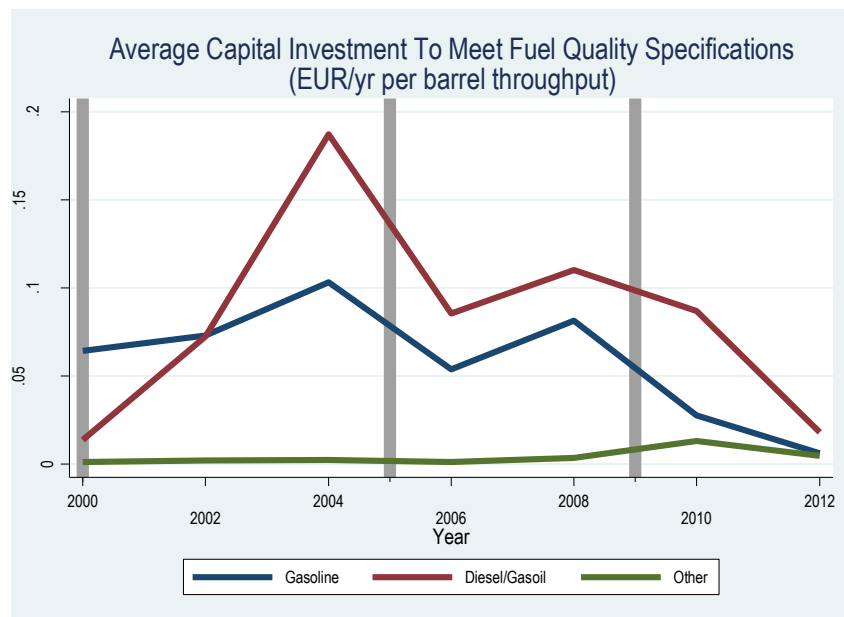
Figure 3.4.9: Average annual capital investment to meet fuel specifications per barrel of throughput of product
Source: Solomon Associates (2014).

Table 3.4.4: Average capital investment per refinery per barrel of throughput
Source: Own calculations based on data from Solomon Associates (2014).

| Year | Average Capital Investment (EUR/yr per barrel of throughput) | | |
	To Meet Clean Fuel Quality Specifications	To Meet Gasoline Quality Specifications	To Meet Diesel Quality Specifications
2000	0.08	0.06	0.01
2002	0.14	0.07	0.07
2004	0.29	0.10	0.19
2006	0.14	0.05	0.09
2008	0.19	0.08	0.11
2010	0.13	0.03	0.09
2012	0.03	0.01	0.02

Correspondingly, based on the Solomon Associates (2014) data (see Figure 3.4.9 and Table 3.4.4), the average annual capital costs of meeting the fuel quality requirements per barrel of throughput are:

- for meeting the gasoline fuel specifications: EUR 0.06 per barrel of throughput;
- for meeting the diesel and gasoil specifications: EUR 0.08 per barrel of throughput;
- for meeting the clean fuels requirements overall: EUR 0.14 per barrel of throughput.

Here we observe that the average investment cost per barrel of throughput for meeting all clean fuel requirements is almost exclusively comprised of the individual costs of meeting gasoline and diesel specifications, with the influence of the 'other fuels' category being negligible.

Operating Costs

In this section we derive an estimate for the refineries' additional operating costs that are affected by the fuel quality legislation. As we can see in Figure 3.4.10, the growth of the average total annual operating costs per refinery over the 2002-2012 period has almost the same growth pattern as the variable operating costs and the total energy costs (which are a subcategory of variable OpEx). We are confident that the increase in the total operating costs of European refineries can be attributed mainly to the increase in the corresponding energy costs. Thus, to obtain an estimate of the effects of compliance with the fuel quality legislation, one should obtain an estimate of the share of the energy expenditures that is affected by the fuel quality legislation.
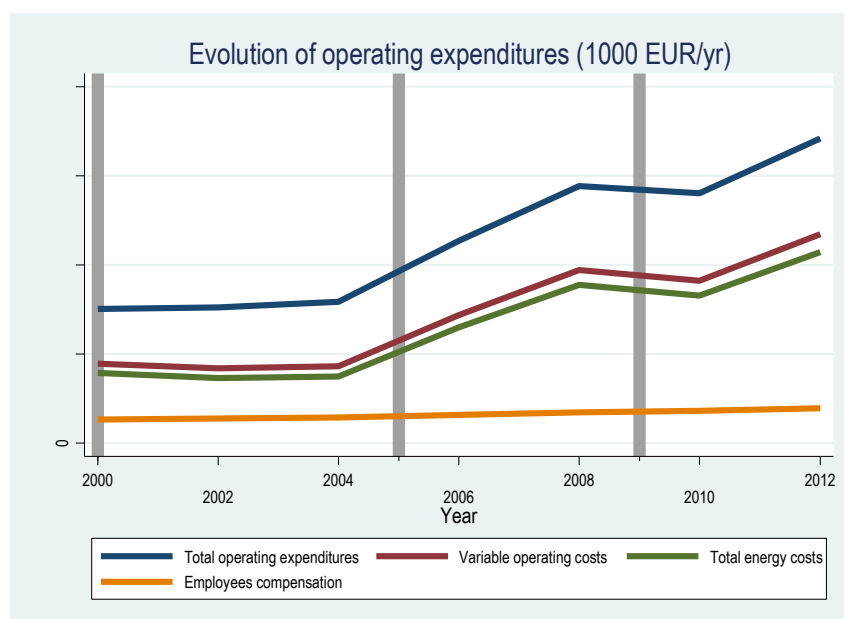
Figure 3.4.10: Evolution of the EU-28 refineries' average annual operating costs during 2000-2012
Source: Solomon Associates (2014).

Here we make a simplifying assumption for calculating the contribution of a particular unit in the refinery's total energy balance which is to prorate the total fuel-related energy use by the unit's capacity[175]. The data in the study of the US Department of Energy (2007) supports this assumption as shown (Table 3.4.12 in Annex) from the estimates of the share of process units related to the fuel quality legislation (hydrocracking, hydrotreating and hydrogen production) in the total throughput of a representative 2005 US refinery and in the total corresponding energy consumption. The fuel quality-related capacities accounted for 30 % of total annual capacity, while being responsible for 25 % of total annual energy use.

We note that this information and the above figures give us only a rough means to estimate the total energy costs of a representative European refinery that can be related to fuel quality legislation compliance, because of the differences in the operation mode between US and EU refineries. For example, US refineries are mainly directed to gasoline production while EU refineries work towards maximising diesel production. Also, the configuration of a representative 2005 refinery does not consider the investments made in 2008 and therefore the estimated energy consumption in the fuel quality-related units may be underestimated. Nonetheless, in the absence

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[175] This has been suggested during communications with the industry.

of an alternative reliable measure, we will employ a one-to-one correspondence assumption about the ratio of the installed fuel quality-related capacity and its share in the total energy use.
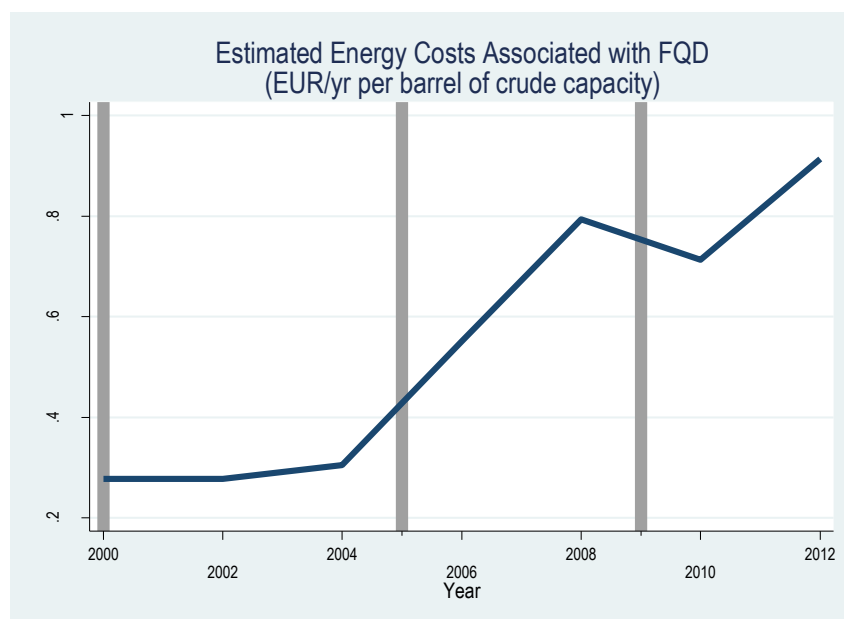
Figure 3.4.11: Estimated energy costs associated with fuel quality legislation during 2002-2012
Source: Own calculations based on data from Solomon Associates (2014).

Assuming a constant proportionate relationship between the capacity and the energy use shares (1 % share of fuel quality-related throughput capacity translates into 1 % fuel quality-related share in total final energy use), the estimated average fuel quality-related energy costs can be computed as presented in Table 3.4.13.

Table 3.4.5: Average fuel quality-related energy costs evolution (for hydrotreating, hydrogen production and hydrocracking)
Source: Own calculations based on data from Solomon Associates (2014).

Year	Average Energy Costs (thousand EUR/yr)	Share of FQ-related capacities (% of sum of all capacities)	Estimated average FQ-related energy use (GJ/yr)	Estimated average FQ-related energy costs (thousand EUR/yr)	Estimated average FQ-related energy costs per barrel of throughput (EUR/bbl)
2000	78663	25 %	5387856	20008	0.33
2002	72823	27 %	5486525	19328	0.34
2004	74534	29 %	6129750	21252	0.37
2006	129893	30 %	6600876	39052	0.66
2008	177863	31 %	6744096	55224	0.95
2010	165556	32 %	6948584	52321	0.91
2012	214277	33 %	7562959	70243	1.15

The estimated total effect on operating costs of the fuel quality-related measures over the whole 2000-2012 period amounts to approximately EUR 50 million per year. This corresponds to an absolute increase in the annual operating costs of EUR 0.82 per barrel of throughput between 2000 and 2012.

Nonetheless, it should be noted that during 2000-2012 the average energy use (expressed in GJ) related to the fuel quality legislation increased by 40 %, while the average fuel quality-associated energy costs grew by 251 %. This indicates that the majority of the energy costs increase (regardless of whether it is fuel quality-related or not) in the EU-28 comes from the growing energy prices.

We can disentangle the effect of the fuel quality-related energy use increase by only considering the costs of additional energy used by the fuel quality-related capacities during 2000-2012. This is done by calculating the additional fuel quality-related energy expenditures as the difference between the current energy expenditures and the cost of the 2000 energy consumption level taking into account the current energy per unit cost (presented in more detail in Table 3.4.13 in Annex).

In such a way, we estimate that the total increase in annual operating costs attributable to additional fuel quality-related efforts amounts to EUR 8.9 million per refinery per year or EUR 0.15 per barrel of throughput.

Unfortunately, given the data available, it is not possible to disentangle the elements of additional energy costs that can be attributed to meeting the gasoline and distillates fuel quality standards separately. Thus, the above operating cost estimates are best applied in conjunction with the additional capital cost estimates for meeting the clean fuel standards in general.

Summing the average capital investment and operating costs per barrel of throughput gives us an indicative figure for **the total fuel quality regulation-related cost of EUR 0.29 (approximately USD 0.35) per barrel of throughput**. This average impact can be put in the context of the refineries' net margins by looking at the data available from IHS (2014) and from several other sources used by the industry: IEA[176], ENI[177], BP[178] and Wood Mackenzie[179]. These data show that the average net margins during the 2000-2012 period were in the range between USD 1.7 and USD 3.8 per barrel, which is rather wide.

Comparison with other Assessments' Results

In this subsection we compare our findings to the results of other assessments of fuel quality-related regulations (presented in more detail in the Annex), which are:

- the ICCT (2012) ex ante estimation of the additional investments required for producing low-sulphur gasoline and diesel fuels;
- the Purvin & Gertz (2000) assessment of the additional investments and refinery operating costs associated with lowering the sulphur content in fuels.

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[176] IEA Oil Market Report 2014, https://www.iea.org/oilmarketreport/omrpublic/

[177] ENI Fact Book 2013, https://www.eni.com/en_IT/attachments/publications/reports/reports-2013/fact-book-2013-eng.pdf

[178] BP Statistical Review of World Energy June 2014, Workbook: http://www.bp.com/statisticalreview

[179] Collected from several publications:
Wood Mackenzie (2010), Impact of the use of biofuels on oil refining and fuels specifications, Final Report to European Commission, https://ec.europa.eu/energy/sites/ener/files/documents/2011_06_impact_biofuels_0.pdf
Neste Oil (2012), Credit Update March 2012
Neste Oil (2013), Presentation on Neste Oil Capital Markets Day, September 2013.

One important difference should be mentioned when comparing the results of these studies with our analysis. The above assessments are forward-looking exercises based on the outcomes of numerical models. This is different from our ex post valuation approach that focuses primarily on the analysis of past developments in the actual observed variables. Therefore, the above studies are used with the purpose of checking the robustness of the results obtained from the analysis of the Solomon Associates (2014) data.

To provide the best possible comparability, the quantitative results of all studies regarding the capital and operational costs of meeting the fuel quality specifications will be expressed in euros per litre of product sold. Referring back to the observation that almost all capital investments for compliance with clean fuel specifications concern production of only gasoline and diesel, we use only these two product groups in the denominator of the calculated per litre of product variables[180].

Table 3.4.6: Overview of previous assessments' estimates of the incremental effects of meeting the fuel quality specifications

Source	Annual Capital Expenditures to meet fuel quality requirements (euro cent per litre of final product)			Annual Operating Expenditures to meet fuel quality requirements (euro cent per litre of final product)			Total Annual Costs to meet fuel quality requirements (euro cent per litre of final product)		
	Gasoline	**Diesel**	**All Fuels**	**Gasoline**	**Diesel**	**All fuels**	**Gasoline**	**Diesel**	**All fuels**
This study	0.16	0.19	0.18			0.12			0.30
ICCT (2012)	0.18-1.6	0.34-1.82		0.09-0.58	0.12-0.68				
Purvin & Gertz (2000)							0.1-0.3	0.3-0.9	

Compared to the other assessments' results of the effects of meeting stricter fuel quality specifications, we see that the estimates based on the ex post data from Solomon Associates (2014) are situated within or close to the interval bounds (mostly at the lower end) of the estimates produced by the previous modelling exercises. We, therefore, argue that our estimates based on historical data are to be considered as describing the lower bound of the cost effects of fuel quality regulation on European refineries.

Meeting vapour pressure requirements

Between 1999 and 2000 the vapour pressure requirements changed from 70 kPa (10.2 psi) to 60kPa (8.7 psi) and they are expected to remain at this level as far as 2020. The ICCT (2012) study calculated the incremental cost of compliance with the tightening of the vapour pressure requirement from 10 psi (68.9 kPa) to 9 psi (62 kPa), which is comparable with the EU legislation's parameters. The incremental annualised capital investment costs of such an adjustment have been estimated at 0.8 euro cents per litre of gasoline sold. In the context of this fitness check, it is reasonable to argue that the overwhelming majority of the investments required to comply with this requirement were implemented before 2000 and, thus, their effect in the 2000-2012 period is very likely to be negligible compared to the effects of other fuel quality requirements.

Decreasing content of other substances

Polycyclic aromatic hydrocarbons

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[180] We used the corresponding weight to volume conversion factors of 0.74 for gasoline and 0.83 for diesel.

The current set of fuel quality directives implies that, from 2009, the road diesel polyaromatic hydrocarbons are reduced to 8 %, having previously been 11 %[181]. According to Concawe[182], the majority of the capital expenditures for decreasing PAH would be for new hydrodearomatisation plants and hydrogen production plants, which have the same type of capacities required for decreasing the sulphur content in fuels. Furthermore, it is also shown that that the maximum PAH content could be reduced to 8 % at the same time as the sulphur content is reduced to 10 ppm at no additional cost.

Thus, the measures for reducing the PAH content in fuels are inherently connected with the measures for sulphur reduction and do not currently produce additional (to those related to sulphur control) cost effects for the industry.

Metallic additives

In general, marketing of leaded gasoline has been prohibited since 1 January 2000[183]. However, Directive 1998/70/EC Article 3.3 allows the marketing of leaded gasoline up to a maximum level of lead of 0.15 g/l (while benzene content complies with the specifications in Annex I) given that sales of this gasoline would not exceed 0.5 % of total sales. In line with Article 3.6 of Directive 2009/30/EC, small quantities of lead in gasoline not exceeding 0.15 g/l might be allowed to a maximum of 0.03 % of total sales.

At the moment it is reasonable to state that the effect of the Fuel Quality Directive in the context of limiting the lead content in gasoline during the 2000-2012 period is negligible as the main efforts towards meeting these requirements were undertaken before then.

The second common metallic additive is methylcyclopentadienyl manganese tricarbonyl (MMT). In Europe, Member States have relied on different mechanisms to restrict MMT. For example, the Czech Republic prohibited use of MMT as late as 2008, while in Germany the so-called gasoline-lead law requires producers of additives to demonstrate no additional health risk. Since the main producer of MMT, Afton Chemical, has not demonstrated this, the use of MMT in European countries has been avoided as a result of a consensus among automakers, refiners, and the public health community in favour of restricting the use of manganese compounds in fuels[184]. In the context of the Fuel Quality Directive, the content of manganese in fuel was restricted in 2011 to 6 mg/L and in 2014 to 2 mg/L, or potentially zero depending on the outcome of an environmental and health risk assessment.

As in the previous case, the effect of this part of the legislation on European refiners can be considered negligible given the fact that refiners did not need to take measures in 2000-2012 to adopt it.

FAME content in diesel

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181 Monitoring has shown that the EU average content of PAH was under 4 % with a maximum of 7 % in some EU Member States.

182 Concawe 4/05 of June 2005, Evaluation of automotive polycyclic aromatic hydrocarbon emissions.

183 Directive 1998/70/EC Article 3.1.

184 ICCT (2009), Methylcyclopentadienyl Manganese Tricarbonyl (MMT): A Science and Policy Review, http://www.theicct.org/sites/default/files/publications/MMT_dec08.pdf.

In principle, the FAME content in diesel and jet fuel is subject to well defined technological limits regulated by international and CEN standards[185]. Using FAME in blended fuels presents a number of technological challenges for refiners which lead to a general consensus recommending very limited use (i.e. in very low concentrations) of FAME in diesel and other fuels[186]. Handling FAME takes place primarily during blending and very often outside the actual refineries. There is no reliable way to provide an estimate of the additional FAME regulation-related costs incurred by the refineries themselves or to disentangle them from the impacts of other directives, such as the Renewable Energy Directive.

The fuel market effects of the established FAME limits of the FQD appear to be very limited. Given that during 2000-2012 the European market for diesel fuels continued to exhibit excess demand, the increasing use of FAME was also unlikely to have any visible product displacement effects on refineries' production.

3.4.4. Efficiency of the legislation

This section discusses the efficiency of the fuel quality legislation by examining the estimates of the legislation's possible benefits alongside the costs. One should be very careful while attempting to compare these two aspects, as this fitness check contains an assessment of the costs incurred at the level of one industry, while the general benefits from legislation are quantified at the societal level.

Regarding the quantification of the benefits associated with the fuel quality legislation, we have very limited tools at our disposal to calculate this in a reliable way. Probably the most reliable estimate can be obtained for the effects of decreasing the emission intensities of SO_2. Using the EEA (2013) data presented in Section 4.1, we can calculate the estimated monetary effect of decreasing the SO_2 emissions from burning gasoline and diesel transport fuels using the damage per tonne emission estimates provided by the EEA (2014).

In this assessment we compare the situation where the average sulphur content in gasoline and diesel would have remained at the level determined by the fuel quality legislation's year 2000 limits (150 ppm for gasoline and 350 ppm for diesel) with the observed situation where the sulphur content in gasoline and diesel declined between 2001 and 2011 to 6 ppm and 7 ppm, correspondingly (see Figure 3.4.1).

To calculate the total SO_2 emission decrease, we use the gasoline and diesel production volume data from Solomon Associates (2014). Because the Solomon Associates (2014) data only covers even years, we use the production values from adjacent even years to approximate the corresponding odd year variables. Then this dataset is combined with the EEA(2013) data on the average sulphur content in road fuels to estimate the total reduction in SO_2 emissions over the 2001-2011 period.

The effective emissions decrease is calculated as the difference, year by year from 2001 to 2011, of the baseline sulphur content (150 ppm for gasoline and 350 ppm for diesel) minus the actual content numbers, multiplied by the production volumes of gasoline and diesel, correspondingly.

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[185] The European Committee for Standardization (CEN) via its EN 14078 diesel fuel specification allows the blending of up to 7 % v/v FAME complying with the EN 14214 specification.

[186] Concawe (2009), Guidelines for handling and blending FAME, Report No. 9/09. Brussels: Concawe.

To assign a monetary value to emission reduction benefits we use EEA (2014), which in Table A2.9 gives estimated ranges for regional damages from SO_2 emissions. To produce a conservative estimate, we take the low end of the given range (so-called VOLY[187] estimate), and use a simple average of the EU-28 countries. This gives us an average value of EUR 11 290/tonne of SO_2 emissions (2005 prices).

Putting the figures together gives a total SO_2 emissions decrease benefit of EUR 196.8 million per average EU-28 refinery during 2001-2011.

The total additional investment and operational costs incurred by the refineries during the same period (2001-2011) are estimated at EUR 103 million in investment costs for compliance with clean fuels standards and EUR 98 million in operational costs, resulting in costs of EUR 202 million per refinery.

The above-mentioned regulation compliance costs are incurred at the level of the refining industry alone. The repercussions of the compliance costs at the societal level have not been quantified. They can, however, be placed in a broader context that also includes the societal and economic role of the industry. In 2011, the EU refining industry had average revenues per refinery[188] of around EUR 96 million (IHS (2014)). According to Solomon Associates (2014), an average EU-28 refinery site in 2011 employed 533 workers and paid approximately EUR 40 million in wages. Furthermore, the total employment effect of the average EU refinery (taking into account the Input-Output relationships of EU refining with other sectors, see Refining Overview Chapter) is estimated at 2 136 workers.

Regarding the question of whether the incurred costs are comparable and affordable, we would like to point out that here we used the most conservative (lower limit) estimate of the monetary benefits from avoided SO_2 emissions. It should be noted that the VSL assessment[189] from the higher band of the EEA (2014) interval suggests the total benefits would have been three times higher[190]. Still, one should be aware that in this case we observe the cost estimates at the industry level alongside the benefit estimates calculated for society as a whole.

In the context of the refining sector's objectives, the question of legislation efficiency also concerns the administrative costs for reporting and compliance incurred by the refiners. It has been observed in the available information (such as in UK Department of Transport (2010)) that the FQ legislation itself does not impose visible additional costs related to compliance enforcement and control. The actual measurements and tests of fuel quality should already be carried out as part of the monitoring system for the air quality of road transport emissions. Therefore, here we can argue that the fuel quality legislation alone has a very limited effect on the administrative costs of refineries.

The fuel quality legislation, from its early documents, required that Member States establish a system that monitors compliance with the fuel quality requirements on the basis of the analytical methods referred to in European standards. Member States should take measures to ensure that the economic operators submit reliable information and make available to the Member State, on

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[187] Value of a Life Year.

[188] Based on there being 75 active refineries by the end of 2011.

[189] Value of Statistical Life.

[190] With the average benefit of EUR 33 396/tonne of SO_2 emissions (2005 prices).

request, the data used to prepare the information. Member States should require economic operators to arrange for an adequate standard of independent auditing of the information submitted, and to provide evidence that this has been done. The auditing verifies that the systems used by economic operators are accurate, reliable and protected against fraud and it evaluates the frequency and methodology of sampling and the robustness of the data.

The series of annual fuel quality monitoring reports is published by the European Commission (http://ec.europa.eu/clima/policies/transport/fuel/documentation_en.htm), with the first appearing in 2004 for reporting years 2001 and 2002. This indicates that a comprehensive fuel quality sampling, reporting and compliance control system had already been established in the EU by 2001. Given the fact that the refining producers have to maintain a similar reporting system in the framework of other legislative regulations (such as concerning air quality and road transport fuel emissions mentioned above), we can state that the additional administrative compliance costs for refineries related to fuel quality legislation during the 2000-2012 period should be very limited.

Another aspect of efficiency concerns the compatibility of the objectives of different pieces of legislation. In general, legislation that is contradictory or that duplicates other regulatory measures increases the complexity and cost of compliance. In the case of regulations affecting the European refining industry this is a point worthy of attention.

Though the fuel quality legislation appears to be aligned with other directives directly or indirectly related to the quality characteristics of the refining products, it should still be noted that the measures required for implementation of the legislation's main objectives, i.e. improvement of fuel quality and decreasing the content of harmful substances, can have mixed effects in terms of the GHG-related objectives. As discussed above, in most cases, improving the fuel quality required more extensive and intensive processing of refinery feeds and products, which is more energy-intensive and, holding all other parameters equal, leads to additional GHG emissions.

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3.4.5. Annex

Detailed parameters of fuel quality legislation

Table 3.4.7: Regulatory specifications for petrol/gasoline – Annex I
Source: Directive 1998/70/EC, Directive 2003/17/EC, Directive 2009/30/EC.

Parameter	Unit	Minimum[191]	Maximum		
			2000	2005	2009
Research octane number		95			
Motor octane number		85			
Vapour pressure	kPa		60.0	60.0	60.0
Distillation					
- evaporated at 100 °C	% v/v	46.0			
- evaporated at 150 °C	% v/v	75.0			
Hydrocarbon analysis					
-olefins	% v/v		18.0[192]	18.0	18.0
-aromatics	% v/v		42.0	42.0	35.0
-benzene	% v/v		1.0	1.0	1.0
Oxygen content	% m/m		2.7	2.7	3.7
Oxygenates					
-Methanol	% v/v		3.0	3.0	3.0
-Ethanol	% v/v		5.0	5.0	10.0
-Iso-propyl alcohol	% v/v		10.0	10.0	12.0
-Tert-butyl alcohol	% v/v		7.0	7.0	15.0
-Iso-butyl alcohol	% v/v		10.0	10.0	15.0
-Ethers	% v/v		15.0	15.0	22.0
Other oxygenates	% v/v		10.0	15.0	10.0
Sulphur content	mg/kg		150.0	150.0	10.0
Lead content	g/l		0.005	0.005	0.005

Table 3.4.8: Regulatory specifications for gasoline – Annex III
Source: Directive 1998/70/EC, Directive 2003/17/EC, Directive 2009/30/EC.

Parameter	Unit	Minimum[193]	Maximum		
			2000	2005	2009
Research octane number		95			
Motor octane number		85			
Vapour pressure	kPa		60.0	60.0	60.0
Distillation					
- evaporated at 100 °C	% v/v	46.0			
- evaporated at 150 °C	% v/v	75.0			
Hydrocarbon analysis					
-olefins	% v/v			18.0	18.0
-aromatics	% v/v		35.0	35.0	35.0
-benzene	% v/v			1.0	1.0
Oxygen content	% m/m			2.7	3.7
Oxygenates					
-Methanol	% v/v			3.0	3.0
-Ethanol	% v/v			5.0	10.0
-Iso-propyl alcohol	% v/v			10.0	12.0
-Tert-butyl alcohol	% v/v			7.0	15.0

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[191] The given minimum limits remain the same in all reviewed directives.

[192] Maximum olefin content for regular unleaded gasoline (MON=81, RON=91) is set to 21 % v/v. The limit shall not preclude the introduction onto a MS' market of another unleaded gasoline with lower octane numbers.

[193] The given minimum limits remain the same in all reviewed directives.

Parameter	Unit	Minimum[193]	Maximum		
			2000	2005	2009
-Iso-butyl alcohol	% v/v			10.0	15.0
-Ethers	% v/v			15.0	22.0
Other oxygenates	% v/v			10.0	15.0
Sulphur content	mg/kg		50.0	50.0	10.0[195]
				10.0[194]	
Lead content	g/l			0.005	0.005

Table 3.4.9: Timeline for the regulation of sulphur levels for petrol/gasoline

Source: Directive 1998/70/EC, Directive 2003/17/EC, Directive 2009/30/EC.

Date	Fuel	S regulation	Directive
1.1.2000	unleaded petrol/gasoline	150 mg/kg[196]	1998/70/EC Article 3.2.a
	unleaded petrol/gasoline	50 mg/kg [197]	1998/70/EC Article 3.2.b
1.1.2005	unleaded petrol/gasoline	50 mg/kg	1998/70/EC Article 3.2.c
1.1.2005	unleaded petrol/gasoline	10 mg/kg[198]	2003/17/EC Article 3.2.d
1.1.2009	unleaded petrol/gasoline	10 mg/kg	2003/17/EC Article 3.2.e
	petrol/gasoline	10 mg/kg[199]	2009/30/EC Article 3.2

Table 3.4.10: Regulatory specifications for diesel

Parameter	Unit	Maximum		
		2000	2005	2009
Density at 15 °C	kg/m^3	845.0	845.0	845.0
Distillation				
- 95 % v/v recovered at	°C	360.0	360.0	360.0
Polycyclic aromatics hydrocarbons	% m/m	11.0	11.0	8.0
Sulphur content	mg/kg	350.0	350.0	10.0
FAME content EN14078	% v/v	-	-	7.0

[194] Directive 2003/17/EC Article 3.2 requests the unleaded petrol of a given specification to be available and marketed on an appropriately balanced basis within the territory of a Member State.

[195] By 1.1.2009 all unleaded gasoline marketed within Member States must comply with the specification.

[196] Until 1.1.2003 marketing of unleaded gasoline not in compliance with Annex I (i.e. max S = 150 mg/kg) may be permitted. Rules apply for the application and reasoning; see Directive 1998/70/EC Article 3.4.

[197] Until 1.1.2007 marketing of unleaded gasoline not in compliance with Annex III (i.e. max S = 50 mg/kg) but in compliance with Annex I (i.e. max S = 150 mg/kg) may be allowed. Rules apply for the application and reasoning; see Directive 1998/70/EC Article 3.5.

[198] MS shall take all necessary measures to ensure that unleaded gasoline of maximum sulphur content is marketed within their territories no later than 1.1.2005. Specific provisions might be adopted for the introduction of gasoline of a maximum sulphur content of 10 mg/kg for the outermost regions.

[199] Specific provisions might be adopted for the introduction of gasoline of a maximum sulphur content of 10 mg/kg for the outermost regions.

Table 3.4.11: Timeline for the regulation of sulphur content for diesel fuel and gas oil
Source: Directive 1998/70/EC, Directive 2003/17/EC, Directive 2009/30/EC.

Date	Fuel	S regulation	Directive
1.10.1994	diesel	0.2 % (2000 mg/kg)	1993/12/EEC Art.2.1
1.10.1996	diesel	0.05 % (500 mg/kg)	1993/12/EEC Art.2.1
1.10.1994	gas oil[200][201]	0.2 % (2000 mg/kg)	1993/12/EEC[202] Art.2.1
1.1.2000[203](no later)	diesel, gas oil[204]	350 mg/kg	1998/70/EC/Art. 4.1.a (Annex IV)
1.1.2000 (from)	diesel	50 mg/kg	1998/70/EC/Art. 4.1.b (Annex IV)
1.1.2005 (no later)	diesel[205]	50 mg/kg	1998/70/EC/Art. 4.1.c (Annex IV)
1.1.2005 (no later)	diesel	10 mg/kg[206]	2003/17/EC/Art. 4.d (Annex IV)
1.1.2009 (only)	diesel	10 mg/kg	2003/17/EC/Art. 4.e (Annex IV)
	gas oil[207]	2000 mg/kg	2003/17/EC/Art.3.a.b
1.1.2008	gas oil	1000 mg/kg	2003/17/EC/Art.3.a.b
1.1.2008	diesel	10 mg/kg	2009/30/EC/Art.4.1
1.1.2008	gas oil[208]	1000 mg/kg	2009/30/EC/Art.4.2
1.1.2008	gas oil[209]	1000 mg/kg	2009/30/EC/Art.4.2
1.1.2011	gas oil	10 mg/kg[210]	2009/30/EC/Art.4.2

[200] Derogation for Greece applies up to 30.9.1999 allowing gas oil for marine use to exceed the 0.2 % sulphur content, see Directive 1993/12/EEC Art.2.3.

[201] Does not include gas oils contained in the fuel tanks of vessels, aircraft or motor vehicles crossing a frontier between a third country and MS, see Directive 1993/12/EEC Art.1.2. Does not include aviation kerosene for which a limit should be set on 1.10.1999 at the latest; see Directive 1993/12/EEC Art.2.2.

[202] The EC, upon the information provided by the MS, might authorise a higher limit for gas oil for a period of less than six months; see Directive 1993/12/EEC Art.3.

[203] The marketing in Member States of diesel fuels not in compliance with Annex II might be allowed up to 1.1.2003 (procedures given), see Directive 1998/70/EC Art. 4.2.

[204] MS may apply the same limits they apply for diesel according to Directive 1998/70/EC and 1993/12/EEC also for gas oil used in engines in non-road mobile machinery and agricultural tractors; see Directive 1998/70/EC Art.2.

[205] The marketing of diesel fuels not in compliance with Annex IV, but in compliance with Annex II may be authorised up to 1.1.2007, see Directive 1998/70/EC Art. 4.3.

[206] Exception is granted to the outermost regions within the EU.

[207] Intended for non-road mobile machinery, agricultural and forestry tractors; see Directive 2003/17/EC Art 3.5.

[208] Intended for non-road mobile machinery, inland waterway vessels, agricultural and forestry tractors; see Directive 2009/30/EC Art 4.2.

[209] See footnote 32.

[210] Until 31.12.2011 it may be permitted to market gas oil intended for use by non-road mobile machinery, inland waterway vessels, agricultural and forestry tractors and recreational crafts up to 20 mg/kg. A maximum limit of 1000 mg/kg applies for the sulphur content of fuels for rail vehicles, agricultural and forestry tractors, provided the proper functioning of emission control systems is not compromised.

Fuel Specification-Related Capital Investments and Energy Use
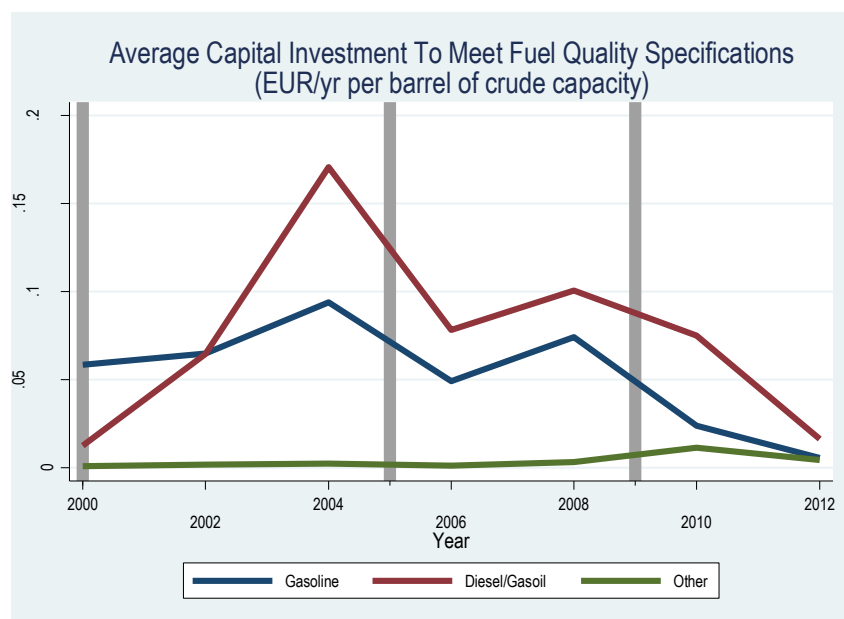
Figure 3.4.12: Average capital investment per barrel of input to meet fuel specifications
Source: Solomon Associates (2014).

Table 3.4.12: Estimated 2005 energy balance for the US petroleum refining industry
Source: DOE(2007).

Process	Specific Energy Use[a] (10³ Btu/bbl)	Average Use[b] (10³ Btu/bbl)	Capacity (10⁶ bbl/cday)[c]	Annual Energy Use (10¹² Btu/year)
Atmospheric Distillation[d]	82 – 186	114	15.86	658.8
Vacuum Distillation	51 – 113	92	7.14	238.5
Fluid Catalytic Cracking[e]	209	209	5.48	417.5
Catalytic Hydrocracking	159-321	168	1.43	87.5
Delayed Coking	114 – 230	166	2.03	122.9
Fluid Coking	258	258	0.07	6.7
Flexicoking	167	167	0.11	6.6
Visbreaking[f]	136	136	0.0052	0.29
– Coil	25 – 95	63	0.0106	0.24
– Soaker				
Catalytic Reforming	213 – 342	269	3.4	331.1
Alkylation	330 – 340	335	0.43	52.9
– Sulphuric Acid	255	255	0.65	60.3
– Hydrofluoric Acid				
Catalytic Hydrotreating	61 – 164	88	13.7	442.0
Ethers Production	295 – 564	403	0.10	16.2
Isomerisation	359	359	0.20	26.2
– Isobutane	102 – 236	175	0.42	26.9

– Isopentane/Isohexane – Isobutylene	476	476	n/a	n/a
Lube Oil Manufacture	1,506	1,506	0.17	92.2
Hydrogen Production	63 – 158[g]	111[g]	0.05	290.5[g]
TOTAL[h]	-	-	51.26	2877.3
Share of Total associated with FQD (%)			30 %	25 %

a Gross energy use, which includes losses incurred during the generation and transmission of electricity (electricity conversion factor of 10 500 Btu/kWh). Does not include hydrogen or oxygen consumption or production (by-product).

b Average energy use based on estimated utility requirements for a range of technologies. See individual chapters for additional details.

c bbl/cday = barrels per calendar day (365 days per year). Includes the 2005 capacity factor of 90.4 %.

d Includes energy consumed for the desalting of crude.

e Includes energy from coke combustion that is used to drive the cracking reaction.

f Assumes 33 % of capacity are coil-type, and 67 % are soaker-type visbreakers.

g Includes both natural gas consumed as feedstock and fuel and electricity used in steam methane reforming. Values are in 10^3 Btu/kg H_2.

h Does not include sulphur recovery and management processes, operation of cooling towers, and other supporting processes. The production energy of ethanol, a fuel additive, is not included here because ethanol production is classified under a separate NAICS.
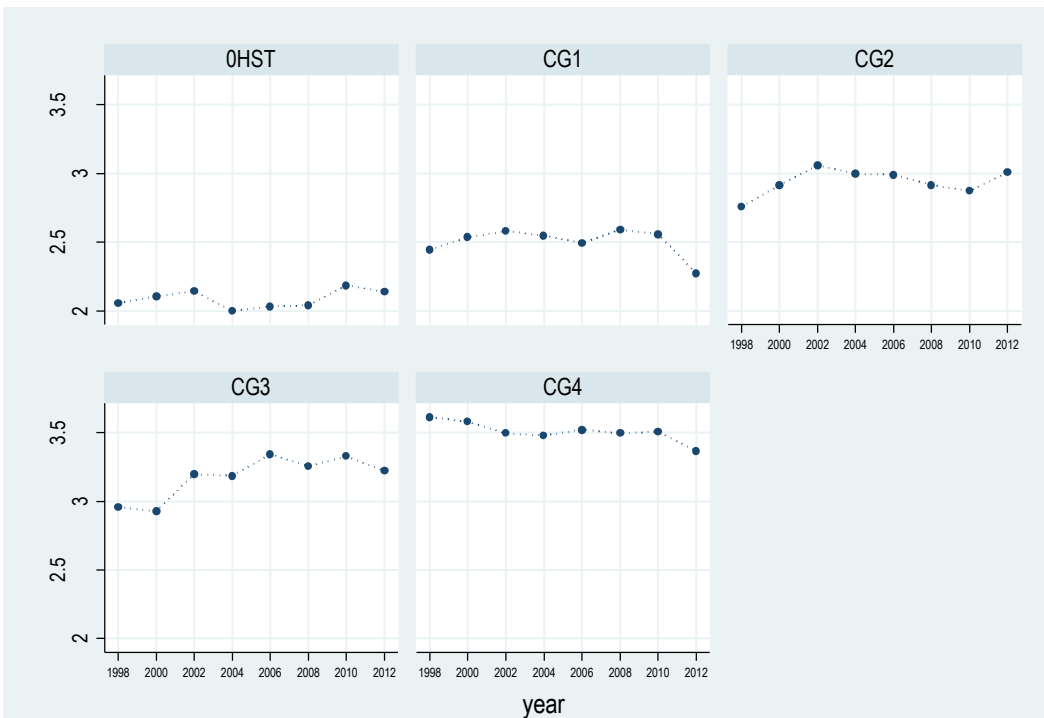
Figure 3.4.13: Energy use intensity of EU-28 refineries
Source: Solomon Associates (2014).

Table 3.4.13: Calculation of additional FQ-related energy costs in relation to 2000 (for hydrotreating, hydrogen production and hydrocracking)

Source: Own calculations based on data from Solomon Associates (2014).

Year	Estimated average FQ-related energy use (GJ/yr)	Estimated average FQ-related energy costs (thousand EUR/yr)	Estimated average 2000 FQ-related energy costs in current prices (thousand EUR/yr)	Additional energy costs since 2000 (thousand EUR/yr)	Additional energy costs since 2000 (EUR per barrel of throughput)
2000	5 387 856	20 008	20 008.27	0.00	0.00
2002	5 486 525	19 328	18 980.35	347.59	0.01
2004	6 129 750	21 252	18 679.87	2 572.17	0.04
2006	6 600 876	39 052	31 875.46	7176.43	0.12
2008	6 744 096	55 224	44 118.27	11 105.52	0.19
2010	6 948 584	52 321	40 568.76	11 751.76	0.20
2012	7 562 959	70 243	50 041.16	20 201.86	0.33

Comparable assessments of the costs of meeting fuel specifications

ICCT (2012) Assessment

The primary objectives of the ICCT (2012) study were (i) to identify the primary additions to refining process capability required for producing low-sulphur gasoline and diesel fuels with refining operations and crude oil slates typical of those currently used, and (ii) to assess, by means of refinery LP modelling, the capital and operating costs required for transition to ultra-low-sulphur fuels. The refining analysis estimated refining costs that are the sums of (i) capital charges associated with investments in new capacity, and (ii) direct operating costs (e.g. energy, catalysts and chemicals), summed over all the refining processes represented in the model.

Table 3.4.14: ICCT (2012) Estimated cost of gasoline and diesel fuel sulphur standards

Incremental cost of meeting gasoline and road diesel standards (10 ppm)	Capital investment cost	Refining Operations
Gasoline [euro cent/litre]		
US	0.18	0.09
Brazil	1.6	0.52
China	0.44	0.26
India	0.61	0.22
Mexico	0.8	0.58
Diesel [euro cent/litre]		
Brazil	1.6	0.52
China	0.63	0.53
India	0.34	0.12
Mexico	1.82	0.68

This study considers investment scenarios in different world regions (China, Mexico, Brazil and India), which have a different the starting point, with the target year being forward-looking to 2015. Thus, the results of this assessment are used in the form of an interval describing the highest and the lowest assessed desulphurisation costs.

Purvin & Gertz (2000) Assessment

A cost-benefit analysis of lowering the sulphur content of gasoline and diesel fuels below 10 ppm was prepared by DG Environment based on the study of Purvin & Gertz (2000).

There are likely to be additional investment and refinery operating costs associated with lowering the sulphur content from a maximum of 50 ppm to a maximum of 10 ppm. DG Environment commissioned a report from consultants Purvin & Gertz on the costs to refiners of producing sulphur-free fuels (less than 10 ppm).

The analysis from Purvin & Gertz is based on 'yardstick' catalytic cracking refineries which represent approximately 75 % of the refining capacity in Europe. Costs are expected to be highest for these refineries rather than, for example, hydrocracking refinery configurations. In addition, the study assumed a complete switch to sulphur-free fuel production in 2008. If a phased introduction is implemented then investment costs are likely to be lower. This is because some new technologies under development are likely to make further progress towards market utilisation and because refiners can, at least initially, selectively desulphurise some fuel components for the 10 ppm sulphur pool whilst leaving others for the 50 ppm pool.

Table 3.4.15: Additional refining costs (CapEx+OpEx, euro cents per litre)

ECONOMIC RESULTS	Northern Europe		Southern Europe	
	Gasoline	Diesel	Gasoline	Diesel
Cost, €/tonne				
@ 4% Discount Rate	1-2	3-5	2-4	5-7
@ 7% Discount Rate	1-2	3-5	2-4	5-7
Auto Oil 1 Approach [1]	1	3-5	2-4	5-7
Price Premium €/tonne	1-3	4-7	2-4	7-10
Cost Cents per litre				
@ 4% Discount Rate	0.1-0.2	0.3-0.4	0.2-0.3	0.4-0.6
@ 7% Discount Rate	0.1-0.2	0.3-0.4	0.2-0.3	0.4-0.6
Auto Oil 1 Approach [1]	0.1	0.3-0.4	0.2-0.3	0.4-0.6
Price Premium c/litre	0.1-0.3	0.3-0.6	0.2-0.3	0.6-0.9

Note : (1) (Capex + 9.75*Annual Opex)/(15 years production)

3.5. Directive on Clean and Energy-Efficient Vehicles

We do not consider this particular Directive relevant for further quantitative analysis as we conclude that its impact on the EU oil refining sector is minimal and empirically indiscernible. While the Directive has now been successfully transposed into national legislation, this happened with a delay in the majority of MS. The short time since transposition does not allow the effects of the adopted measures to be empirically observed yet. In addition, as the Directive specifically targets vehicle procurement in the public sector, its overall short- to medium-term impacts on the car markets are expected to be insignificant. Its potential effect on the oil refining sector is second-order and can be foreseen to be negligible as well.

3.5.1. Objectives and measures

The Directive on Clean and Energy-Efficient Vehicles[211] entered into force on 4 June 2009, with its transposition into national legislation due by 4 December 2010. Its stated objective (Article 1) is to promote and stimulate the market for clean and energy-efficient vehicles, and improve the contribution of the transport sector to the EU's environment, climate and energy policies. To this end, the Directive applies specific requirements with respect to the public procurement procedures in order to incentivise production of vehicles with low levels of energy consumption and emissions. Namely, the Directive requires 'contracting authorities, contracting entities as well as certain operators to take into account lifetime energy and environmental impacts … when purchasing road transport vehicles'. Energy and environmental impacts to be taken into account include: energy consumption; emissions of CO_2; and emissions of NO_X, NMHC and particulate matter. Purchasers may also consider other environmental impacts.

According to the European Commission's first report on the application of the Directive (EC, 2013), all but one MS had fully transposed the Directive into the national legislation (the remaining MS to do so, Latvia, was in the process of completing the transposition). The majority of MS reportedly did not have any issues with transposing the Directive. In a number of cases, the process of transposition involved amendments to existing public procurement acts rather than new legislation.

3.5.2. Effectiveness of the legislation

Arguably, the Directive has had little impact on the market for cleaner vehicles to date. Indeed, in 2012 none of the stakeholders participating in the survey on the Directive's implementation were able to provide evidence of its direct impact on the market (Ricardo-AEA, 2012). This is largely explained by the fact that the Directive has only been in force for a short period of time, with delayed implementation in the majority of countries (only three MS met the transposition deadline of December 2010). Moreover, in some MS, where a relatively low number of vehicles are purchased by public authorities, it may not be possible to empirically observe a non-negligible impact even after a longer period of time. While it could have a stronger effect in the long run through general culture shifts, these would be very difficult to detect empirically. In addition, since the Directive is only one of a set of policy instruments targeting energy efficiency and emission reduction in the EU, discerning its specific impacts is further complicated.

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[211] Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles.

The Commission's report (EC, 2013) summarises manufacturers indicating that '[...] it was felt that it would be extremely difficult to assess the impacts of Directive 2009/33/EC as similar anticipated impacts can also have been stimulated by other policy measures. Although the market for low emission vehicles is expanding, it is difficult to attribute this to the implementation of this Directive, and it is more likely to be due to other factors (including technological developments, other EU legislation, national vehicle taxation policies, market conditions, existing government incentive schemes etc.).' The report concludes that '[b]elated transposition of the Clean Vehicle Directive by most Member States has limited the experience with this Directive to [the] date [of publication of the report] and has therefore provided challenges for the assessment of its impacts within the scope of this monitoring report. This situation is further aggravated by the absence of reporting obligations for Member States.'

3.5.3. *Impact on the EU petroleum refining sector*

As regards the impact of the Directive on the oil refining sector, it might be expected to be negligible, at least in the short to medium term. Given that the Directive specifically targets procurement in the public sector, its overall impact on the car markets can be foreseen to be insignificant. Theoretically, if the legislation eventually produces the desired effects through the changes in general culture, it may imply some second-order impacts on the oil refining sector through reduction of the overall fuel demand. Namely, three impact channels might prove to be relevant:

(i) an overall reduction in transport fuel demand due to the increased energy efficiency of vehicles;

(ii) a relative shift in fuel demand towards diesel (due to higher efficiency of diesel engines);

(iii) a potential increase in demand for biofuels, being cleaner-burning than fossil fuels.

None of these, however, affect the oil refining sector directly and they are not expected to be significant in the short to medium term.

Overall, we conclude that the Directive has so far had no discernible impact on the oil refining sector because:

- it is only one part of the EU legislation addressing environmental and energy security challenges, being a complementary demand-side measure;
- as it specifically targets procurement in the public sector, its overall impact on the vehicle markets can be expected to be insignificant in the short run;
- its impact on the oil refining industry is second-order through reduction in overall transport fuel demand and therefore is i) potentially insignificant as well and ii) difficult to assess empirically without further data;
- too short a time has passed since its transposition into national legislation (only three MS completed transposition by the due date of 4 December 2010).

We therefore do not consider the Directive on Clean and Energy-Efficient Vehicles in our further quantitative analysis and modelling within this report.

3.5.4. Efficiency of the legislation

As discussed above, for a number of reasons, the specific impacts of the legislation on clean and energy-efficient vehicles could not be observed to date. We therefore do not consider it feasible to conduct any meaningful analysis of its cost-benefit performance in the scope of this report.

REFERENCES TO RELEVANT SOURCES

European Commission (2013): Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the application of Directive 2009/33/EC on the promotion of clean and energy efficient road transport vehicles. COM(2013) 214 final, Brussels, 18.4.2013

Ricardo-AEA (2012): Monitoring Report of the Directive 2009/33/EC on the promotion of clean and energy efficient road transport vehicles, Final Report. Available at: http://ec.europa.eu/transport/themes/urban/studies/doc/2012-monitoring-report.pdf

3.6. Industrial Emissions Directive

The Industrial Emissions Directive (IED) 2010/75/EU required transposition by January 2013 and hence is–formally speaking–not included in the scope of the REFIT. However, given that the IED is a recast of seven pre-existing directives, large parts of it were actually established earlier.[212] In view of this, this section focuses on the preceding legislation with relevance for the EU refining sector. In particular, this includes the Integrated Pollution Prevention and Control Directive 2008/1 (IPPC, going back to 1996/61) and the Large Combustion Plants Directive 2001/80/EC.[213]

The most important findings (derived further below) can be summarised as follows:

- The EU refining sector's SO_2 and NO_X emissions have decreased both in absolute terms (data for 2007 to 2012) and in terms of the average emission intensity (emissions per throughput, data for 2004 to 2012).
- In the 2000-2012 period, each EU-28 refinery on average incurred capital expenditures of EUR 5 million per year for compliance with emissions and effluents regulation, with a notable increase between 2000-2006 (average EUR 3.8 million per refinery) and 2007-2012 (average EUR 6.4 million per refinery). These investments accounted for a fairly constant share of 10 % of refineries' total annual capital investments.
- Complexity and, to a lesser extent, capacity influence a refinery's capital costs related to pollution regulation. Using the concept of equivalent distillation capacity to adjust for these two factors shows that the average capital cost impact from pollution regulation differs by up to a factor of two between EU regions.
- The cost burden from the observed capital and estimated associated operational expenditures is EUR 0.13 per barrel of throughput (EUR 0.09/bbl during 2000-2006 and EUR 0.16/bbl during 2007-2012). The operational cost component had to be estimated from the reported capital costs based on a rule-of-thumb percentage value, and hence has a relatively higher uncertainty. Also, the cost impact from switching to cleaner refinery fuels (high-sulphur to low-sulphur fuel oil or natural gas) could not be analysed due to lack of data.
- Data for capital expenditure on pollution control in other global refinery regions indicates higher numbers for the US Gulf and East Coast than in the EU and not much lower numbers for the Middle East, with increasing convergence between these regions in recent years. For Russia, the numbers were significantly lower at all times. Hence, the overall competitiveness impact vis-à-vis the US and the Middle East is judged to be rather low. It appears to be more significant vis-à-vis Russia, where refiners have a capital cost burden from pollution regulation of about one third of that in the EU, and associated operational costs might also be lower, e.g. due to lower energy prices.
- An important secondary impact from EU pollution regulation is its contribution to the roughly 50 % demand drop for inland fuel oil observed during 2000-2012, by about 30 million to 45 million tons in absolute terms. The concomitant reduction of supply was achieved through–in decreasing order of importance–(i) increased conversion capacity, (ii) increased uptake of

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[212] Apart from bringing together and consolidating different pieces of legislation, the IED also increases the legal obligation of local competent authorities to base permit conditions on the so-called BAT conclusions.

[213] The other five directives regard waste incineration, solvent emissions, and waste from the titanium dioxide industry.

fuel oil by the marine fuels market, and (iii) shut-down of EU refining capacity. A negative competitiveness impact from this secondary legislative effect seems likely, but could not be quantified in this section.

3.6.1. Objectives and measures

The Integrated Pollution Prevention and Control (IPPC) Directive has the objective of minimising pollution from industrial processes and its associated negative impact on air, soil, and water. As large industrial installations, refineries represented 7.7 % of EU-wide industrial SO_2 emissions in 2007 and 1.8 % of EU-wide industrial NO_X emissions. Refineries also contributed less than 2 % of the EU-wide industrial emissions of particulate matter and volatile organic compounds (VOCs), as well as some amounts of waste water contaminated with oil and oil-related substances (JRC 2013, p.26).[214] According to the European Environmental Agency, the 79 most polluting refineries were responsible for 10 % of the total EU-wide damage costs associated with air pollution (NO_X, SO_X, PM_{10}, NMVOC, NH_3) from industrial facilities in the year 2009 (EEA 2011).

The IPPC Directive requires industrial installations to obtain operating permits from competent (national, local) authorities and defines the conditions under which they can be granted. These permits need to specify, inter alia, emission limits for polluting substances, requirements for waste processing, measures to be put in place to deal with leaks or other malfunctions, and requirements concerning the monitoring of emissions and its reporting to the competent authorities.

Specific emission limits for the various pollutants depend on the sector and the installation but should follow so-called BREF ('Best Available Techniques REFerence)' documents, which are regularly updated in an EU-wide process.[215] However, even though the IPPC Directive requested that competent authorities base permit conditions on the pollutant emission levels associated with the best available techniques (BAT) listed in the 2003 refinery BREF, this was not a strict legal obligation during the 2000-2012 period (but is under the IED 2010/75[216]).

In terms of timing, the IPPC Directive had to be transposed by October 1999, but was first applicable only to new installations built after this date, and existing ones if they had undergone 'substantial change'. The final deadline for compliance for all existing installations–including refineries–was 30 October 2007.

Following a similar objective, the Large Combustion Plants Directive (LCPD) 2001/80/EC applies to combustion plants with a thermal capacity equal to or higher than 50 MW – typically power plants but also combustion plants within refineries – and defines explicit maximum binding emission limit values (ELVs) for SO_2, NO_X, and particulate matter (dust). It came into force in November 2002, with the severity of regulation differentiated according to the installation's age, thermal capacity, and

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[214] For an analysis of the local pollution impact from individual refineries see, e.g., Baldasano et al. (2014), Baltrėnas et al. (2011).

[215] The latest available version is the BREF for the Refining of Mineral Oil and Gas (JRC 2015) and the BAT conclusions adopted in October 2014, but for the analysis here – focused on the IPPCD – the relevant document was the 2003 version (EC 2003) with its 'conclusions on BAT'.

[216] The IED stipulates that competent authorities shall set emission limit values that ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques as laid down in the decisions on BAT Conclusions. Their legally binding nature is an important change compared to the IPPC Directive.

employed fuel.[217] Combustion plants authorised after November 2002 have the more stringent emission limits, while for combustion plants authorised before 2002 they are less stringent. For plants authorised before July 1987 ('existing' plants), the emission limits started applying from 2008 on, with an option for Member States to apply a 'National Emission Reduction Plan' (NERP) setting an overall emission ceiling instead of plant-by-plant compliance (8 MS use this option), as well as the possibility to exempt plants which were near the end of their lifetime (i.e. operating no more than 20 000 hours between 2008 and 2015). Finally, it should be mentioned that the Directive envisaged a specific approach for multi-fuel-fired combustion plants operated in refineries, allowing the averaging of SO_2 emissions across plants in certain cases.

3.6.2. Effectiveness of the legislation

The European Commission's own assessment of the first phase of the IPPCD from 1999 to the mid-2000s emphasised the considerable delay in Member State transposition, leading it to open infringement cases against several EU-15 Member States (EC 2005, p.3). An evaluation of the second phase until the end of 2007 reached further conclusions, namely a generally weak implementation and even missing compliance in some instances, and criticised the 'low proportion of permits reflecting the implementation of BAT' (EC 2010, p.3f.). Of 61 individually investigated installations (from 12 different sectors, including refining), over 50 % had permit conditions significantly deviating from the BREF reference standard (*idem*, p.4). Consequently, 'without further emission reduction from IPPC installations, the positive health and environmental effects [..] will not materialize' (EC 2007, p.3).

A refining-specific assessment of the IPPCD's implementation can be found in the multi-sector study of Entec (2010a,b). However, due to the lack of a refining BREF prior to 2003 and the limited data available at the time (mostly from 2006), the study could not evaluate the full effects of the IPPCD (Entec 2010a, p.24ff). It concedes that significant progress toward lower emissions was achieved, but also that '80-90 % of the installations exceed the SO_2 and 60-70 % exceed the NO_X load bubble benchmarks', i.e. the amount of emissions per throughput suggested in the BREF document (Entec 2010a, p.54). However, it should be noted that at the time there was no single accepted benchmark value for these pollutants, since in the 2003 BREF (EC 2003, p. 398) there was no consensus on the range of values under the load bubble concept that could be associated to BAT benchmarks.

Furthermore, the study found that actual emission intensities in 2006 varied widely between Member States and individual installations, e.g. between Member States by two orders of magnitude for SO_2 and one order of magnitude for NO_X (Entec 2010a, p.53).[218] Entec's analysis suggests several explanations: first, in several Member States the Directive's main policy impact, i.e. the definition and granting of operating permits to refineries, only occurred in the years 2006 to 2008. As a reason for this it cites the lack of a refining BREF prior to 2003 and the sector-specific relatively long lead time for implementing new technical measures (e.g. need to wait for turnaround period).

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[217] The predecessor directive existed already since 1988, but only set individual limit values for 'new' plants (i.e. post July 1987). Directive 1999/30/EC did not set limit values for individual existing plants, only national ceilings.

[218] In contrast to these atmospheric emissions, effluent discharges to water had a significantly higher compliance rate with the BREF load bubble benchmarks, even though actual levels still varied strongly (Entec 2010a, p.54). However, it needs to be noted that the load values and their application were officially contested by industry, as noted in the 2003 BREF (EC 2003, p. 401).

Second, the observed varying emission levels are also described as being a consequence of the variation in the permit conditions set by the competent authorities (*idem*, p.53). Apparently, one reason for this variation is a lack of clearness in the BREF document - as epitomised by the often encountered split views on the best available techniques and their associated emission levels - as well as the overlap with other sectors' BREFs. For example, the latter point is particularly relevant for the third of European refineries with petrochemical integration. The resulting ambiguities have been 'used as a justification not to impose ELVs [Emission Limit Values] in line with the BAT-AELs by certain competent authorities' (*idem*, p.54).

Another issue is that the permit's comprehensive scope, given its coverage of emissions, waste, water, etc., often requires the involvement of different competent authorities, e.g. if industrial water pollution falls under the domain of a different authority to that of air pollutants. When, as observed, in some Member States 'little evidence was provided to indicate the effective coordination of different authorities', inconsistencies in permit conditions can arise (*idem*, p.31).

Assessment based on refinery data

Starting with sulphur emissions, Figure 3.6.1 suggests that emission regulation – whether triggered by the IPPCD, LCPD, or related legislation like the Air Quality Directive[219] or National Emission Ceilings[220] (NEC) Directives – was effective: the EU-28 average emission intensity of SO_2 (tonne of SO_2 per tonne of throughput per refinery) decreased by 44 % from 2004 to 2012.

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[219] Discussed in a separate chapter of this report.

[220] 'Directive 2001/81/EC of the European Parliament and the Council on National Emission Ceilings for certain pollutants (NEC Directive) sets upper limits for each Member State for the total emissions in 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia), but leaves it largely to the Member States to decide which measures – on top of Community legislation for specific source categories - to take in order to comply.' (http://ec.europa.eu/environment/air/pollutants/ceilings.htm)
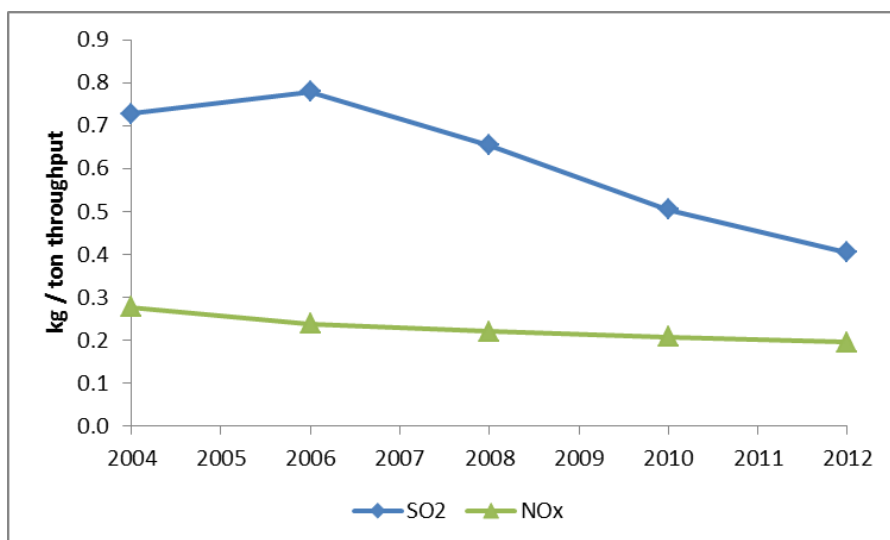
Figure 3.6.1: SO₂ and NOₓ emission intensity, averages for EU-28 countries (kg/tonne of throughput)
Source: Solomon Associates (2014).

As discussed below, this is linked to refineries' investments in units for removing sulphur from flue-gas, leading to a significant increase in the EU-28 overall capacity in such units.[221] In fact, the total sulphur recovery rate relative to all sulphur entering refineries was reported by Concawe to have risen from 39 % in 1998 to 45 % in 2006 and 55 % in 2010 (JRC 2013, p.132; Concawe 2010). Based on the Solomon Associates (2014) data, our own estimates suggest similar numbers, namely 43 % for 2000, going up to 48 % in 2006, 55 % in 2010 and 58 % in 2012.[222] In addition, according to Concawe, the share of total incoming sulphur that left refineries by means of SO₂ emissions was 7 % in 1998, going down to 4 % in 2006 and 2010 (JRC 2013, p.132; Concawe 2010). This is consistent with our own estimates based on Solomon Associates (2014), indicating 4 % in 2004 and 2006, 3 % in 2008, and 2 % in 2010 and 2012.[223]

The 29 % decline observed between 2004 and 2012 in refineries' NOₓ emission intensity (kg of NOₓ per tonne of throughput) – see Figure 3.6.1 – suggests that legislation was also a driver for NOₓ abatement.

The decline of sulphur emission intensities is also manifest at the regional level, as shown in Figure 3.6.2: in almost all regions the average refining emission intensities have become lower, especially in Iberia, south-eastern Europe, and France.[224] The figure also indicates the significant heterogeneity in emission intensities present at the regional level. Such differences can be expected due to regional differences in configuration and crude slate; our data does not allow us to assess whether different regional stringencies of permit conditions – as discussed in Entec (2010a) – may have also played a role.

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[221] See also the positive impact of regulation on SO₂ emissions in the Rotterdam refining area observed by Velders et al. (2011).

[222] The increase of the recovery rate is probably due more to the Fuel Quality Directive (FQD) than to the IPPCD.

[223] For our own estimates based on the Solomon Associates (2014) data the sulphur content of the non-crude inputs was taken to be the same as the sulphur content of the crude input, given the lack of more specific data.

[224] The Baltic and central Europe regions show an increase, but this is very likely due to a change in the refinery sample composition, as over time more and more refineries from EU-13 accession countries – with on average higher sulphur intensities than their EU-15 peers – participated in the Solomon study.
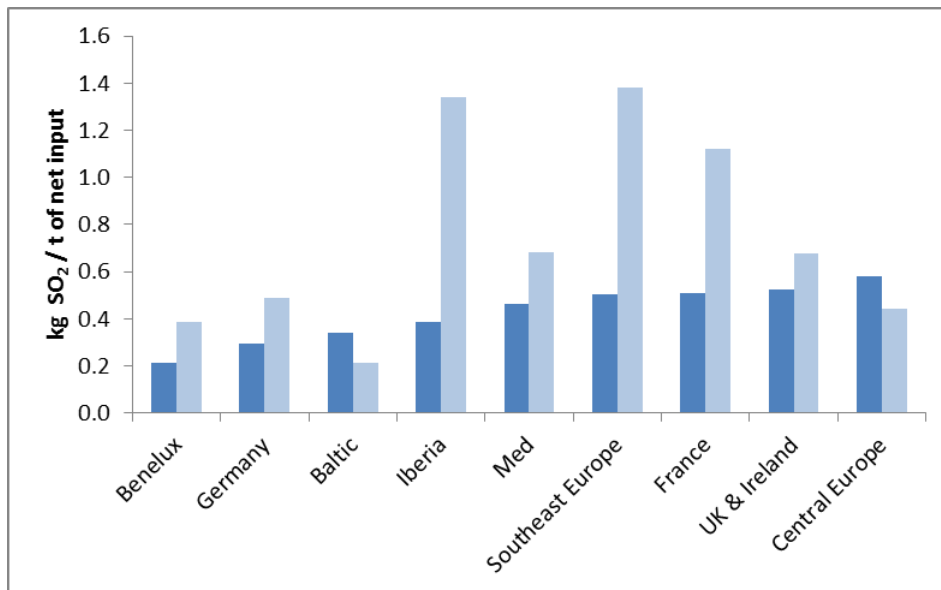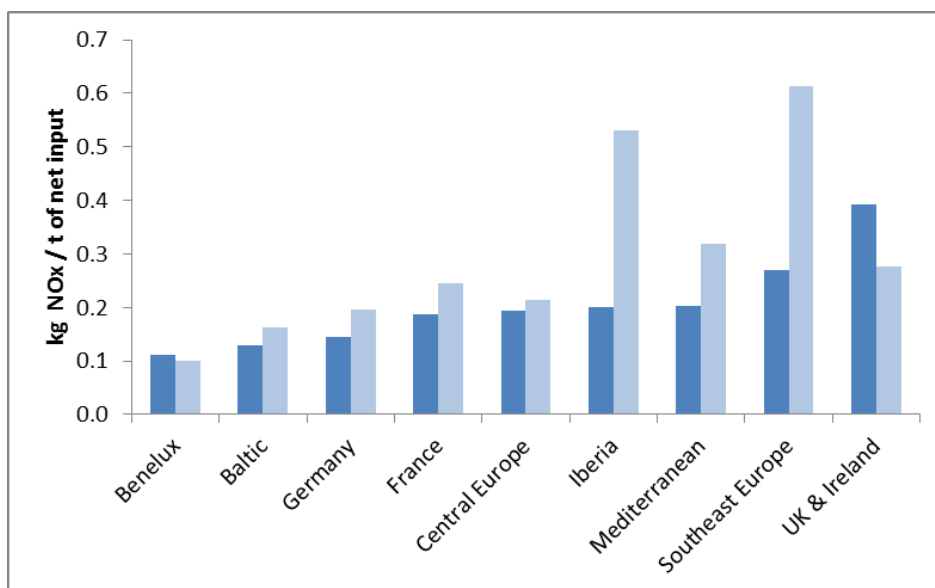
Figure 3.6.2: SO₂ emissions per net input in 2012 (dark), and 2004 (light)
Note: (i) 2004 is the earliest available data. (ii) Variable sample composition, especially in Southeast and Central Europe, as well as in the Baltic region.
Source: Solomon Associates (2014).

Figure 3.6.2 indicates for the regional averages in the year 2012 that SO₂ emission intensities are found to be significantly above the EU-28 average of 0.4 kg/tonne, in the central European region (0.6 kg/tonne), while the lowest value of 0.2 kg/tonne is observed in Benelux. The Benelux region does not display particularly high capital investments in overall emissions control (in fact, they are rather low as per Figure 3.6.6), but – perhaps because a high share of these overall investments targeted SO₂ – it still has a very high average sulphur recovery unit capacity and actual sulphur recovery rate. One possible driver of the low SO₂ emission intensity in Benelux could be the need for a relatively tighter regulation due to this region's coinciding high density of population and refineries (Amsterdam-Rotterdam-Antwerp 'ARA' – hub). Central Europe and the UK and Ireland are the regions with the highest SO₂ emission intensity, despite high investments (central Europe) and low-sulphur crude supply (UK and Ireland).

As can be seen in Figure 3.6.3, for NO$_x$ emission intensity (year 2012), Benelux also shows the lowest value, with 0.1 kg/tonne, while the UK and Ireland region has the highest with 0.4 kg/tonne, compared to an EU-28 average of 0.2 kg/tonne. Compared to the other regions, the UK and Ireland also shows a surprising increase in the emission intensity. Although the low value of the Benelux region will in part be the consequence of a significant effort made in this region, it should be noted that emission intensity is not indicative of regulatory compliance or non-compliance, since emission limit values are not formulated in kg/tonne of net input, but rather in concentration levels or kg of emissions over time.

Figure 3.6.3: NOₓ emissions per net input in 2012 (dark), and 2004 (light)
Note: (i) 2004 is the earliest available data. (ii) Variable sample composition, especially in Southeast and Central Europe, as well as in the Baltic region.
Source: Solomon Associates (2014).

The EU-27 refineries' SO_2 and NO_X emissions have also fallen in absolute terms, as shown in Figure 3.6.4 based on data from the European Pollutant Release and Transfer Register (E-PRTR). However, the fall by 45 % (539 kt in 2007 to 299 kt in 2012) for SO_2/SO_X and by 28 % (from 184 kt in 2007 to 132 kt in 2012) for NO_X not only reflects industry's abatement effort, but also the fact that the number of facilities fell by 13 % (from 109 to 95) for SO_2/SO_X and 12 % (114 to 100) for NO_X.[225]

3.6.3. Impact on the EU refining sector

Evidently, the *primary* impact channel of this type of legislation on the refining sector is the direct one, because it affects the way in which a refinery is operated.[226] However, since the IPPCD did not specify EU-wide obligatory emission limits, its impact on EU refineries to some extent depended on how the competent authorities applied IPPC Article 9(4), used the BREF, and took into account local circumstances for determining the actual permit conditions.

For existing installations, Member States had, until the end of 2007, the possibility to choose the emission limit values (except in the case of significant plant upgrades), given the deadlines for implementation of the Directives (30 October 2007 in the case of the IPPCD and 1 January 2008 in the case of the LCPD). Given, however, that in most countries some form of national regulation for industrial pollution most likely already existed prior to the IPPC and LCP Directives, it is evident that a rigorous attribution of economic impacts to individual EU directives on emission regulation,

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[225] Figures do not include accidental releases, which for SO_2 increased from 182 tons in 2007 to 881 tons in 2012, and for NO_X decreased from 87.5 tons in 2007 to 27.8 tons in 2012 (source: E-PRTR).

[226] The following analysis subsumes the impacts of the Air Quality Directive (AQD), see Chapter 10.

including also the National Emission Ceilings (NEC) or Air Quality Directive (AQD) is not feasible.[227] As a consequence, we adopt a pragmatic approach and have used existing studies and industry data on the economic impact of overall emission and effluent regulation on refineries.
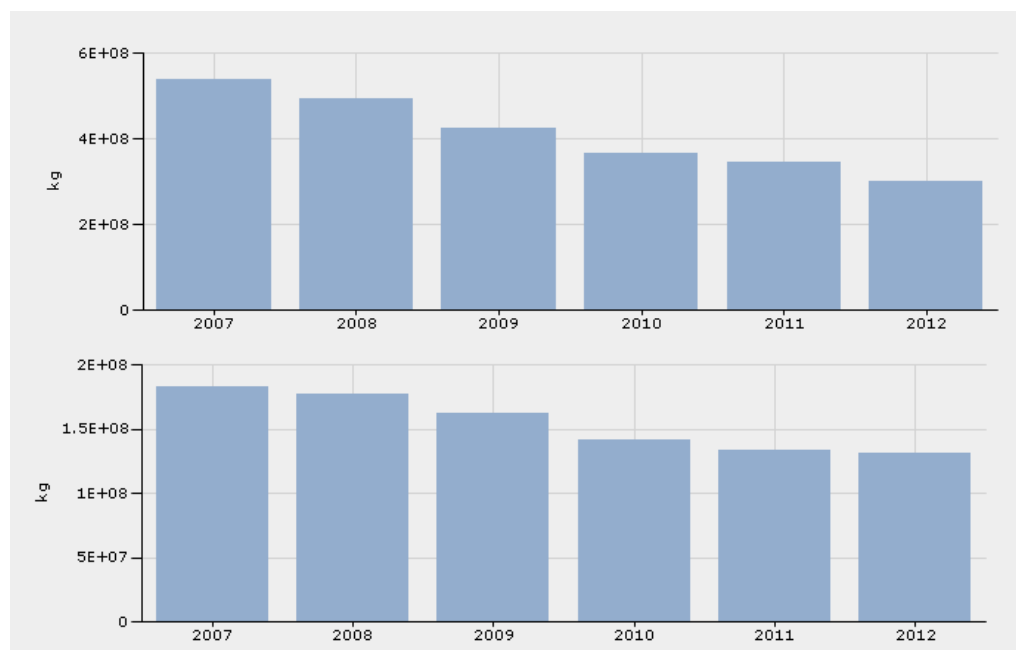
Figure 3.6.4: EU-27 total emissions from mineral oil and gas refineries of SO₂ (top, number of facilities fell from 109 in year 2007 to 95 in 2012) and NOₓ (bottom, facilities decreased from 114 to 100) *Source: European Pollutant Release and Transfer Register database (E-PRTR).*

An important *secondary* impact of EU pollution legislation–to be discussed further below–occurred indirectly by reducing the demand for inland heavy fuel oil.

Available studies on observed cost impact

Only a very few ex post studies of refineries' costs associated with pollution control are available. One study from 2009 commissioned by the Spanish ministry of environment (INERCO 2009) surveyed industry's costs associated with the Spanish implementation of the IPPCD (national law 16/2002). Eight of ten Spanish petroleum refineries participated, and the results show that, among the roughly 30 included sectors, refineries experienced the highest cost impact, with an average cost as high as EUR 108 million per installation. However, these costs are cumulative and include total investment as well as additional operational costs, over varying time periods that may exceed 10 years. Hence, it is not possible to derive annualised or 'per barrel' figures for a proper appraisal of this cost figure.

Another study of the French refining sector cites a cost of EUR 1-2 per tonne of crude intake for emission control in French refineries (Legrand et al., 2012, p.45), which would correspond to around EUR 10 million/year for an average French refinery, but it is not clear whether this refers to current or future legislation.

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[227] Since the IPPC Directive is the only one to regulate effluents, it would theoretically be possible to uniquely attribute all refinery costs related to this issue. However, we do not have specific refinery cost data.

A study of the Greek refining sector (Danchev and Maniatis, 2014) qualitatively discusses the impact of the entry into force of the IED in 2013, citing compliance costs estimated earlier by the industry association Europia (*idem*, p.45). Similarly, a study of the Italian refining sector (IHS 2014a) computes future costs to be incurred by refineries due to the IED for the time period 2013 to 2030 (*idem*, p.116ff), building on a similar analysis done earlier for the UK refining sector (IHS 2013).

Technically speaking, investments in pollution control are typically directed at refinery emissions of SO_2, NO_X, and particulate matter (dust), as well as at waste water treatment (e.g. IHS 2013, p.154). A short review of the abatement options and their estimated costs can be found in AMEC (2011, p.E1), as well as in the latest refinery BREF (JRC 2015).

Analysis of industry data

Combustion for energy generation, cracking, and desulphurisation are important refinery processes responsible for the largest share of air pollutant emissions, with the most important physical outlets being flue-gas from combustion units, the fluid catalytic cracker unit (FCC), the sulphur recovery unit (SRU) and flares. End-of-pipe abatement can be achieved by, inter alia, installing scrubbers, electrostatic precipitators and selective catalytic (or non-catalytic) reduction (SCR, SNCR). Primary air emissions abatement techniques can also be applied, e.g. switching to low-sulphur fuels, in particular gaseous fuels or low-sulphur fuel oil.

The latter, a move toward a cleaner fuel mix over the years 2000-2012, is visible in Figure 3.6.5, which shows an increase in the share of gaseous fuels from 54 % to 64 % and a corresponding decline of the share of liquid fuels, mainly heavy fuel oil, from 24 % to 11 % (measured in caloric terms). In line with this observation, the refinery survey (Concawe 2014) indicates an increasing number of refineries reporting additional operational expenditures related to 'use of gas to replace liquid fuel', which rose from 42 % of all responding refineries in the year 2000 to 77 % in 2012.
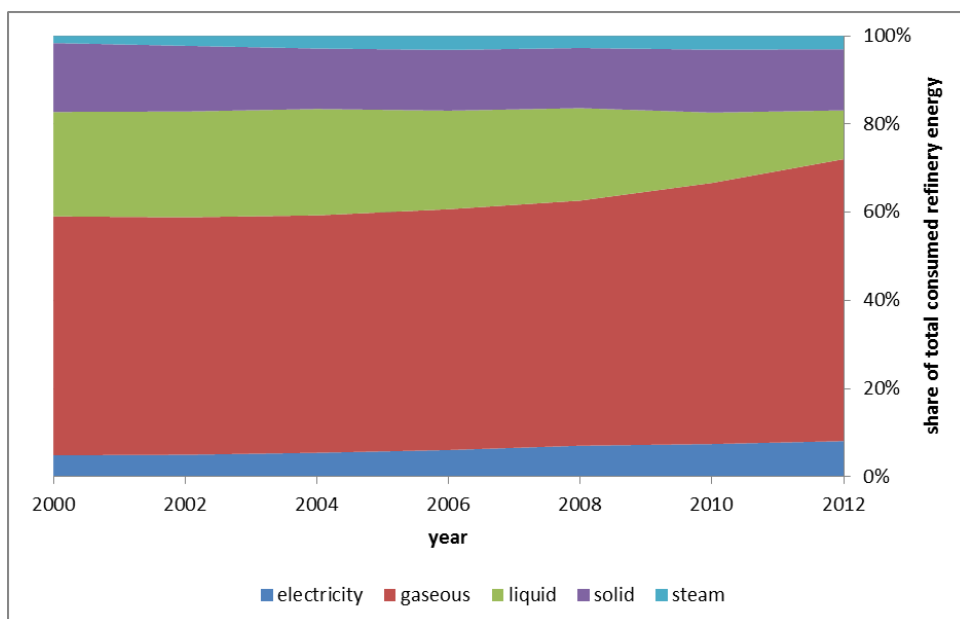
Figure 3.6.5: Sources of net energy consumption of an average EU-28 refinery, by caloric shares
Note that the categories 'electricity' and 'steam' refer to externally purchased energy.
Data source: Solomon Associates (2014).

With the available data it is not possible to quantify the economic costs of this switch toward cleaner fuels (e.g. costs of boiler conversion and fuel cost differentials), and even less so to quantify the relative share that could be attributed to emission regulation. Among others, one reason for this is that the increased use of gaseous fuels also contributes to CO_2 abatement and possibly to energy efficiency improvements. Moreover, given the historically high crude oil prices observed since the mid-2000s, switching from oil to natural gas might have been economically beneficial in terms of operating costs.[228] In fact, according to the refinery data from Solomon Associates (2014), energy from gaseous fuels (consisting overwhelmingly of natural gas) had, on average, the lowest cost per Gigajoule of energy of all the types of refining energy considered, from 2000 to 2012.

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[228] See, e.g. the oil vs natural gas price comparison on page 45 of a 2014 industry presentation (http://www.sec.gov/Archives/edgar/data/1035002/000119312514084525/d685822dex9901.htm) or as part of this analysis: http://www.aerius-holding.com/language/en/2014/06/natural-gas/. Both suggest that at least since 2010 natural gas had – measured in calorific terms – a price discount between 40 % and 60 % vis-à-vis Brent crude oil. The price of fuel oil would typically be 60 % to 80 % of the crude oil price.
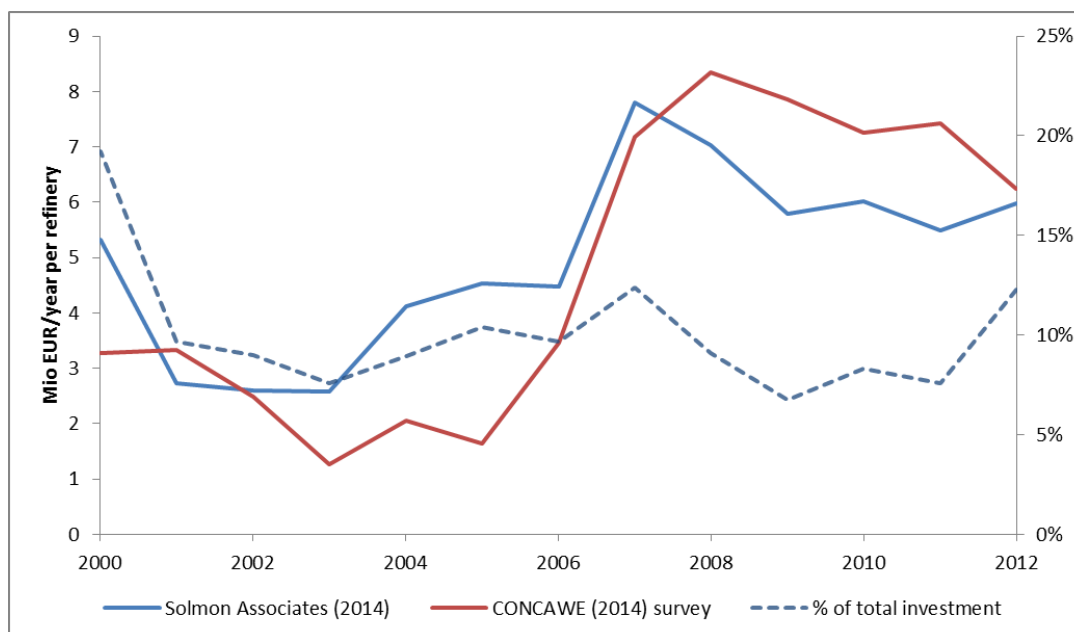
Figure 3.6.6: Yearly capital investments per refinery associated with emission and effluent regulation (atmospheric emissions, waste water treatment, processing of solid and hazardous wastes)
Data source: Solomon Associates (2014).

In terms of capital expenditures, Figure 3.6.6 shows the yearly investments (per refinery) related to emission and effluent regulation, with an overall average of EUR 5 million per refinery and per year from 2000 to 2012, with a significant difference between the 2000-2006 period (average EUR 3.8 million per refinery) and the 2007-2012 period (average EUR 6.4 million per refinery).[229] In addition to the Solomon Associates (2014) data, these capital costs were also reported in the Concawe (2014) survey, as shown in the figure.[230] Although the two sources are in agreement with regard to the average yearly investment figure of EUR 5 million, they differ in terms of the annual trends: the former shows an average increase of EUR 0.28 million per year[231], while the latter shows an average increase of refiners' capital costs of EUR 0.52 million per year, due to the inclusion of large investments in the Repsol Cartagena refinery (see Box 6.1 below).

Based on visual inspection, both datasets are consistent with a shift towards a higher level of capital expenditures in the second half of the time period. In particular, both have their highest values in and after 2007, possibly linked to the fact that 2008 was the year in which the LCP regulation started to cover plants of all ages and thus might have prompted investments in required additional equipment in many EU countries. The observed timing is also consistent with

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[229] Includes all investments related to environmental pollution abatement such as waste water treatment and atmospheric emissions, as well as those related to the processing of solid and hazardous wastes.

[230] The coverage of the two sources is generally quite similar, but Concawe (2014) included data for the Spanish Cartagena refinery of Repsol, with very large pollution-related investments of EUR 655 million during the years 2008-11, which was not included in Solomon Associates (2014). This leads to a significant divergence during these years. For example, without Cartagena the annual average increase would be EUR 0.34 million instead of EUR 0.52 million.

[231] Based on the slope of a linear best-fit. Taking the EU-15 Solomon Associates (2014) data only, so as to take account of the potential bias in the EU-13 data due to regulatory catch-up during accession and pre-accession, the trend increases somewhat to EUR 0.32 million/yr.

the fact that October 2007 was the final deadline for IPPC implementation.[232] Overall, this suggests that regulation was a driver for the high values observed in the 2007/08 period.

Uneven investment levels are also observed across complexity groups, with Solomon Associates (2014) yielding average yearly investments of EUR 2.4 million, EUR 4.8 million, EUR 4.2 million, EUR 6.6 million, and EUR 8.3 million for the five groups, going from the simplest (HST) to the most complex (GOC D). Hence, there is a clear trend showing that average capital expenditures for emission and effluent control can be explained to some extent by average complexity: a transition to a higher complexity group on average implies EUR 1.4 million of additional yearly capital costs, or EUR 1.0 million per unit of the Solomon Index for Refinery Complexity.[233,234]

The fact that refineries with more units and more complex processes have higher pollutant volumes and hence higher average capital expenditures for pollution control is not surprising. This suggests that some part of the observed growing trend in annual capital expenditures for emission and effluent control (EUR 0.28 million per year for the Solomon Associates (2014) data) is directly linked to the increase of the average EU-28 refinery complexity[235] from 7.5 to 9. This increase will itself in part be driven by environmental regulation (e.g. when conversion capacity is increased to reduce the output of fuel oil which is more difficult to sell due to pollution regulation) and in part by market forces (increasing demand for road diesel, or for products used by the petrochemical industry). The shut-down of refineries, which disproportionally affected refineries of below-average complexity, also contributes to the observed increase.

Overall, the simple regression analysis from above suggests that the complexity increase of 1.5 units implies a total increase in capital expenditures of EUR 1.5 million – or EUR 0.12 million per year – and hence explains 43 % of the observed trend shown by the Solomon Associates (2014) data (or 23 % with regard to the Concawe (2014) data).[236] An analysis of the capital expenditures for pollution control separately for each complexity group shows a significant trend only for the group of the highest complexity (GOC D), with an average increase of EUR 0.76 million per year, and resulting capital expenditures of EUR 10 million per year per refinery during the most recent years of the 2000-2012 period (Concawe 2014[237]).The interlinkage between rising complexity and

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[232] 'The implementation of the IPPC Directive in the mineral oil and gas refineries sector started relatively late and, based on the installations assessed, significant progress in the permitting process in some Member States was only made in the period from 2006 to 2008' (Entec 2010a, p.52). The 'late start' may be explained by fact that the REF BREF (EC 2003) was only adopted by the Commission in 2003, and that substantial plant modernisation can only occur during the turnaround shut-downs scheduled every couple of years.

[233] Concawe (2014) data yields EUR 2.5 m, EUR 2.5 m, EUR 3.3 m, EUR 6.7 m, and EUR 5.3 m for the five groups, implying a somewhat lower value of EUR 1 million of additional investment costs for each step upwards in complexity. The large Cartagena investment was excluded here due to its dominating size and because of the unusual jump by four complexity categories.

[234] Average investments also correlate with size, i.e. name plate capacity, but more weakly than with complexity.

[235] Solomon Index for Refinery Complexity.

[236] Perhaps unexpectedly, higher complexity does not necessarily imply higher emission intensities: e.g., the Baltic region and Germany show comparatively low SO_2 and NO_x emission intensities, while at the same time having complexities above the EU average (see also Entec (2010a, p.29)). Interestingly, for SO_2 the data suggests an inverted U-shaped relationship between complexity and emission intensity, with values of 0.21, 0.37, 0.61, 0.42, and 0.37 k/tonne for the refinery complexity groups in ascending order. The likely reason for this observation is that fluid catalytic crackers – which constitute a major source of SO_2 emissions – tend to have relatively more important roles in refineries of intermediate complexity. See also JRC (2013, p.138).

[237] Concawe (2014) data without the Cartagena refinery, due to its singular character in terms of investment and expansion, and in order to stay consistent with Solomon Associates (2014) data.

associated higher environmental capital expenditures is also illustrated by the case of the Cartagena refinery expansion, discussed in Box 6.1.

Box 6.1: The expansion of the Repsol refinery in Cartagena. Over the years 2008-2011 Repsol invested EUR 3.15 billion in upgrading its Cartagena refinery, reportedly the largest ever industrial investment in Spain. By doubling its crude oil capacity and installing a hydrocracker and a coker, the refinery's complexity rose from the lowest ('HST') to the highest ('GOC D') category. The expansion also came with a particularly high investment of EUR 655 million in emission and effluent control–the largest within the Concawe (2014) data sample–and representing 21 % of the total investment. With the permission of Repsol, the following detailed numbers can be given for this project:

Capacity expansion

- Waste water treatment and management: EUR 36 million
- Precipitation/Neutralisation: EUR 23 million
- Control of fugitive emissions: EUR 3 million

Coker installation

- Waste water treatment and management: EUR 30 million
- Control of fugitive emissions: EUR 19 million

Other

- Waste water treatment and management: EUR 92 million
- Control of fugitive emissions: EUR 153 million
- Sulphur recovery units (60 000 bbl/day) + Amine treating: EUR 239 million
- Low-NO_X burners: EUR 12 million
- Flares: EUR 48 million

Sources: Repsol, http://www.ogj.com/articles/2012/04/repsol-opens-cartagena-refinery-expansion.html

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Finally, the Solomon Associates (2014) data shows that investments related to pollution control accounted for about 10 % of total annual investments (scale on the right-hand side of Figure 3.6.6, with no discernible trend over the 2000-2012 time horizon. Even in the peak year (2007), when environmental expenditures were particularly high (likely due to the final deadline for IPPC permit applications and for the LCPD), they represented just 12 % of overall investments. Hence, on average all types of refinery investment have experienced similar increases to those related to emission and effluent regulation, making at least a partial dependence on the general business cycle also quite plausible.

Impact on refining costs

To assess the impact of investments related to emission and effluent control on refineries' economic performance, we consider as a first indicator the observed investment costs relative to total throughput (processed crude and other feedstocks). For the EU-28 average from 2000 to 2012, one obtains EUR 0.09/bbl, with a maximum of EUR 0.12/bbl reached in 2008 (2007 would most probably be slightly higher, but total throughput is not available for that year).

As these only represent the investment costs, the implied additional operating costs must still be included. Unfortunately, the Solomon Associates (2014) data does not encompass the specific operating costs associated with these investments. To derive an estimate, we therefore use the rule-of-thumb that the annual operating costs of the 'average' pollution control device amount to 6.3 % of its capital costs. This value is taken from a (forward-looking) assessment of the IED compliance costs for UK refineries by the industry consultant IHS, where GBP 900 million of investments were estimated to imply GBP 57 million of annual OpEx (IHS 2013, p.155), or 6.3 %.[238] The same—or very similar—value was later also used for estimating the IED-related operating costs of Italian refineries (IHS 2014a, p.117). Under the assumption that each year's investments became operational on 1 July, and that their lifetime extends to at least 2012, the implied incremental annual operating costs per refinery amount to EUR 0.17 million in 2000 and EUR 3.9 million in 2012.[239]

As a caveat, it should be mentioned that not all of these costs are necessarily additional. For example, when more advanced pieces of equipment replace older ones, the total operational cost may be unaffected or increase only slightly, or—in the case of more energy-efficient equipment— may even decrease. As unit-specific data on operational costs is not available, we cannot explore this argument further. For simplicity, we compute the operational cost impact on the barrel of total throughput by assuming full additionality, yielding EUR 0.03/bbl as the overall (undiscounted) average and a maximum of EUR 0.06/bbl in 2012. It should also be noted that the operational costs related to these investments will extend beyond this study's cut-off year, 2012, a fact that is not reflected in the above numbers.

For convenience, the combined results for capital and implied operational costs related to emission and effluent regulation (as noted before, without the costs of switching to cleaner fuels) are summarised in Table 3.6.1. Overall, the numbers suggests an average economic impact of EUR 0.13/bbl of throughput, representing a share of about 3 % of total operating costs. For 2000-2006 the figures are EUR 0.09/bbl and 2.9 %, and for the period 2007-2012 EUR 0.16/bbl and 3.1 %, respectively.

A comparison with estimated historical EU cracking margins leads to the same view. According to BP (2014), the average 2000 to 2012 north-western Europe cracking margin was USD 4/bbl (and USD 4.8/bbl from 2007 to 2012), while IEA (2014) gives estimates (which exclude non-energy OpEx) for various EU refining centres, with a resulting average margin range between USD 5.2/bbl (Brent North-West Europe) and USD 6.9/bbl (Urals Mediterranean) for the years 2007 to 2012 (earlier data not available). The economic impact is more severe when comparing the costs to EU hydroskimming margins, which according to IEA (2014), during 2007 to 2012 had an average value between USD -0.85/bbl (Urals Mediterranean) and USD 1.24/bbl (Es Sider Mediterranean).

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[238] For specific techniques, values range from 4.7 % (low-NO_x burners on heaters and boilers) to 8.3 % (recovery of SO_x from FCC sour water stripper off-gas); a few items have only CapEx or only OpEx (IHS 2013, p.155).

[239] In 2000 CapEx was EUR 5.3 m, which-with 6.3 %-implies annual OpEx of EUR 0.33 m in all of the following years, except in 2000 itself, where it is counted half-or EUR 0.17 m-since the investment is assumed to become operational on 1 July of the year in which it is made. In 2001 we have the full EUR 0.33 m from the year 2000 investments, plus 0.5 x 6.3 % x EUR 2.7 m, which gives a total of EUR 0.4 m. In 2002 we have EUR 0.33 m from 2000 and the full 6.3 % of EUR 2.7 m from 2001, plus the 0.5 x 6.3 % x EUR 2.6 m. In 2012 we get 6.3 % of the cumulative investments up to 2011, plus 0.5 x 6.3 % x EUR 6.0 m.

**Table 3.6.1: Overview of refineries' expenditures related to emission and effluent regulation**

Note: Numbers represent averages across all EU-28 refineries for which data was obtained. The annual average capital expenditures obtained from Concawe (2014) are reported in brackets. Operational costs are estimated by assuming them to be 6.3 % of capital costs per year. A factor of 7.33 was used to convert tons into barrels of processed input.
Sources: Solomon Associates (2014) and own calculations. Total CapEx (used to compute column 3), total refinery throughput (used for columns 4 and 7), and total refinery OpEx (used to compute column 6) are reported in Solomon Associates (2014). Column 5 is estimated as explained above.

Year	Emission & Effluent CapEx, Ø [€ m]	..relative to total CapEx	CapEx per barrel of processed input [€/bbl]	Implied OpEx [€ m]	..relative to total OpEx	OpEx per barrel of processed input [€/bbl]
2000	5.3 [3.3]	19 %	0.09	0.2	0.1 %	0.00
2001	2.7 [3.3]	10 %		0.4		
2002	2.6 [2.5]	9 %	0.05	0.6	0.4 %	0.01
2003	2.6 [1.3]	8 %		0.8		
2004	4.1 [2.1]	9 %	0.07	1.0	0.6 %	0.02
2005	4.5 [1.6]	10 %		1.2		
2006	4.5 [3.5]	10 %	0.08	1.5	0.7 %	0.03
2007	7.8 [7.2]	12 %		1.9		
2008	7.0 [8.4]	9 %	0.12	2.4	0.8 %	0.04
2009	5.8 [7.9]	7 %		2.8		
2010	6.0 [7.3]	8 %	0.10	3.1	1.1 %	0.05
2011	5.5 [7.4]	8 %		3.5		
2012	6.0 [6.2]	12 %	0.10	3.9	1.1 %	0.06
cumulative	64.5 [61.8]			23.2		
average	5.0 [4.8]	10 %	0.09	1.8	0.8 %	0.03

Cost impacts on refining in different EU regions

An important caveat of the above analysis is its focus on the *average* EU-28 refinery, while actually the data on EU refineries displays significant heterogeneity across regions. For instance, while the associated capital costs of the average EU refinery over 2000-2012 were EUR 5.0 million per year, at the regional level the numbers range from EUR 3.7 million/year in the Baltic region to EUR 9.1 million/year in Germany. As discussed before, this is explained to some extent by differences between regions in complexity (in fact, Germany has the highest average complexity) and also capacity. In addition, variations in the local crude diet–e.g. only 0.4 % average sulphur content in the UK and Ireland vs 1.3 % in Iberia–imply that similar limits on SO_2 emissions can require different levels of effort.

As a consequence, comparing the impact on costs across EU regions is not straightforward. One possibility of an indicative ranking is to adopt the concept of 'equivalent distillation capacity', which is defined as the product of capacity and complexity, and compute the average capital expenditure per barrel of such a complexity-weighted refining capacity. The result is shown in Figure 3.6.7.
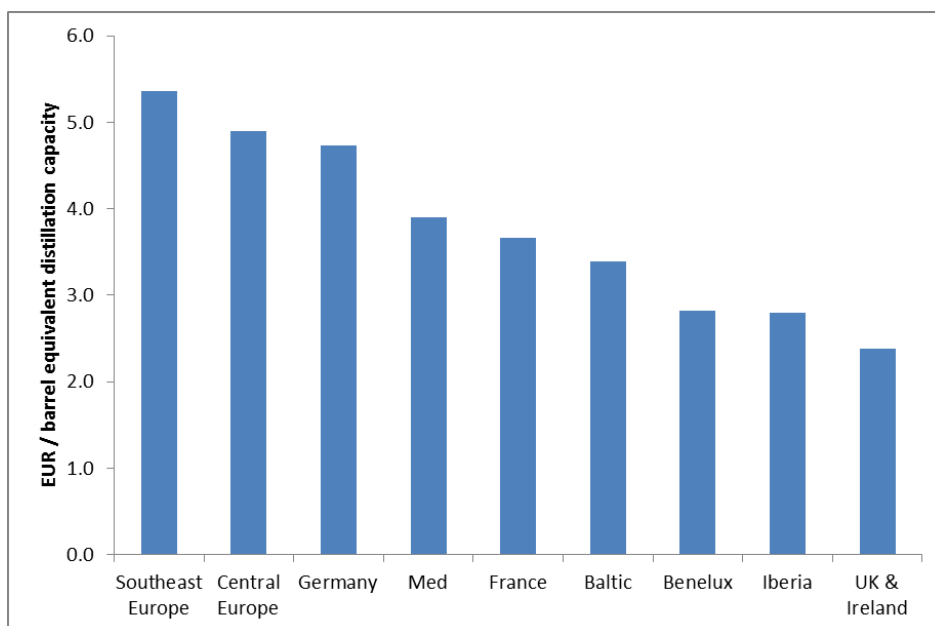
Figure 3.6.7: Capital expenditures related to pollution regulation per barrel of equivalent distillation capacity (= capacity times complexity), average annual figures for 2000-2012
Data source: Solomon Associates (2014).

The graph shows that the two regions with the highest investments in pollution control were south-eastern and central Europe. This was not obvious before because the small average size of refineries in these regions to some extent masks the actual significance of the reported investment figures. However, this finding might be partially explained by these countries' need to catch up with EU regulation during the accession and pre-accession phase.

The UK and Ireland shows a relatively low investment level, compared to regions of similar complexity as well as similar capacity. As already mentioned, to some extent this is explained by the fact that the crude supply of this region has an exceptionally low sulphur content compared to the other EU regions, which–ceteris paribus–reduces the need to invest in SO_2 abatement. However, in 2012 the UK and Ireland region actually had the second highest sulphur emission intensity in terms of SO_2 per tonne of net input (Solomon Associates 2014) of all EU regions (see also Figure 3.6.2), reiterating the findings of the latest refining BREF that

'refineries with similar sulphur content in the treated crude oil can have very high differences in specific emissions, and many sites achieving very high specific emissions are actually those treating the most favourable crudes' (JRC 2013, p.138).[240]

Moreover, the low-sulphur crude argument only holds with regard to SO_2 abatement expenditures (representing around 40 % of all pollution abatement projects, as indicated by the Concawe (2014) data) and does not affect the need to invest in NO_x, dust, or water pollution abatement.

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[240] As already mentioned, it needs to be pointed out that emissions intensity is not indicative of refineries' regulatory compliance or non-compliance, since emission limit values are not formulated in kg/tonne of net input, but rather, for example, in concentration levels or kg of emissions over time.

Sulphur dioxide abatement

The combustion of refinery fuel (e.g. high-sulphur residual fuel oil) associated with energy generation constitutes the most important source of SO_2 emissions from refineries. Flue-gas from sulphur recovery units constitute another, albeit lesser, source (JRC 2013, p.28). These units process H_2S generated during hydrodesulphurisation. Although hydrodesulphurisation is also required for purely technical reasons (e.g. protection of catalysts in catalytic reforming), this process is mostly driven by product-related legislation, i.e. it is employed to remove sulphur from refinery products (see the Fuel Quality Directive section). The legislation considered here on refinery pollution affects the next step, i.e. the handling of the resulting H_2S.

Without restrictions on SO_2 emissions, H_2S could be oxidised to SO_2 and released into the atmosphere. Instead, it is generally collected and transferred into a sulphur recovery unit. Based on the so-called Claus process, it is then transformed into elemental sulphur and water. Unconverted H_2S and SO_2 can be further processed by means of a tail gas treatment unit and incinerator to reduce the remaining SO_2 and H_2S to the lowest possible levels.

Figure 3.6.8 lists various SO_2 abatement options and the share of refineries which reported related capital and/or operational expenditures in the refining survey conducted by Concawe. The total time horizon is split in two: 2000 to 2006, which was less affected by the SO_2 regulation considered here, and 2007 to 2012. As can be seen, lowering the sulphur content of inputs (feedstock and energy inputs) was the most important strategy for refiners for reducing SO_2 emissions. There is an increase in SO_2 abatement activities in the second period, most notably in the form of increased usage of SO_2-reducing additives to the FCC catalyst and low-sulphur feedstock, as well as fuel (oil to gas) switching.

In the refinery data from Solomon Associates (2014), the increasing restriction on sulphur emissions is reflected in the expansion of sulphur recovery units and additional tail gas treatment. At an EU-wide average level, this expansion was between 30 % and 40 % per refinery over 2000-2012, with a markedly greater increase observed in the EU-13 accession countries (this might explain the observed high investment costs of these regions). Iberia shows the largest expansion in absolute terms, south-eastern Europe the highest expansion rate over recent years, while in Benelux as well as in the UK and Ireland the average sulphur recovery capacity per refinery has roughly remained constant.
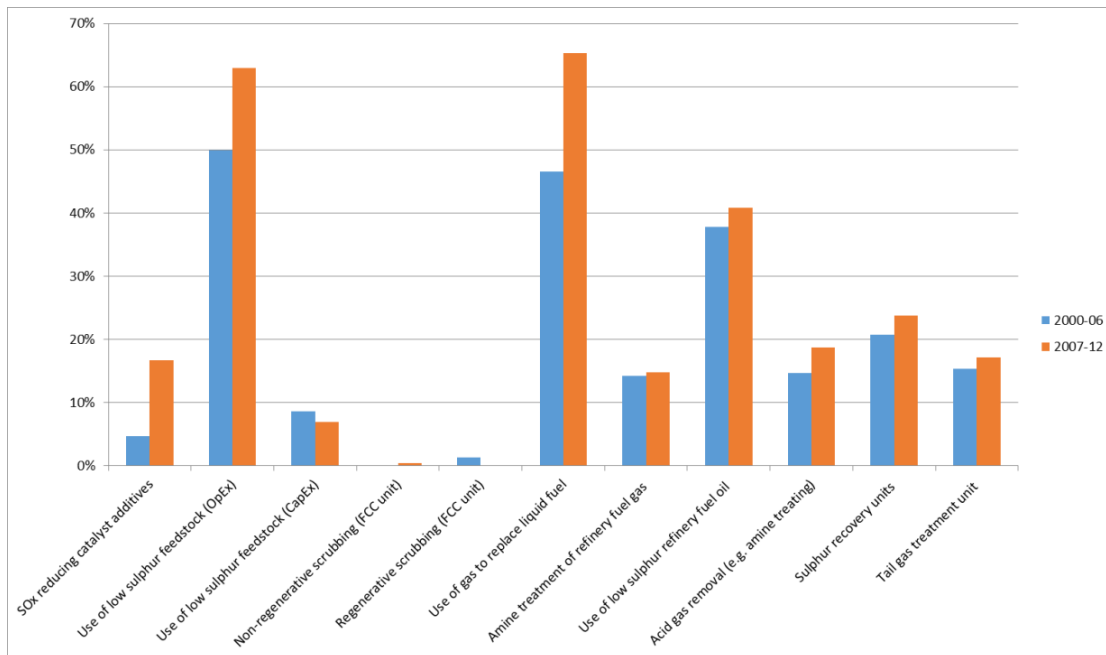
Figure 3.6.8: SO₂ abatement measures incurring annual CapEx and/or OpEx in EU refineries

Note: Shown is the percentage of responding refineries who reported costs in the given category (i.e. sum of all 'yes' divided by sum of all 'yes' and all 'no', excluding responses 'not applicable' or 'data not available'). Figures are yearly averages, i.e. a value of 50 % for 2000-2006 indicates that on average in each of these seven years 50 % of refineries had a related cost entry.
Source: Concawe (2014).

Time-wise, most of the associated sulphur recovery capacity expansion–about two thirds–occurred after 2008, i.e. when the LCPD became applicable to installations of all ages and right after the IPPC permit deadline in October 2007. This is clearly visible in the data for Germany and the Mediterranean region, where sulphur recovery capacity was nearly constant from 2000 to 2008 and then increased by 20 % between 2008 and 2010.

Comparing, as done in Figure 3.6.9, the 2012 sulphur recovery capacities across regions shows that – in absolute terms – the highest levels are found in Benelux, Germany, Iberia, and the Mediterranean, while the UK and Ireland and south-eastern Europe have the lowest recovery capacities. However, when taking into account refineries' size and crude oil sulphur content, the overall picture becomes more homogenous, with all regions covering more than 100 % of their crude oil related sulphur intake, and the UK and Ireland and south-eastern Europe actually emerging as the two regions with the highest relative recovery capacity. For the UK and Ireland this is explained by its exceptionally low-sulphur crude oil supply, for south-eastern Europe by its small average size of refineries.
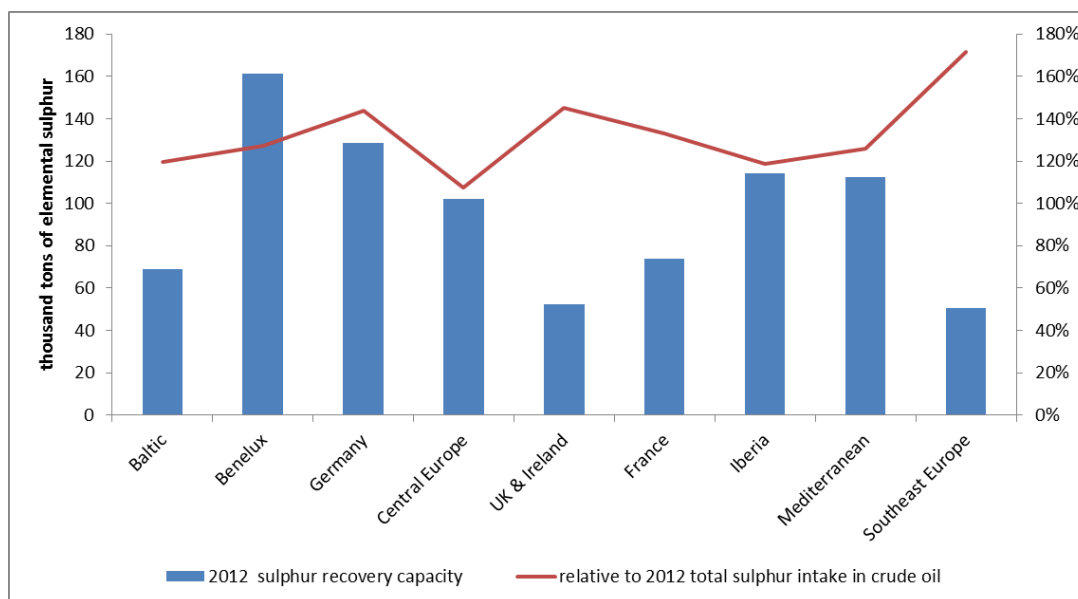
Figure 3.6.9: Average regional sulphur recovery capacity (total S product), shown in absolute terms and relative to the total sulphur intake from crude oil input (=total crude oil processed times its average sulphur content)

Note: capacities do not include tail gas treatment units, because for four EU regions this data was unavailable. In those regions where data was available these capacities typically account for around 5 % of total sulphur recovery capacity. Data source: Solomon Associates (2014).

Nitrogen oxide (NO_X) abatement

Nitrogen oxides constitute another important pollutant which is regulated both by the IPPC and the LCP Directives. Refineries generate NO_x emissions mainly by means of combustion processes. Along with sulphur, nitrogen is a natural component of crude oil and natural gas, which is released during combustion. However, the main source is the nitrogen that is contained in the combustion air itself (JRC 2013, p.28). Major points of emission include furnace and boiler stacks, the flare system, and fluid catalytic crackers (*idem*, p.27). Available abatement options consist of, *inter alia*, low-NO_x burners and selective catalytic and non-catalytic reduction (AMEC 2011, p. E2; JRC 2013).
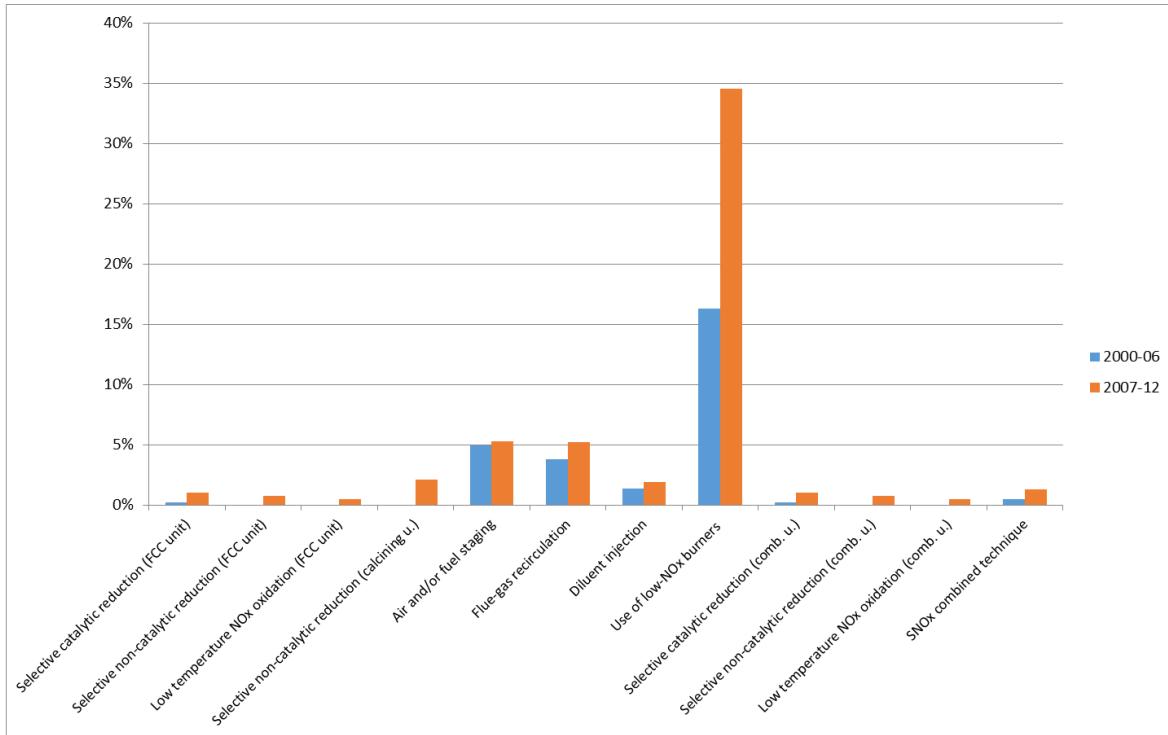
Figure 3.6.10: NOₓ abatement measures incurring annual CapEx and/or OpEx in EU refineries

Note: Shown is the percentage of responding refineries who reported costs in the given category (i.e. sum of all 'yes' divided by sum of all 'no', excluding responses 'not applicable' or 'data not available'). Figures are yearly averages, i.e. a value of 5 % for 2000-2006 indicates that on average in each of these seven years 5 % of refineries had a related cost entry.
*Source: Concawe (2014).*

Our data does not encompass the specific costs incurred by NOₓ abatement measures. However, there is strong evidence in the data that such measures were implemented. First, Figure 3.6.10 depicts refineries' reports on costly NOₓ abatement measures from the Concawe survey. It shows that the use of low-NOₓ burners was the dominant abatement strategy, and was applied by 35 % of all responding refineries in each year during 2007-2012, up from just over 15 % before that. Second, the data from Solomon Associates (2014) shows that average EU-28 refinery's specific NOₓ emissions fell by 30 % between 2004 (earliest available data) and 2012, from 0.28 kg per tonne of input to 0.20 kg. However, for the associated costs we have to revert to the figures given for overall investments in emission and effluent control, as discussed above.[241]

Other pollutants: Carbon monoxide, dust, volatile organic compounds

The Concawe survey also includes data on abatement measures directed at the reduction of carbon monoxide (CO), particulate matter (dust), and volatile organic compounds (VOCs). Figure 3.6.11 depicts the percentage shares of refineries which reported related capital or operational costs.

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[241] Table 4.49 in JRC (2013) lists some cost examples for retrofitting with low- and ultra-low-NOₓ burners.
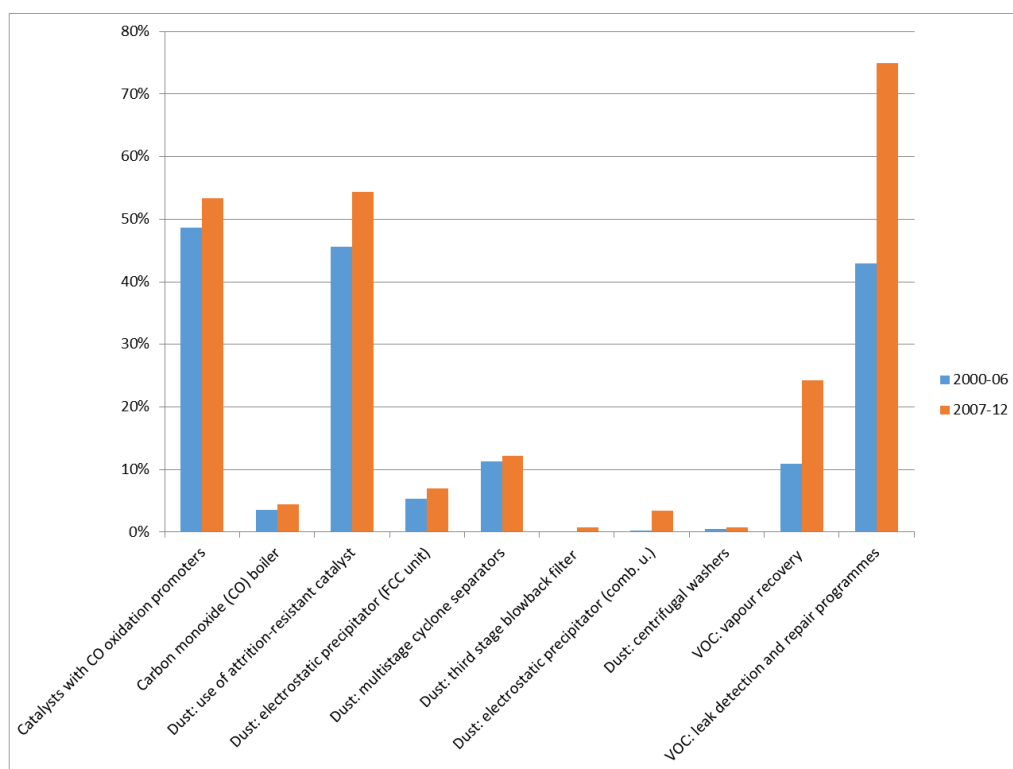
Figure 3.6.11: Abatement measures directed at CO, dust, or VOCs which incurred annual CapEx and/or OpEx in EU refineries

Note: Shown is the percentage of responding refineries who reported costs in the given category (i.e. sum of all 'yes' divided by sum of all 'yes' and all 'no', excluding responses 'not applicable' or 'data not available'). Figures are yearly averages, i.e. a value of 75 % for 2007-2012 indicates that on average in each of these six years 75 % of refineries had a related cost entry. 'Use of attrition-resistant catalysts' refers to dust abatement in the FCC unit.
Source: Concawe (2014).

It can be observed that the use of special catalysts to reduce CO and dust emissions from FCC units was a widespread measure before and after 2007. Regulation seems to have had the strongest effect on VOC abatement (perhaps also due to VOC Stage I legislation 1994/63/EC), with a particularly strong increase in leak detection and repair programs. However, abatement cost information broken down into the specific pollutants particulate matter, CO, or VOCs is *not* included in our data (except in the case of the Cartagena refinery, Box 6.1, which suggests substantial costs for VOC abatement, given the high figure given for 'control of fugitive emissions'). The related costs are subsumed in the figures given for general emission and effluent abatement investments.
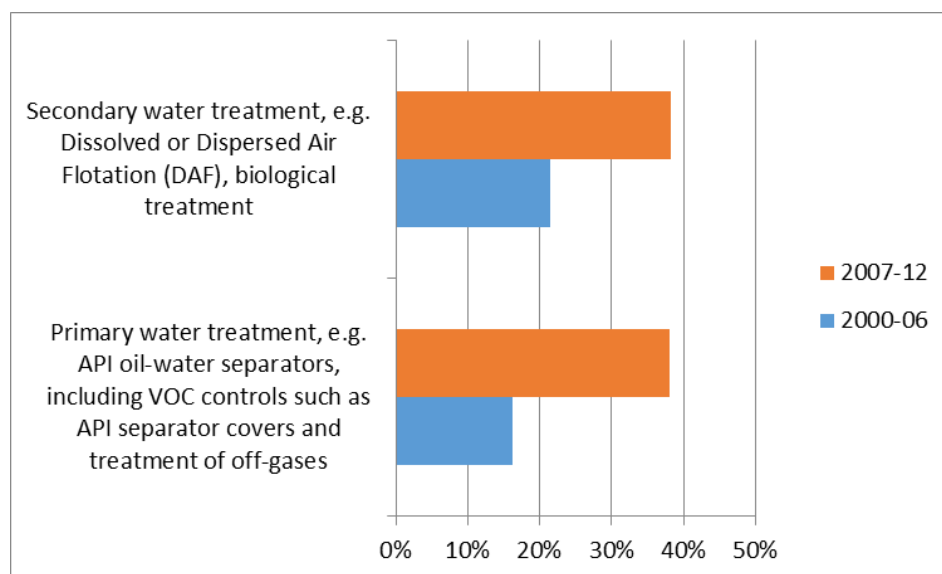
Waste water treatment

Finally, the Concawe industry survey also asked refineries to report capital expenditures related to waste water treatment.[242] The increasing frequency of such projects is shown in Figure 3.6.12. In terms of costs, according to Concawe (2014), those refineries that undertook waste water-related measures had average annual capital costs of EUR 0.7 million during 2000-2006, and more than twice as much, EUR 1.6 million annually, during 2007-2012. Making the assumption that all other refineries – which did not report any such projects – actually had no costs would yield a sector-wide average of EUR 0.3 million and EUR 1.1 million, respectively, for the two time periods. However, refineries that did not report such projects–but obviously still had to comply with effluent

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[242] Applicable Best Available Techniques with regard to pollution to water can be found in EC (2003), p.399ff.

legislation–may have made similar investments before the year 2000. Figure 3.6.12 confirms that investment in both primary and secondary water treatment measures increased significantly after 2006. The overall cost share of such measures–relative to total costs for emission and effluent control–has in fact increased from 15 % during 2000-2006 to 19 % in 2007-2012.

Figure 3.6.12: Waste water treatment measures which incurred annual CapEx in EU refineries
Note: Shown is the percentage of responding refineries who reported costs in the given category (i.e. sum of all 'yes' divided by sum of all 'yes' and all 'no', excluding responses 'not applicable' or 'data not available'). Figures are yearly averages, i.e. a value of 38 % for 2007-2012 indicates that on average in each of the six years 38 % of refineries had a related cost entry. Note that numbers do not add up to 100 % because not all refineries invested in waste water treatment during 2000-2012.
Source: Concawe (2014).

Impact of the IPPCD and LCPD on the demand for inland fuel oil

An important *secondary* impact of this legislation occurred indirectly through the demand-side channel. Namely, by capping the SO_2 emissions of power plants and other large combustion plants, the LCP Directive advanced the phase-out of residual fuel oil as an energy source for such installations (Purvin & Gertz 2009, p.5), with evident negative demand repercussions for the refining sector. An accurate quantification of this impact is beyond the scope of our analysis, but the IEA data and the figure shown by Purvin & Gertz (*idem*) suggest that the EU annual demand for inland residual fuel oil fell by approximately 30 Mt to 45 Mt over 2000-2012. For instance, just the fuel oil input to conventional thermal power stations dropped from 34 Mtoe to 8 Mtoe annually (Eurostat 2014). As a consequence, year 2012 inland fuel oil demand was reduced by roughly half compared to the year 2000, which to a significant extent can be attributed to the impact of the LCP Directive.

As the fuel oil used in the power sector and heavy industry was typically replaced by non-oil products (in particular natural gas), refineries could not provide a substitute themselves. This is reflected by the fact that the total fuel oil output of EU refineries dropped by 40 Mtoe, or 34 %, from 2000 to 2012. Its relative share shrank from 16 % to 12 % of total refineries' output (Eurostat 2014). As part of this shift, the marine fuel market became the most important fuel oil outlet.

The economic cost for refineries resulting from the lower fuel oil demand cannot be quantified directly. Increasing the conversion capacity to reduce fuel oil output in favour of distillate-grade

products is a costly strategy, probably pursued by many refineries, as reflected in the significant number of refineries that migrated from the lowest two complexity groups towards higher ones (see refining overview section). However, with the overall demand for petroleum products in the EU in decline, the move towards increased production of distillate products, especially gasoline, is unlikely to be a feasible option for all refineries. Second, another option is an increased orientation toward the marine fuels market. Third, the reduction observed in EU refining capacity–which disproportionally affected simple refineries with a high fuel oil output–has also contributed to the reduction of refineries' fuel oil output.

The industry data from Solomon Associates (2014) confirms a drop in average fuel oil output consistent with Eurostat (2014) statistics, with the relative share in all final refinery products falling from 16 % to 13 % from 2000 to 2012. Taking the average EU-28 refinery data from Solomon Associates (2014), and multiplying by the number of active mainstream refineries – 95 in 2000 and 86 in 2012 (see list of refineries in the Appendix) – implies a total annual fuel oil output (excluding marine bunkers) of 78 Mt in 2000 and 47 Mt in 2012, hence a drop of 31 Mt annual production. Albeit at the lower end, this number is consistent with the aforementioned drop in EU inland fuel oil demand.

Based on the Solomon Associates (2014) data, it is possible to identify the different factors that contributed to the 31 Mt per year decrease in inland fuel oil supply:

- the 9 % reduction of EU refining capacity – nine closures (including conversions to terminals etc.) from 2000 to 2012 – implies a *ceteris paribus* fuel oil output reduction of 7.4 Mt;[243]
- the increased conversion capacity – fuel oils (including marine bunkers) representing 13 % instead of 16 % of the final product output barrel – implies a further reduction of 12.9 Mt;[244]
- an increased uptake from the marine fuels market explains the remaining reduction of 10.4 Mt.

In sum, this simplified analysis suggests that the most important strategy of EU refiners in the face of declining inland fuel oil demand was to increase conversion capacity (42 % contribution), followed by increased supply to the marine fuel market (34 % contribution), and, finally, the shut-down of capacity (24 % contribution). However, the economic costs implied by these strategies cannot be estimated here; they will be assessed – as far as possible - by means of the OURSE numerical model.

Impact on the international competitiveness of EU refining

Higher production costs due to environmental regulation can lead to a competitive distortion and disadvantage for EU refineries if they compete with non-EU refineries that are not subject to the same level of regulation. The impact of such a distortion will be more severe if demand is very

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[243] This assumes that the shut-down capacity is representative of the refining sector as a whole. In reality, seven out of the nine closed refineries were of the lowest or second lowest complexity category considered here, which typically have relatively higher shares of fuel oil output. Hence, their closures likely contributed somewhat more.

[244] There are also two smaller contributions due to a slightly increased average capacity (182 000 to 188 000 bbl per day) and drop in utilisation rate (83 % to 81 %), but the two exactly cancel out (data: Solomon Associates 2014).

sensitive to prices (high elasticity), and if typical margins are too low to absorb the additional costs.[245]

However, in the case of the European situation, there are factors that have the potential to mitigate the competitiveness impact of EU pollution regulation. First, the French government-commissioned study of Legrand et al. (2012) analyses the observed 'crisis of the French refining industry' in which 'during 2008 to 2011, four refineries out of 13 were shut down' (p. 7). The study declares its main objective is to consider:

'Among possible explanations, the economic impact of environmental rules was mentioned since it would have more impact than in other equivalent countries. This report discusses such assumption. It therefore analyses compulsory environmental constraints in France and draws comparisons with the situation in some other European States.' (p.7)

As one of its main findings, the report asserts that the French situation reflects the difficulties experienced by the refining sector throughout Europe and that environmental regulation does not seem to be the main cause of these difficulties:

'Thereby, it quickly turned out that, on the one hand, the observed difficulties are similar all over Europe, and, on the other hand, the prevention of pollutions and other environment impacts does not seem to be the main reason for these troubles. All the people we met in France and abroad have confirmed such a finding.' (p.7)

As for the reason for why this is the case, it is observed that European

'environmental requirements, although they are among the most stringent in the world, remain however comparable or equivalent to regulations in other OECD countries' (p.7).

The above assertion holds when considering competition to European refineries from regions such as the United States and the OECD members from South-east Asia, and to a (much) lesser extent for competitors from the FSU and the Middle East.

Second, the assessment by Amec (2011, p.40) notes the possibility to pass on the incremental costs of regulation due to market power and costly entry. In particular:

'The high annual cost will be an additional barrier to entry for new entrants – however it is already very difficult to enter the industry due to very high investment costs (e.g. infrastructure, network distribution, and advertising costs) and the industry is therefore dominated by larger multinational companies.'

The study, nonetheless, mentions that this assertion only partially holds for the refining sector. The entry costs into production of refining products are high, but entering the market as an importer of refined products is much less costly, therefore the refining industry is subject to stronger pressure from international competition than, for example, the electricity generation industry.

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[245] Empirical studies of the US refining sector found that environmental regulation does not necessarily reduce productivity (Shadbegian and Gray 2005), or that – even when it does initially – over time refineries are able to adapt and substantially dampen the effect (Sharma 2013).

In the scope of this study and with the available data, it is not possible to make a comprehensive assessment of the cost pass-through issues faced by the EU refining industry. However, it is still necessary to mention this aspect of regulation costs impact as the one also influencing the competitiveness of the industry.

Our own available data (Solomon Associates 2014a) on worldwide capital expenditures related to emission and effluent regulation is depicted in Figure 3.6.13. Due to the heterogeneity in refineries' size and complexity we again normalise the average annual capital costs by the equivalent distillation capacity, as done earlier in Figure 3.6.7. For the three most important competitor regions of the EU the figure shows that the past expenditure level was 60 % higher in the US, 28 % lower in the Middle East, and 64 % lower in Russia.
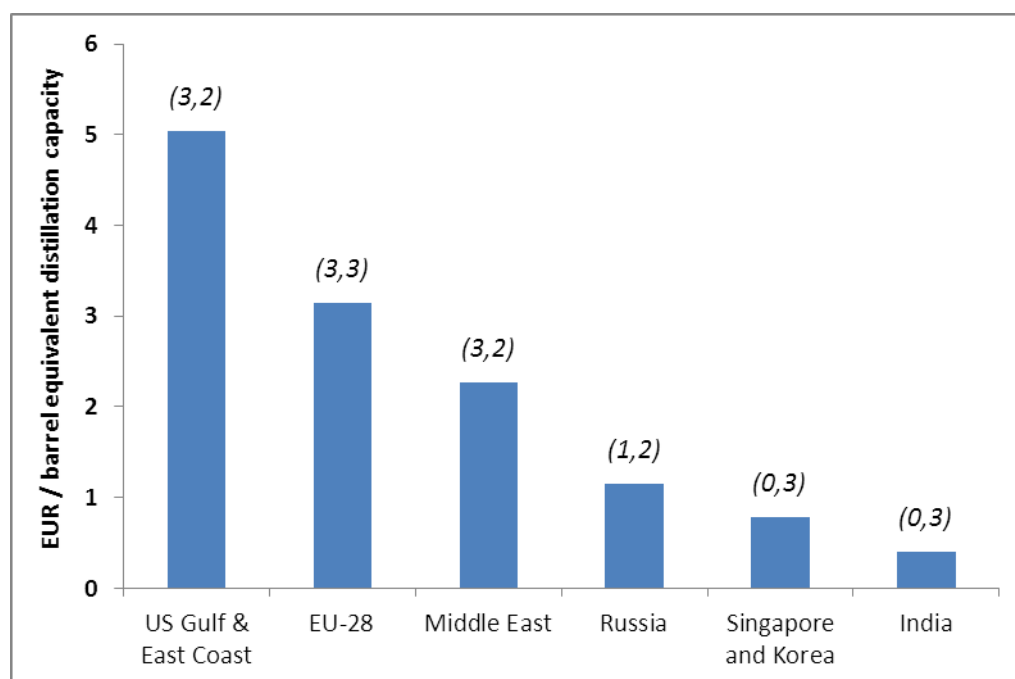
Figure 3.6.13: Capital expenditures related to refinery pollution regulation per barrel of equivalent distillation capacity
Note: Average annual figures for 2000-2012, except for India (from 2007 on) and Russia (from 2005 on). The averages for 2011-2012 are shown in parenthesis.
Data source: Solomon Associates (2014a).

Besides the overall capital cost impact over 2000 to 2012, the data also points to two noteworthy trends observable in the most recent years:

- US expenditures at or below EU level in 2012: similar to the EU's observed cost peak in 2007/08, the US also had an expenditure peak, but in 2005/06. Afterwards the US experienced a persistent decline, eventually reaching a level comparable to the EU's in 2011-2012.
- Catch-up of the Middle East with the EU/US: the opposite trend is seen in the Middle East, where capital expenditures for pollution control rose persistently, reaching the EU/US level in 2011-2012.

At the aggregate level, the oil product trade patterns of the EU show, for the more recent years, Russia and the US as the main sources of diesel imports, and the Middle East as the main source of jet fuel imports. A major destination of EU gasoline exports is the US (see refining overview

chapter). Hence the previous focus on these three regions. However, it should be pointed out that at the regional level the situation might be different. For central and eastern Europe, Russia constitutes the single most important non-EU competitor country, which – for instance – supplied 36 % of all oil product imports to Poland in 2012 (IEA 2014a).

A limitation of the above data is that it only captures the capital costs associated with pollution regulation, while it lacks information on the operating costs. That said, operational costs very likely represent the smaller cost component: e.g. in our own analysis of EU refinery data they constitute around only a quarter of the total cost burden of pollution regulation, and about a third in the most recent years. They are also relatively small in absolute terms: for the EU they never exceeded EUR 0.06 per barrel of throughput (see Table 3.6.1) and hence only represent about 1 % of total refinery operational costs. As a consequence, any regulation-driven disadvantage in operational costs between the EU and competitor regions cannot be larger than this amount. Even if, say, the other regions incurred only a third of the 2000-2012 average pollution regulation-related operational expenses, the associated competitiveness 'gap' of the EU would be EUR 0.02 per barrel.

A potential second data caveat stems from the fact that the different regions' overall refining capacity has in some cases expanded and in other cases – like in the EU's – contracted. In fact, the US' Gulf Coast refining capacity expanded by 15 % (but declined in the East Coast region), the Middle East's by 27 % and Russia's still by 4 % from 2000 to 2012, while in the meantime the EU's contracted by 4 % (BP 2014). As exemplified by the Cartagena expansion project (Box 6.1), newly built refinery capacity can lead to momentary high investments in pollution control equipment, because installations like sulphur recovery units and the associated infrastructure must be built from scratch, rather than through upgrades of existing structures. As a consequence, the high capital expenditure observed, particularly in the US regions, may to some extent be attributable to the high share of newly added capacity found in this region, rather than to the severity of regulation.

In sum, while the above analysis remains imperfect, it still provides a valuable first-order estimate of the comparative cost burden for the EU refining sector and its main competitors. First, in view of the data it appears safe to say that pollution regulation did not lead to a competitive disadvantage for EU refineries vis-à-vis the US East and Gulf Coast regions, at least not when the whole 2000-2012 time horizon is considered. In the most recent years, when capital expenditures were at almost equal levels, lower operational costs in the US (due to lower energy prices) might have created a slight cost disadvantage for the EU, but the effect is small in absolute terms (few cents per barrel of throughput). Second, Middle East refineries have historically experienced a lower capital cost burden than those in the EU, but this advantage has vanished in more recent years. Similar to the US, this region likely benefits from comparatively lower operational costs, due to relatively lower energy prices. But again, the effect is small in absolute terms. Third, the Russian refinery sector, which has become an increasingly important EU competitor, clearly enjoys a regulatory cost advantage, given its two thirds lower capital expenditures as well as its presumably lower operational costs (due to less installed abatement equipment and lower energy prices). Given, however, the overall moderate cost burden still observed for EU refineries (EUR 0.13 per barrel or 3 % of total OpEx over 2000-2012), which represents the theoretical upper limit of the cost disadvantage vis-à-vis Russia, the competitiveness impact is also judged to be moderate in absolute terms.

Finally, besides the direct regulatory cost burden, we also identified an indirect legislative effect in the form of a reduced demand for inland fuel oil. For this effect, the competitiveness impact on EU refineries is mitigated by the fact that it affects all suppliers to EU markets, domestic as well as non-EU refineries. However, for two reasons EU refineries might still be affected disproportionally. First, the home market is an important factor for any refinery's economy (especially for inland refineries), given that product transport is costly and requires dedicated infrastructure. Hence, a

shrinking EU fuel oil demand probably puts greater economic pressure on domestic refineries than on non-EU ones. Second, the most important coping strategy – increased conversion capacity – leads to a production process that requires the use of more energy, for which European refineries face a relatively higher cost than refineries in most of the relevant competitor regions. Unfortunately, given that various market interactions determine the net outcome of this effect, it is not possible to provide a further quantification here.

3.6.4. Efficiency of the legislation

This section discusses efficiency by putting the legislation's overall benefits into perspective with its costs and assessing whether the benefits are achieved at proportionate and affordable costs.[246] If relevant and possible, it also discusses regulatory gaps, inconsistencies, overlaps or evidence of excessive administrative burdens.

Costs and benefits of SO_2 and NO_X abatement

As discussed in Section 6.2, pollutant emissions have generally decreased (see Figure 3.6.4), which in part is attributable to the pollution and air quality legislation considered here. As a back-of-the-envelope comparison of costs and benefits we suggest the following approach: Focusing on two major pollutants for which sufficient data is available, SO_2 and NO_X, and assuming that they were the objective of 60 % of all pollution abatement-related capital expenditures[247], we compute the total capital costs by summing up the reported investments from emission and effluent regulation for the years 2004 (earliest emission data) to 2011. The year 2012 is excluded because we assume that an investment in year X will have an impact on emission intensity only from the successive year ($X+1$) onwards. Also, we restrict the analysis to the EU-15, since the EU-13 accession countries sample in the Solomon Associates (2014) data is characterised by high sample fluctuations in the earlier years. In addition, we focus on one 'average' EU-15 refinery to neutralise the effect of the overall decreasing sample size.

Based on the Solomon Associates (2014) data, the resulting total capital cost related to SO_2 and NO_X abatement from 2004 to 2011 is EUR 27.7 million per refinery (i.e. 60 % of EUR 46.2 million, close to the sum of the first column in Table 3.6.1 over the years 2004 to 2011, which would give the corresponding number for the average EU-28 refinery). Taking into account the associated incremental operational costs by adding – as before in Table 3.6.1 – 6.3 % of the capital costs (cumulatively, with an effective date of 1 July for new investments) adds another EUR 6.6 million, leading to a total sum of EUR 34.3 million for NO_X and SO_2 abatement costs.

The above-mentioned regulation compliance costs are incurred at the level of the refining industry alone. The repercussions of the compliance costs at the societal level have not been quantified. They can, however, be placed in a broader context that also includes the societal and economic role

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[246] Official mandate of the Fitness Check, p.6: 'What are the costs and benefits associated with the implementation of the specific legislation? Can any costs be identified that are out of proportion with the benefits achieved? (http://ec.europa.eu/smart-regulation/evaluation/docs/2014_refining_fc_mandate_final_en.pdf)

[247] This should be a relatively high estimate, given that expenditures on water treatment account for about 20 % of all pollution abatement capital investments according to Concawe (2014), leaving 20 % for expenditures on PM, CO, VOCs, etc.

of the industry. In 2011, the EU refining industry had average revenues per refinery[248] of EUR 96 million (IHS (2014)). According to Solomon Associates (2014), an average EU-28 refinery site in 2011 employed 533 workers and paid approximately EUR 40 million in wages. Furthermore, the total employment effect of the average EU refinery (taking into account the Input-Output relationships of EU refining with other sectors, see Refining Overview Chapter) is estimated at 2 136 workers.

In terms of abatement benefits, we assume that without regulation the EU-15 average emission intensities of SO_2 and NO_X would have remained at the levels observed in 2004: 0.72 kg and 0.27 kg of SO_2 and NO_X per tonne of input, respectively (Solomon Associates 2014). This gives effective abatement as the difference, year by year from 2005 to 2012, between the 2004 and actually observed intensity, multiplied by the average refineries' observed net raw input. Because the Solomon Associates (2014) data only provides emission intensities for the odd years, we double the number derived from only using the even years. Doing so yields 11 863 tons of total abated SO_2 emissions and 3 932 tons of NO_X per average EU-15 refinery, over a total of eight years.[249]

Hence, we find that from 2005 to 2012 the average EU-15 refinery abated nearly 12 000 tons of SO_2 and 4 000 tons of NO_X emissions, at an estimated total cost of EUR 34.3 million.

To assign a monetary value to these benefits we use EEA (2014), which in Table A1.7 and A1.10 gives estimated ranges for regional damages from NO_X and SO_2 emissions, respectively. These damage costs quantify a series of impacts but still exclude some, e.g. direct human health impacts as well as ecosystem impacts (biodiversity, forest production). Since two different methods are used for the valuation of mortality ('VSL' and 'VOLY'), two different damage costs are provided for each pollutant. To produce a conservative estimate, we take the lower end of the given range and use a simple regional average of those eight EU-15 countries where most refineries are located: BE, DE, EL, ES, FR, IT, NL, UK. The damage costs obtained are 2 418 EUR per tonne of NO_X emissions and 8 224 EUR per tonne of SO_2 emissions (2005 prices). Putting the figures together gives a total SO_2 and NO_X abatement benefit per refinery of EUR 108.4 million.

Evidently there are various caveats associated with this back-of-the-envelope computation, of which we want to highlight the following: First and as mentioned before, the cost of switching to low-sulphur refinery fuel is not included in the abatement cost figure. Second, computing the regulatory costs of the refining sector by means of the abatement costs of the *average* refinery neglects the possibility that increasing regulatory costs may also contribute to the decision to close a refinery (although we do not have any evidence with regard to this point for specific closures). These two aspects imply a potential downward bias in the abatement cost estimate. On the other side, the assumption that SO_2 and NO_X emission intensities would have remained flat at their 2004 level is probably overly optimistic, since the Fuel Quality Directive and the declining supply of low-sulphur North Sea crude oil could have led to an increasing energy and – in consequence – pollution intensity with some likelihood. Hence, this assumption probably creates a downward bias for the benefit estimate. Likewise, total benefits would have been two to three times greater if the higher of the two damage cost estimates provided by EEA (2014) had been used.

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[248] Based on there being 75 active refineries by the end of 2011.

[249] E.g., SO_2 abatement in 2012 is (0.72 kg/tonne-0.37 kg/tonne) x 8893000 tonne of net raw input = 3113 tons of SO_2.

Heterogeneity of regulatory stringency

As discussed in the reviewed assessments of the IPPCD, the observed differences in pollution control of both SO_2 and NO_x suggest that emission regulation did not have an equal effect – and plausibly did not exert the same regulatory pressure – across all EU regions and refineries. This is justified to some extent by the special circumstances of individual refineries, e.g. proximity to large cities, sensitive soils, or other local environmental conditions.

However, this observed heterogeneity is also likely linked to the already mentioned fact that EU pollution legislation gave national/local authorities considerable leeway to determine actual emission limits and achieve air quality targets (at least during the 2000-2012 period considered here). For instance, national and regional level targets, like those associated with the Air Quality Directive or National Emissions Ceiling Directive, could be implemented by putting a relatively higher or lower burden on refining or industry in general, as opposed to other sectors (e.g. transport, residential), possibly leading to a certain inconsistency from the point of view of the refinery sector.[250]

Other intra-EU differences not directly related to emission limits, such as 'variations in permitting fees, different schemes of financing permit-related activities of competent authorities and variations in the length of permitting' may have also occurred, as pointed out in an analysis of the IPPCD's competitiveness impacts by Ifo (2006, p.11).

Specific data on the administrative burden associated with the legislation is not available; however, it was not singled out in the available studies or in personal consultations with industry as an area of special concern. This is consistent with the view that administrative burden is typically more relevant to small and medium-sized enterprises, rather than large enterprises like refineries.

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[250] A legal perspective on the uneven implementation of the IPPC Directive can be found in Oosterhuis and Peeters (2014).

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3.7. Strategic Oil Stocks Directive

- Based on the existing evaluations and evidence, the overall benefits of emergency stockholding are generally seen as high given its importance for the EU and national energy security policies.
- Analysing the MS-specific arrangements, we conclude that the obligation is generally financed in a competitiveness-neutral way; where the obligation is imposed on the industry, strong indications exist that the costs of stockholding can be (fully) passed on to end consumers. Competition on a 'level playing field' is, however, a necessary condition for the full pass-through to occur.
- Under certain national arrangements, the oil refining industry can benefit from stockholding obligations by renting out its spare storage capacity and/or by selling 'tickets'.
- The latest Council Directive (2009/119/EC) aims at further optimising the system with a number of specific measures. Since the Directive allowed for a transposition period until the end of 2012, with additional exceptions for certain MS until the end of 2014, it appears premature to precisely assess its impacts at the moment.

3.7.1. Objectives and measures

Earlier in this report (see 'Overview of the European Union petroleum refining sector'), we reviewed the fundamental role oil plays in the EU economy, both as an important energy resource and an industrial input provider. We emphasised that while a reliable supply of oil products is one of the main pillars of the EU's energy security, its indigenous oil resources are limited. Indeed, the import dependence on crude oil, expressed as a percentage of consumption, reached 88 % in 2012 – the highest level among the fossil fuels consumed (EC, 2014).

Recognising its import dependency and the importance of oil supply security, the EU has kept this issue high on its political agenda in recent decades. The obligation to maintain minimum stocks of crude oil and/or refined oil products for strategic purposes in the EU can in fact be traced back to 1968, when it was imposed on its then six member countries (Council Decision 68/416/EEC of 20 December 1968). Respective directives amended the obligation in 1973 and 1998; and the Directive of 2006 consolidated and codified the previous legislative acts for the purpose of clarity and coherence. In the period between 2000 and 2012, the above legislative acts on strategic stockholding were relevant until 2009, when they were repealed by Council Directive 2009/119/EC[251].

The strategic stockholding obligations system in general pursues the following objectives:

- to secure a sufficient supply of crude oil and/or oil products in case of a temporary disruption;
- to assure that stocks can be effectively released to the market whenever deemed necessary;
- to provide market stability by establishing a credible assurance of supply security.

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[251]Council Directive 2009/119/EC of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products.

It needs to be noted that the majority of the EU Member States are also members of the International Energy Agency (IEA). The member countries of the IEA commit to hold strategic oil reserves (calculated as 90 days of net imports in the previous calendar year) that can be used as an emergency mechanism for addressing potential oil supply shocks. Most of the EU MS are thus required to ensure that their stocks comply with two different sets of obligations – stemming from the EU and from the IEA commitments; in addition, more Member States are preparing to join the IEA (with Estonia having joined in 2014).

Table 3.7.1: Stockholding obligations before and after 2009 under the EU and the IEA systems

	Council Directive of 20 December 1968 imposing an obligation on Member States of the EEC to maintain minimum stocks of crude oil and/or petroleum products (68/414/EEC), amended by Council Directives 72/425/EEC and 98/93/EC	Council Directive of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products (2009/119/EC)	Stockholding commitments under Agreement on an International Energy Programme of 18 November 1974 (the IEA agreement)
Minimum stocks	90 days of average daily inland consumption for each product category below	90 days of average daily net imports or 61 days of average daily inland consumption, whichever of the two quantities is greater; stocks to be reported with 10 % reduction to account for unavailable stocks	90 days of average daily net imports; stocks to be reported with 10 % reduction to account for unavailable stocks
Product categories	a) motor spirit and aviation fuel (aviation spirit and jet-fuel of the gasoline type); b) gas oil, diesel oil, kerosene and jet-fuel of the kerosene type; c) fuel oils Stocks may be maintained in the form of crude oil, intermediate products, or finished products	MS may opt to maintain 'specific' oil product stocks, composed of one or several predefined oil products; if there is no commitment to hold at least 30 days of specific stocks, a minimum of one third of the total obligation should be held in the form of refined products	No limitations; product stocks converted into crude oil equivalent
Net exporting countries	May deduct their production from internal consumption up to 25 % of the latter	Hold 61 days of average daily inland consumption	No stockholding obligation
Stockholding arrangements	MS may establish a stockholding entity; two or more MS may use a joint stockholding entity	MS may set up Central Stockholding Entities (CSEs), at any location within the Community, as a not-for-profit body or service	Not specified
Reporting	Monthly	Monthly. Commercial stocks reported separately. Each MS keeps and continually updates a register of all emergency stocks, with a summary copy sent to the Commission yearly by 25 February	Monthly

It is thus important to consider the current EU stockholding obligations together with the emergency response system put in place by the IEA, as the two pursue identical goals and use very similar instruments. On the other hand, an independent EU system is deemed necessary because not all of the EU MS are members of the IEA, and because of the potential regional disruptions that affect one or more MS but do not necessarily trigger the IEA mechanism (as the latter is focused on more global disruptions). At the same time, the two stockholding systems should function in a

complementary way, reinforcing each other and not resulting in an excessive administrative burden. The most important features of the two sets of stockholding obligations under the EU legislation (before and after 2009) together with the set of stockholding commitments of the IEA members are summarised in Table 3.7.1 below.

The current Directive (2009/119/EC) modified the previous EU stockholding obligations by adopting several specific measures, most importantly, by obliging the MS to:

- Implement appropriate provisions in order to ensure that they maintain oil stocks at all times within the Community, corresponding at the very least to 90 days of average daily net imports or 61 days of average daily inland consumption, whichever of the two quantities is greater. When calculating their stocks, MS must reduce (discount) the quantities of stocks held by 10 %, which are assumed to be inaccessible.
- Hold at least one third of their stock in the form of refined products if there is no commitment to maintain at least 30 days of specific stocks (see below).
- Account and report separately on the stocks held for commercial purposes.
- Ensure that the stocks are available and physically accessible at all times.
- Keep and report to the Commission a continually updated and detailed register of all emergency stocks held.

In addition, the Directive allows MS to commit to maintaining *specific oil product stocks*. In this case, they should be maintained at a minimum level defined in terms of number of days of consumption and be composed of one or several predefined oil products[252].

In order to maintain their stocks, each MS can set up a non-profit *Central Stockholding Entity* (CSE) at any location within the Community; the CSEs and MS are allowed to delegate (part of) their stock management to another MS, CSE or economic operator on certain conditions. The Directive also provides the relevant mechanisms and procedures for *coordination of the emergency reaction* in case of shortage.

With a view to decreasing the related administrative burden on the participants and enhancing the overall transparency of the system, the Directive also aimed at aligning the calculation and reporting method within the EU with that of the IEA.

The transposition period of the Directive was until 31 December 2012. By derogation, Member States that were not members of the IEA by 31 December 2012 and fully relied on imports to cover their oil product consumption at the moment of adoption were granted a transition period until 31 December 2014. Before this date, they were required to maintain oil stocks corresponding to 81 days of average daily net imports.

3.7.2. Effectiveness of the legislation

Based on the available evaluations, we conclude that stockholding obligations applied by the EU as a policy instrument in the field of oil supply security have been fulfilling their main objective[253].

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[252] Specific stocks shall be composed of one or several of the following products: ethane, LPG, motor gasoline, aviation gasoline, gasoline-type jet fuel (naphtha-type jet fuel or JP4), kerosene-type jet fuel, other kerosene, gas/diesel oil (distillate fuel oil), fuel oil (high sulphur content and low sulphur content), white spirit and SBP, lubricants, bitumen, paraffin waxes and petroleum coke.

According to a recent study by the European Commission (EC, 2014), most of the Member States hold sufficient oil stocks to meet the minimum requirements of the current Directive or are close to reaching that target (Table 3.7.2). This seems to provide an adequate buffer to cope with potential supply disruptions and contribute in a meaningful way to the EU's enhanced energy security.

Indeed, the release of emergency oil stocks is generally considered the easiest and the fastest way of mitigating large oil supply shortages (the IEA advocates to its members holding emergency oil stocks as the main tool to address potential supply disruptions). While stock release is not the only policy tool for emergency response to fuel shortages – alternative measures include, for example, demand restraint; fuel switching; increase in domestic oil production; temporarily relaxing fuel specifications; switching to alternative supply routes – it seems to be the most efficient and practical for the EU. With limited domestic production, as well as high dependency of the domestic economic activity upon petroleum products, the EU could not fully rely on the above alternative mechanisms in case of emergency. They are able, however, to effectively complement stock releases whenever required, for example, in case of a prolonged disruption.

The EU initially introduced a stockholding obligation of 65 days, which was later increased to 90 days of internal consumption, and changed by the current Directive to 90 days of net imports or 61 days of internal consumption, whichever is higher. Overall, the EU currently possesses emergency oil stocks equivalent to approximately 100 days of net imports (EC, 2014). This choice of obligation is to a certain extent arbitrary, based more on the tradition and adopted practices than on precise calculations, which are hardly possible given the intangible elements involved. Indeed, the optimal size of emergency stocks is always based on a compromise between energy security and the associated costs, with benefits that are not immediate and straightforward to measure. Sufficiency of the stock obligation is thus not a fixed concept and might depend, on the one hand, on the actual availability of emergency stocks and, on the other hand, on the risk and estimated extent of a potential oil supply disruption.

One possible way to estimate the sufficient amount of emergency stocks is to use historical data on the major oil supply disruptions in the past. In this respect, one indication is that during the largest oil shortage since the 1950s, the Iranian revolution of 1978-1979, 15 days of stocks were needed to provide sufficient coverage[254]. It seems, therefore, that the current EU stockholding obligation ensures a relatively high degree of safety with respect to potential temporary disruptions.

An equally relevant issue is the optimal composition of emergency stocks – in particular, whether they should be stored as crude oil or as final products, or a certain mixture of the two. While ensuring immediate availability of refined products for the market, long-term holding of finished product stocks has several disadvantages. Namely, crude oil is in general easier and cheaper to store; in addition, given the availability of sufficient refining capacity, holding crude oil and other feedstock instead of the finished products can secure some flexibility for meeting the demand for specific categories of products in the event of a crisis. The latter is almost impossible to predict with precision in advance, and may differ from the normal consumption patterns.

Thus, stockholding obligations that are overly prescriptive in terms of the stock composition could reduce the overall effectiveness and unnecessarily increase the costs of the system. The current

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[253] 'Ensuring a high level of security of oil supply in the Community through reliable and transparent mechanisms based on solidarity amongst Member States, maintaining minimum stocks of crude oil and/or petroleum products and putting in place the necessary procedural means to deal with a serious shortage' (Article 1 of Council Directive 2009/119/EC).

[254] IEA World Energy Outlook 2005.

Directive, on the other hand, seems to strike the right balance between guaranteeing the short-term availability of refined products and leaving a sufficient degree of flexibility in terms of the stock composition to the MS. While obliged to hold a minimum of one third of its emergency stock in the form of refined products, it is at the discretion of each MS to decide on the exact composition of the stocks, taking into account its geographical position, refining facilities and consumption patterns. Moreover, by inviting MS to maintain stocks of specific predefined products, in proportions determined by their domestic consumption patterns, the Directive reinforces short-term availability of finished refined products in case of emergency.

In addition to an appropriate stockholding arrangement, it is equally important to establish the effective emergency measures and procedures to address oil supply disruptions. A crucial issue in this respect is the actual availability of stocks in case of a disruption. To this end, the current Directive provides certain specific measures to ensure this availability, for example, by not allowing the MS to include in their stock quantities crude oil or petroleum products which are subject to a seizure order or enforcement action. In addition, each MS is required to provide details on the stocks held outside its national territory. The Directive, at the same time, provides a safety buffer in the form of a 10 % discount, applied when calculating the actual stocks; this reduction attempts to approximate the Minimum Operational Requirements (MOR) of the oil industry, which are stocks assumed not to be readily available[255].

For the same purpose, the Directive strictly distinguishes between commercial and emergency stock data. The MS are required to report the level of commercial stocks (defined as stocks held by economic operators independently of the requirement under the Directive) separately, which implies that industry stocks held without an obligation cannot be considered emergency stocks. In addition, '[w]here emergency stocks and specific stocks are commingled with other stocks held by economic operators, transparency of emergency stock levels should be emphasised.'[256] This seems a reasonable precaution as, depending on their definition, stocks held by the oil industry for commercial reasons can be quite high, while their availability in times of a crisis can be less certain.

On the other hand, commingling (physically storing commercial stocks together with the emergency stocks), if properly designed, can be an efficient practical solution which does not compromise the overall visibility and robustness of the system. It allows the stockholding system to benefit from the economies of scale, as well as make use of existing distribution channels to promptly release products to the end users. It also allows for the regular refreshment of the products. Appropriate control should, naturally, be in place in order to ensure the constant availability of the emergency stocks.

Regarding the actual stockholding implementation by the MS (discussed in more detail below), the central stockholding arrangement has clear advantages. In particular, such stocks can be considered fully available in case of a disruption, while a certain amount of the industry stocks is needed to continue their normal operations (MOR). Furthermore, in case of an emergency stock release, the central entity stock releases are considered easier to monitor. However, a system based on the industry stocks is not necessarily inferior, given that reliable control procedures are established.

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[255] There is no universally accepted definition of the Minimum Operational Requirements (MOR). The concept is often used referring to the minimum amount of oil and oil products which is needed for the day-to-day operation of the oil industry, such as tank bottoms. MOR is narrower than working stocks, as the latter may include stocks held for profit optimisation rather than as a necessary minimum.

[256] Recital 19 of Council Directive 2009/119/EC.

The risk of non-transparency potentially resulting from the diverging national stockholding solutions is to a certain extent mitigated by the reporting requirements of the Directive, as well as the control procedures foreseen. Indeed, the Directive specifies that '[t]he Commission may, in coordination with Member States, carry out reviews to verify their emergency preparedness and, if considered appropriate by the Commission, related stockholding'[257].

3.7.3. Impact on the EU petroleum refining sector

In assessing the cost impacts of the EU strategic oil stocks legislation, we will first estimate the cumulative burden that stockholding obligations impose on the Member States compared to the hypothetical situation where no obligatory stocks would need to be held. An equally relevant question in terms of policymaking concerns the incremental impact of the current obligations in addition to the previously existing ones, as well as to the international stockholding commitments that are independent of the EU legislation.

Below we discuss the cumulative costs of stockholding that result from the past and current EU legislation on strategic oil stocks, together with the existing IEA commitments. We then proceed to review the incremental obligations resulting from the current Directive on strategic stockholding and, most importantly, the distribution of costs between the government and market participants and the incremental burden potentially resulting from these obligations for the refining sector.

Overall costs of holding emergency oil stocks

Table 3.7.2 presents the data on emergency stocks held by the EU MS at the end of 2013, according to their EU and IEA reporting submissions. It is helpful to consider some relevant cost components to estimate the order of magnitude for the cumulative burden associated with establishing and maintaining these stock amounts.

A publication by the IEA (Stelter and Nishida, 2013) examines the costs of emergency stockholding as well as its benefits. According to the report, the costs of creating and managing oil stocks depend, among others, on the size and type of storage facilities (above-ground tanks or underground caverns), as well as the composition of stocks (crude or refined products). In particular, the following expenditure components need to be considered: set-up costs (capital investment and amortisation for construction of the storage facility and the purchase of the oil stocks); operating and maintenance costs (labour, utilities and insurance); refreshment costs for maintaining quality specifications of petroleum products; and land costs.

The total yearly costs of setting up and maintaining the emergency stocks were estimated at USD 7-10 per barrel. This is broadly consistent with the figure presented in the European Commission's impact assessment for the current Directive (EC, 2008), where (on the basis of submissions from MS) the average costs were estimated as EUR 31/tonne/year. The IEA (Stelter and Nishida, 2013) identifies the acquisition of stocks as the most important cost component, representing from 50 % to 85 % of the overall costs. Building storage facilities and related infrastructure, according to the study, account for up to one fifth of the yearly costs. It therefore seems that the bulk of the costs related to the current stockholding obligations were incurred by the majority of the MS as a result of previously existing obligations and due to their membership in the IEA, i.e. before 2000.

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[257] Article 18.

The share of operating and maintenance expenses varies considerably between storage options, from 5 % for caverns to a quarter for above-ground facilities. Refreshment of oil products and land costs both correspond to a marginal share of overall costs. Naturally, the identified costs are only indicative of the order of magnitude, and the actual figures for specific countries may differ depending on various local factors.

Importantly, the IEA's cost assessment did not include historical costs, while the part of emergency stocks set up earlier benefitted from significantly lower prices than the current ones. This makes it important to estimate the incremental burden of the current Directive in addition to the overall costs of national stockholding obligations. It also makes it clear that the 'new' MS can be in a relatively disadvantaged cost position if they need to establish or significantly increase their stocks as a result of accession.

Incremental impact of the current Directive

As outlined above, there remain some important differences between the current EU and IEA stockholding obligations. In addition, eight MS are not currently members of the IEA (see Table 3.7.2). One immediate implication of this is that the EU stockholding system represents an additional compliance burden in the following senses:

- on the MS which are not members of the IEA[258];
- on the net exporting MS (Denmark) and MS with low net imports (Estonia, UK), which benefit from relatively low IEA obligations;
- with respect to the composition of stocks (minimum of a third of stocks in finished products for the EU vs no restrictions for the IEA);
- With respect to (non-)inclusion of commercial stocks in the quantity of emergency stocks.

As a result of the above differences, the stock levels taken into account by the European Commission are typically lower than those reported by the IEA. Therefore, one can observe that the actual stocks expressed in days of net imports, published by the IEA, are consistently higher than the ones reported by the EC (Table 3.7.2).

On the other hand, the current Directive has modified the methodology for calculating minimum emergency stocks in several dimensions *relative to the previous EU obligations,* namely:

- in line with the IEA methodology, a 10 % reduction for unavailable stocks was introduced;
- the requirement for a minimum of one third of stocks to be held as finished products was introduced instead of the previous three product categories;
- the exporting MS stopped benefitting from the 25 % reduction in domestic consumption; however, their minimum stocks are based on 61 days of internal consumption – this is more or less equivalent to their obligation under the previous directive.

In addition, the new MS had to fulfil the obligation upon their accession, potentially resulting in significant one-off costs[259] (for this reason, under a Treaty of Accession to the EU, a certain transitional period was normally granted to the new MS for accumulating obligatory stocks).

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[258] Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Malta, Romania and Slovenia.

It appears that while the cumulative burden of holding strategic oil stocks (in comparison to no obligation at all) might be quite high, the incremental obligations introduced by the 2009 Directive did not result in substantial additional costs in most cases.

In their responses to the public consultation on the proposal for the current Directive, MS did not in general estimate the incremental burden of the Directive as significant. For example, Slovenia noted that the new obligations would, in principle, 'not result in difficulties for the Slovenian emergency stocks system', however, the introduction of the 10 % discount for unavailable stocks would 'increase the price of stockholding obligation [by] approximately 2,4 million Euro per year'. Greece held similar views, arguing that the discount created additional compliance costs with its obligation increasing by 10 % as a result. The UK estimated that, with increasing net imports, its IEA obligations would in the medium term gradually come close to its EU obligations, and therefore did not expect the Directive to be excessively binding.

The obligatory holding of (part of) the stocks as finished products was, however, stressed to be potentially costly in a number of responses. The reason is that crude oil is, in general, significantly easier and cheaper to store, as refined products are less stable and require more (costly) precautions if stored over a long period. For example, jet fuel demands extremely careful and expensive management in order to meet the strict quality controls imposed for safety reasons. Moreover, a growing amount of finished products is blended with bio-components, which makes them very difficult to be stored for a long time without costly replacement (refreshment).

It can thus be concluded that the Directive, while not resulting in drastic changes to the existing minimum stockholding obligations for the majority of the MS, has brought about a certain tightening of requirements and related cost increases in particular cases. Similarly, it imposes somewhat stricter conditions for holding strategic stocks than the IEA system. One observes that the majority of the MS that were granted an extension until December 2014 (non-IEA members relying fully on imports) held stocks slightly below the 90-day minimum – on average 83 days of net imports at the end of 2013 (Table 3.7.2). This suggests that the EU obligations have been binding for at least some MS.

Share of the industry in stockholding obligations

In a recent publication (IEA, 2014), the IEA outlines several possible ways of financing emergency stocks used in its member countries. Namely, two main systems are in place: government/public agency stocks ('public stocks') and obligatory stocks held by the industry ('industry stocks'). Each of these can be financed in several different ways, which might also be expected to be used for fulfilling the EU stockholding obligations as well.

As regards *public stocks*, the two most common practices for financing their set-up costs are (i) funding directly from the budget or through a government loan, and (ii) reliance on private creditors in the form of bank loans or bonds. As for the running costs for public stocks, three principal methods of financing can be used: (i) from the budget, (ii) through a levy paid by market operators, and (iii) through a tax paid by the final consumers. For the *industry* stocks, the obligations and associated financial costs are in most cases distributed in proportion to a company's oil import share or domestic market share. Several countries (Italy, Turkey and the UK) impose a higher stockholding obligation on refineries than the other market participants due to their presumably

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[259] For example, it was estimated by national authorities in Croatia that, in view of insufficient oil stock facilities, 480 000 m^3 storage facilities for crude oil and 260 000 m^3 for petroleum products have had to be additionally constructed since 2009.

larger operating stocks. Out of the 19 IEA countries with industry stocks, only the governments of Japan and Switzerland provide explicit financial support to market operators.

Many IEA, as well as EU, member countries allow oil companies or stockholding agencies to meet their obligations through leasing agreements, referred to as *tickets*. Tickets are specific arrangements under which the seller agrees to hold or reserve a certain amount of crude oil or oil products on behalf of the buyer in return for an agreed fee. In case of a supply disruption, the holder of the ticket can buy the stocks. Such arrangements provide some flexibility in strategic stockholding by offering a feasible alternative to physically acquiring oil stocks and building or renting additional storage capacity. Countries that permit ticket arrangements, however, often restrict their usage by imposing a limit on the share of stocks that can be held in tickets. Others (Austria, Hungary, Switzerland and Turkey) explicitly forbid the usage of tickets. The IEA notes that, in practice, the proportion of stocks held abroad in the form of tickets is small, amounting to around 1 % of the total stocks held by the IEA countries[260].

Stockholding Regimes in Europe
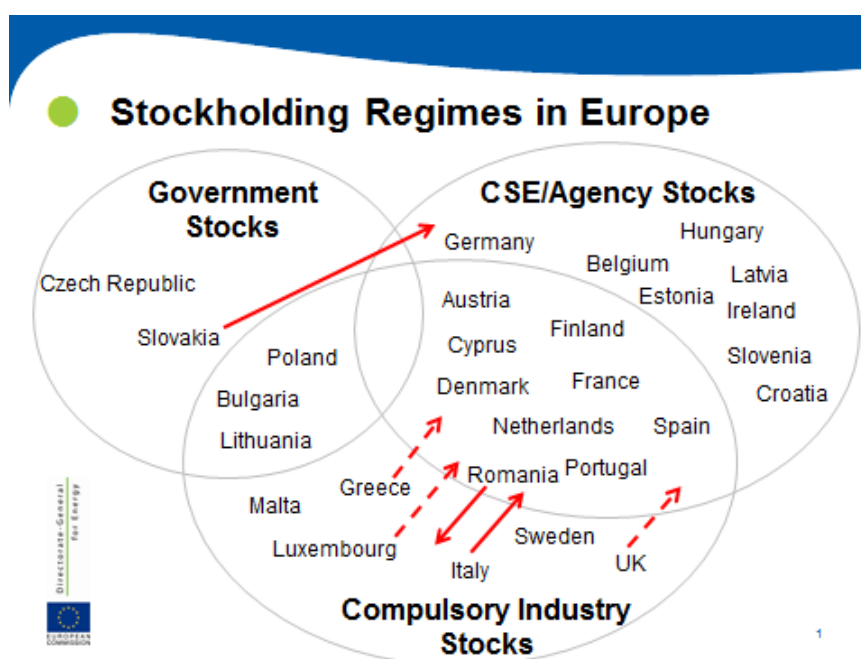
Figure 3.7.1. Schematic representation of stockholding arrangements in the EU Member States
Note: Arrows show the most recent changes (dotted arrows indicate possible/planned future changes).
Source: European Commission, DG Energy.

As discussed above, the EU obligations leave a certain degree of freedom to the national governments with respect to specific stockholding arrangements. Thus the degree of obligation borne by the oil refining sector might differ from one MS to another. Often, the obligation is imposed on the industry, whereby the latter may establish an independent stockholding entity; in the minority of MS the obligation is assumed directly by the government and financed from the public budget; in other MS the stockholding is shared between the government and the industry in certain proportions (see Figure 3.7.1, and for more details Table 3.7.2). Stocks held by the CSEs are typically financed by a fee payable by wholesalers of domestic and/or imported oil products, which is built into the consumer price in a transparent way[261]. However, in the case of a stockholding

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[260] IEA public data.

[261] For example, from our discussions with the Spanish central stockholding agency, we infer that the proportion of its fee in the average price of diesel in 2013 was around 0.3 %, or EUR 0.42 per litre.

obligation imposed directly on the industry, the related costs are much more difficult to obtain and verify and the degree of transparency might be reduced[262].

Arguably and independently of a particular arrangement, the realised costs of stockholding obligations, if imposed on the industry, can be included in the pricing margins and thus transferred to the end consumers. In practice, it is crucial, for an effective pass-through to be possible, that the obligation is imposed in a non-discriminatory manner on all the product suppliers (e.g. both refiners and oil product importers) – otherwise, competitive pressure coming from the market participants with lower costs may impose upper bound constraints on consumer prices and result in an uneven playing field.

Distortions to the 'level playing field' might, for example, occur when the stockholding obligation is imposed both on refineries and trading companies. As refiners typically hold extended storage capacity as part of their own operational management (to ensure continuity of operations), the obligation might be expected to weigh relatively heavier on traders, if not sufficiently compensated by lower obligations[263]. The impact assessment accompanying the proposal for the current Directive (EC, 2008) notes: 'Although the current legislation calls for "fair and non-discriminatory" stockholding arrangements, this is difficult to realize if all or part of the emergency oil stocks are held by the industry. … [I] mposing on everybody the obligation of keeping e.g. 90 days' stocks turns out to be more costly for importers. … In addition, small importers may face difficulties in finding access to storage facilities'. Certain MS (e.g. the UK) currently recognise this potential distortion by imposing lower minimum stock levels on importers than on refiners (although this premise is currently under review in the UK's case). A recent assessment by the IHS consultancy for the UK (IHS, 2013) is that 'since incremental CSO [Compulsory Oil Stocking Obligation] affects both refiners and non-refiners, there is the potential for the costs to be passed onto UK consumers'.[264] However, the obligation established in this way can only approximate equal distribution of the costs and needs constant monitoring and adjustment. In this sense, financing the stockholding obligations through an agency with fees related to the sales of final products in a transparent way – as implemented in most MS – appears to be a more neutral way of cost distribution.

The European Commission's impact assessment mentioned above did not identify any significant issues potentially negatively affecting the sector, either under the previous legislation or under the current one. Overall, it can be concluded that, while the actual obligations for the industry can differ from one MS to another depending on the nationally adopted stockholding arrangements, in the majority of MS the obligation is financed in a competitiveness-neutral way. As discussed above, whenever the obligation is imposed on the industry without corresponding compensation, the costs of stockholding can be (fully) passed on to consumers, while any distortions restricting the possibility of the full pass-through need to be identified and corrected.

At the same time, it needs to be taken into account that CSEs often fulfil strategic stockholding obligations with recourse to the storage capacity of the industry (for the whole or part of the

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[262] In certain MS (e.g. Greece) it is a legal requirement that all obligated companies publish their CSO costs.

[263] As a side note, an industry scheme whereby traders are relatively more affected by the obligation than refiners, interestingly, may create a relative advantage for domestic refining – as opposed to refining abroad and importing. In this sense, stockholding regulations could actually promote the domestic presence of refining capacity.

[264] The study does estimate the cost impact of the UK's stockholding obligation to be relatively strong – in fact, it is associated with the largest incremental cost among the 10 legislative costs considered. However, the oil stocking obligation is qualified as the one with the possibility of effective pass-through. As a consequence, it is excluded from the assessment of the overall impact of legislation on the refining margins, and is only analysed in terms of its potential impact on consumers. Nevertheless, it is noted that securing the required financing may be more difficult – and hence costly – for some refiners than others (IHS, 2013).

obligation); this is usually done through public tenders (this is the case, for example, in France, Germany and Spain). Refineries in MS with a CSE can thus potentially benefit from the stockholding obligations by renting out their spare storage capacity at competitive prices. In addition, if they have surplus stocks over and above their stockholding obligations, they can sell tickets to other operators[265].

3.7.4. Efficiency of the legislation

Given the wider objective pursued by the stockholding obligations, their wider societal benefits in terms of oil supply safety are considered to be quite high. While these benefits are extremely difficult to quantify, given the probabilistic nature of future supply shocks and the intangible elements involved, there are some attempts to do so. For example, a recent publication by the IEA (Stelter and Nishida, 2013) estimates the collective economic benefits of the IEA emergency stocks for all the net importing countries. The study simulates a wide range of possible disruptions over a 30-year period, using randomly generated future time paths for oil supply and oil price. The report finds that the economic benefits of holding emergency oil stocks are quite significant (up to about USD 50 per barrel on a yearly basis, under the assumptions of the study). These benefits result, in particular, from reducing GDP losses and import costs in the event of a supply shock – in other words, from the value of the 'insurance' provided by emergency stocks.

Moreover, several global oil supply shocks in recent decades have enhanced the perceived benefits of taking precautions against such disruptions. However, the exact amount of emergency stocks that a specific country would find optimal in the absence of any obligations is difficult to directly observe. As an indication, the same study (Stelter and Nishida, 2013) notes that some non-IEA member countries, such as China and India, recently started to set up emergency stocks on their own, applying the 90 days of net imports target.

As a general observation, collective energy security possesses the characteristics of a *public good*[266] – it is therefore crucial to ensure that an effective and fair public mechanism for its financing is established. This issue is relevant both at the EU level (in that all the MS equally contribute to the common energy security) and at the level of the individual MS (in that the nationally established obligations are shared between the participants of the system in a fair and transparent way). This is especially relevant whenever the obligation is imposed on individual market operators, as it should not result in any unjustified incremental burden. By being flexible about the mechanism of holding and financing strategic oil stocks, the EU allows MS to regulate this issue internally. This seems to represent an appropriate solution, assuming that national governments are best positioned to observe local market conditions and ensure that stockholding obligations are distributed and financed in a non-distortive way.

Because the Directive allowed for a transposition period until the end of 2012, with an additional exception regarding the size of the obligation for certain MS until the end of 2014, it is not possible to precisely detect its actual impacts to date. The cost impact on the MS in general, and on the oil

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[265] This is particularly relevant for refineries operating in MS where no obligation is imposed on the industry; such refiners can sell tickets to operators abroad.

[266] The characteristic features of a public good are non-excludability and non-rivalry in consumption, meaning that no individual can be effectively excluded from using the good, and that the use of the good by one individual does not reduce its availability to others. Public goods provide a very typical example of a market failure, whereby private incentives do not lead to an efficient outcome for the society as a whole. Namely, the first characteristic of public goods, non-excludability, often results in 'free-riding', whereby access to the good is independent of the individual contribution to its financing. As a result, due to the lack of relevant incentives, the good may be underproduced or not produced at all.

refining sector in particular, would ideally be assessed with the cost data reported by the industry and national authorities, taking into account the incremental cost channels identified above. Our discussions with the public authorities and the industry have not revealed any particular issues with the transposition and implementation of the Directive – in fact, it was generally perceived as simplifying compliance with the EU stockholding obligations without increasing them in any significant way.

Based on the available evaluations, our *overall assessment* of the EU strategic stockholding obligation is thus:

- The cumulative burden of holding strategic oil stocks (in comparison to no obligation at all) can be quite high. The costs of establishing the stocks (which constitute the bulk of the total costs of the obligation) were, however, incurred by the majority of the MS as a result of previously existing obligations and due to their membership in the IEA before 2000 (with the exception of the new MS). The incremental obligations introduced in 2000–2012 have not resulted in substantial additional costs (notably, an increase due to the 10 % discount for unavailable stock was considered to be relatively important for certain MS).
- The overall benefits of emergency stockholding are generally seen as significant due to its contribution to the EU and national energy security. Due to their public good nature, the mechanism for financing emergency stocks needs to ensure prevention of distortions and free-riding.
- Resulting from differing stockholding arrangements, the actual obligation for the oil refining industry can differ from one MS to another. Overall, it can be concluded that the obligation is financed in a competitiveness-neutral way.
- Where the obligation is imposed on the industry, strong indications exist that the costs of stockholding can be (fully) passed on to consumers. The 'level playing field', however, is a necessary condition for the possibility of a full pass-through to occur.
- The oil refining industry can in some cases benefit from the stockholding obligation by renting out its spare storage capacity to CSEs and/or by selling 'tickets'.
- The latest Council Directive (2009/119/EC) aims at further optimising the system with a number of specific measures. Since the Directive allowed for a transposition period until the end of 2012 with an additional extension for certain MS until the end of 2014, it is too early to empirically detect its impacts on the oil refining industry to date.

Table 3.7.2. Stockholding by EU MS

Sources: EC, 2014; IEA public data.

MS	Stockholding arrangement	EU stocks on 31.12.2013	IEA stocks in December 2013
Austria	CSO[267] imposed on industry; most stocks held by CSE[268] (ELG)	3.0 Mt (99 days of net imports)	113 days of net imports
Belgium	CSO imposed on industry; all stocks held by CSE (APETRA)	5.1 Mt (102 days of net imports)	140 days of net imports
Bulgaria	1/3 of the stocks held by CSE (SASRWTS), with the rest to be covered by companies	0.8 Mt (70 days of net imports)	Not a member
Croatia	CSO imposed on industry; all stocks held by CSE (HANDA)	0.7 Mt (89 days of net imports)	Not a member
Cyprus	CSE (KODAP/COSMOS) maintains the stocks; financed by compulsory membership of importers	0.5 Mt (84 days of net imports)	Not a member
Czech Republic	All stocks are public and held by CSE (ASMR)	2.3 Mt (102 days of net imports)	136 days of net imports
Denmark	CSO imposed on industry; about 70 % of the stocks are held by CSE (FDO)	1.5 Mt (74 days of consumption)	Net exporter
Estonia	All stocks held by CSE (OSPA); financed by government and partly by excise duties on imports	0.2 Mt (73 days of consumption)	Member since 2014
Finland	Public stocks held by CSE (NESA), complemented by a CSO imposed on industry	3.7 Mt (162 days of net imports)	219 days of net imports
France	CSO imposed on industry which has to delegate part of their obligation to CSE (SAGESS)	19.3 Mt (91 days of net imports)	105 days of net imports
Germany	CSO imposed on industry; all stocks held by CSE (EBV)	24.8 Mt (105 days of net imports)	141 days of net imports
Greece	CSO imposed on industry; the newly adopted law allows for establishment of a CSE	3.3 Mt (96 days of net imports)	107 days of net imports
Hungary	All stocks held by CSE (HUSA); financed by compulsory membership of importers	1.1 Mt (98 days of net imports)	163 days of net imports
Ireland	Stocks are public; almost all stocks held by CSE (NORA)	1.6 Mt (92 days of net imports)	118 days of net imports
Italy	CSO imposed on industry; the newly established CSE (OCSIT) will gradually take over 1/3 of the obligation	13.2 Mt (90 days of net imports)	122 days of net imports
Latvia	The Ministry of Economy acts as the CSE; purchases emergency oil stocks services through open tenders	0.3 Mt (94 days of net imports)	Not a member
Lithuania	Public CSE (Lithuanian Oil Products Agency) holds 30 days of stocks, with the rest covered by companies	0.5 Mt (95 days of net imports)	Not a member
Luxembourg	CSO imposed on importers; the new draft law envisages a CSE but its role is not clear yet	0.7 Mt (91 days of net imports)	92 days of net imports
Malta	CSO imposed on industry, overseen by the Malta Resources Authority (MRA)	0.2 Mt (78 days of net imports)	Not a member
Netherlands	CSO is shared between public CSE (COVA) and oil companies	5.6 Mt (108 days of net imports)	222 days of net imports
Poland	CSO imposed on industry, complemented by public stocks held by the Material Reserve Agency	6.6 Mt (101 days of net imports)	118 days of net imports
Portugal	Public CSE (ENMC) holds 1/3 of emergency stocks, with the rest of the obligation imposed on industry	2.7 Mt (94 days of net imports)	115 days of net imports
Romania	CSO imposed on industry	1.4 Mt (69 days of consumption)	Not a member

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[267] Compulsory stockholding obligation.

[268] Central stockholding entity.

MS	Stockholding arrangement	EU stocks on 31.12.2013	IEA stocks in December 2013
Slovakia	CSO imposed on industry; stocks held by the CSE (EOSA)	0.7 Mt (96 days of net imports)	137 days of net imports
Slovenia	All stocks are public and held by CSE (ZRSBR)	0.6 Mt (96 days of net imports)	Not a member
Spain	CSO imposed on industry; about half of the stocks held by CSE (CORES)	14.8 Mt (99 days of net imports)	102 days of net imports
Sweden	CSO imposed on industry	2.6 Mt (84 days of net imports)	124 days of net imports
United Kingdom	CSO imposed on industry[269]	11.7 Mt (60 days of consumption)	228 days of net imports

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[269] The UK held a public consultation in 2013 on the future stockholding system, and the industry is clearly in favour of setting up an industry-run CSE.

3.8. Marine Fuels Directive

After a review of the objectives and measures of the relevant European and international legislation regarding the sulphur content of marine fuels (Section 3.8.1), we discuss the effectiveness of the legislation in relation to its objectives (Sector 3.8.2). In Section 3.8.3 we assess its impact on the EU refining sector, and, finally, in Section 3.8.4 we review evidence with regard to its overall efficiency. Overall, the reviewed studies and our own data analysis have led to the following main findings:

- EU and international sulphur regulation for marine fuels did not result in significant additional investment costs for refineries. This is the case because
  - the supply of regulation-compliant residual marine fuels was achieved by drawing on the existing pool of fuel oils and blending high-sulphur variants with low-sulphur variants, rather than investing in new desulphurisation capacity;
  - it is also highly unlikely that European refiners have had to invest in additional distillation capacity to meet marine diesel/gasoil demand, given the very low observed production level ($\approx$0.6 % of refinery production and declining).
- Marine fuels sulphur regulation has not driven fuel oil-based products out of the EU bunker market: even though their relative share stopped growing in 2008, and since then has perhaps weakly trended downwards, there is no switchover towards distillate-grade marine fuels.
- Price impacts from the regulation have been absent or profit-neutral for refineries (i.e. costs for higher-priced inputs, like low-sulphur fuel oil, were passed on to markets):
  - global (outside SECA) limit of 4.50 % and later 3.50 %: no discernible price impact;
  - SECA limit of 1.50 % and later 1.00 %: a mark-up of USD 20-80 per tonne vis-à-vis non-SECA bunkers, consistent with the price difference observed between very heavy high-sulphur and light low-sulphur crude oils;
  - marine gasoil shift from 0.20 % to 0.10 %: small price impact of about USD 10 per tonne.
- Given that no significant investment costs were incurred and that price impacts only reflected the natural scarcity of low-sulphur crude oil (i.e. higher input prices that were passed on to markets), we conclude that the cumulative economic impact from marine fuel legislation during 2000-2012 on the refining sector can – within the purpose of this study – be neglected (apart from minor logistical costs related to transport and blending).
- EU refineries were negatively affected by a declining demand for residual-grade products in general, but this was driven by lower inland industrial consumption (see section on the IED), while the demand for residual marine bunkers–apart from a dip after the financial crisis in 2009–grew overall.
- Independent from marine fuels regulation, the price of *all* residual-grade bunker fuels (low- and high-sulphur) experienced a systematic rise in 2009, narrowing the gap to gasoil by about 15 percentage points, which should provide refiners with some financial compensation for the overall shrinking fuel oil market.
- While in steady decline on an EU average level, residual fuel oil retains importance, especially in the Baltic countries, Benelux, France, and Iberia, with shares from 16 % to 20 % of the refinery output barrels in 2012. Refineries in these regions depend on marine fuel markets as an outlet for their residual fuel oil and are therefore potentially vulnerable if future legislation reduces its usability as a marine fuel.

3.8.1. *Objectives and measures*

The 'Marine Fuels Directive' in this study refers to the EU's current central legislation on the sulphur content of certain liquid fuels including marine fuels, namely Directive 2012/33/EU transposing into EU legislation the main international requirements of Annex VI of the International Maritime Organization (IMO) MARPOL convention. Given the recent nature of this regulation and the 2000-2012 time period analysed in the REFIT, we will also consider the earlier EU legislation on the sulphur content of certain liquid fuels, i.e. Directives 2005/33/EC and 1999/32/EC (amended by Directive 2012/33/EU), as well as 2009/30/EC regarding fuel usage on inland waterways.

The primary regulatory objective is to reduce local, regional and international SO_X air pollution from the combustion of liquid fuels on ships. International shipping alone (i.e. without domestic navigation) contributes as much as 10 % to global SO_2 emissions (Mestl et al., 2013), more than twice as much as those from the road and aviation sector combined (Eyring et al., 2005). SO_X and the resultant formation of particulate matter harm the environment (acidification, eutrophication and crop loss) and human health (increased mortality and morbidity). The air quality of harbour cities is particularly affected (EC 2011).[270]

A secondary legislative objective is to strengthen the incentives for the development and adoption of new and alternative approaches and technologies for compliance within marine transport, such as low-emission shoreside electricity, use of gas-powered engines in ships, and innovation in new emission abatement technology.

The IMO provisions of Annex VI of the Protocol on the prevention of pollution from ships (MARPOL). are binding for the IMO member countries, which ratified it (79 out of 171 parties including most EU Member States) and imposed–from May 2005 onwards–an upper limit of 4.5 % on the sulphur content of any fuel oil used on ships outside 'Sulphur Emission Control Areas' (SECA). Only some sea areas have been designated as SECAs: the Baltic Sea (in 2006), the North Sea including the English Channel (in 2007), and North American sea areas (in 2012) – in these areas the sulphur limit has a lower value of 1.50 %. Following an IMO revision process in 2008, a further adjustment to 1.00 % within a SECA (from July 2010) and 3.50 % elsewhere (by 2012) was approved.[271]

Complementing this, EU legislation (Directive 2005/33/EC) further imposes a 1.50 % sulphur limit for all passenger ships to/from the EU on a regular service (since 2006), and a 0.10 % sulphur limit for inland waterway traffic and ships at berth (since 2010).[272] In line with IMO legislation and the wider regulatory objectives, the modified Article 4c in 2005/33/EC allows for the possibility to also achieve the implied emission reductions by alternative on-ship abatement technologies, e.g. flue-gas desulphurisation with on-board scrubbers.

The IMO and directly corresponding EU legislation refers to generic 'marine fuels', thereby covering both of the most commonly used fuel types for ships, namely bunkers based on fuel oil and

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[270] See also COM 2002/0595, Communication from the Commission to the European Parliament and the Council – A European Union strategy to reduce atmospheric emissions from seagoing ships.

[271] It is envisaged to further lower these limits to 0.10 % by 2015 for SECAs and 0.50 % globally by 2020 or 2025. These are mandatory in EU Directive 2012/33/EU: 0.10 % sulphur content as of 2015 for the EU SECAs and 0.50 % outside SECAs as of 2020 with no option to postpone this entry into force date to 2025.

[272] Some derogation rules apply.

distillate-grade marine fuels (marine gasoil and marine diesel).[273] Parts of the specific European legislation refer to distillate-grade fuels only, namely Directive 1999/32/EC regarding the 'reduction in the sulphur content of certain liquid fuels'. It prescribed a maximum sulphur content of 0.2 % for all marine distillate-grade fuels used in the EU, with an effective date of 1 January 2000.[274] The subsequent directive (2005/33/EC) tightened this limit to 0.1 % for marine gasoil by 2008[275], but eased the limit for marine diesel oil to 1.5 % with effect from 2006, so as to ensure a sufficient supply of SECA-compliant marine fuels in the EU.
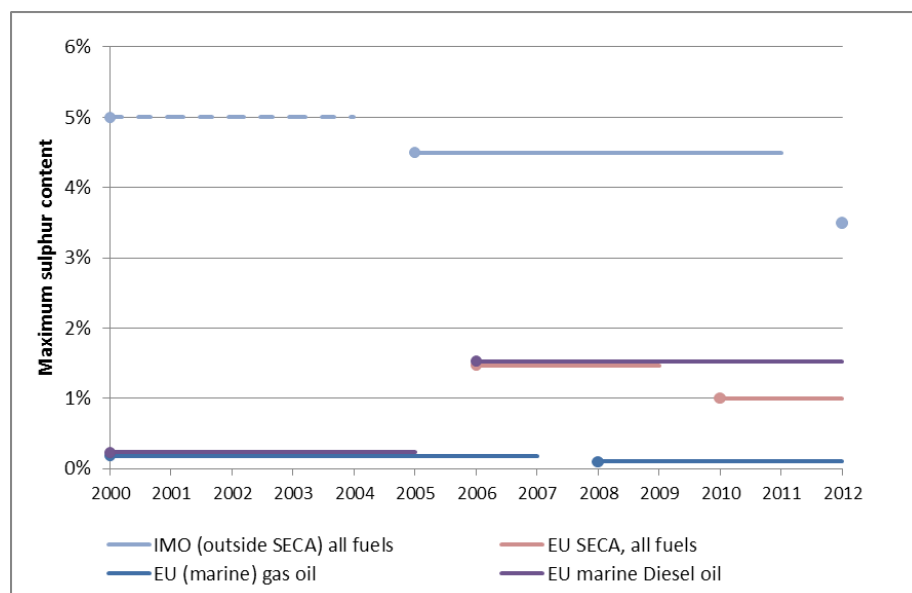
Figure 3.8.1: Relevant limits on the sulphur content of marine fuels
Note: The EU's first SECA was the Baltic Sea in 2006, while the North Sea (including the English Channel) was added in 2007. The dashed line represents the widely used – but not legally binding – ISO specification for residual-grade marine fuels. Note that, for better visibility, lines corresponding to identical values have been slightly separated, and some specifications (inland traffic, for ships at berth) have been omitted.

As an illustration of the overall regulatory situation, Figure 3.8.1 shows the timeline of all provisions (except for inland and at berth) within the 2000-2012 time horizon of the fitness check. In essence, the legislation established four basic product types with specific sulphur limits:

i.   generic <u>outside-SECA marine fuels</u>: 4.5 % (from May 2005), adjusted to 3.5 % from 1 January 2012 (and in EU legislation as of 21 November 2012);

ii.   inside <u>SECA marine fuels</u>, to be used in the Baltic and North Sea, as well as by EU ferries: 1.5 % by 2006, adjusted to 1.00 % in 2010;

iii.   <u>marine gasoil</u> (the main option for inland waterways and ships at berth): 0.2 % by 2000, adjusted to 0.10 % in 2007;

iv.   <u>marine diesel oil</u>: 0.2 % from 2000 to 2006, then relaxed to 1.5 %.

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[273] 'Marine fuel' means any petroleum-derived liquid fuel intended for use on board a vessel including fuels defined in ISO 8217. There are two key groups of marine fuels according to the ISO 8217: Marine distillate fuels (marine gas oil and marine diesel oil) including grades DMX, DMA, DMZ, DMB and marine residual fuels including grades RMA, RMB, RMD, RME, RMG and RMK, see Directive 2005/33 Article 1.2(c).

[274] In addition, 1999/32/EC set and 2005/33/EC later confirmed a limit of 1 % sulphur on all heavy fuel oils used within the territories of EU Member States (shoreside), taking effect in 2003.

[275] An additional change concerned the transition from regulating fuels 'used' in the EU to those 'sold' in the EU.

Markets generally reflect this structure. The most widely sold bunker products, IFO380 and IFO180 (residual marine fuel oils with a small distillate component required to meet maximum viscosity and density specifications), are offered in a generic specification corresponding to product type (i) in the list above, and a 'low-sulphur' ECA specification corresponding to type (ii). Product type (iii) is found on EU markets in the form of 'low-sulphur MGO' or just MGO, while the fourth one is quoted as marine diesel oil (MDO) but overall plays a much lesser role than the other product types and actually seems to be absent from several important markets, including Rotterdam and Houston.[276] Given that its sulphur limit was actually relaxed, it can be assumed that no relevant impact on refineries is associated with MDO regulation, and therefore this product type will not be analysed further.

3.8.2. Effectiveness of the legislation

The direct *effectiveness* of the marine fuel sulphur regulation consists of its impact on the sulphur content observed in marine fuels. According to data reported by the IMO, the global average sulphur content of marine bunkers has indeed decreased after the onset of sulphur regulation in 2005, from a long-term average of 2.7 % to 2.35 % in 2009 (EC 2011, p.74). However, the representativeness of the latter value was questioned because of the chosen statistical approach (*idem*).[277] With a corrected approach, the IMO monitoring data shows a value of 2.51 % sulphur for the year 2012 (fuel oil-based bunkers), hence confirming the – slight – downward trend (IMO 2013, p.31).

Using data from one particular testing organisation, a research article by Mestl et al. (2013) indicates that the global average concentration found in high-sulphur bunkers (i.e. only non-SECA) has essentially not changed, being 2.86 % in 2006 and 2.77 % in 2012 (with 0.06 percentage points as the typical mean absolute year by year deviation), which would be consistent with the conclusion that regulation up to 2012 led to reblending but not to desulphurisation.[278]

Local benefits for the European Union rest on the legislation's ability to achieve the envisaged sulphur limits for SECA (including ferries) and inland waterway navigation, as well as for marine gasoil. According to fuel sampling carried out in and before 2008, very good compliance was achieved for fuels sold for SECA use (4.1-9.2 % of samples were non-compliant, however three fifths of these non-compliant samples were within the margins of error associated with the specific method of analysis), while non-compliance was more frequent for marine gasoil (sulphur content in excess of 0.1 % in 19.5-25.5 % of the samples) and was 'often' observed in the case of marine fuels used by EU ferries (EC 2011, p.49ff). Again, it was emphasised that the monitoring of sulphur content needs to be further improved.

A clear positive environmental impact of the 0.1 % sulphur limit for ships at berth was found by Schembari et al. (2012), based on air quality measurements in Mediterranean harbour cities, and Velders et al. (2011), for the Rotterdam area. The significant impact of ships' emissions on harbour

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[276] In 2003, MDO had a share of around 3 % within the total global marine fuels consumption (Tallett et al., 2006).

[277] IMO averaging was based on the number of samples. This worked until the introduction of the SECAs, when it was observed that the batches of SECA fuel were typically smaller than the batches of regular fuel, thus creating a bias towards a lower average S level. This was recognised by the IMO and corrected (EC 2011 p.74).

[278] The consideration of the global scale is relevant within the EU Refining Fitness Check because of (i) the interlinkage between IMO MARPOL and EU marine fuels regulation, and (ii) because sulphur dioxide is a long-range pollutant, meaning that EU benefits also depend on the global effectiveness of regulation.

city air quality suggests that emission limits applying to ships near harbours or at berth constitute a particularly effective measure.

The impact of the SECA regulation can be observed in Figure 3.8.2, showing the SO_2 emissions for various European sea areas from 2000 to 2011. While emissions in the Mediterranean Sea in particular increased steadily (+28 % overall), they declined notably after 2005 in both the Baltic and North Sea (-57 % overall), the two EU SECA zones.[279]

European inland SO_2 emissions, also shown in Figure 3.8.2, persistently declined, cumulatively by 57 %, and were approaching the level of emissions from shipping. This was one of the motivations for including marine fuels in the scope of sulphur regulation (EC 2011, p.39). Indeed, without regulatory intervention, it was expected that by 2020 ship-based emissions would exceed land-based SO_2 emissions in the EU (EC 2011, p.7). Moreover, the fact that SO_2 can be transmitted over long distances, as shown by Donkelaar et al. (2008) for the example of emissions from China impacting the US west coast, constitutes one important reason for coordinating policies at the EU and international level (another reason being the fact that ships travel internationally and thus benefit from uniform regulation).
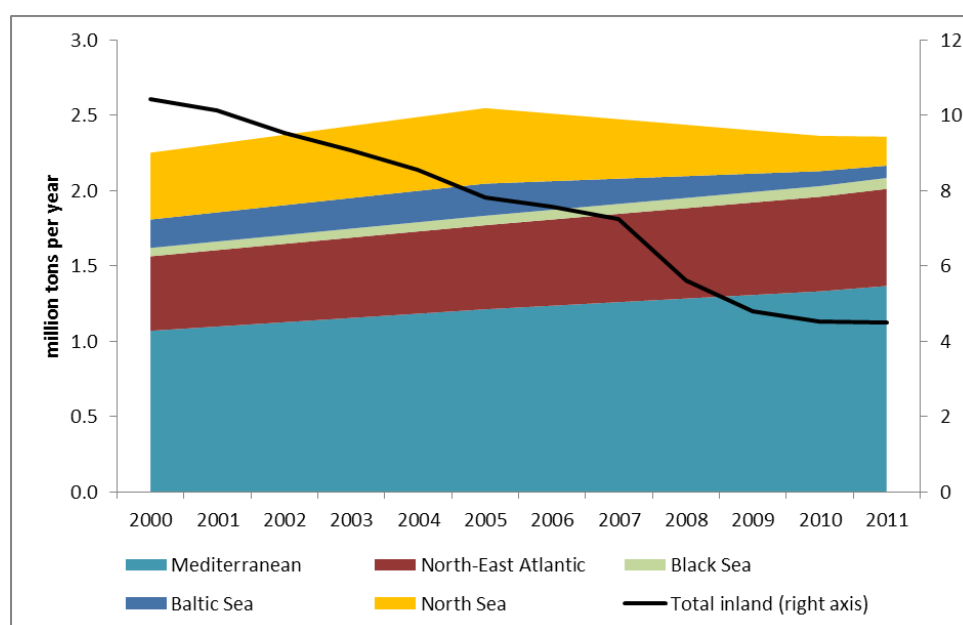
Figure 3.8.2: SO₂ emissions in the EU-27, international shipping and total inland
Note: The missing 'Total inland' values for 2000 and 2001 are 10.4 Mt and 10.1 Mt. Note that only the European areas of the different seas are included in the statistics.
Source: EMEP Centre on Emission Inventories and Projections.[280]

3.8.3. Impact on the EU refining sector

The EU market of international bunker fuels amounts to about 50 Mtoe per year, of which typically over 80 % is residual grade (i.e. with fuel oil as the dominant component). The market also includes around 5 Mtoe per year of marine fuels for domestic navigation, for which the share of fuel oil is

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[279] It should be noted that the values for regional SO_2 emissions are prone to significant measurement uncertainty (Smith et al., 2011).

[280] http://www.ceip.at/ms/ceip_home1/ceip_home/ceip_topnavi/home_emep/

lower, namely 27 % on average over 2000-2012. Hence, the market for marine fuels is significant, but still only a fifth of the size of the market for road fuels (all data from Eurostat (2014)).

Turning to the regulatory impact, by limiting the sulphur content of marine fuels, legislation only indirectly impacts European refineries, because the refineries themselves are not regulated but instead the quality of certain products–wherever produced–in order for them to be sold or used on EU markets. The refining sector has three basic options for supplying bunker fuels with lower sulphur content: (i) reblending of higher-sulphur fuel products with lower-sulphur ones, (ii) decreasing the sulphur content of crude oil inputs, (iii) additional product desulphurisation.[281]

Each of these options creates additional costs for refineries, roughly in ascending order. As a consequence, market price increases for marine fuels and demand reactions could be expected. Below we review existing studies on the impacts of marine fuel legislation and analyse the available evidence in terms of the impact on marine fuel prices, demand, and on refineries' production.

The available Member State studies do not provide a quantitative impact analysis: the Greek study (Danchev and Maniatis 2014) discusses the strong and persisting decline of demand for all petroleum products, including international bunkers, after the onset of the economic crisis (*idem*, p.17). In the same vein, the UK study (IHS 2013) points out that bunker demand experienced the highest percentage drop of all petroleum products in Europe from 2008 to 2010 (*idem*, p. 34). It otherwise focuses on the impact of *future* marine fuels legislation entering into force in 2015 and later (*idem*, p. 143ff.), just like the Italian study (IHS 2014a, p.106ff.). Finally, the Irish study (Purvin & Gertz 2012) does not analyse the subject.

Outside-SECA marine fuels: no significant economic impact

Considering first the introduction of the global limit of 4.5 % in 2005, and its adjustment to 3.5 % on 1 January 2012: all available studies agree that the 4.5 % limit had no impact on refining, given that it was set at the higher end of the actually observed sulphur content of bunkers, and also because the relevant ISO technical standard already indicated a maximum of 5.0 %.[282]

In the EU-15, the pre-policy average sulphur content of residual-grade marine bunkers was 2.9 %, with a range from 0.1 % to 4.3 %, which is thought to also be representative of the EU accession countries (Beicip-Franlab 2002, 2003). The relatively wide range of sulphur contents in Europe's production is explained by the low sulphur content of European North Sea and North African crude oil, which overall represented 43 % and constituted two important sources of the EU-15 crude supply in 2000, and the high-sulphur Middle Eastern crude oil, which constituted about 27 % (Solomon Associates 2014).

As a consequence, the global limit essentially required no response at all from refiners in the EU. Only with the arrival of the stricter 3.5 % provision did a small share of fuels from the high-sulphur 'tail' end of the observed distribution become incompatible with legislation; however, by reblending

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[281] In addition, there are technical response options for ship owners, e.g. installing on-board scrubbers to capture SO_2 emissions. In this case refineries would not have to alter their fuel quality. However, although a potentially important option for the future, scrubber usage has only been a niche option in the 2000-2012 time period considered here (UK Chamber of Shipping 2013). The use of LNG engines also falls into this category.

[282] For example, EPA (2008): 'The new level was set based on a survey of residual bunkers' qualities (the intermediate fuel oil, or "IFO," grades), which showed that essentially all bunkers currently supplied have sulfur contents below 4.5 % (see Figure 1-1). Since the same survey showed global average residual bunker fuel content is currently around 2.7 %, this change has limited practical impact on bunker fuel's quality.'

with available lower-sulphur bunkers, compliance could be achieved without the need for costly desulphurisation.

A sample-based study of the sulphur contents of global residual-grade bunkers supports this finding, showing that the 2012 switch effectively eliminated fuels with sulphur contents above 3.5 % from markets, but that at the same time the global average sulphur content of residual-grade bunkers hardly decreased (Mestl et al., 2013). The study concludes that 'compliance with the new [3.5 %] regulation is achieved by blending high sulfur fuel with lower sulfur fuel, rather than by removing high sulfur fuel from the market or removing the excess sulfur' and that hence the global IMO regulation has had 'negligible negative economic' impacts on refineries on average.[283] Negligible in the sense that the costs they incurred were some additional operational costs related to the transport and blending of suitable fuel oil components.

SECA marine fuels: reasonable price mark-up, no evidence for structural break in market

The 2006 introduction and successive enlargement of the EU SECA, with its limit of 1.5 % and later 1.0 % sulphur, led to the first large-scale introduction of low-sulphur intermediate fuel oils. Though representing an area of just 0.3 % of global waters (Notteboom 2011), the intense maritime traffic in the Baltic and North Sea imply that around 50 % of total European marine fuel demand was affected, i.e. about 20 Mt of residual-grade bunker fuel per year (EPA 2008, p.4-22; Concawe 2009, p.9).[284]

A standard impact indicator of sulphur regulation is the resulting fuel price increase. It is generally expected that more strict sulphur limits on marine fuels will lead to larger spreads between high- and low-sulphur product variants and that the price of very low-sulphur products will approach that of heating oil (e.g. Beicip-Franlab 2002, 2003; Purvin & Gertz 2009; EC 2011).

An increase of up to EUR 50-90 per tonne for 1.5 % sulphur bunkers as compared to standard grades was expected, with an additional EUR 15 per tonne (Beicip-Franlab 2002, 2003) or USD 8-9 (ENTEC 2009) after the tightening to 1.0 % in July 2010.[285] Actual spreads are quite volatile, but from 2007 to 2011 most values for the total 1-3.5 % sulphur content spread were between USD 15 and USD 70 (Purvin & Gertz 2011, p.4). Similarly, a British ferry operator stated that the cumulative price effect of going from no regulation in 2004 to the 1 % limit in 2011 was USD 60 per tonne.[286] The switch to 1.0 % in 2010 did not create a significant impact, with 'some increase in 1 %S fuel oil prices as supplies were put in place but the price spike was shortlived and price spreads quickly returned to an equilibrium level' (Purvin & Gertz 2011, p.3). Hence, available studies suggest that the price mark-up for low-sulphur bunkers proved to be in the expected range, but towards the lower end.

Additional evidence is provided by our own data analysis, based on monthly prices from the IEA. As can be observed in Figure 3.8.3, the price spread between low- and high-sulphur fuels from 2006 to 2012 was mostly in the range of USD 20-80 per tonne, consistent with the 5-10 % mark-up

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[283] This might have been different for some specific locations which did have a significant share of above 3.5 % bunkers before 2012, e.g. Fujairah (Purvin & Gertz 2011, p.8).

[284] Information on SECA-grade fuel demand is actually not readily available, which for all impact analyses constitutes a 'major uncertainty' (Purvin & Gertz 2009, p.29).

[285] Note, however, that the Beicip-Franlab estimate should be understood as an upper bound estimate, as it refers to the production of additional low-sulphur fuel that cannot be supplied by reblending.

[286] See http://www.publications.parliament.uk/pa/cm201012/cmselect/cmtran/1561/1561vw10.htm

reported by Mestl et al. (2013). There is a recognisable dependence of the spread on the crude oil price. On average, at a typical crude price of USD 100/bbl (≈ USD 753 per tonne) a spread of about USD 55 per tonne would be observed.

If it is true that increasingly stricter sulphur legislation raises the relative demand for low-sulphur products, then the spread should grow over time (Purvin & Gertz 2009a, p.12). However, this hypothesis turns out to be difficult to verify because of the spreads' dependence on the crude oil price, which was increasing and highly volatile over the years 2000-2012.[287] Comparing in Figure 3.8.3 the spreads observed from July 2006 to December 2012, which was significantly affected by sulphur regulation, with earlier data illustrates this problem: the number of data points with a similar crude price but from different regulatory periods is actually quite limited.[288] Despite this caveat, the distribution of data points and the two fitted linear trends do not seem to support the conclusion that spreads were higher in the second period. If at all, the observed spreads for the post-July 2006 period seem to be relatively lower than would have been implied by past values.
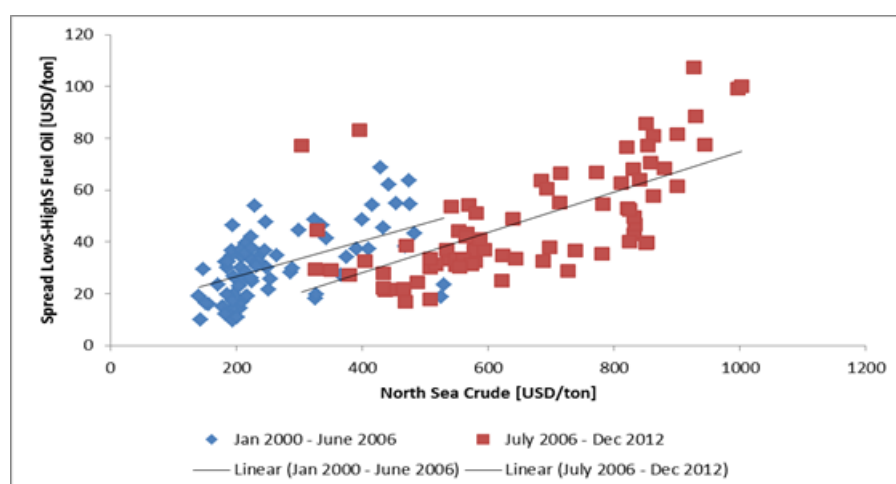
Figure 3.8.3: Observed price spread between low- (1 %) and high- (3.5 %) sulphur fuel oil, in relation to crude oil price
Note: The data is split according to pre- and post-sulphur regulation. Based on IEA data for Rotterdam.

Consequently, we conclude that the transition to the SECA regime in Europe did not lead to a change in market fundamentals, i.e. it did not provoke a large-scale scarcity of low-sulphur bunkers, which might have justified an investment in additional desulphurisation capacity. Even though the stringency of sulphur regulation for marine fuels has gradually increased over time, it did not lead to a widening price gap between low- and high-sulphur bunker fuels.

We also confirm the Commission's own impact assessment stating that 'the entry into force of the second SECA in the North Sea in August 2007 seems not to have had any significant impact on marine fuel prices' (EC 2011, p.75). In fact, the observed price mark-up of 5-10 % for low- over high-sulphur bunker fuels is consistent with economic fundamentals as it seems to be determined mainly by the price difference between low- and high-sulphur crude oils: e.g. taking as a rough

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[287] Amongst other things, this dependence of the spread on the crude price is due to the fact that desulphurisation (whether by hydrocracking or hydrotreating) is an energy-intensive process, and energy costs tend to be related to crude costs.

[288] This difficulty of identifying trends in the presence of a non-stationary crude oil price is also recognised by EC (2011, p.75): 'The price of all refined products is heavily influenced by the price of crude oil which exhibited a sharp rise in 2008 where crude prices rose to $125 per barrel'.

indicator the 'price de-escalator' of EUR 0.35 per 0.1 percentage point of sulphur used for North Sea crude oil by Platts (a pricing service) would imply a EUR 7/bbl, or roughly EUR 50/tonne, spread for 1 % vs 3 % sulphur crude, just as the one found for fuel oil.

Marine gasoil: very modest price impact of ≈1 %

Third, the switch from 0.2 % to 0.1 % sulphur for marine gasoil in 2008. In this case the available IEA data allows us to observe the price spread directly, as both fuel qualities were reported for the 11 months directly after the switch. As shown in Table 3.8.1, the average spread amounted to USD 1.41 per barrel (≈1 % increase), or USD 10.5 per tonne.

Table 3.8.1: Comparison of observed prices for 0.2 % and 0.1 % marine gasoil
Data from IEA, referring to Rotterdam.

Month	MGO 0.2 %S [USD/bbl]	MGO 0.1 %S [USD/bbl]	Spread [USD/bbl]
Jan-08	106.83	107.83	1.00
Feb-08	113.89	114.37	0.48
Mar-08	126.90	127.80	0.90
Apr-08	136.72	137.87	1.15
May-08	157.66	158.88	1.22
Jun-08	162.80	163.81	1.01
Jul-08	162.63	163.78	1.15
Aug-08	136.33	137.67	1.34
Sep-08	123.71	125.71	2.00
Oct-08	94.26	97.12	2.86
Nov-08	74.99	77.38	2.39

An ex ante estimation projected a lower price increase of only EUR 2 per tonne, but this figure has to be seen in the context of a crude oil price that was one fourth of the level observed in early 2008 (Beicip-Franlab 2002). Since desulphurisation is energy-intensive, and refinery energy in Europe largely comes from crude oil, an upwards correction seems plausible. A similar point is made in EC (2011), stating that 'any price increase effect from the lowering of the sulphur content of MGO from 1 January 2008 (from 0.2 % to 0.1 %) in the EU is probably masked by the changes in the crude price.'

A structural shift in 2009 towards higher prices for bunker fuels

An exogenous factor with an impact on the EU refinery sector has been the recent evolution of residual marine fuels from a low-value product of refining into a higher value product. Rulfs (2011) pointed out in a conference presentation that the prices of heavy fuel oil moved from around 50-60 % to 80 % of the crude oil price between 2005 and 2011, coinciding with the period in which most of the current sulphur legislation entered into force.

The occurrence of this structural shift is confirmed by our own analysis based on IEA price data. In this, we use marine gasoil instead of crude oil as the benchmark for assessing 'relative' prices. The reason for this choice is that there are many different variants of crude oil, while marine gasoil is a relatively more narrowly defined product

Accordingly, in Figure 3.8.4 we display the time evolution of the spread between marine gasoil and 380 cst bunker, as well as between marine gasoil and 1 % low-sulphur fuel oil (LSFO), and compare it to that of the price of marine gasoil itself. As can be seen, until the end of 2008 the spreads' evolution closely followed that of the MGO price, but in early 2009 a structural break occurred, after which the spreads for both products became relatively lower, meaning that they

experienced a relative gain in value (we omitted the graph, but the exact same pattern is observed for 3.5 % high-sulphur fuel oil).
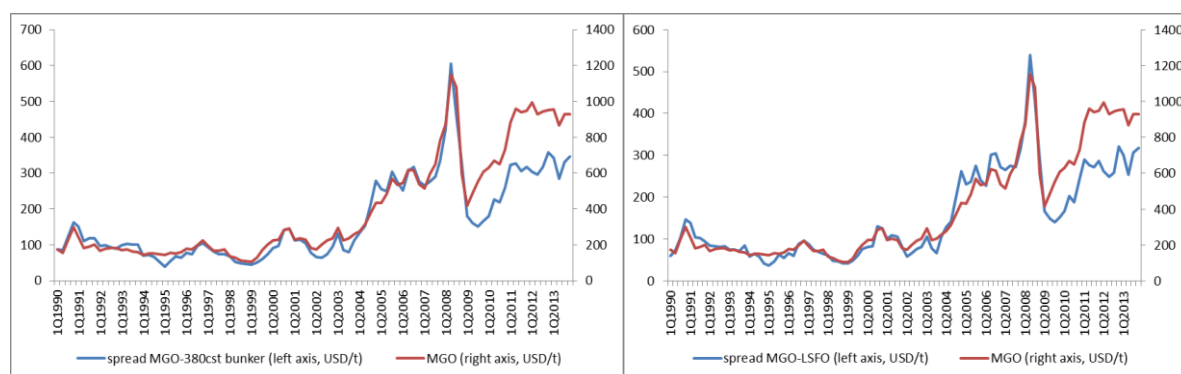
Figure 3.8.4: Spread between marine gas oil (MGO) and 380 cst bunker fuel (left panel), and between MGO and 1 % low sulphur fuel oil (right panel), with overlay of the MGO price itself (shown on differently scaled Y axis on the right)
Data for Rotterdam prices from IEA.

The appreciation of the value of the heavier bunker fuels with respect to MGO is quantified in Table 3.8.2, which compares the average percentage values of all three reported products with respect to MGO before and after the first quarter of 2009. In Rotterdam the price gap to MGO narrowed by about 15 percentage points for all three products considered, which at a MGO price of USD 800/t would imply a price increase of the residual-grade bunkers of about USD 120/tonne. As can be noted, this is not a European phenomenon, as prices in Houston were affected in a similar way.

It is a priori not clear what the driver of this change is. According to Rulfs (2011), one explanation is a supply-demand conflict: on one hand there was a worldwide falling share of residual fuel oil in the output of ever more complex refineries (decline from 24 % to 13 % from 1990 to 2011 (IEA)), while on the other hand international shipping expanded.[289] Anecdotal evidence suggests that a decrease of heavy crude oil production by OPEC in early 2009 also contributed to the appreciation.[290] More stringent sulphur regulation is less likely to matter, given that all types of bunker fuels were gaining in value, even the high-sulphur ones which would have been expected to lose value under a demand shift towards low-sulphur products. In any case, the appreciation of these traditional 'low-value' products is one instance of an exogenous (i.e. not related to regulation) factor with a positive impact on the refining sector – globally and in the EU.

Passing from the price to the quantity perspective, a number of trends can be observed. With a market share of 24 % (2010/11 figure from the IEA), European refining represents an important global player in the international bunker market.[291] Globally, the share of residual fuel oil (80 % of marine fuels consist of residual fuel oil) in refinery output has been steadily declining, from 24 % in 1990 to 18 % in 2000 and 13 % in 2011. Global fuel oil production has also declined in absolute terms, with a contraction of 15 % from 1990 to 2000, and 17 % from 2000 to 2011 (IEA). In the EU context, this reflects the tendency of refineries to become more complex, and the aim of

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[289] As discussed, in many industrialised countries, including the EU, the fuel oil demand of the power sector is declining due to the conflict with emission regulation.

[290] Personal communication with refinery operator.

[291] The EU market shares could in reality be somewhat smaller, as the IEA data is thought to represent a rather conservative estimate of global marine fuel oil demand. Several sources discuss the large uncertainty of this number, reporting estimates ranging from 220 Mt to 330 Mt to 500 Mt per year (e.g. Gätjens 2012; EPA 2009; Lewis 2011).

refiners to produce higher valued distillate products, while demand for most types of heavy fuel oil is declining. In contrast, global demand for international marine bunkers has been growing at a relatively steady rate of 3 % per year (IEA).

Table 3.8.2: Price of residual-grade marine fuels expressed as a percentage of the price of distillate-grade marine gasoil
Data source: IEA data from 1990 to 2013.
Note that fuel specifications and delivery conditions might not be exactly the same in Houston and Rotterdam.

		Rotterdam			Houston, US	
		380 cst bunker	High-Sulphur Fuel Oil	Low-Sulphur Fuel Oil	380 cst bunker	High-Sulphur Fuel Oil
1990 Q1 until 2008 Q4		51.6 %	46.7 %	55.8 %	62.8 %	60.0 %
2009 Q1 until 2013 Q4		66.2 %	63.9 %	70.0 %	79.6 %	78.9 %
Difference		+14.7 %	+17.2 %	+14.2 %	+16.8 %	+18.9 %

Impact on marine fuel production and demand: market stable overall, but dip after 2008

The EU has followed the global trend, except that the 34 % drop in absolute fuel oil production – from 116 Mtoe in 2000 to 76 Mtoe in 2012 – was markedly more drastic (Eurostat 2014). Residual fuel oil production has contracted relatively faster than overall refinery output, letting its relative share fall from 16 % to 12 %. One key driver for this decline has been the phase-out of residual fuel oil as a fuel in the power sector and other heavy industry areas, where it has been substituted by natural gas, due to a large extent to the EU Large Combustion Plants Directive (Purvin and Gertz 2009, p.5). In view of this, the comparatively steady European residual bunker demand of 40 Mtoe per year has gained in importance, now taking up more than 50 % of EU residual fuel oil production. Its significance will likely increase in the future, given that global shipping is expected to grow. At the same time, the fact that the EU has turned from a moderate net importer to a moderate net exporter of residual fuel oil (3 Mtoe per year during 2007-2012) indicates that there is still excess capacity (all data Eurostat 2014).

Eurostat (2014) demand figures for marine fuels in the EU are reported separately according to use – domestic navigation (inland waterways and coastal areas, including fishing fleets) or international bunkers – and according to fuel category – residual- or distillate-grade fuel oil. As mentioned before, inland navigation became subject to a 0.10 % sulphur limit in 2010. As a consequence, a decrease in the share of fuel oil in this market should be expected, which indeed is the case, with a drop from 36 % in 2009 to 27 % in 2012 (Eurostat 2014). As compensation the share of marine gasoil has increased. However, due to the relatively small size of the domestic marine fuels market this does not have a large overall impact.

On EU international bunker markets, the sale of marine gasoil/diesel declined until 2005, by 4 % per year on average, and became relatively stable afterwards, with 1 % growth per year (Eurostat 2014). For residual fuel oil the trend was very different: a strong average growth of 4.4 % per year until 2008 was followed by a strong average contraction of 4.8 % per year until 2012. It is, however, unlikely that this decline was related to EU and IMO sulphur regulation for SECAs and ferries; it rather reflects the decline in global trade and the practice of slow steaming in the aftermath of the global financial crisis.

Figure 3.8.5 combines the aggregate EU marine fuels demand for domestic and international bunkers, for both fuel grades. The graph also indicates the overall percentage share of residual fuel oil relative to all marine fuels, which rose until 2007, and fell slightly afterwards. Overall, we find:

- Although the trend towards a higher share of residual fuel oil stopped in 2008, and perhaps has even reversed, there is no significant switchover in the market towards distillate-grade marine fuels.
- However, there is a clear decrease of overall marine fuel demand after 2008, especially for international bunkers (-18 % to 2012), which is most likely attributable to the global economic crisis. The recent demand levels are nevertheless still within the 'normal' range of historical values.

In terms of cost impacts on EU refineries, the first observation further supports earlier conclusions that it seems unlikely that the past requirements in marine fuel legislation obliged refineries to increase conversion capacity in order to supply more distillate-grade fuels.

The second observation suggests that in the years after the crisis the low demand for marine fuel oil might have aggravated the problem of excess capacity and low utilisation rates in the EU. The existence of excess capacity in residual fuel oil production–and hence marine fuel oil supply–is not a new phenomenon. Already during the first half of the 2000s bunker prices at the EU's largest selling point, Rotterdam, were low by global standards, because of declining inland demand for heavy fuel oil (Purvin & Gertz 2009, p.28). An analysis of more recent prices confirms that this has not changed, with standard and low-sulphur bunker prices still remaining below those observed in competitor regions, e.g. the Rotterdam 380 cst bunker price was on average USD 13/tonne lower than in Houston and USD 30/tonne lower than in Singapore during 2012 (IEA).
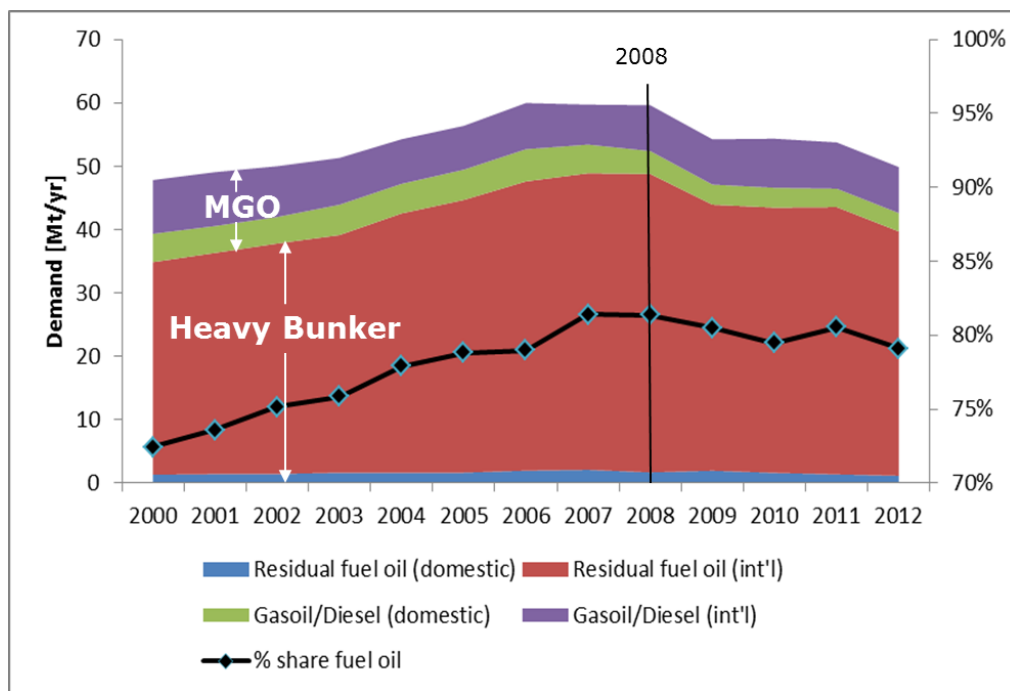
Figure 3.8.5: Total demand for marine fuels in the EU-28, including both domestic navigation and international bunkers
Note: 'Residual fuel oil' refers to the total residual-grade compenent in marine fuels, 'Gasoil/Diesel' to the destillate component. The relative share of residual fuel oil relative to total marine fuels is shown on the right axis.
Source: Eurostat (2014).

Only for gasoil does the data show a relative increase in EU prices: the price difference with Houston was near zero until 2007, and rose to on average USD 2.8/barrel during 2008–2012. Singapore, where prices used to be slightly higher than in Rotterdam, was at a similar level recently

(IEA). This reflects the EU's lack of gasoil production capacity, but this is the case not because of a strong expansion of marine gasoil demand, but rather due to the dieselisation of road transport.

The EU's recent net exports of fuel oil, on average 5 Mt or 7 % of total production during 2010-2012 (Eurostat 2014), while being a net importer in the early 2000s, are another indicator of an increased excess capacity for this product. However, the simultaneous US exports to the Netherlands of fuel oil–about 3 Mt in 2011–which to a large extent seemed to be geared towards low-sulphur SECA-grade marine fuel[292], suggest that local shortfalls of this type of marine fuel might still occur.

Available EU refining data confirms EU-wide trends, but also points to heterogeneity

Suggesting a good cross-consistency, the EU refining industry data (Solomon Associates 2014) broadly confirms most of the trends discussed before:

- The share of fuel oil in total EU-28 output declined from 16 % in 2000 to 13 % in 2012. Since at the same time the share of marine bunkers output increased from 3 % to 4.4 %, their relative importance as an outlet for fuel oil has increased, amounting to 33 % in 2012. However, this figure is still smaller than the 50 % share indicated by Eurostat (2014) data.
- Production of mid-distillate marine fuels (MGO, marine diesel) is very small, with 0.6 % of average EU-28 refinery output, and a slightly declining trend.
- There is a marked difference between the EU-15 and new EU-13 region in that during 2000-2012 the latter hardly produced any marine fuels, even though the share of fuel oil in total output is similar.
- The highest complexity group has the lowest relative fuel oil output (10 % in 2012), while the second-lowest complexity group GOC A has the highest share of fuel oil (21 %) and marine bunkers.
- Regions with a particularly high share of fuel oil and marine bunker output (in 2012) are mostly situated in western and northern Europe: Benelux (20 % of final product output is fuel oil), the Baltic region (17 %), Iberia (17 %), and France (17 %). The latter two have the highest shares of fuel oil going to the marine bunker market, 51 % and 40 %, respectively.
- Regions with low shares of fuel oil in the total final product output (in 2012) are Germany (5 %), the UK and Ireland (9 %), and central Europe (9 %).

From the observation of the declining and practically negligible amount of marine mid-distillate output, it can be confirmed that it is very unlikely that the sulphur regulation considered here resulted in additional conversion capacity for the production of such fuels. Moreover, while the trend towards higher complexity generally meant that EU refineries' residual fuel oil output is decreasing, there are several regions that still have a high output share of residual fuel oil and that rely on marine bunker markets as an important outlet. This makes them potentially vulnerable if residual fuel oil was to be pushed out of this market due to stricter sulphur regulation.[293]

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[292] http://www.platts.com/latest-news/oil/houston/feature-us-fuel-oil-exports-to-europe-near-record-8194393

[293] It should be noted that even very stringent sulphur limits would not necessarily push fuel oil out of the bunker market. Even with a higher sulphur content than nominally allowed, it may still be used if on-board scrubbers are employed such

While the impact of marine fuel quality regulation post-2012 is outside the scope of this report, a separate subsection of this report presents some relevant qualitative considerations.

3.8.4. Efficiency of the legislation

This section discusses efficiency by putting benefits into perspective with costs and assessing whether the benefits are achieved at proportionate and affordable costs.

The efficiency of EU marine fuel legislation, i.e. how far policy objectives were achieved at the least possible costs, has not been explicitly addressed in any of the available studies. However, given that the level of regulation considered here, i.e. during the years 2000 to 2012, did not have a significant cost impact it could be assumed that it was efficient. No information was available on monitoring or enforcement costs.

No studies were found that quantify the benefits achieved from sulphur reductions specifically linked to the Marine Fuels Directive. Chanel et al. (2014) and Le Tertre et al. (2014) are two examples of more general studies that quantify the benefits from various pieces of sulphur regulation – including one concerning seagoing ships –in 20 European cities.

As discussed above, we did not find evidence that past marine fuel legislation had undermined the competitiveness of the EU refining sector from 2000 to 2012. No information was found on the associated administrative burden, but we also did not receive any comments from industry suggesting that this is considered an important issue.

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3.9. Energy Efficiency

Taking into account the existing evaluations, our *overall assessment* of the EU energy efficiency policy in the 2000-2012 period is as follows:

- The two directives previously addressing energy efficiency in the EU – the ESD and the CHP Directives – were admittedly not sufficiently effective in reaching their objectives, and their impacts were marginal. This can be attributed to their open wording and the non-binding nature of the obligations.
- The current Directive on energy efficiency was due to be transposed into national legislation by June 2014. Due to the insufficient time since transposition, the effectiveness and impacts of the sets of specific measures implemented by national governments are difficult to measure at this stage.
- As a general observation, the Directive has the potential to achieve its objectives more efficiently than the predecessor directives, as it introduces binding measures together with indicative energy efficiency targets, with the possibility of recourse to binding national targets in the future.
- The impact of the Directive on the oil refining sector can potentially be twofold and stem from the operational requirements and/or from the demand side. However, without knowledge of specific energy-saving measures at the national level and the related cost-benefit data, the magnitude, and even the direction, of the overall impact are at the moment indiscernible.
- Moreover, it can be expected that the EU's energy-saving progress would be determined to a large extent by emission reduction and renewable energy targets rather than energy efficiency measures on their own – for this reason, the impact of the Energy Efficiency Directive is inherently difficult to separate out empirically.
- We therefore do not consider the Energy Efficiency Directive further in our quantitative analysis and modelling.

3.9.1. Objectives and measures

Energy efficiency is generally defined as the ratio of output to energy consumption. Improving energy efficiency is often seen as an important way to reduce energy demand, thereby increasing energy security, lowering carbon emissions and contributing to sustainable economic growth. In the EU, the importance of promoting energy efficiency is reflected, among others, in one of the Europe 2020 headline targets – 20 % increase in energy efficiency by 2020[294].

In the 2000-2012 period, the following legislative instruments were specifically targeting energy efficiency issues in the EU: Directive 2004/8/EC; Directive 2006/32/EC; Directive 2009/125/EC and

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[294] Namely, the objective is to achieve 20 % primary energy savings in 2020 compared to a baseline. This translates into a saving of 368 million tons of oil equivalent (Mtoe) of primary energy by 2020 compared to the projected consumption for that year of 1842 Mtoe.

Directive 2010/30/EU (summarised in Table 3.9.1). Currently, energy efficiency is addressed by Directive 2012/27/EU[295].

Table 3.9.1. Recent history of the EU legislation on energy efficiency

Name of the Directive	Obligations	Effective date	Under current Directive 2012/27/EU
Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC; also referred to as the *Cogeneration Directive* (CHP Directive)	=> MS to ensure, on the basis of the harmonised efficiency reference values and within six months of their adoption, that the origin of electricity produced from high-efficiency cogeneration can be guaranteed according to objective, transparent and non-discriminatory criteria introduced by each MS. => MS to ensure that the guarantee of origin of the electricity enables producers to demonstrate that the electricity they sell is produced from high-efficiency cogeneration. => MS to analyse the national potential for the application of high-efficiency cogeneration.	21 Feb 2004 Transposition deadline: 21 Feb 2006	Repealed
Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC; also referred to as the *Energy Services Directive* (ESD)	=> MS to adopt an indicative energy-saving target of 9 % by 2016 in the framework of a national energy efficiency action plan (NEEAP). => Public sector procurement policy improving energy efficiency (e.g. purchase of energy-efficient equipment and vehicles, and of low-energy products). => Energy distributors, distribution system operators and energy retail businesses (selling electricity, natural gas, heating oil and district heating) assist in developing and implementing programs and promote measures to improve energy efficiency. => MS to ensure that end-users are provided with competitively priced individual metering and informative billing that shows their actual energy consumption.	17 May 2006 Transposition deadline: 17 May 2008	Repealed, except for Article 4(1) to (4) and Annexes I, III and IV, to be repealed from 1 January 2017.
Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products	Recast		Amended
Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products	Recast		Amended

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[295] Directive 2012/27/EU of the European Parliament and the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

Name of the Directive	Obligations	Effective date	Under current Directive 2012/27/EU
Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings	Set of measures to promote the energy performance of buildings and building units.	8 July 2010 Transposition deadline: 9 July 2012	

The current Directive on energy efficiency[296] entered into force on 4 December 2012, with most of its provisions to be transposed by Member States by 5 June 2014. The Directive pursued an ambitious objective to 'establish a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date'. In particular, it aimed at promoting measures to 'remove barriers and overcome market failures that impede efficiency in the supply and use of energy' and provided for the 'establishment of indicative national energy efficiency targets for 2020'.

The main objective of the Directive was to reinforce and consolidate previous regulatory efforts to improve energy efficiency. The motivation behind the review of existing legislation stemmed from the following: (i) the EU has become increasingly dependent on energy imports; (ii) energy use is admittedly a major contributor to greenhouse gas emissions; (iii) by 2012, mid-term evaluations showed that the ambitious Europe 2020 energy efficiency targets would not be achieved without additional actions at the EU level.

To this end, the Directive has put in place the following measures[297]:

- The *legal definition and quantification of the EU energy efficiency target:* to achieve by 2020 energy consumption of no more than 1 474 Mtoe of primary energy[298] or no more than 1 078 Mtoe of final energy (with the accession of Croatia, the target was revised to no more than '1 483 Mtoe of primary energy or no more than 1 086 Mtoe of final energy').
- The obligation for each Member State to set an *indicative national energy efficiency target* in the form they prefer and, by 30 April 2013, to notify the Commission of it together with its conversion in terms of primary and final energy consumption in 2020.
- The obligation for Member States to achieve a certain amount of final energy savings[299] over the obligation period (1 January 2014 – 31 December 2020) by using *energy efficiency obligation schemes* or other targeted policy measures.
- The possibility for *consumers to better manage their energy consumption* through efficient and free-of-charge access to data on real-time and historical energy consumption.
- The obligation for large enterprises to carry out an *energy audit* at least every four years,

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[296] *Energy efficiency* is understood in the Directive as 'the ratio of output of performance, service, goods or energy, to input of energy', whereby *energy* refers to 'all forms of energy products, combustible fuels, heat, renewable energy, electricity, or any other form of energy, as defined in Article 2(d) of Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics'.

[297] Summary on DG ENER website, available at: http://ec.europa.eu/energy/efficiency/eed/eed_en.htm.

[298] Primary energy consumption is defined as gross inland consumption minus non-energy uses.

[299] *Energy savings* are understood as 'an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalisation for external conditions that affect energy consumption'.

with a first energy audit at by 5 December 2015 the latest. Incentives for SMEs to undergo energy audits to identify the potential for reduced energy consumption.

- *Public sector* to lead by example by renovating 3 % of buildings owned and occupied by the central governments starting from 1 January 2014 and by including energy efficiency considerations in public procurement.
- *Efficiency in energy generation*: monitoring of efficiency levels of new energy generation capacities, national assessments for cogeneration and district heating potential and measures for its uptake to be developed by 31 December 2015.
- *Efficiency in energy transmission and distribution*: achieving efficiency gains by ensuring that national energy regulators take energy efficiency criteria into account in their decisions.

While providing a common framework for improving energy efficiency at the EU level, the Directive left significant flexibility to Member States with respect to the specific measures to be implemented. At the same time, the following indicative policy instruments were suggested:

'(a) energy or CO_2 taxes that have the effect of reducing end-use energy consumption;

(b) financing schemes and instruments or fiscal incentives that lead to the application of energy-efficient technology or techniques and have the effect of reducing end-use energy consumption;

(c) regulations or voluntary agreements that lead to the application of energy-efficient technology or techniques and have the effect of reducing end-use energy consumption;

(d) standards and norms that aim at improving the energy efficiency of products and services, including buildings and vehicles, except where these are mandatory and applicable in Member States under Union law;

(e) energy labelling schemes, with the exception of those that are mandatory and applicable in the Member States under Union law;

f) training and education, including energy advisory programmes, that lead to the application of energy-efficient technology or techniques and have the effect of end-use energy consumption.'

MS were required on 30 April 2014, and every three years thereafter, to submit National Energy Efficiency Action Plans presenting their intended energy efficiency improvement measures.

3.9.2. *Effectiveness of the legislation*

In 2011, the Commission conducted an impact assessment of the proposal for the current Directive on energy efficiency. In this framework, the implementation and results of the legislative instruments previously tackling energy efficiency in the EU – Directive 2004/8/EC (CHP) and Directive 2006/32/EC (ESD) – were analysed. The impact assessment concluded that, while the ESD and the CHP Directive to a certain extent addressed important barriers in the relevant sectors (such as insufficient political commitment; lack of incentives for consumers and energy suppliers; low awareness; cultural barriers, etc.), the general character and open wording of the obligations limited their practical effectiveness.

The mid-term evaluations of the ESD and the CHP Directive demonstrated that they had not succeeded in fully exploiting the energy-saving potential of the sectors they covered. It was estimated that primary energy savings from the implementation of the ESD would only reach 50-

95 Mtoe in 2020, significantly under the Europe 2020 target of 368 Mtoe. The effectiveness of the CHP Directive was also shown to be limited – for example, the overall share of electricity from high-efficiency cogeneration only increased from 10.5 % in 2004 to 11.0 % in 2008.

Due to the open wording of most of the Directives' provisions and lack of clarity with respect to their minimum requirements, they were not likely to increase the level of ambition at the MS level (for the same reason, better enforcement was not possible from the Commission's side). In addition, several policy changes took place since the adoption of the two Directives: (i) a new target for 20 % energy efficiency was endorsed by the European Council in 2007, which made the level of ambition of the ESD inadequate; (ii) the Renewable Energy Directive (Directive 2009/28/EC) was adopted in 2009, which set a higher priority for technologies using renewable energy relative to CHP and could further delay the market uptake of the latter; (iii) the third internal energy market package was published in 2009, which set obligations for the introduction of smart meters but not specific measures targeted at their usage for the benefit of final consumers. It was therefore concluded in the impact assessment that the ESD and the CHP Directive were no longer fully suited to the market and political reality, and would not lead to sufficient improvements in energy efficiency without additional incentive mechanisms adopted at the EU level.

As a result, the Energy Efficiency Directive of 2012 aimed at creating the right market conditions and legal environment to facilitate full realisation of the 20 % energy-saving objective in the EU. In order to identify and exploit the potential for effective energy savings in as many areas as possible, its scope includes all end-use (residential, commercial and industrial) and energy generation sectors. The transport sector, which has been subject to a specific set of emission control measures at the EU level, is not covered however. The new Directive extended the scope of the two preceding ones and merged them into one legislative text for simplification and better coherence.

The impact assessment concluded that there was no need to introduce binding national targets for energy savings – instead, the Directive provides a set of binding measures. The national energy-saving obligation schemes are a key part of this package; they aim at an annual final energy reduction of 1.5 %. The obligation is placed by MS on their energy utilities operators (suppliers or distributors), since the latter are considered to be best placed to have at their disposal information on the energy consumption of their clients. The public sector, via purchasing of efficient products, buildings and services, is given prominence in the system of energy-saving measures. The role of the public sector consists of promoting the uptake of energy-efficient technologies and processes rather than direct energy savings. Information on actual energy consumption provided to households and companies on a frequent basis through their energy bills and on the savings possibilities for large companies through energy audits are, in turn, important for reducing the information gap that is one of the barriers to efficiency. A number of regulatory measures were proposed to be implemented at the national level to support more efficient energy generation, transmission and distribution. For example, clear connection rules and priority access to the electricity grid for high-efficiency cogeneration were established in order to put CHP on an equal footing with renewable energy technologies.

Overall, on this basis it can be concluded that the current Directive seems to have a high potential for achieving its goals effectively, because:

- it introduces binding measures rather than binding targets, which makes it possible not only to evaluate the progress in implementation at every stage, but also to understand and correct any bottlenecks in the process;
- this is complemented with indicative non-binding national energy efficiency targets set by the MS themselves, which introduces an additional incentive mechanism;

- in addition, if in 2014 the Commission comes to the conclusion that the EU's 20 % target is not likely to be achieved by 2020, it will propose binding national targets.

3.9.3. Impact on the EU petroleum refining sector

As discussed above, the two preceding directives – the ESD and the CHP Directive – proved to be insufficiently effective and only marginally contributed towards energy efficiency improvement due to their non-binding nature and the open wording of the measures. We therefore conclude that they did not impact the oil refining sector in any considerable way.

As for the present Directive, it does not appear feasible to conduct a meaningful empirical evaluation of its impacts at the moment: while a very short time has passed since its transposition into national laws (which was due by June 2014), the wide range and non-prescriptive character of the suggested policy measures make it difficult to assess or forecast any specific impacts so far. Ultimately, the degree to which the industry is affected, and any resulting costs and/or benefits, will depend on the specific national policy measures and the way they are implemented.

As a general observation, the impact of policy measures aimed at improving energy efficiency on the oil refining industry could be twofold. Given that refining sector is both an important producer of energy and its major consumer, such measures could affect it from the operational point of view[300] and/or from the demand side.

On the *operating* side, it needs to be stressed that refineries are themselves very interested in improving their energy efficiency[301]. As we discussed in Chapter 2, energy is one of the most important refining inputs, accounting for a major share of the EU refineries' operating costs. Refineries therefore pay specific attention to their energy consumption; they widely employ optimisation models in order to improve the cost (including energy) efficiency of their processes. Examples of energy-saving measures in refining processes include 'improvements in furnace efficiency, heat integration, use of cogeneration (combined heat and power generation or CHP) and general energy housekeeping, with the main focus being on heat use and waste heat recovery' (IHS, 2013). In this sense, the objectives of the Directive are supported and reinforced by the economic incentives of the industry. In economics terms, the cost-minimising behaviour of the industry generates a relevant *positive externality*[302] for the society as a whole: due to refineries being interested in the cost efficiency of their operations, society overall benefits from reduced energy consumption.

Statistical data supports these theoretical observations. According to Concawe, the share of cogeneration in electricity generation in the EU refineries rose from 76 % to 92 % over the 1992-2010 period, while the total cogeneration capacity increased by 125 % (Concawe, 2012). Based on the data for the sample of the EU refineries provided in Solomon Associates (2014), we observe

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[300] However, as mentioned above, the Directive (partly) excludes the amounts of energy consumed by the oil refining sector from the calculations towards energy efficiency targets, as this sector is part of the EU ETS.

[301] For example, an assessment by the IEA finds that 'when the value of productivity and operational benefits to industrial companies were integrated into their traditional internal rate of return calculations, the payback period for energy efficiency measures dropped from 4.2 to 1.9 years' (http://www.iea.org/newsroomandevents/pressreleases/2014/september/name-125300-en.html).

[302] Externality refers to the outcome of a certain activity of economic agents that unintentionally affects other, non-related agents. Depending on their effect on unrelated parties, externalities may be classified as either positive or negative.

that high efficiency electricity production[303] in the EU refining sector grew steadily and increased from 201.1 MWh/year on average per refinery in 1998 to 361.4 MWh/year in 2012, i.e. by almost 80 %.

In addition, the Directive foresees mandatory energy audits for large enterprises, which, while potentially associated with a certain incremental administrative burden, could in general be in line with the cost optimisation interests of refineries as outlined above.

On the *demand side*, however, the Directive could potentially have a negative impact on refineries as a result of the reduced overall consumption of energy products. The exact magnitude of this impact will depend on the amount of energy savings achieved, which in turn will be determined by the concrete measures implemented at the national level and their effectiveness. Importantly, the Directive allows for the sales of energy used in *transport* to be partially or fully excluded from the calculation of energy savings – this appears to be very relevant for the refining industry, where the majority of outputs are transportation fuels.

3.9.4. *Efficiency of the legislation*

As discussed above, while the two preceding directives – the ESD and the CHP Directive – proved to have a limited impact on energy efficiency improvements due to their open wording and non-binding measures, the current Directive can be expected to induce more significant changes. At the same time, the Directive identifies the channels for achieving its objectives in a cost-efficient way, such as energy improvements resulting in significant savings in public and private energy spending, and making full use of Community Structural and Cohesion Funds. It also explicitly mentions that for the implementation of particular measures, 'due regard should be accorded to the cost-effectiveness at Member State level of implementing energy efficiency measures on the basis of an appropriate level of analysis and evaluation'. Nonetheless, the obligation to carry out regular energy audits can be expected to be present across all Member States.

In the Commission's impact assessment, potential energy savings resulting from the current system of measures were estimated as significant; however, the scale of the actual savings, and thus the cost-benefit performance of the adopted policy measures, would depend on specific national implementation and the individual reactions of consumers. In addition, it needs to be noted that the non-binding approach to energy saving in the EU is different from the one adopted for renewable energy (where the Renewable Energy Directive sets binding national targets for 2020) and for greenhouse gas emissions (where the EU emissions trading system (ETS) creates binding targets for 2020: at the firm level for the sectors it covers, and through the effort-sharing decision at the national level for the sectors it does not cover). It can therefore be expected that the EU energy-saving progress would be determined to a large extent by emission reduction and renewable energy targets rather than the energy efficiency measures on their own – for this reason, the impact of the Energy Efficiency Directive would be inherently difficult to separate out empirically.

At the same time, as energy consumption is closely correlated with emissions volumes, energy efficiency measures have the additional benefit of reducing harmful emissions. In terms of the overall climate policy, energy-saving obligations can strongly contribute to reaching the emission targets, for example, in the sectors that are not part of the EU ETS. On the other hand, the need to comply with two sets of obligations at the same time might disproportionally affect the relevant

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[303] This category includes cogeneration and other high efficiency electricity production, for example, with the use of extraction steam turbines.

sectors. In this respect, the current Directive explicitly suggests (Art. 7, 2b) excluding (up to a certain limit) from the calculation of energy savings reported by MS all or part of the energy used in industrial activities subject to the ETS (including 'refining of mineral oil').

REFERENCES TO RELEVANT SOURCES

Concawe (2012): 'EU refinery energy systems and efficiency', Report No. 3/12, Brussels, March

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3.10. Air Quality Directive

- The observed effectiveness in achieving the objectives of the EU air policy was mainly attributed to the effective EU-level source control measures – most importantly, fuel quality policies and instruments addressing large emission sources such as the Large Combustion Plants Directive, the Waste Incineration Directive, and the Integrated Pollution Prevention and Control Directive, all currently consolidated in the new Industrial Emissions Directive[304].

- Therefore, the impacts of the Ambient Air Quality Directives (AAQDs) can only be observed indirectly, in terms of the impacts of more specific, targeted policy measures. The EU petroleum refining sector is directly subject to regulation under the fuel quality legislation as well as the industrial emissions legislation. We thus conclude that in 2000-2012 the above-mentioned fuel quality (FQD) and industrial emissions (IED) policy instruments addressed the air quality-related issues in the oil refining sector in a much more targeted way than the AAQDs. In our assessment, we therefore do not attempt to disentangle the analysis of the AAQDs' impacts from that of the FQD and IED, which are analysed in the respective chapters of this report.

- The 2013 ex post review of the EU Air Quality Policy Framework by the European Commission (EC, 2013) concluded that the overall EU air quality policy was coherent and achieving its objectives effectively. Actions leading to these successes have also been found to be efficient and in accordance with the 'polluter pays' principle.

3.10.1.   Objectives and measures

Over the past decades, air pollution has been increasingly recognised as posing significant risks to human health and the environment. Despite substantial improvements in Europe's air quality in recent years, air pollution is considered the number one environmental risk factor of premature deaths in the EU, as well as being responsible for substantial quality-of-life, economic, ecological and biodiversity impacts (EC, 2013). To this end, the EU has put in place a number of policy measures addressing the quality of air. The EU Air Quality Directives, which set maximum ambient concentrations for a range of parameters and define the standards for assessing and managing air quality, are an important component of the current EU air quality policy framework.

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[304] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). See also the relevant section in this report.

> **Box 3.1. What are the main air pollutants – and where do they come from?**
>
> - *Particulate matter* (PM) is fine dust, emitted by road vehicles, off-road vehicles and machinery, power generation, agriculture and households, and from natural sources such as sea salt, wind-blown soil and sand (primary PM) or formed through atmospheric processes (secondary PM). Health concerns focus on particles of less than 10 micrometres (μm) in diameter (PM_{10}) – especially those of less than 2.5 μm across ($PM_{2.5}$).
> - *Sulphur dioxide* (SO_2) is emitted by power generation, industry, shipping and households. It harms human health and contributes to acidification of soils and inland waters. It also contributes to secondary PM formation.
> - *Nitrogen oxides* (NO_X) are emitted by road vehicles, shipping, power generation, industry and households. They harm human health and contribute to acidification and eutrophication. Nitrogen oxides are also a key component in increased levels of ground-level ozone (O_3). They also contribute to secondary PM formation
> - *Ammonia* (NH_3) is emitted by livestock farming and the use of fertilisers in agriculture. It harms human health as it is a building block for so-called secondary PM and contributes to acidification and eutrophication.
> - *Volatile organic compounds* (VOCs) are emitted by the use of solvents in products and industry, road vehicles, household heating and power generation. VOCs are the key component in the formation of ground-level ozone.
> - *Ground-level ozone* (O_3) is a secondary pollutant produced by chemical reactions of NO_X and VOCs in sunlight. It harms human health, the environment, crops and sensitive construction material like metals and paints.
>
> *Source: EC, DG Environment factsheet 'Cleaner air for all. Why is it important and what should we do?' Available at:*

The air quality legislation relevant in the 2000-2012 period aims at reducing to acceptable levels the emissions of certain air pollutants, the most important of which are listed in Box 3.1 above. The corresponding legislative instruments include[305]:

- Council Directive 96/62/EC on ambient air quality assessment and management, commonly referred to as the *Air Quality Framework Directive* (describing the basic principles of air quality assessment and management, and defining the pertinent pollutants); and its four 'daughter' directives:
  - o Council Directive 1999/30/EC setting the limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (*the 'first daughter directive'*);
  - o Directive 2000/69/EC of the European Parliament and of the Council relating to limit values for benzene and carbon monoxide in ambient air (*the 'second daughter directive'*);
  - o Directive 2002/3/EC of the European Parliament and of the Council relating to ozone in ambient air (*the 'third daughter directive'*);
  - o Directive 2004/107/EC of the European Parliament and of the Council relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (*the 'fourth daughter directive'*); as well as:
- Council Decision 97/101/EC establishing a reciprocal exchange of information and data from networks and individual stations measuring ambient air pollution within the Member States; and

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[305] Summary by DG Environment: http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm.

- Commission Decision 2004/461/EC laying down a questionnaire for annual reporting on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC and under Directives 2000/69/EC and 2002/3/EC of the European Parliament and of the Council.

The Ambient Air Quality Directives (AAQDs) are part of the broader EU air quality policy, which has been evolving since the 1980s, building on national and international efforts in the field of pollution control. In its current form, this policy builds on the following main elements (EC, 2013):

(i) the 2005 Thematic Strategy on Air Pollution (TSAP) which sets out the overall policy direction, including interim objectives for 2020 towards the EU's long-term target and cost-effective actions to achieve those objectives while ensuring overall policy coherence;

(ii) the AAQDs;

(iii) the National Emission Ceilings Directive (NECD) which limits the total emissions from each Member State for a set of pollutants;

(iv) a range of measures at the EU, national and international levels controlling pollution at the source to achieve the objectives set in the above-mentioned instruments;

(v) international action under the CLRTAP and other international platforms, including the exchange of scientific and technical information.

The current Directive 2008/50 on ambient air quality[306] entered into force on 11 June 2008, with a two-year transposition period (with the exception of certain provisions that needed to be implemented sooner). With respect to the preceding legislation, the Directive introduced the following key elements[307]:

- it merged most of the relevant legislation[308] into a single directive with no changes to the existing air quality policy objectives;
- new air quality objectives for $PM_{2.5}$ (fine particles) including the limit value- and exposure-related objectives – exposure concentration obligation and exposure reduction target;
- the possibility to discount natural sources of pollution when assessing compliance against limit values;
- the possibility for time extensions of three years (PM_{10}) or up to five years (NO_2, benzene) for complying with limit values, based on objective conditions and the assessment by the European Commission.

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[306] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

[307] Summary by DG Environment: http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm.

[308] Framework Directive 96/62/EC, 1-3 daughter Directives 1999/30/EC, 2000/69/EC, 2002/3/EC, and Decision on Exchange of Information 97/101/EC.

3.10.2.   *Effectiveness of the legislation*

The justification for legislative EU-wide action on air pollution has long been established based on the trans-boundary nature of air pollution. The present EU air quality policy focuses mainly on the trans-boundary aspect of air pollution and related controls. Both the NECD and the AAQDs define commonly agreed targets, while leaving the choice of the means to achieve them up to the Member States.

In 2013, the European Commission published – as a result of a comprehensive ex post review of the EU Air Quality Policy Framework – an impact assessment accompanying a communication and several legislative proposals on the quality of air (EC, 2013). Overall, the review concluded that the existing policy framework was logical and coherent, and already contributed to significantly reducing air pollutant emissions and impacts. However, it suggested that a better match needed to be ensured in practical implementation between different policy measures (including realising potential synergies between the AAQDs and the NECD). In addition, the scope and objectives of the NEC Directive were found to be out of line with the latest scientific findings and international agreements, and were recommended to be adapted to better focus on the health hazards of pollution by introducing new ceilings for $PM_{2.5}$ and short-lived climate pollutants in line with the 2012 Gothenburg Protocol requirements.

For the AAQDs, the health relevance of the pertinent pollutants and standards of the original policy were reviewed and confirmed, with the caveat that the level at which certain standards are currently set (mainly for PM) provides only partial protection for human health. The effectiveness of the AAQDs in achieving their objectives were assessed in terms of the extent of compliance with the limit values set. Widespread compliance with the limit values for benzene, lead, CO, and SO_2 set in the Directive was observed. In addition, the non-binding target values for heavy metals (arsenic, cadmium, nickel) were also broadly complied with. Part of the outstanding health and environmental problem was found to be due to the lack of compliance with existing EU legislation.

However, and as may be reasonably expected, the effectiveness observed in achieving the objectives of the EU air policy was mainly attributed to the effective EU-level source control measures – most importantly, fuel quality policies and instruments addressing large emission sources such as the Large Combustion Plants Directive, the Waste Incineration Directive, and the Integrated Pollution Prevention and Control Directive, all currently consolidated in the new Industrial Emissions Directive[309]. For the EU source controls, the scope and objectives were also concluded to remain broadly valid. Updated emissions data and projections confirmed that the sectors driving the relevant pollutant emissions were correctly identified. Evaluation of the emission reductions achieved under the NECD also showed that the best compliance was achieved where a substantial proportion of emissions was regulated by EU source legislation (e.g. for SO_2). The potential for cost-effective reductions was argued to be greater for the sectors where emissions had been reduced less, i.e. the ones not subject to strict source control measures.

3.10.3.   *Impact on the EU petroleum refining sector*

As discussed above, the impacts of the AAQDs can arguably only be observed indirectly, in terms of the impacts of more specific, targeted policy measures. The EU petroleum refining sector is directly subject to regulation under the fuel quality legislation as well as the industrial emissions

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[309] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). See also the relevant section in this report.

legislation. We thus conclude that in 2000-2012 the above-mentioned fuel quality (FQD) and industrial emissions (IED) policy instruments addressed the air quality-related issues in the oil refining sector in a much more targeted way than the AAQDs. In our assessment, we therefore do not attempt to disentangle the analysis of the AAQDs' impacts from that of the FQD and IED, which are analysed in the respective chapters of this report. We refer the reader to these sections for further discussion on the impacts of these policies on the EU oil refining sector.

3.10.4.   Efficiency of the legislation

As discussed above, the 2013 ex post review of the EU Air Quality Policy Framework by the European Commission (EC, 2013) concluded that the overall EU air quality policy was coherent and achieving its objectives effectively. Actions leading to these successes have also been found to be in accordance with the 'polluter pays' principle.

Without any comparison to the potential costs for the oil refining industry or judgment on their proportionality, below we briefly discuss the wider benefits of air quality regulation. Estimations of health-related external costs due to pollution range between EUR 330 billion and EUR 940 billion per year depending on the valuation methodology (EC, 2013). They include both direct health costs and indirect losses for the economy, such as workdays and productivity decreases. Pollution, in particular the eutrophication problem, has substantial biodiversity and resulting economic impacts (for example, from reduced fish populations). It also affects the tourism sector due to the loss of recreational value of the natural landscape as a result (EC, 2013).

On the other hand, as discussed above, the success of the EU air quality policy framework in achieving its goals can be largely attributed to the effective source control measures rather than broader air quality regulation through the AAQDs. For a discussion on the costs and benefits of these more targeted policy instruments, we again refer the reader to the respective sections of this report.

REFERENCES TO RELEVANT SOURCES

European Commission (2013): Staff working document - Impact assessment accompanying the documents COM(2013)917, COM(2013)918, COM(2013)919, COM(2013)920, SWD(2013)532. Brussels, 18.12.2013, SWD(2013) 531 final

4. **Economic impact of the analysed directives on the EU oil refining sector's competitiveness**

In this chapter we present the results of a cumulative economic impact analysis of the 10 individual legislation packages described in detail above. The corresponding legislation packages are:

1. the Renewable Energy Directive (RED);
2. the Energy Taxation Directive (ETD);
3. the EU Emissions Trading System (EU ETS);
4. the Fuel Quality Legislation (FQD);
5. the Directive on Clean and Energy-Efficient Vehicles (DCEEV);
6. the Industrial Emissions Legislation: the Integrated Pollution Prevention and Control Directive (IPPCD) and the Large Combustion Plants Directive (LCPD)[310];
7. the Strategic Oil Stocks Directive (SOSD);
8. the Marine Fuels Directive (MFD) [311];
9. the Energy Efficiency Directive (EED);
10. the Air Quality Directive (AQD).

In the methodology proposed for this fitness check we identify three main impact channels by which the relevant legislation can affect the competitiveness of the refining industry (presented in Figure 3.10.1). First, in the most direct way, a piece of legislation can require a costly effort from the refining sector by impacting the way a refinery has to be operated. Second, a legislation package may impose particular specification/quality requirements on petroleum products sold in the European markets, which indirectly affects the refineries' operations. Third, and, again, representing an indirect effect, a legislation package can also result in changes in the relative and absolute demand for existing petroleum products.

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[310] The Industrial Emissions Directive (IED) 2010/75 required transposition by January 2013 and hence had hardly any tangible effects in the period covered by this assessment. However, given that the IED is a recast of seven pre-existing directives, large parts of it were actually established earlier. The assessment does include such preceding legislation with relevance for the EU refining sector. In particular, this includes the Integrated Pollution Prevention and Control Directive 2008/1 (IPPC, going back to 1996/61) and the Large Combustion Plants Directive 2001/80.

[311] The MFD, known in the maritime community as the 'Sulphur Directive' mostly addresses marine fuels, i.e. Directive 2012/33/EU of the European Parliament and of the Council of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of certain liquid fuels.
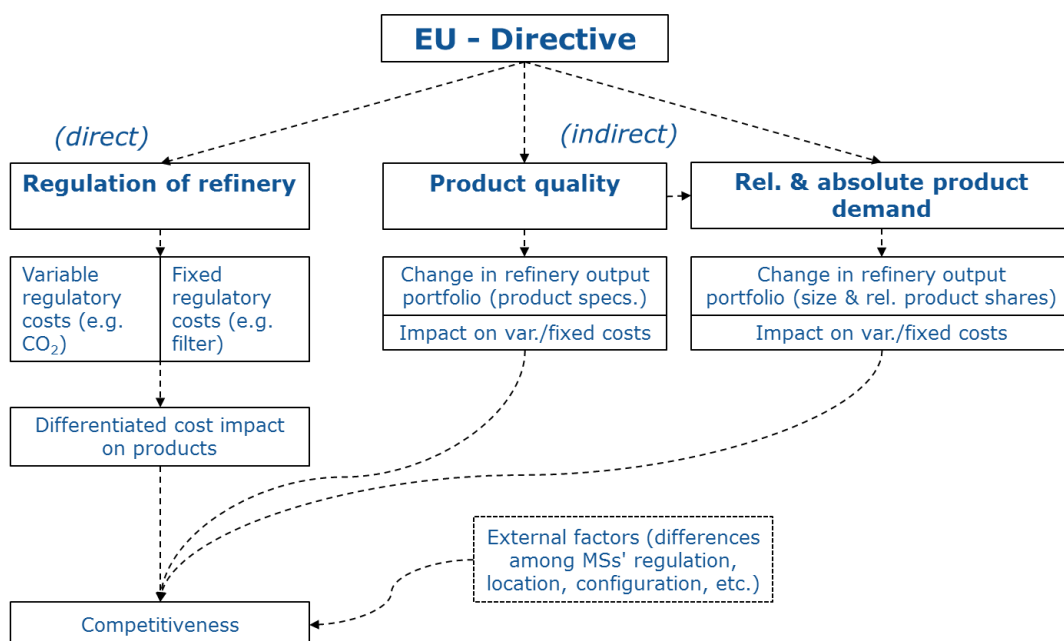
Figure 3.10.1: Graphical representation of the three impact channels in a common conceptual framework

In Table 4.1.1, Table 4.2.1, and Table 4.3.1 and in the sections below we present a detailed overview of the main effects produced by the different pieces of legislation considered in this fitness check, grouped by the main corresponding impact channel.

4.1. Impact on refineries' operations

Table 4.1.1: Impact on refineries' operations in 2000–2012 via direct regulation

	Associated capital investments	Associated operating costs	Cost[312] per barrel of throughput
EU Emissions Trading System (EU ETS)	No evidence of investments specifically targeting abatement of CO_2 emissions	– No direct impact at sector level (permit costs for CO_2 emissions) until 2012, because sector on average received more free permits than verified emissions – Indirect impact: possible higher price for electricity purchased by the refineries, but very limited due to the refineries also producing electricity, for which there is no free allocation in the ETS	Until 2012 only indirect effects could be experienced, but the purchased electricity is <10 % of the average refining energy consumption, and the electricity costs grew at the same pace or slower than the other energy sources. Thus, the attributable impact likely negligible.
Integrated Pollution Prevention and Control Directive (IPPC) and the	Annual average of EUR 5 m per refinery, higher (EUR 6.4 m) after 2006	Estimated as 6.3 % of capital investments, yielding EUR 1.8 m annually per refinery	EUR 0.13 per barrel over 2000 to 2012

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[312] Capital and Operating costs

	Associated capital investments	**Associated operating costs**	**Cost[312] per barrel of throughput**
Large Combustion Plants Directive			
Strategic Oil Stocks Directive (SOSD)	Implementation mechanisms differ greatly at national level. Majority of the costs incurred before 2000.	Considered of low relevance for refineries and affects them in a competitiveness-neutral way.	Own additional cost for refineries is negligible.
Energy Efficiency Directive (EED)	Only transposed very recently. The impact cannot be disentangled from the impacts of other legislation, as well as the cost optimisation goals of refineries.		Own additional effect is not discernible.
Air Quality Directive (AQD)	The impact cannot be disentangled from the impacts of the emissions and effluent regulation, FQL and MFD.		Own additional effect is not discernible.

Table 4.1.1 includes the five legislation packages that potentially have a direct impact on the operation of the refineries: the EU ETS, the IED, the SOSD, the EED and the AQD. From this group it was possible to quantitatively analyse the effects of two legislation packages: the EU ETS and emission and effluent regulation. Regarding the effects of the other three pieces of legislation (the EED, the SOSD and the AQD), it is not possible to disentangle their additive effects from the influence of other legislation (or other international commitments as in the case of IEA membership).

Regarding the impact of the EU ETS on the refining industry, the available data indicate that during the first two phases of the EU ETS the freely allocated emission permits were enough to cover the emissions of the majority of refineries (due to over-allocation), thus it appears that this legislation did not provide direct incentives to refineries to adjust. The industry's efforts to improve its energy (and, thus, carbon emissions) performance were driven by cost optimisation considerations rather than by emission allowance constraints. Overall, we conclude that, during its first two phases, the EU ETS was not associated with significant costs for the oil refining sector as a whole; rather, the EU refineries on the whole had an opportunity to receive additional income by selling the surplus emission allowances.

Furthermore, our assessment shows that, as the result of restrictions imposed by the Industrial Emissions legislation in the 2000-2012 period, each EU-28 refinery had on average incurred capital expenditures of EUR 5 million per year for compliance with emission and effluent regulation, with a notable increase between 2000-2006 and 2007-2012. These investments accounted for a fairly stable share of 10 % of refineries' total annual capital investments. In relative terms, the cost effect from the observed capital and estimated associated operational expenditures is EUR 0.13 per barrel of throughput (EUR 0.09/bbl during 2000-2006 and EUR 0.16/bbl during 2007-2012), with significant uncertainty on the estimated operational cost component.

Regarding energy efficiency regulation, it was not feasible to conduct a meaningful empirical evaluation of its impacts at the moment for several reasons: only a very short time has passed since its transposition into national laws (which was due by June 2014), and the wide-ranging and non-prescriptive character of the suggested policy measures make it difficult to assess or forecast any specific impacts so far. Furthermore, the behavioural effects of the EED cannot be

disentangled from actions undertaken by refineries due to economic incentives (such as reducing energy costs) and to comply with other legislation's requirements.

The SOSD regulates the strategic oil stocks requirements simultaneously with a broader international regulation in the framework of the IEA. The cumulative burden of holding strategic oil stocks, in comparison to no obligation at all, can be high. But the costs of establishing the stocks were, however, incurred by the majority of the EU Member States as a result of previously existing obligations and due to their membership of the IEA before 2000 (it should be noted that the IEA obligations also include commercial stocks). The incremental obligations introduced in 2000-2012 have not generally resulted in substantial additional costs.

Similarly, the impacts of the AQD can arguably only be observed indirectly, in terms of the impacts of more specific, targeted policy measures.

4.2. Impact through product specifications

There are four pieces of legislation that impact the European refineries by affecting the actual specifications of refining products (presented in Table 4.2.1). The effects of three of them have been analysed in detail.

Table 4.2.1: Impact on refineries in 2000–2012 through product specifications

	Associated capital investments	Associated operating costs	Cost per barrel of throughput
Renewable Energy Directive (RED)	New blending, storage, and transport facilities: EUR 0.5 m per year per refinery (Concawe 2014)	Not estimated	EUR 0.01 per barrel over 2000 to 2012
Fuel Quality Legislation (FQL)	On average EUR 8.5 m reported investments per year per refinery.	Estimated EUR 8.9 m annually per refinery over 2000 to 2012	EUR 0.29 per barrel over 2000 to 2012.
Marine Fuels Directive (MFD)	Negligible, given that the required fuel specifications were achieved by using low-sulphur crude oil and by reblending.	Only logistical costs associated with reblending.	Likely negligible due to use of existing blending capacities

The impact of the RED on the EU refining sector contains the additional expenditures associated with the blending, storage, and transportation of biofuels, which amounted to EUR 0.5 million annually per refinery during 2000-2012, which, in relative terms, corresponds to about EUR 0.01 per barrel of refineries' throughput. Furthermore, the RED was likely to cause certain shifts in demand for refining products, which will be discussed in the section below.

The economic impact of the fuel quality legislation on the refining sector is comprised of the capital expenditures induced by the legislation and the corresponding change in the operating costs. The data show that the actual expenditures of the industry in the framework of FQL compliance are comparable to the expected expenditures estimated in ex ante impact assessments. The economic impact of the FQL is to a great extent associated with the Directive's limits on the sulphur content of fuels. Other provisions of the Fuel Quality Directive did not result in tangible economic impacts during 2000-2012.

According to the available data, the declared investment costs[313] for fuel specifications compliance during 2000-2012 for EU-28 refineries give an estimate of the average annual capital investment costs of EUR 8.5 million per refinery per year or, in relative terms, EUR 0.14 per barrel of throughput. The corresponding total increase in annual operating costs amounted to EUR 8.9 million per refinery per year or EUR 0.15 per barrel of throughput, from which the majority of the energy costs increase most likely comes from growing energy prices.

The impact of the requirements imposed on refineries by the Marine Fuels Directive is very likely to be extremely low, because the quality objectives were achieved via greater use of low-sulphur crudes and reblending with no significant investment costs (apart from minor logistical costs related to transport and blending, which still mostly made use of the existing capacities) and the market price impacts only reflected the natural scarcity of low-sulphur crude oil. We did not find further evidence that past marine fuel legislation had undermined the competitiveness of the EU refining sector from 2000 to 2012. No information was found on the associated administrative burden, but we also did not receive any comments from industry suggesting that this is an important issue.

4.3. Impact via market demand shifts

We have identified six legislation packages that could have possible effects on the European refineries via the refining products market channel (presented in Table 4.3.1). For two of them, the RED and ETD, we obtain a more detailed picture of the demand-related effects, while for the other four we provide a qualitative assessment.

For the quantitative assessment of the market demand-related effects of legislation (such as the RED and ETD) we rely on the results of the OURSE[314] model which sheds light on the impact of the changes in fuel demand due to regulation, which cannot be observed otherwise[315]. The model also provides valuable insights into the relative size of the impacts that can be attributed to different groups of legislation.

Table 4.3.1: Impact on refineries in 2000-2012 via market demand-related impact channels

	Demand impact	Contributed to 'Dieselisation'?	Impact on refineries
Renewable Energy Directive (RED)	1 % reduction in average gasoline demand during 2000-2012, 3 % reduction in 2012	No. Has helped to limit an increase in the EU diesel deficit.	Could have marginally contributed to the utilisation rate reduction (between 0.9 % and 1.9 %). The OURSE model estimates the possible forgone revenues from utilisation reduction at 3.7 euro cents per barrel of processed crude.
Energy Taxation Directive (ETD)	Estimated reduction of 0.2 % in average annual demand	No. But nor did it contribute to the work against it.	Likely negligible due to a very small effect on fuel

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[313] Attributed by the refineries in the Solomon Associates (2014) survey responses.

[314] OURSE - Oil is Used in Refineries to Supply Energy.

[315] Details of the modelling results are presented in the Annex and the modelling procedure is described in Temurshoev et al. (2015).

	for both gasoline and diesel		demand.
Directive on Clean and Energy-Efficient Vehicles (DCEEV)	During 2000-2012 the impacts on the car and, thus, fuel markets were insignificant.	Not known so far, expected contribution in the short to medium term insignificant.	The potential effect on the oil refining sector is second-order and is so far negligible as well.
Integrated Pollution Prevention and Control Directive (IPPC) and the Large Combustion Plants Directive	Reduction of heavy fuel oil demand from power sector (combined effect with Directive on the sulphur content of fuels)	No. Likely to be neutral as deeper conversion increases both gasoline and diesel production.	Requires refineries to react to reduced fuel oil demand: deeper conversion, orientation towards marine fuels, or shut down. The average effect cannot be quantified directly.
Energy Efficiency Directive (EED)	The impact cannot be disentangled from the impacts of the RED, ETD and IED.		Own additional effect is negligible.
Air Quality Directive (AQD)	The impact cannot be disentangled from the impacts of the FQL, MFD and IED.		Own additional effect is negligible.

The Renewable Energy Directive's effect on European refineries is rather product-specific. The most relevant implication of the RED is the potential reduction of EU demand for fossil-based fuels due to their substitution by biofuels. However, at the EU level this was very likely *not* the case for biodiesel (which accounted for 80 % of all EU biofuels from 2000 to 2012), because Europe has an overall shortage of diesel production capacity and is thus a net importer of diesel. EU net imports of diesel have at all times exceeded consumption of biodiesel. At the same time, the increasing share of biogasoline in the EU fuel markets, together with the excess gasoline production of the EU refineries, leads to some policy effects contradictions.

The refineries, in order to avoid excess gasoline production, may further reduce their utilisation rates leading to a reduction of diesel output, thus increasing the EU's current reliance on imports and undermining the security of the fossil diesel fuel supply. Secondly, higher consumption levels of biogasoline may lead to increased imports, which would put the few currently important suppliers of ethanol, like Brazil, in a strategic position. The OURSE model estimates the possible forgone revenues from utilisation reduction at 3.7 euro cents per barrel of processed crude.

Finally, as a means to avoid excess gasoline production, EU refineries might try to shift their product portfolio further towards diesel by deeper processing of residuals, which implies an increase in the energy consumption of refineries (and thus reduced economic performance) and higher CO_2 emissions.

Regarding the ETD's impact on the refining sector, we find a negligible reduction in total EU demand for gasoline and diesel. The gasoline and diesel tax levels of, respectively, 17 and 16 Member States, representing 85-88 % and 77-78 % of the total EU-27 gasoline and diesel markets, were not affected by the ETD, because their tax levels were already higher than the minimum ETD levels before these minimum excise rates were adopted. At the EU level, we also did not find any discernible impact of the ETD in terms of the European consumption switch from gasoline to diesel. However, for seven Member States (Bulgaria, Czech Republic, Lithuania, Latvia, Malta, Poland and Romania) the ETD seems to have marginally contributed to their diesel to gasoline demand switch.

The results of the OURSE model show that the RED and ETD legislation are assessed to cause a reduction in the EU refineries' crude distillation unit utilisation rates, on average, of 0.9 % to 1.9 % over the entire 2000-2010 period. These reductions are larger in northern Europe (NE) than in southern Europe (SE) by an average factor of 1.8 to 2.2, caused mainly by the higher penetration of biofuels in NE than in SE and also the larger demand changes in NE caused by the ETD. The model further shows that the RED/ETD-related forgone profits due to lower fuel demand are driven mainly by the RED, which accounts for about 89 % of these effects. Nevertheless, it was not possible to quantify those costs.

The Directive on Clean and Energy-Efficient Vehicles is recent and, while it has been successfully transposed into the national legislation, this happened with a delay in the majority of MS. The short time since transposition does not allow the effects of the adopted measures during 2000-2012 to be empirically observed yet. In addition, as the Directive specifically targets vehicle procurement in the public sector, its overall short- to medium-term impacts on the car markets are expected to be insignificant. Its potential effect on the oil refining sector is second-order and can be foreseen to be negligible as well.

The product market effects of the emission control regulation (the IPPCD and LCPD for the time period covered in the assessment) are likely to have contributed to the roughly 50 % demand drop for inland fuel oil observed during 2000-2012, by about 30 million to 45 million tons in absolute terms. Correspondingly, the concomitant reduction of supply by the refineries was achieved through (in decreasing order of importance): (i) increased conversion depth, (ii) increased uptake of fuel oil by the marine fuels market, and (iii) shut-down of EU refining capacity. A negative impact from the secondary legislative effect is possible, but how much the IPPCD and LCPD contributed to the reduced demand for fuel oil and what the economic impacts of this were on the refining sector could not be quantified in this section.

And finally, it is possible to acknowledge that the EED and AQD legislation have had certain effects of demand for final refining products, but, as was mentioned above, due to their generality, it is not possible to distinguish their individual effects from the effects of other legislation (such as the IED and RED).

Using the so-called relative trade balance (RTB) indicator, the OURSE model showed that the European refining industry would have been somewhat more internationally competitive in a counterfactual situation where tighter fuel quality and industrial emissions specifications had not been imposed in Europe. This result, however, is not exclusively about the external competitive strength of Europe, but also reflects the resulting trade structure of domestic and foreign demand for refined products as implied by the optimal reaction of all refineries worldwide to the new counterfactual European circumstances without the stricter (for example, SO_2-related) requirements.

4.4. Cumulative cost impact of directives

Finally, we summarise the impacts of the individual pieces of legislation via each of the three identified impact channels by pooling together the quantified impacts obtained from the available data. Based on the Solomon Associates (2014) dataset, in Figure 4.4.1 we present the estimates of the total capital and operating cost effects per barrel of throughput of the three legislation packages (the IED, RED, and FQL) which, according to our analysis, are responsible for most of the overall regulatory impact on European refineries in the form of additional capital expenditures and the corresponding additional operating costs.
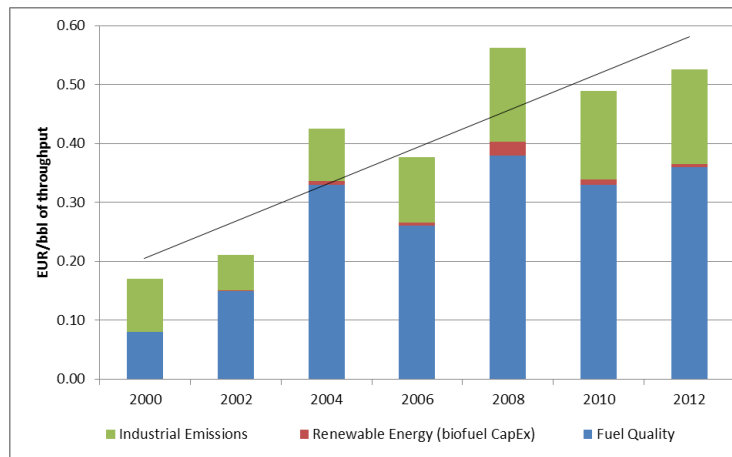
Figure 4.4.1: The estimated quantifiable CapEx and OpEx impact of the legislation on EU refineries during 2000–2012

As we see in Figure 4.4.1, the total cost impact of the three main legislation packages exhibited an upward trend during 2000-2012 with a clear increase between 2000 and 2008 (from EUR 0.17 to EUR 0.56 per barrel of throughput) and appearing to have stabilised afterwards at EUR 0.50 per barrel of throughput. This figure does not contain the modelled effect of the demand shift due to the RED, which comes from the two aggregated time periods[316] and cannot be presented on a per-year basis.
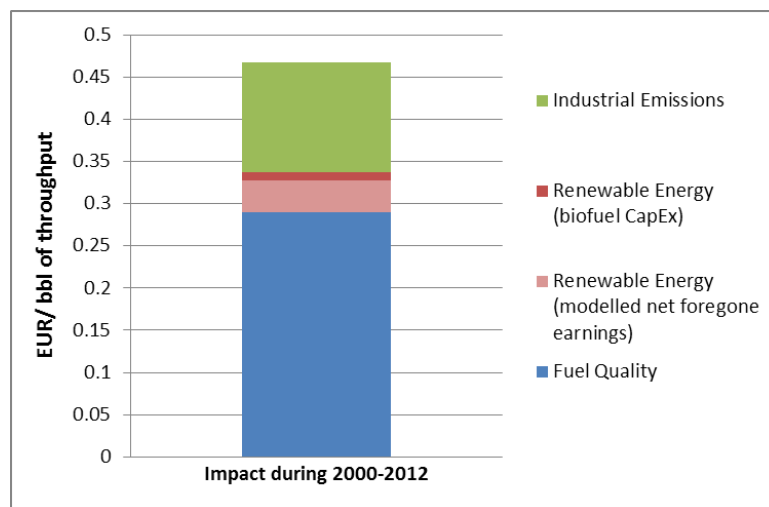
Figure 4.4.2: The average estimated quantifiable impact of the legislation on EU refineries during 2000–2012
Source: IHS (2014), Solomon Associates (2014a,b,c) and own calculations with OURSE model.

The total quantified average cost effect during 2000–2012 (including CapEx, OpEx, and demand shift effects) was assessed to be EUR 0.47 per barrel of throughput (as shown in Figure 4.4.2).

Finally, within this fitness check, the specific data on the administrative burden associated with the legislation is not available; however, it was not singled out in the available studies or in

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[316] Analysing the corresponding scenarios in 2000, 2005, and 2010.

consultations with industry as an area of special concern. This is consistent with the view that administrative burden is typically more relevant to small and medium-sized enterprises, rather than large enterprises like refineries.

Observed interactions in legislation's impacts
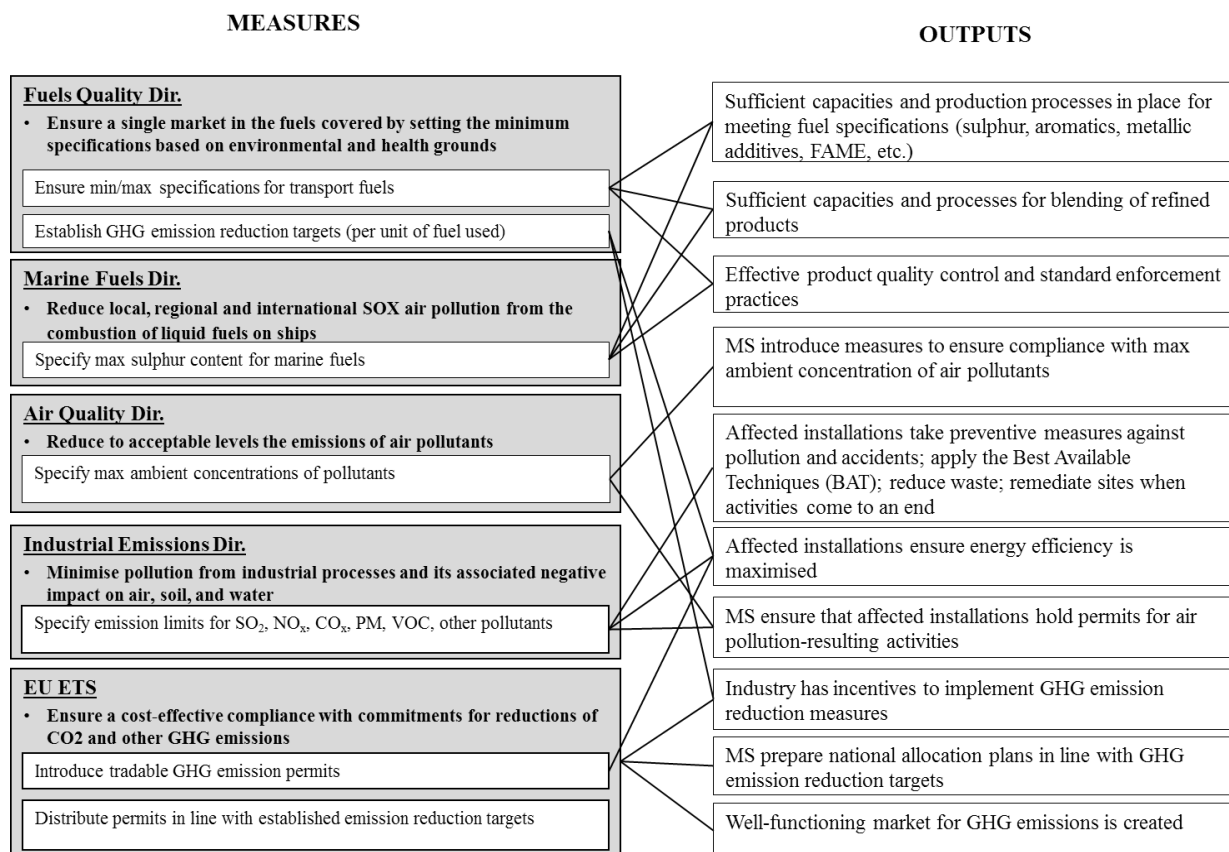
Figure 4.4.3: The 'most interactive segment' of the Intervention Logic
Note: the full intervention logic is presented in Figure 7.2.1 in the Annex.

Referring back to the discussion in the previous sections (and presented in Table 4.1.1, Table 4.2.1, and Table 4.3.1), we can with a certain degree of confidence assert that this total cost effect implicitly covers the effects produced by several pieces of legislation whose impact has been judged as unquantifiable or undistinguishable from the others. In particular (observing the 'most interactive' segment of the Intervention Logic in the Annex):

- the cost effect of the fuel quality legislation implicitly contains the influences of the Air Quality Directives, the Energy Efficiency Directive (by stimulating refineries to make additional efforts to improve energy efficiency and mitigate the effects of extra energy use to meet the fuel quality requirements), and the Marine Fuels Directive (by helping to achieve objectives otherwise not possible by reblending and crudes switch);
- the capital cost effect of the Renewable Energy Directive partially covers the effects of the Energy Efficiency Directive related to the use of renewables;
- the cost effect of complying with the Industrial Emissions legislation also contains the implicit impacts from established objectives of the Air Quality Directive and the Energy Efficiency Directive, when applied to European refining sector.

Specifically for the RED legislation regarding its relevance and coherence, we note that it underwent modifications to alleviate certain problems that primarily came from apparent competition between the objectives of increasing the use of renewables and general societal considerations regarding the sustainability of food production and land use. Such modifications include restrictions on the use of food crops for biofuel production, measures to incentivise biofuel feedstocks that do not lead to land-use expansion, and inclusion of indirect land-use change emissions in the reporting of greenhouse gas savings.

The objectives and measures of the fuel quality legislation appear to be aligned with other directives directly or indirectly related to the quality characteristics of the refining products (for example, in the part where gasoil specifications in the FQL may overlap with those imposed by the MFD). It, nonetheless, should be pointed out that the measures required for improvement of fuel quality and to decrease the content of harmful substances in emissions have mixed effects in terms of the GHG-related objectives (such as those envisioned by the ETS and EED). In most cases, improving the fuel quality required more extensive and intensive processing of refinery feeds and products, which is more energy-intensive and, holding all other parameters equal, leads to additional GHG emissions.

Considering the cost pass-through possibilities

To round up the discussion on the cumulative cost impact of the EU regulation on the refining industry, we present several points on the issue of (regulation) costs pass-through possibilities. The current literature on this topic generally argues that the cost pass-through of domestic firms depends on the strategic interaction vis-à-vis its foreign competitors. The stronger the competition from the foreign competitors that are not subject to given policy measures in the market, the fewer possibilities for cost pass-through a domestic company generally has. More specifically, the ability of the producer to pass on additional costs is determined by the competitors' expected reaction to the changes in the producer's own price or output.

In general, in an oligopolistic market without strategic interaction, the firms treat the output of the other firms as given and, therefore, have the ability to fully pass on the incremental costs. In reality, the market for refining products in Europe is subject to foreign competition which has different degrees of intensity for different products. Thus, in certain cases we can expect that the possibilities for cost pass-through are better (for example, for low-sulphur transport fuels, where all producers, both European and foreign, must comply with standards and incur additional compliance costs) than in the others (as in the case of all products affected by the industrial emissions regulation or emissions trading system which mostly affect the European producers). Having said that, the strategic interaction between domestic and foreign firms limits the ability to pass on costs implied by the local (limited only to EU) climate policy. To determine the actual magnitude of the possible costs pass-through is an empirical task.

In the scope of this study and with the available data, it is not possible to make a comprehensive assessment of the cost pass-through issues faced by the EU refining industry. It is nonetheless worth mentioning this aspect of regulation costs impact as the one also influencing the competitiveness of the industry.

4.5. Short overview of identified legislation's benefits

This study does not intend to perform a detailed and comprehensive cost-benefit analysis of the legislation packages relevant for the European refining sector. In this section we present a short overview of the identified positive benefits produced by legislation and present them in the context of the refining industry (as shown in Figure 4.5.1).

It should be noted that it has been possible to produce the quantified estimates of benefits only for several individual legislation packages, while for the rest only qualitative insights from previous assessments are available (Table 4.5.1 presents a more detailed picture). Therefore, it is not possible to aggregate those individual effects and present a reliable, general view of the beneficial impacts of the observed legislation packages as a whole.
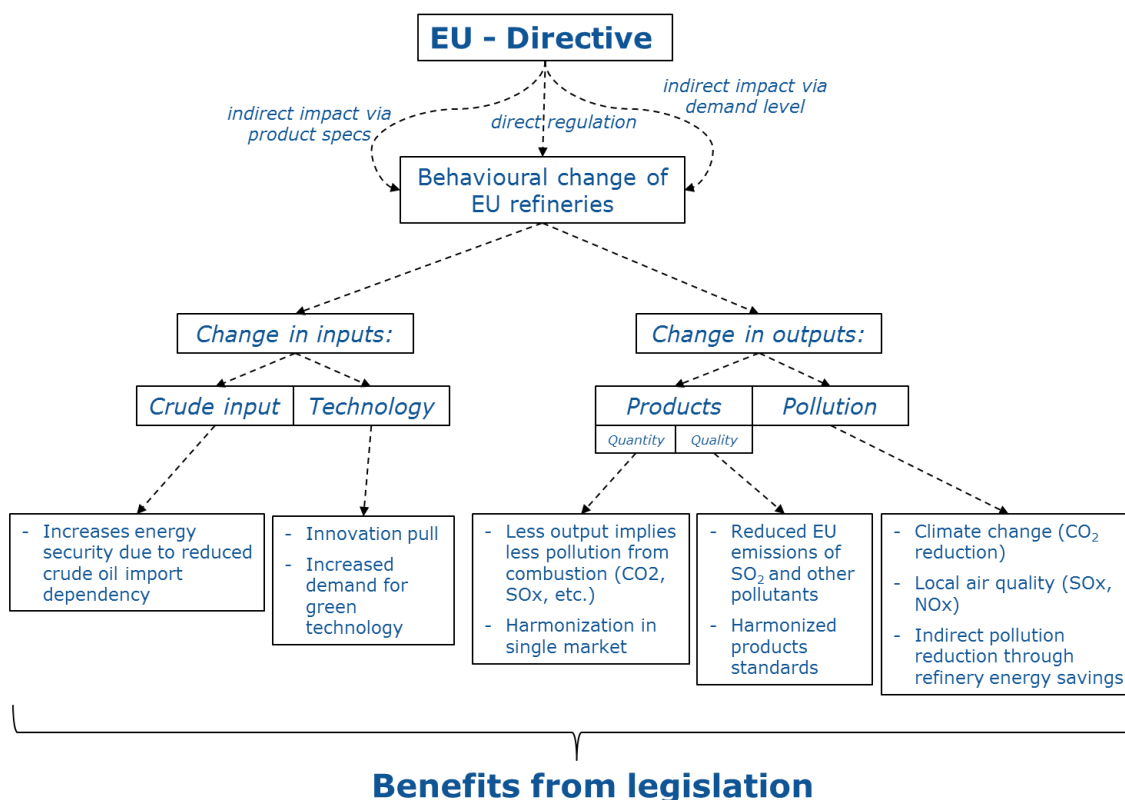
Figure 4.5.1: Graphical representation of benefits corresponding to the three impact channels in a common conceptual framework

As has also been mentioned in reference to the cumulative costs of legislation, a concrete assessment of benefits is only possible for the legislation packages that require compliance with the clearly defined limits and standards, as is the case of the fuel quality legislation and the industrial emissions legislation package. For other directives, the estimates are much less precise or only qualitative in nature.

The identified benefits are presented in Table 4.5.1 with the goal of providing a general overview, which is not yet suitable for a consistent cost-benefit analysis. For such an analysis one needs to form a balanced view on the broad societal benefits of legislation, but also on the benefits provided by the industry (e.g. job creation, GDP), and the possible societal costs (such as the loss of economic activity caused by refineries shutdown).

Table 4.5.1: Overview of the legislation's benefits identified in the course of the study

Legislation	Identified benefits
The Renewable Energy Directive (RED)	• Biofuels are estimated to generate less greenhouse gas emissions than a comparable amount of conventional fossil fuels. However, these numbers do not include additional emissions from indirect land-use changes or agricultural intensification. • The positive effect in terms of a reduced crude oil and oil product import dependency.
The Energy Taxation Directive (ETD)	• An evident benefit of excise duties is that they generate additional tax-related income that could be used for a 'growth-friendly tax shift' (for example, allowing the reduction of the tax on labour and/or the stimulation of environmentally friendly activities, green investments, and research and development). • The increase in fuel prices due to the increase in taxes reduces the demand for private transport, while increasing the demand for public transport. • It contributes to development of a more uniform common EU market for refining products which can also have positive effects on refining sector.
The EU Emissions Trading System (EU ETS)	• Emission trading schemes are commonly acknowledged as an economically efficient mechanism of emission control. They do so by creating the corresponding markets and infrastructure for emissions permits trading, embedding the 'polluter pays' principle in steering the incentives of potential polluters and making it attractive for them to implement emission-reducing technologies. • The initial phases of the ETS provided a valuable learning experience. The ETS process during 2005-2012 was not immune to several inefficiencies, such as: the lack of a level playing field due, for example, to heterogeneous definitions and allocation methods used by Member States; generally overoptimistic emission projections while allocating allowances; as well as the long and cumbersome procedures of National Allocation Plans' approval. These have been addressed in the next phases.
The Fuel Quality Legislation (FQD)	• There are available broad general estimates of the monetary benefits associated with decreasing the damage from the SO_2 emissions avoided by complying with the transport fuel sulphur standards. The estimated benefits amount to around EUR 16.2 billion in total during 2001-2011. • The higher quality road fuels allow the reduction of particulate matter emissions from the older (pre-2005) vehicles without retrofitting them with additional scrubbers or filters. • The fuel quality standards contribute to the development of a more homogeneous EU market for refining products.
The Directive on Clean and Energy-	• Specific impacts of this legislation were not observed for the 2000-

Legislation	Identified benefits
Efficient Vehicles (DCEEV)	2012 period.
Integrated Pollution Prevention and Control Directive (IPPCD) and the Large Combustion Plants Directive (LCPD)	• The broad general benefits estimates are available only for avoided SO_2 and NO_x emissions. The volume estimates show that from 2005 to 2012 the average EU-15 refinery has abated nearly 12 000 tons of SO_2 and 4000 tons of NO_x emissions. • An estimated total SO_2 and NO_x abatement benefit per average EU-15 refinery is EUR 108.4 million. Multiplication by the total number of EU-15 refineries, 63 mainstream refineries were operating at the end of 2011 in the EU-15, and taking into account incurred costs, yields total net benefits of around EUR 4 billion.
The Strategic Oil Stocks Directive (SOSD)	• Most of the Member States hold sufficient oil stocks to meet the minimum requirements or are close to reaching those targets. This seems to provide an adequate buffer to cope with potential supply disruptions and contribute to the EU's enhanced energy security. • The societal advantages of strategic stockholding in terms of oil supply safety are considered to be high. These benefits result, in particular, from reducing GDP losses and import costs in the event of a supply shock.
The Marine Fuels Directive (MFD)	• Sulphur reductions allow SO_2 emissions to be avoided.
The Energy Efficiency Directive (EED)	• In the Commission's impact assessment, the potential energy savings resulting from the current system of legislation were estimated as significant; however, the scale of the actual savings depends on specific national implementation and the individual reactions of consumers. • It can be expected that the EU's energy-saving progress would be determined to a large extent by emission reduction and renewable energy targets rather than energy efficiency measures on their own.
The Air Quality Directive (AQD)	• In general terms, the estimates of wider benefits of air quality regulation have a wide range of values. They include both direct health costs and indirect losses for the economy, such as workdays and productivity decreases. • It is likely these benefits would be determined to a large extent by more targeted measures (such as the FQD, IED, etc.) rather than the AQD measures on their own.

4.6. Relevant considerations beyond 2012

The focus of this fitness check is on the ex post assessment of the legislation's impacts during the period between 2000 and 2012. Nonetheless, we identified several pieces of legislation for which it

may be beneficial for this exercise to provide some implications for developments beyond 2012. Below we present a short overview of such observations.

EU Emissions Trading System

The current, third phase with a duration of eight years was initiated in January 2013 and brought some key changes to the functioning of the EU ETS. Instead of the MS-driven allocation of emission allowances used during the earlier phases, Phase III adopted Community-wide harmonised rules for allocation. Auctioning has become a more prominent method for allocating emission allowances. The overall emission cap is subject to the annual reduction factor of 1.74 % from 2013 onwards. The European Council in 2014[317] endorsed a binding EU target of a minimum 40 % reduction in domestic GHG emissions by 2030 compared to 1990, with the reductions in the ETS and non-ETS sectors amounting to 43 % and 30 % by 2030 compared to 2005, respectively. The annual factor to reduce the cap on the maximum permitted emissions will be changed from 1.74 % to 2.2 % from 2021 onwards.

Importantly, raising the share of auctioning in the third phase of the EU ETS has brought about concerns regarding the potential migration of production in the affected industries towards world regions without or with weaker emission reduction commitments – the so-called carbon leakage. As a remedy, the sectors identified (according to explicit criteria and after stakeholder consultations) as being at risk of carbon leakage will continue to be entitled to receive a higher share of free emission allowances[318] till 2019; the free allocation is determined by an adopted efficiency benchmark, based on emission performance[319]. Manufacturing of refined petroleum products has been included in the current list of qualifying sectors and subsectors deemed to be exposed to the risk of carbon leakage for the periods of 2013-2014 and 2015-2019[320]. Existing measures will continue after 2020, to prevent the risk of carbon leakage due to climate policy, as long as no comparable efforts are undertaken in other major economies in order to provide an appropriate level of support for sectors at risk of losing international competitiveness. The benchmarks for free allocations will be periodically reviewed in line with technological progress in the respective industry sectors.

In view of these changes, the impact of the EU ETS on the competitiveness of the oil refining sector would need to be reassessed in the third and later phases. By gradually tightening the emissions cap, employing a cross-sectoral correction factor (CSCF), and introducing the benchmarking principle for free allocation, excluding electricity-related emissions, the third phase is expected to become more costly for the affected sectors. While this change is driven by the need to increase the effectiveness of the system in reducing GHG emissions and to drive innovation, this will be associated with an increasing cost pressure on the industries covered. It is, therefore, of increasing importance to balance the protection of competitiveness in these industries with the overall goals of the ETS.

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[317] Conclusions of the European Council of 23 and 24 October 2014.

[318] The criteria introduced include a given threshold of CO_2 emission or international trade intensity, or a combination of both. For details, see Directive 2009/29/EC amending Directive 2003/87/EC Article 10a paragraph 15.

[319] The starting point to set an ex ante benchmark is the average performance of the 10 % most efficient installations in a sector or subsector in the Community in the years 2007-2008, see Directive 2009/29/EC Article 10a / 2. According to Commission Decision 2011/278/EU of 27.4.2011, the benchmark value applied to the refined oil products was set to 0.0295 per year. In order to capture the differences in refinery configurations, a CWT (CO_2 weighted tonne) approach was adopted. Free allocation is subsequently corrected to exclude electricity use and production to achieve consistency with Directive 2003/87/EC Article 10a (1).

[320] See Decision 2010/2/EU of 24.12.2009, Decision 2014/746/EU of 27.10.2014.

As a preliminary observation, using the EUTL data, we observe that in 2013 the EU refining sector was overall allocated 19.92 million EUA[321] less than its verified emissions, and 67 % of refineries were short of emission allowances as a result (meaning much lower over-allocation than in the previous phases), which suggests that in the current period the sector is likely to face higher emissions trading costs than in the two initial phases of the ETS[322]. In 2013 the EEA published data showing that the EU refining sector (industry Code 2 and 21) has free allocation to cover 73.9 % of its emissions. While these figures would need to be considered in the context of all the relevant direct and indirect cost-benefit channels discussed above, any formal analysis of the resulting impact on the sector goes beyond the scope of this report (one set of quantified model-based estimates of the future ETS impact is presented in Concawe (2014)).

Renewable Energy Directive

Several national-level studies have provided a more forward-looking assessment of the effects of the RED at the Member States level. The studies by IHS (2013 p.158f.; 2014a, p.121f.) of the UK and Italian refining sectors, respectively, make a forward-looking assessment of the implications of the 10 % RES-T target for 2020, with annual cost estimates for the years 2013 to 2030, and 2035. The UK study also briefly mentions the increasing substitution of gasoil and kerosene for domestic heating by renewables in Germany (IHS 2013, p.35) and in the UK and Ireland region (*idem*, p.43).

The Greek refinery sector study (Danchev and Maniatis 2014) identifies the presence of biofuels as one of three factors that increase the pressure on the EU gasoline surplus, the other two being US light tight oil and the improved fuel efficiency of cars (*idem*, p.14). It also discusses the impact of higher electricity prices, and mentions the 'Special Duty for Emissions Reduction' (ETMEAR) as one possible contributing factor (*idem*, p.21f.).

A study commissioned by France (Legrand et al., 2012) criticises the 'very ambitious' French biofuel policy for its content requirements and implementation rigidities. It also points to the fact that the use of biogasoline results in further deterioration of the EU gasoline surplus position (*idem*, p.29). Last but not least, it mentions that the differences across EU Member States in terms of regulatory biofuel specifications constitute a problem for European operators (*idem*, p.29).

Recently, the RED legislation underwent modifications to alleviate certain problems that primarily came from apparent competition between the objectives of increasing the use of renewables and sustainable food production and land use. The Commission engaged in a discussion on how to improve legislation, leading to stricter greenhouse gas reduction rules and sustainability criteria in Directive 2009/28 than in the preceding 2003/30, and further modifications proposed in a 2012 document (European Commission 2012). As a means to support a transition from first-generation (i.e. based on sugar, starch, vegetable oil) to second-generation or advanced (based on agricultural waste, cellulosic, etc.) biofuels, these reforms envisage, inter alia, restricting the use of food crops for biofuel production, incentivising biofuel feedstocks that do not lead to land-use expansion, and including indirect land-use change emissions in the reporting of greenhouse gas savings.

Finally, if the share of biogasoline on EU fuel markets consistently increases, further policy contradictions might arise. When–so as to avoid excess gasoline production–refineries' utilisation

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[321] It should be noted that the EUTL data does not show electricity production and heat transfers.

[322] Note that the drop in coverage by freely allocated allowances in 2013 relative to 2005-2012 is due, among others, to the introduction of efficiency benchmarks and exclusion of emissions related to on-site electricity production in refineries from the free allocation.

further diminishes and leads to a reduction of diesel output, the EU's current reliance on diesel imports would further increase, undermining the security of supply. Second, with higher consumption levels of biogasoline, a need for its increased import might eventually arise, which would put the few currently important suppliers of ethanol, like Brazil, in a strategic position (Wood Mackenzie 2010, p.23). Third, as a means to avoid excess gasoline production, EU refineries might try to shift their product portfolio further towards diesel, which would imply reduced energy efficiency (and thus reduced economic efficiency) and higher CO_2 emissions (Lonza et al., 2011, p.42).

In general, the greater use of renewables in road fuel is, according to Concawe (2014), expected to cause a further reduction in refinery throughput.

Industrial Emissions Legislation

By October 2018 the refining sector will have to comply with the stricter emission limit values on the effluents of industrial installations to air and water in order to achieve emission levels consistent with the best available techniques (as included in the BAT conclusions adopted by the Commission in 2014). The industry expects that significant (according to the estimates produced by Concawe (2014)) investments will have to be made to meet the air emission levels. With regard to effluent waters, Concawe (2014a) indicates that several European refinery sites will need to upgrade their water treatment facilities to comply with the upper (least severe) emission levels and that additional investment costs and operational costs should be expected for compliance with the lower (more severe) water emission limits.

Furthermore, a national-level study of the Greek refining sector (Danchev and Maniatis, 2014) qualitatively discusses the impact of the entry into force of the IED in 2013, citing compliance costs estimated earlier by the industry association Europia (*idem*, p.45). Similarly, a study of the Italian refining sector (IHS 2014a) computes future costs to be incurred by refineries due to the IED for the time period 2013 to 2030 (*idem*, p.116ff), building on a similar analysis done earlier for the UK refining sector (for more detail see IHS (2013)).

Fuel Quality Legislation and Marine Fuels Directive

The Sulphur Directive impact assessment of 2011 quantifies the future monetised benefits for health and environmental improvements of the latest MFD as well as impacts on refineries.

The study of Concawe (2013) provides an assessment of the additional efforts made by the industry in relation to compliance with fuel quality specifications. The study states that the majority of the capital expenditures for meeting the fuel standards in the period after 2012 will be represented by investments required to address the challenges imposed by the production of marine fuel to the new IMO sulphur specifications transposed into EU legislation in the latest MFD in 2015 for the Sulphur Emission Control Area and 2020 for the global cap.

Concawe (2014) argues that, although the marine fuel sulphur limits can be met by installing flue-gas scrubbers on ships, it is still expected that new requirements will lead to significant changes in marine fuel markets with consequences for refineries in terms of additional capital expenditures as well as operating costs.

5. <u>Analysis of the international competitiveness of the EU oil refining sector</u>

We examine the competitiveness of the EU refining industry by considering the evolution and the main components of refineries' net cash margins, their non-profit-oriented regulatory (capital and operational) expenditures. After assessing whether and how the competitiveness of EU refining has changed, we identify the main driving factors of this observation.

We use two data sources. The first one is provided by Solomon Associates (2014a,b,c), which contains anonymised and aggregated data originating from biennial surveys and studies carried out by the industry consultant Solomon Associates. Even though this data does not contain absolute values for margins, it does allow us to perform analyses of trends and comparisons based on the indexed margins data.

The second available data source for European and global refining margins is IHS (2014). The average European and extra-European margins are estimated by aggregating the total refining capacities of each region into one regional super-refinery. However, it can reasonably be assumed that this affects all regional margins equally, and thus would not undermine the comparative performance analysis. Unfortunately, the available geographical regions do not fully match those of the Solomon (2014c) data.[323] Moreover, the IHS (2014) data is reported normalised by barrel and in constant year 2013 USD, whereas data from Solomon is expressed in current terms. Finally, the selection of refineries in the two datasets will vary slightly according to where the cut-off minimum capacity has been set or whether specialised refineries were included or not.

Figure 4.6.1 shows the 2000-2012 evolution of the net margins as obtained from our two data sources, restricted to the even years since Solomon collects data only biennially. It can be seen that they are in good agreement in terms of the trend behaviour (as shown in Figure 4.6.1). In fact, the coefficient of correlation is 0.96, which implies that they are, apart from a rescaling, two practically identical time series.

To be able to better assess the differences between these two sources of detailed data, we examined several alternative EU refining margin estimates from other sources: the IEA[324], ENI[325], BP[326] and Wood Mackenzie[327]. When compared, the definitions in these sources all aim to present an assessment of the net margins in the sense of the difference between the value of inputs to refining and the value of produced output (a detailed overview of the definitions used is presented in the Annex).

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[323] In the IHS (2014) data, Europe includes some countries like Switzerland and Norway which are not EU-28 members. Instead of Russia, the data is available for the 'Former Soviet Union'.

[324] IEA Oil Market Report 2014, https://www.iea.org/oilmarketreport/omrpublic/

[325] ENI Fact Book 2013, https://www.eni.com/en_IT/attachments/publications/reports/reports-2013/fact-book-2013-eng.pdf

[326] BP Statistical Review of World Energy June 2014, Workbook: http://www.bp.com/statisticalreview

[327] Collected from several publications:
Wood Mackenzie (2010), Impact of the use of biofuels on oil refining and fuels specifications, Final Report to European Commission, https://ec.europa.eu/energy/sites/ener/files/documents/2011_06_impact_biofuels_0.pdf;
Neste Oil (2012), Credit Update March 2012;
Neste Oil (2013), Presentation on Neste Oil Capital Markets Day, September 2013.
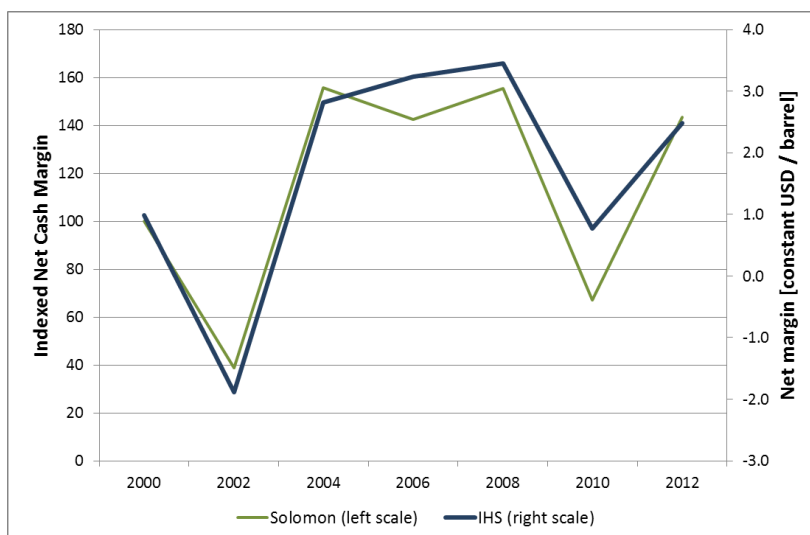
Figure 4.6.1: Average refining margins in Europe
Sources: Solomon Associates (2014a,c) and IHS (2014).

As can be seen in Figure 4.6.2, these sources produce margin estimates that are different in terms of levels, but still reflecting the same trend dynamics. Also, it is observed that the IHS (2014) net cash margins represent a lower bound (except for 2012) than all other estimates, thus likely having a downward bias.
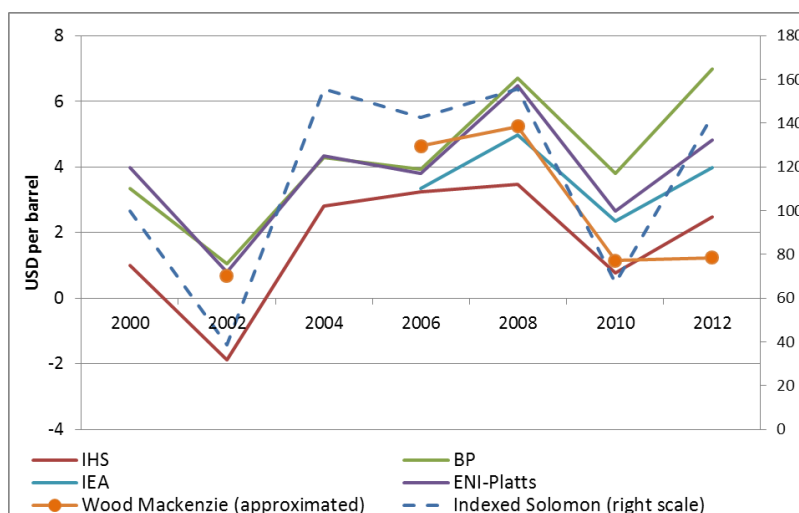
Figure 4.6.2: Variety of refining margin estimates in Europe according to different sources

The visible differences in the margins from these data sources suggest that they use different accounting approaches. Indeed, they differ in aspects such as: used crude and price quotes; using only crude input or including all feedstocks; using different compositions of operating costs. Furthermore, it is not clear how to compare them, given the variation in individual circumstances among refineries (e.g. part of vertically integrated company, part of petrochemical complex, local market power). It is, unfortunately, not possible to use an aggregate estimate of the net margin (by taking, for example, an average of different sources). Apart from the specially acquired data from Solomon Associates and IHS, the alternative indicators are not consistently available for the EU-28 and all the competitor regions. Therefore, for the purpose of this study we make use of the data from IHS (net margin levels) and Solomon Associates (indexed net margins) and present them side by side to illustrate the conclusions in the best possible manner.

The Solomon Associates (2014) data uses the observed refining costs and the observed prices of the actual product volumes at the refineries' gates. Thus, it is considered more reliable in the sense of having the smallest possible estimation bias. The indexed net margins obtained for different regions are well-suited to assess the relative competitiveness position of the EU-28 compared to the competitor regions.

In the data generated by the IHS (2014) model there are a number of assumptions made that result in consistent differences with the estimated margins from other sources. Nonetheless, there seems to be less ambiguity regarding the upswings and downswings. Hence, the observed European margin *trend* can be captured with good reliability which allows us to make conclusions about the extent of margins' movements and the observed spreads between different groups of refineries. The remaining analysis will therefore focus exclusively on trend behaviour and refrain from discussing actual refining margin levels.

5.1. EU Competitiveness trend analysis

Examining the data from IHS (2014) (in levels) and the indexed data from Solomon Associates (2014a,c) allows us to conclude that, in terms of net cash margins, EU refining has lost substantial ground against its most important competitor regions from 2000 to 2012: the US Gulf Coast, the US East Coast[328], the Middle East, South Korea/Singapore and Russia/FSU. As can be seen in Figure 5.1.1, there are differences between the two data sources regarding how the EU-28 region measured up against the competition. According to the Solomon indices, the EU was performing better than the five world regions' average in 2000, but its performance deteriorated and became relatively worse from 2006.
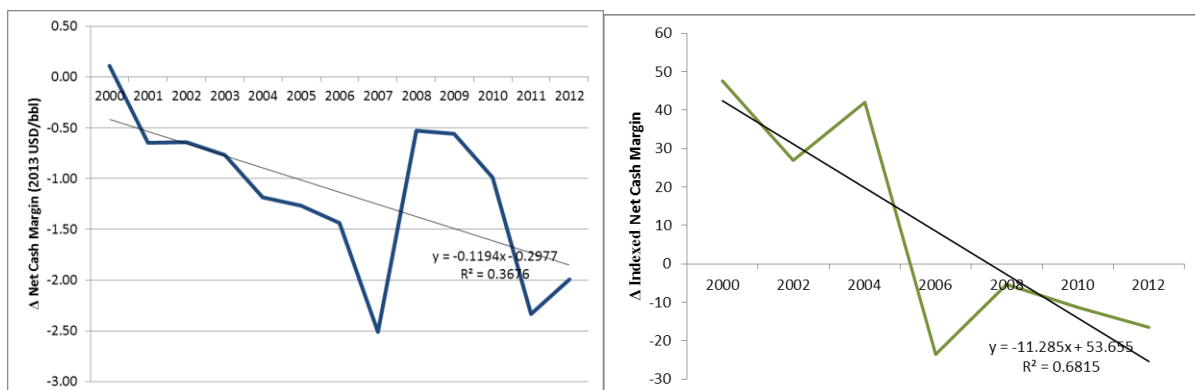
Figure 5.1.1: EU-28 net cash margin vs average of US GC, US EC, ME, K/S, and Russia/FSU[329]
Source: IHS (2014) on the left and Solomon Associates (2014a,c) on the right.

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[328] The US Gulf Coast and US East Coast regions were chosen for the comparison as the ones which were geographically most likely to compete on the European market.

[329] The dataset also includes net cash margins for Russia and India, but not for the entire time horizon. For India only the two points 2010 and 2012 are available, which is deemed insufficient for a trend analysis. For Russia the years 2004, 2008, 2010, and 2012 are available. A consistent integration of the data for Russia into the trend analysis can be achieved by first rescaling it such that the weight of each individual Russian data point for the four available years is the same as the weight of the total (across available years) corresponding to Russia's average in the total average of the four other regions. This means that integrating Russia's data will only influence the slope or the curve and not cause a sudden jump in the intercept.

The data from IHS shows that Europe had a very small average net margin advantage in 2000, which disappeared as early as 2001, and, which, apart from the upshot in 2007-2008, was becoming ever deeper towards 2012.

As has been discussed above, the EU net margin indices from Solomon Associates are more likely to reflect a real-life situation than the estimates produced by the IHS model. For that reason, we have more confidence in concluding that the EU refining sector was, on average, performing better than its competitors during the first years of the 2000-2012 period. Nonetheless, a substantial deterioration in its performance is evident in both sources.

By eliminating one region from the sample of EU competitors and recomputing the numbers from above, one can assess this region's relative contribution to the overall declining trend. It turns out that EU competitiveness most strongly deteriorated vis-à-vis South Korea/Singapore (where a considerable net margin advantage in 2000 changed into a visible disadvantage in 2012), then the US Gulf Coast (increase in disadvantage), Russia (decrease in advantage), the US East Coast (increase in disadvantage), and, finally, the Middle East (decrease in advantage).

Comparing the net margin estimates of the European super-refinery from the IHS (2014) model to the average of the US Gulf Coast, the US East Coast, the Middle East, the Former Soviet Union, and OECD Asia (which includes South Korea) confirms the relative decline of European margins, with USD 0.12/bbl per year (i.e. USD 0.9/tonne per year). In this dataset, the US Gulf Coast emerges as the strongest driving force (USD 0.34/bbl per year) of this trend, followed by the US East Coast and OECD Asia (both USD 0.24/bbl per year), while, compared to the Middle East and the Former Soviet Union, margins in Europe have actually improved.

Given the slightly different data specifications (geographical scope, currency, etc.), and the uncertainty on some relevant market data (e.g. actual crude costs and product prices), the main results stemming from the two data sources are deemed to be in good agreement:

- a decline in European refining margins against those of five important competitor regions, estimated to be USD 0.12 per barrel per year;
- as a consequence, European margins have fallen below the average of its competitors;
- the two US regions (Gulf Coast and East Coast) are major drivers of this trend, but also some of the highly industrialised countries of the Far East.
- the Middle East region has not contributed (or only very little) to this trend; for Russia/FSU, the two data sets give somewhat different results.

5.1.1. Analysis of the trends' drivers

Refining net margins are defined as the difference between gross margins (revenues minus costs for all inputs) and operational costs. Hence, it is possible to identify the relative influence of these two components on the overall trend of net margins.

According to the data from Solomon (2014a,c), European gross margins increased during the 2000-2012 period. This positive evolution is shared by the average gross margins of Europe's competitors, which – apart from the year 2006 (when the US regions had a positive spike) – have been at a similar or even slightly lower level than Europe (see Figure 5.1.2). Hence, there is neither deterioration nor improvement with regard to gross margins, which is also supported by the IHS data. Further analysis reveals that the overall neutral trend is the combined effect of a strong deterioration with respect to South Korea/Singapore and a strong improvement with respect to the

Middle East, as well as a slight improvement with respect to the two US regions and a slight deterioration with respect to Russia.
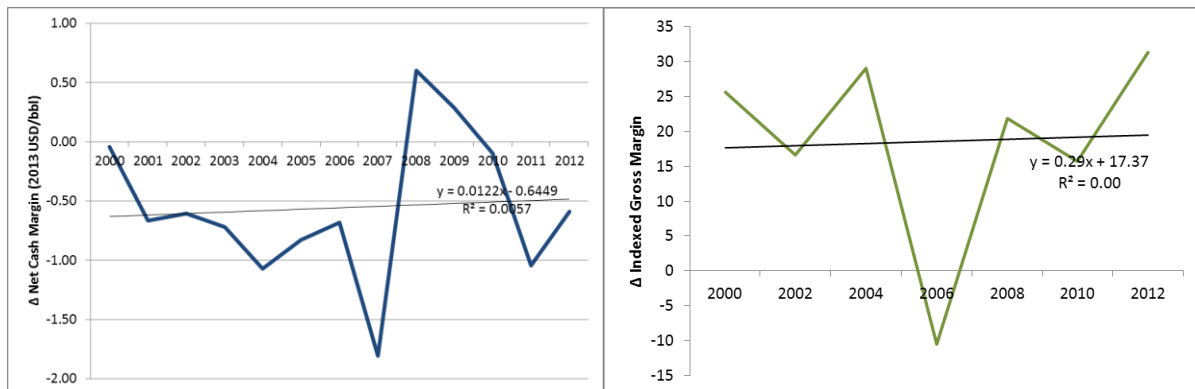
Figure 5.1.2: Difference (Δ) between EU-28 gross margins and the average of the five competitor regions (US Gulf Coast, US East Coast, Russia/FSU, Middle East, and South Korea/Singapore)
Source: IHS (2014) on the left and Solomon Associates (2014a,c) on the right.
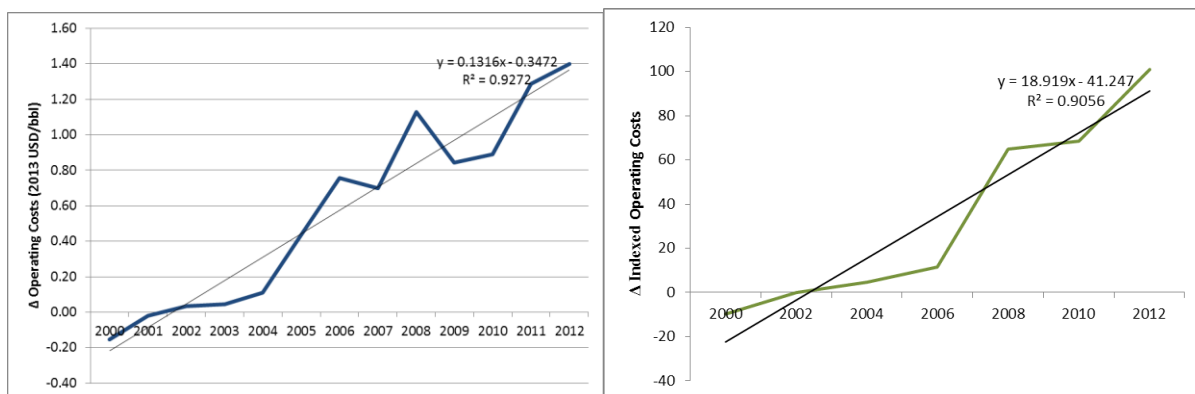
Figure 5.1.3: Difference (Δ) between EU-28 operating costs and the average of the five competitor regions (US Gulf Coast, US East Coast, Russia/FSU, Middle East, and South Korea/Singapore)
Source: IHS (2014) on the left and Solomon Associates (2014a,c) on the right.

The second component determining net margins are the operational costs. Computations based on Solomon (2014a,c) indicate that EU-28 operational costs have steadily grown above the average observed for the competitor regions (see Figure 5.1.3 (right side)). In other words, the observed relative decline of net margins is due entirely to the relative increase in operational costs in Europe.

It is interesting to note that the regions driving this trend are the Middle East and the two US regions (as shown in Figure 5.1.4). The latter two actually had a cost level consistently above the EU-28's for the first years, but between 2006 and 2008 a new trend towards relatively lower costs started, eventually leading to equal and – after 2008 – lower costs than the EU-28 level.
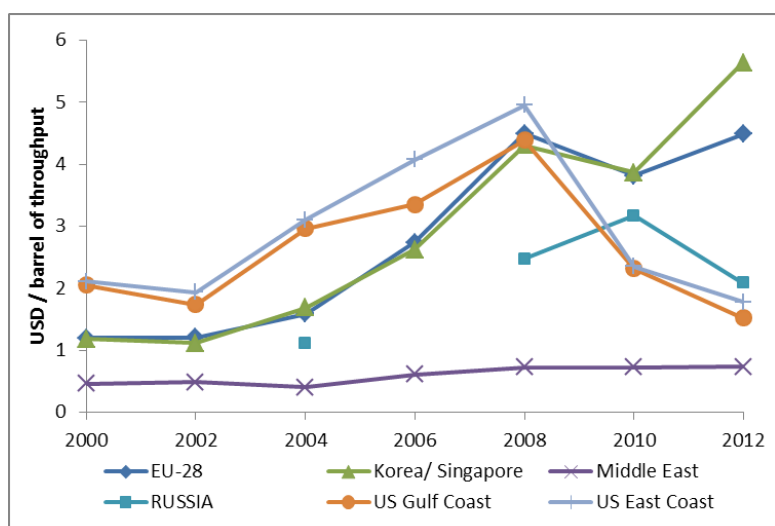
Figure 5.1.4: Average energy costs in the EU-28 and the five competitor regions
Source: Solomon Associates (2014c).

This finding is further supported by the second data source, IHS (2014), in Figure 5.1.3 (left side), where one finds the same very steady increase in European costs vis-à-vis the average of the competitor regions. The robust trend corresponds to an annual increase of USD 0.13 per barrel, again consistent with the view that operational costs are the sole driver of the observed decline in net margins. In contrast to the results obtained from the Solomon (2014a,c) data, the IHS data indicates that Europe's operational costs deteriorated more or less equally vis-à-vis all competitor regions.

To better understand why European refiners' competitiveness was negatively impacted by this unfavourable evolution in operational costs, we analyse its components.

5.1.2. Personnel vs energy vs other OpEx costs

The Solomon Associates (2014c) data breaks down the total operating costs into three categories:

- Personnel costs: this includes the salaries, wages and benefits of the refinery staff. It includes all contractor costs (mainly for maintenance, but contractors are also used in other areas). It also includes an allocation of personnel costs from G&A (General and Admin), and all labour costs associated with turnarounds.
- Energy costs: purchased (heat, electricity, natural gas, solid fuels) and own production.
- Other operating costs.

Analysing the categories one by one shows, for personnel as well as for other operating costs, a statistically insignificant minimal increase of EU-28 costs versus the average of the competitor regions, while a very robust result is that EU energy costs deteriorated, as can be seen in Figure 5.1.5. In fact, the linear regression suggests a relative deterioration of EU-28 energy costs of USD 1.44/tonne per year (USD 0.20/bbl per year), which would explain almost all of the observed relative deterioration in the EU-28 overall operational costs and, consequently, net margins.

Further data analysis shows that EU energy costs deteriorated with respect to all of the competitor regions, except South Korea/Singapore, with which it stayed on roughly the same level. The worst

deterioration (of roughly equal size impact) is observed with respect to the Middle East, the US Gulf Coast, and the US East Coast.
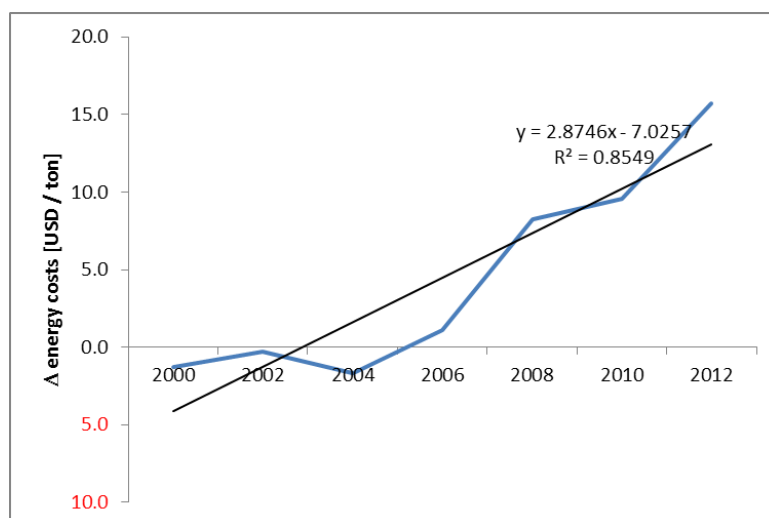
Figure 5.1.5: Difference between average energy operational costs in the EU-28 and the five competitor regions
Data source: Solomon Associates (2014c).

5.1.3. Fixed vs variable operational costs

In the IHS (2014) data, operational costs are broken down differently, namely in fixed (wages, maintenance, supplies, support and functions) and variable (catalyst, chemicals, electricity, and purchased energy) costs. Data analysis shows that fixed operational costs in Europe evolved in line with those of the competitor regions, and hence that the deterioration of variable operational costs is responsible for the observed increase in European operational costs vs those of the competitors (USD 0.13 per barrel increase per year). Further analysis reveals that an increase of about USD 0.03/bbl is associated with the variable costs for catalyst, chemicals and electricity, and the remaining part (USD 0.10/bbl) with the category 'purchased energy' which mostly refers to natural gas.

5.1.4. Utilisation rates

Utilisation rates do not directly affect the margins, but they do play a role indirectly, because in underutilised refineries the fixed costs will weigh more heavily on the net margin. Drawing on the IHS (2014) data, it becomes clear from Figure 5.1.6 that European utilisation rates fell steadily and went from 14 percentage points above the average of the US, Asia, the FSU, and the Middle East in the year 2000 to 7 percentage points below in 2012. This implies a best estimate of a loss of 1.6 percentage points per year. Indeed, EU utilisation rates fell in absolute terms (from above 90 % to below 80 %), while the average of the competitor regions' utilisation increased.
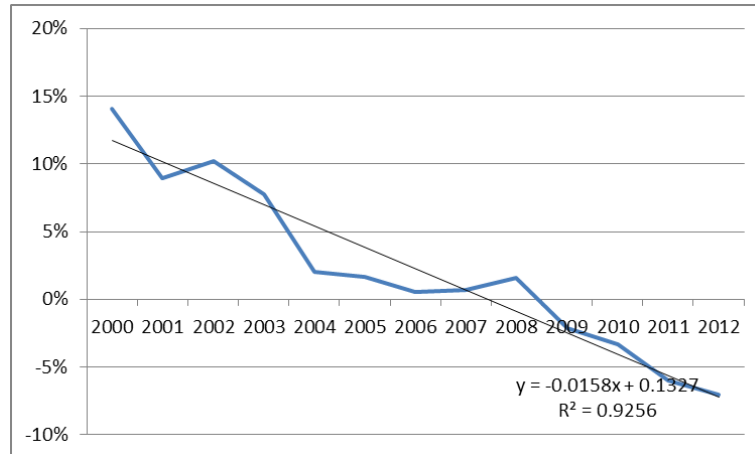
Figure 5.1.6: Difference between EU refineries' utilisation rate and the simple average of the US, the FSU, the Middle East and Asia
Data source: IHS (2014).

5.2. Beyond the 'average' viewpoint

While the analysis of the averages shows a decline in EU competitiveness due to a deterioration of energy costs, it does not convey the same 'dramatic' picture that is found in recent media reports on the sector. For example, according to the Solomon data, the average net cash margins were not negative in any of the years considered. Why then the closure of approximately 10 % of European refining capacity, and further closures deemed likely for the future?

One possible explanation is the large heterogeneity in the EU refining sector, as illustrated by Figure 5.2.1 below. It shows that a considerable share of EU refineries experienced negative net margins in 2012, even though the average was positive. It also appears that the EU-28 had a relatively longer 'tail' in the negative than the other regions.
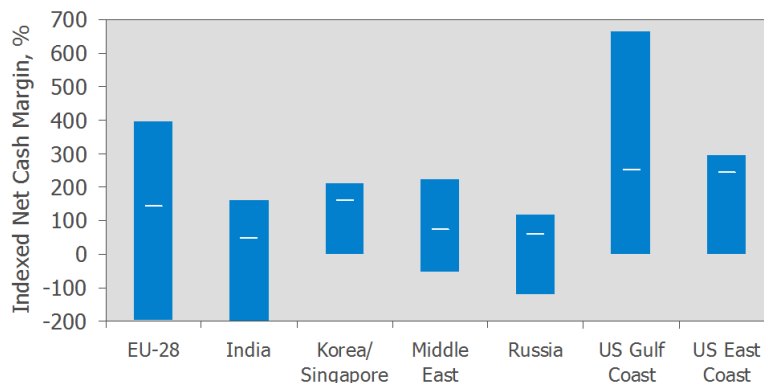
Figure 5.2.1: Net cash margin, operating year 2012
Source: Solomon Associates (2014c).

The last affirmation can be further substantiated by looking at the gap between the overall average net margins and the average of the two worst-performing refineries in each region, shown in Figure 5.2.2. It can be seen that in all years this gap had its largest value in the EU-28 region, confirming the particularly large 'tail' (as a caveat, it should be noted that, of the regions considered, the EU also has the highest number of refineries and that hence, all else being equal, one has a higher chance of finding 'extreme' values in that region.)

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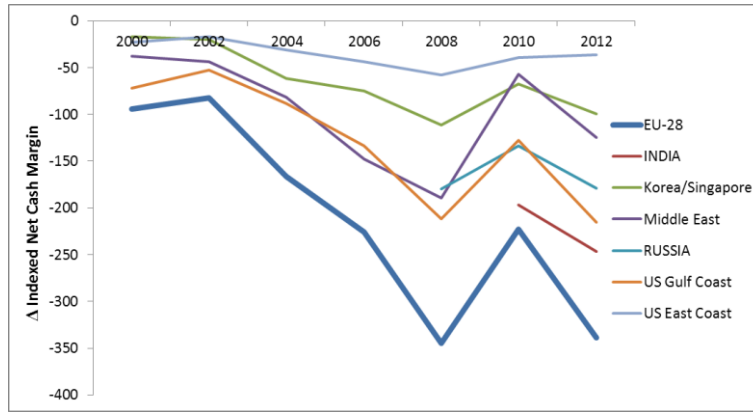
Figure 5.2.2: Average net cash margins of the two worst-performing refineries compared to the regional average net cash margin. *Source: Solomon Associates (2014c).*

Furthermore, the presence of significantly underperforming refineries in Europe can be due to particular individual circumstances, such as whether or not a refinery is part of a vertically integrated company or part of a petrochemical complex. In such a case the refinery can keep operating as part of an integrated system where the losses in one section of the value chain can be cross-subsidised by the profit obtained in the other.

The particularity of the European evolution of refining competitiveness becomes apparent when focusing on the refinery that represents the third/fourth (bottom) quartile break[330] in the Solomon Associates (2014c) data (see Figure 5.2.3): The decrease in margins is significantly stronger. For the refinery that represents the first/second (top) quartile break, we find that it still lost competitiveness vis-à-vis the five competitor regions, but to a lesser extent, such that in 2012 it is still 'competitive', i.e. the observed margin in 2012 is still slightly above the average of the five competitor regions. However, the fact remains that between 50 % and 75 % of EU-28 refineries had margins below that of the competitors.
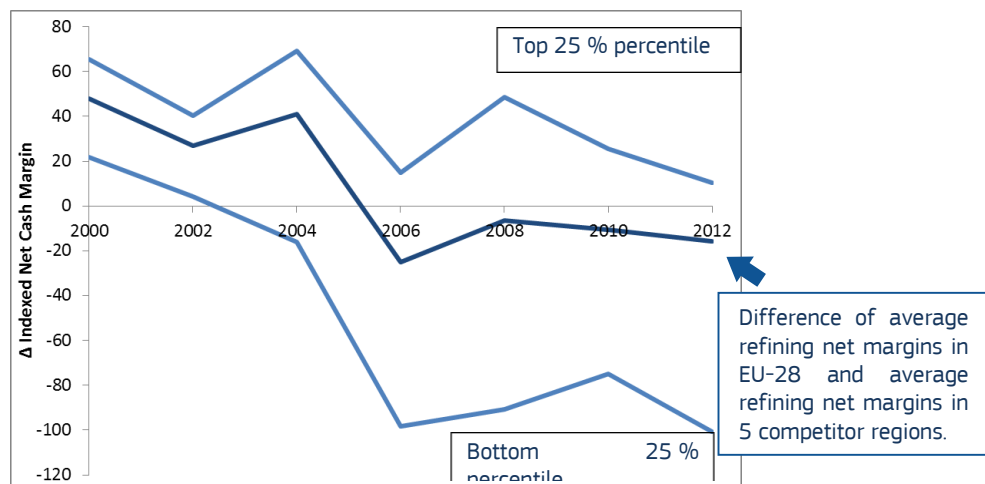
Figure 5.2.3: Variability in EU refineries' indexed net margins compared to those of competitor regions
Source: Solomon Associates (2014, 2014a) data.

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[330] Third/Fourth (bottom) quartile break: Average of the bottom of the third quartile and the top of the fourth quartile.

To provide a benchmark for the changes in net margins from the Solomon data, we make a similar diagram based on the IHS (2014) data, which draws the estimated net margin curves for the overall 50 % and the net margin curves for the first/fourth and third/fourth quartile breaks. The IHS data shows that by the end of the period the best-performing refineries had slightly higher net margins than at the beginning. The performance of the worst-performing refineries visibly deteriorated (by on average USD 0.12/barrel per year) during 2000-2012. At the same time, the performance of the EU's 'middle' refinery in 2012 was virtually the same as in 2000.
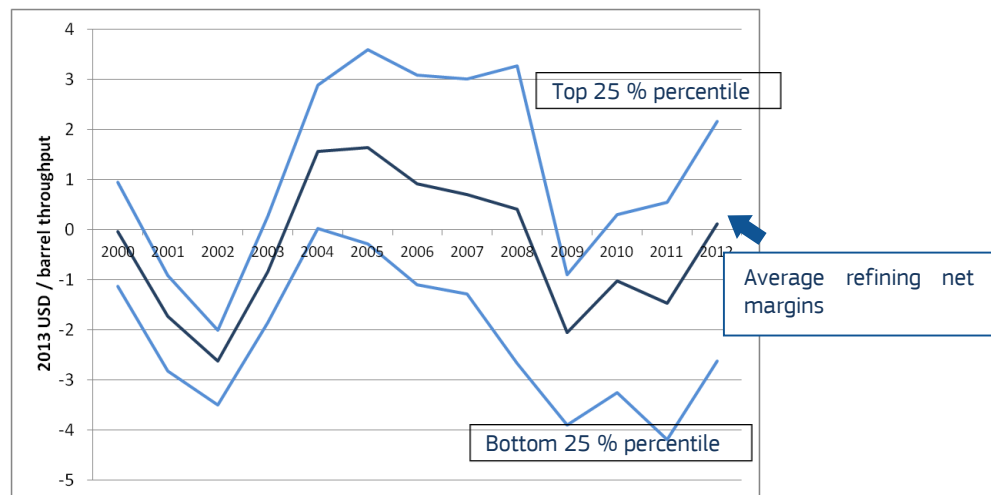
Figure 5.2.4: Variability in EU refineries' net margins
Source: IHS (2014).

According to IHS (2014), the spread in 2012 between the highest net margin and lowest net margin refinery in the EU-28 was USD 19/bbl. The spread between the first/fourth and third/fourth quartile breaks more than doubled during 2012 and reached USD 4.79/bbl by 2012.

Combining the observations from the trends in the net margin levels data from IHS and the trends in relative performance compared with competitor regions from Solomon Associates, we can also conclude that, for the top and middle refineries, the decline in their competitive position can be mostly explained by the better performance growth of the refineries in other regions. In the bottom quartile, the absolute decline in net margins contributed to the loss of the 'weaker' EU refineries' competitive position.

Looking beyond the statistical quartiles data, let us examine the main characteristics of the 20 best-performing and the 20 worst-performing EU refineries according to the IHS (2014) data, as presented in Figure 5.2.5. As we can observe, the spread in net margins between the top 20 and the bottom 20 EU refineries substantially increased between 2000 and 2012, with the margins at the top becoming higher and the margins at the bottom becoming lower.
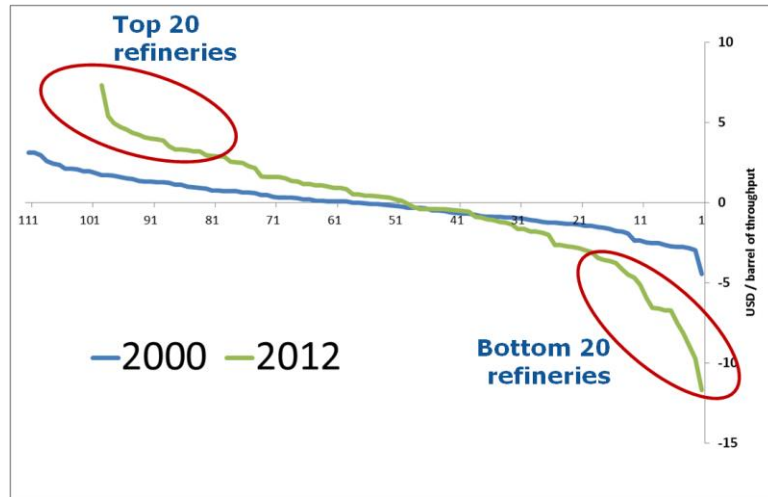
Figure 5.2.5: Net margins of individual EU-28 refineries compared to the EU-28 average
Source: IHS (2014).

When examining the changes in the net margins of individual refineries that were active during 2000-2012, we notice that a few refineries exhibited a switch in their net margin position from positive to negative and vice versa.

The correlation coefficient between the refineries' net margins in 2000 and 2012 is 0.58, which is positive and high enough to state that a refinery with a positive net margin in 2000 was more likely to keep it positive in 2012, and, correspondingly, a refinery with a negative net margin was more likely to continue underperforming. At the same time, the correlation coefficient is not high enough to argue that the weaker refineries in 2000 were deterministically bound to remain weak in 2012 as well.
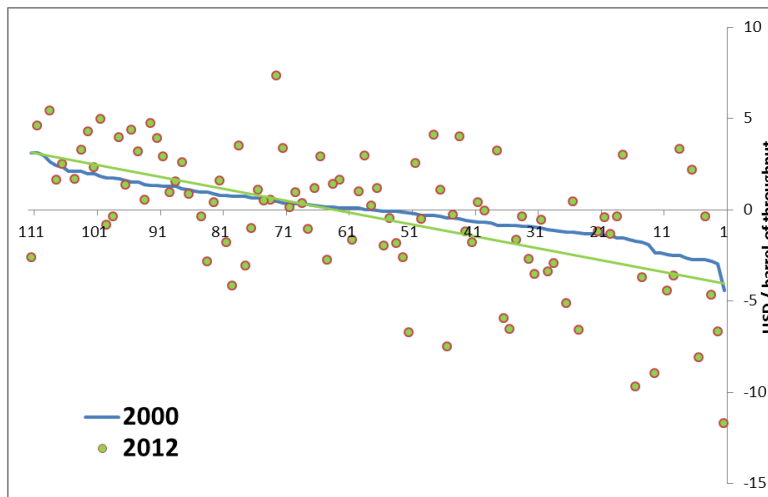
Figure 5.2.6: Net margins of individual EU-28 refineries in 2000 relative to the EU-28 average and compared to their corresponding position in 2012
Source: IHS (2014).

The 20 refineries with the lowest estimated margins can be characterised as follows (based on the IHS (2014) data, simple averages across the refineries' group, not weighted by capacity or throughput):

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- although found almost everywhere, relatively concentrated (half) in south-eastern Europe, with 5 in Italy/Greece (out of 16), 5 in eastern Europe (14), 3 in Scandinavia (7), 3 in Germany/Austria (14), 2 in Benelux (9), 1 in Spain/Portugal (11), 1 in the UK/Ireland (8), and 0 in France (10);
- average replacement costs[331] of USD 2.2 billion, as opposed to USD 3.2 billion for the rest of the sample;
- total refinery cost[332] average of USD 276 million, as opposed to USD 378 million;
- fixed operating costs of USD 123 million vs USD 176 million;
- two in Croatia seem to be restructuring (utilisation 34 %); the others have 82 % utilisation, vs 82 % for the rest of the sample;
- a higher output of heavy products (17 % vs 10 %) and gasoline (38 % vs 34 %), but less mid-distillates (46 % vs 56 %);
- only a slightly lower Nelson complexity[333] of 7.9 vs 8.1 for the rest;
- but significantly smaller: 124 000 vs 204 000 bbl/d CDU capacity, also VDU 34 000 vs 80 000 bbl/d, and total hydrotreating capacity 96 000 vs 138 000 bbl/d.

	Top 20 refineries in 2012	Bottom 20 refineries in 2012
Replacement costs (billion USD)	3.2	2.2
Annual revenues (billion USD)	8.1	5.2
Annual OpEx (billion USD)	0.38	0.28
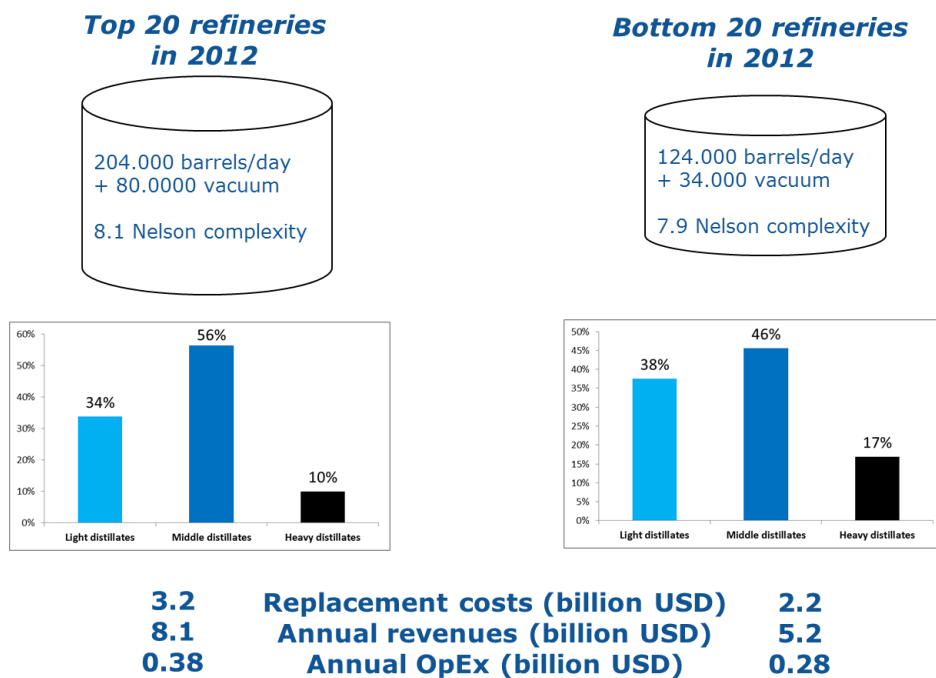
Figure 5.2.7: Comparison of EU-28 top vs bottom refineries in 2012
Source: IHS (2014).

As opposed to this, the 20 refineries with the highest estimated net margins in 2012 are characterised as follows:

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[331] Defined by IHS as the total investment cost of rebuilding all installed capacities of a refinery.

[332] The sum of fixed and variable operating costs.

[333] Nelson Complexity Index representing the measure of a refinery's complexity as a whole.

- relatively concentrated in the following regions: 5 in Spain/Portugal (out of 11), 4 in France (10), 3 in the UK/Ireland (8), 2 in Benelux (9), 2 in Germany/Austria (14), 2 in eastern Europe (14), 1 in Scandinavia (7), and 1 in Italy/Greece (16);
- average replacement costs of USD 3.2 billion (USD 2.2 billion for bottom 20), 45 % higher;
- total refinery cost average of USD 378 million (vs USD 276 million for bottom 20), 37 % higher;
- fixed costs of USD 176 million (USD 123 million for bottom 20), 43 % higher;
- 82 % average utilisation, like the overall average and the average of the bottom 20.
- 34 %, 56 %, and 10 % relative yields of light, middle, and heavy products respectively (vs 38 %, 46 %, and 17 %);
- with 8.1, average complexity not higher than EU refineries overall (7.9 for the bottom 20);
- significantly bigger than average: 204 000 and 80 000 bbl/d of CDU and VDU capacity (124 000 and 34 000 bbl/d for the bottom 20), 65 % larger CDU, 135 % VDU, combined + 80 %.
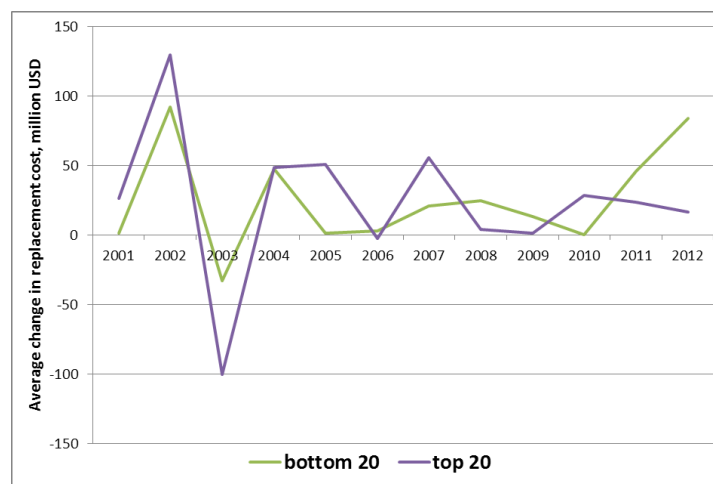
Figure 5.2.8: Average change in replacement cost of the top 20 vs bottom 20 EU refineries in 2012
Source: IHS (2014).
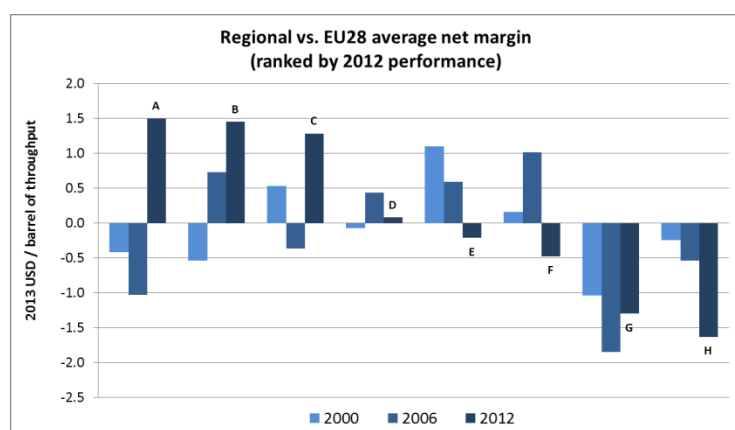
Figure 5.2.9: Comparison of regional net margins compared to Europe-wide average net margins in 2012
Source: Own calculation based on estimated margins of individual refineries from IHS (2014).

It is worth noting that even though the 20 best-performing refineries are on average larger (have higher replacement costs), it does not appear that these refineries have consistently grown faster than the worst-performing ones (as shown in Figure 5.2.8).

Further insight into the regional distribution of the better- and worse-performing refineries can be gained by looking at the evolution of refineries' margins in each region. Figure 5.2.9 shows the evolution of average net margins in different European regions in three points: in 2000, 2006 and 2012. We observe that the weak performance of the worst-performing regions appears to be consistent during the observed period. At the same time, the best-performing regions exhibit visible shifts in their performance between weak and strong performance during this period. In 2012, the distance in net margins between the best- and the worst-performing regions had increased compared to 2000 from USD 2.14/bbl to USD 3.13/bbl.

2.6	Replacement costs (billion USD)	2.5
5.8	Annual revenues (billion USD)	6.3
0.291	Annual OpEx (billion USD)	0.322
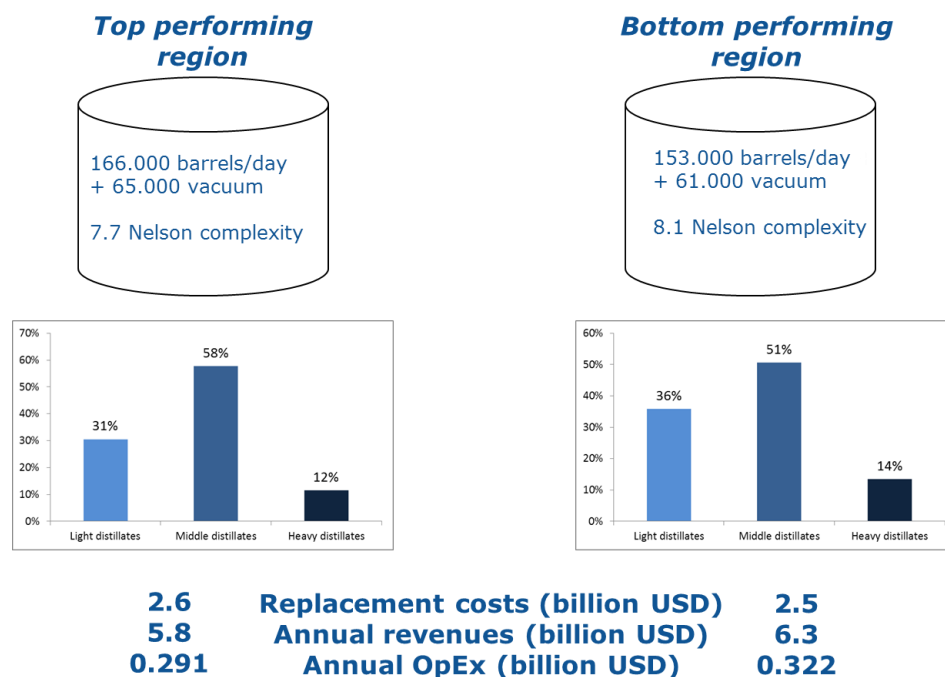
Figure 5.2.10: Comparison of best- vs worst-performing EU regions in 2012
Source: IHS (2014).

Looking in more detail, we see that a best-performing region in 2012 in comparison to a worst-performing one is rather similar in size (capacity, revenues, replacement cost) and visibly differs in operations aspects such as:

- total refinery cost average of USD 291 million per refinery, which is 11 % lower than the USD 322 million for the bottom one;
- 31 %, 58 %, and 12 % relative yields of light, middle, and heavy products respectively, which have a higher share of middle distillates than the worst-performing region (compared to 36 %, 51 %, and 14 %);
- with a 7.7 Nelson complexity, less complex refineries, but not significantly, compared to 8.1 from the worst-performing region.

5.3. Role of energy expenditures and energy per unit costs

In the EU an almost fourfold increase of Energy OpEx per tonne [USD/tonne of throughput] was observed[334]. Since the average energy OpEx of the competitor regions only increased less than twice as much, we need to understand what drove the increase in the EU.

Among the possible explanations for the energy costs increase in Europe one can suggest the following **hypotheses**: (i) decreasing, relative to competitors, energy efficiency (use of energy per throughput); (ii) energy's unit cost increase in Europe, relative to the competitor regions: (ii.a) due to price increases; (ii.b) possibly due to the composition effect, i.e. switch towards more costly forms of energy (e.g. purchased electricity rather than fuel oil, which seems implausible but still possible).

In the sections below we use the information obtained to identify which of the possible explanations above are the most probable. After careful consideration of the available data, we can make the following observations:

- The overall energy intensity of production (energy used per tonne of throughput) does not play a relevant role: although it slightly increased (7 %) from 2000 to 2012, this effect is due to the transition towards higher complexity observed for EU refineries. This is confirmed by the fact that the energy use per throughput remained constant within each complexity class presented in Figure 5.3.1.
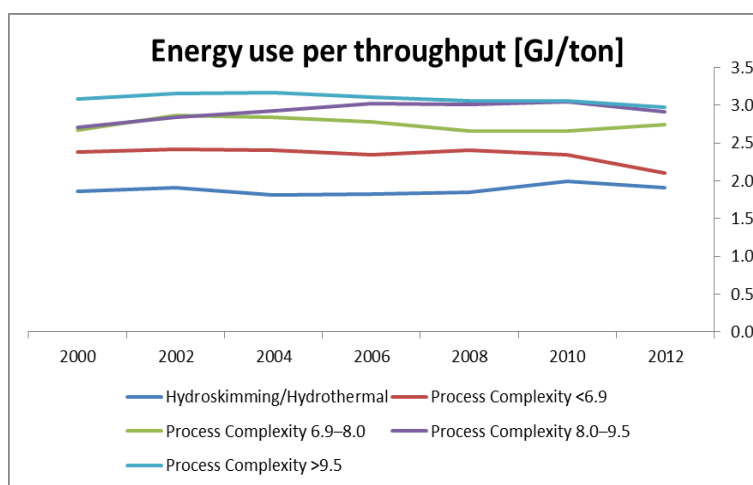
Figure 5.3.1: Energy use [GJ/tonne] in EU refineries by complexity group
Source: Solomon Associates (2014).

Furthermore, the complexity-adjusted Solomon Energy Intensity Index for the EU-28 (in Figure 5.3.2) shows a downward tendency over 2000-2012, actually indicating that the complexity-adjusted energy efficiency of refineries improved.

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[334] Always keep in mind that in EUR terms (in which the Solomon data is given) the increase is less than in USD terms, as the EUR has appreciated. Use the currency exchange table for conversion.
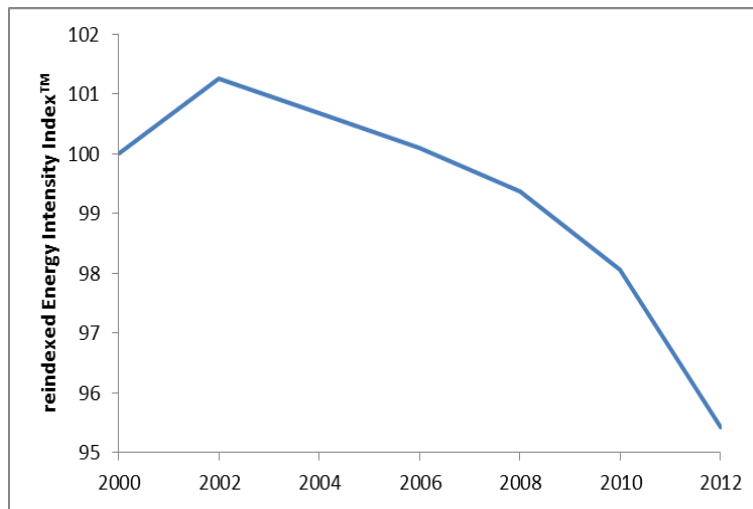
Figure 5.3.2: Solomon Energy Intensity Index (EII) for the EU-28, re-indexed to year 2000 value
Source: Solomon Associates (2014).

- At the same time, energy unit costs increased more or less equally across all complexity classes, as can be seen in Figure 5.3.3.
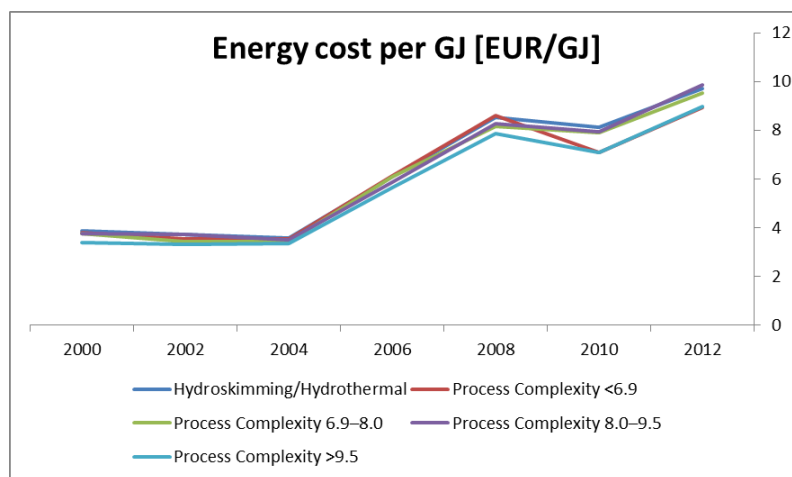
Figure 5.3.3: Energy cost [EUR/GJ] in EU refineries
Source: Solomon Associates (2014).

- The strong increase is observed for all types of energy, including purchased and self-produced (shown at the EU-28 average level in Figure 5.3.4).
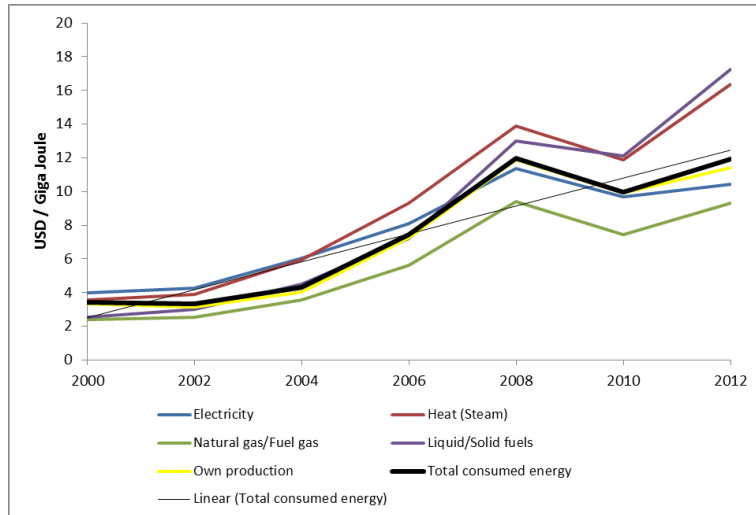
Figure 5.3.4: Unit energy costs [EUR/GJ] for various energy sources
Source: Solomon Associates (2014).

- However, in Figure 5.3.5 we observe some significant regional differences.
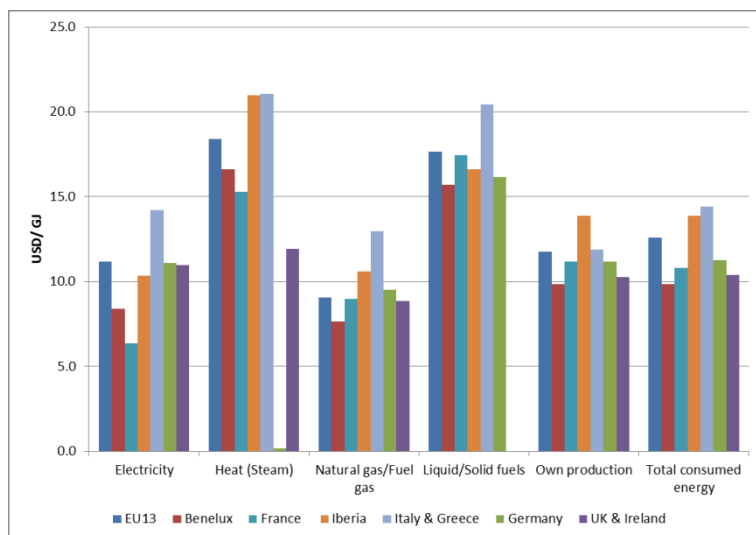
Figure 5.3.5: Unit energy costs [EUR/GJ] for various forms of refining energy in various EU-28 regions in 2012
Source: Solomon Associates (2014).

Thus, the potential impact of having a cross-regional difference of almost USD 5/GJ in the average energy unit cost could be significant (the EU-28 average is USD 11.9/GJ).

A further analysis of regional OpEx and energy-related OpEx is shown in Figure 5.3.6.
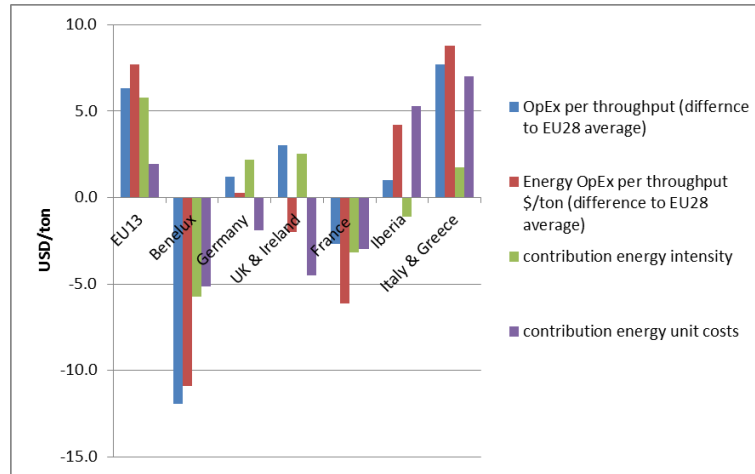
Figure 5.3.6: Difference of regional OpEx and energy-related OpEx with respect to the EU-28 average
Note: Furthermore, a decomposition of the observed difference in energy-related OpEx in terms of an energy intensity and energy per unit cost contribution is shown.
Source: Own computations based on Solomon Associates (2014) data.

Figure 5.3.6 shows that the difference in OpEx per tonne of throughput is significant (almost USD 1/bbl standard deviation), and that most of the large deviations (EU-13, Benelux, Italy and Greece) seem to be driven by differences in energy-related OpEx (Iberia and the UK and Ireland are exceptions). Moreover, we see that for Italy and Greece and Iberia the relatively higher energy OpEx are driven mostly by higher energy unit costs, while in the EU-13 the higher energy intensity is the main driver.

- Comparing the average EU energy use intensity per throughput with that of the average of the five competitor regions, we see that the European refining sector is, on average, more energy-efficient.

Figure 5.3.7: Difference between average refining energy per throughput (barrels of fuel oil equivalent per barrel of throughput) in Europe and the five competitor regions
Source: Solomon Associates (2014).

- At the same time the energy prices in Europe exhibit different trends for different types of energy sources and compared to different competing regions. Figure 5.3.8 shows a slightly faster appreciation of fuel oil prices in Europe vis-à-vis competitors (against a backdrop of a

fourfold increase in international crude oil prices). But natural gas prices increased almost fourfold in Europe, while in the US the 2011 price equals that of 2001. It should be noted that prices in Asia remained even higher than in Europe.
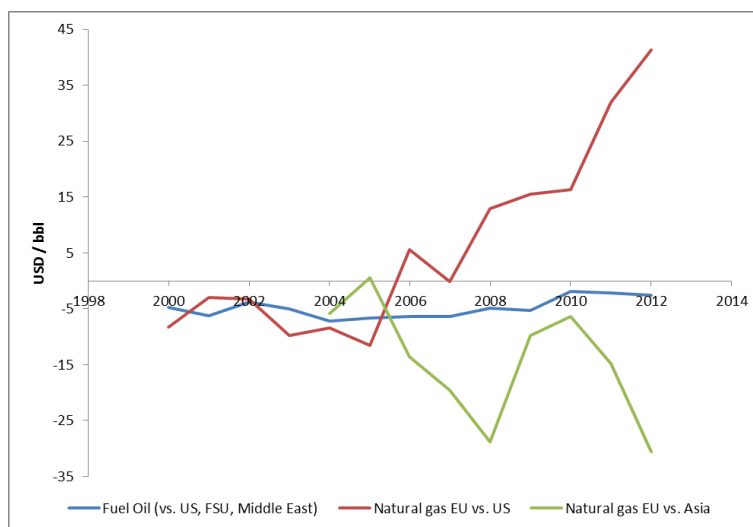
Figure 5.3.8: Difference between fuel oil prices in Europe and four competitor regions (blue); and between natural gas prices in Europe and the US (red) and Europe and Asia (green)
Data source: Solomon Associates (2014c).

Thus, the above observations allow us to conclude on the likely drivers of the energy costs increase in the European refining sector. First, we can rule out the hypothesis that EU refineries during 2000–2012 were less energy-efficient than their competitors in other regions. Second, the very similar dynamics of costs increases for different types of energy source allow us to rule out the influence of the less optimal energy sources' composition. Therefore, we find that the energy price increase that took place during 2000–2012 is primarily responsible for the overwhelming share of the rise in energy, and thus for the increase in the operating costs of the EU refineries.

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6. <u>Summary of the main findings</u>

Observed developments in EU-28 international competitiveness vis-à-vis main competing world regions[335]

1. Compared to the net margins observed in the main competitor regions (the US East Coast, the Middle East, Russia, South Korea and Singapore) the EU margin exhibits a relative decrease of USD 2.1/bbl over the 2000-2012 period. This trend is taken as an indication of a relative loss of competitiveness as it puts pressure on the investment possibilities of the European refining.

2. The data shows that this competitiveness loss can be attributed to the relative increase in energy costs in EU refining, where the increase in energy prices has been the main driver. The effect of increasing energy prices adds to the effect of a regulation-related increase in energy consumption by the European refineries. In absolute terms, the EU energy costs per barrel have increased almost fourfold over 2000-2012, while in the competitor regions they have exhibited a twofold increase on average. Among the competing regions, the Middle East and the US East Coast have a visible energy costs advantage, while only refiners in Asia are in a similar position to those in the EU.

3. All forms of energy sources experienced similar strong user price growth, therefore the energy costs increase in the EU refining sector cannot be attributed to the changes in energy source mix that might have favoured more expensive energy sources. Natural gas appears to be the main energy source whose weight in the total refinery's energy balance determines its competitive position in terms of energy expenditures.

4. At the level of individual refineries, we can talk about increasing differences between the best- and worst-performing refineries during 2000-2012. In general, the international competitiveness of the bottom 50 % of EU refineries declined more than that of the top 50 %. The observed performance gap (measured by their net margins) between the EU-28 refineries widened. The spread between the 20 best-performing and 20 worst-performing refineries in the sample increased more than twofold from about USD 2.7 to USD 5.9/bbl of throughput despite the fact that the EU closed a number of refineries during 2000-2012.

5. If we look at the particular characteristics of the European refineries and compare the top performers with the bottom ones, it is observed that the top 20 EU refineries considered in this study are on average larger and have 65 % higher capacity than the bottom 20 EU refineries, and that they have a larger share of the mid-distillates in their product mix.

6. The EU refining industry still exhibits large differences among regions in terms of the net margins. These differences appear to be fairly persistent for the worst-performing regions as they have average net margins below the EU average, while the performance of the top regions exhibited considerable shifts during 2000-2012.

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[335] US (East Coast) PADD 1 & 3, Middle East, Russia, S.Korea & Singapore.

Impact of EU legislation on investments in EU refining industry

7. Among the legislation packages investigated in this study, the fuel quality legislation and the Industrial Emissions legislation have been identified as ones leading to sizable additional investments by refineries in desulphurisation and emission abatement capacities.

8. The fuel demand shift due to the Renewable Energy Directive's impact could have contributed to decreasing utilisation rates at European refineries and some foregone revenues. The European refineries have also invested in additional logistic and blending capacities related to biofuels in compliance with the Renewable Energy Directive.

9. The refineries' compliance with the norms imposed by the fuel quality legislation requires more extensive and intensive processing of the feeds and product, which leads to increased energy consumption and, thus, higher operating costs.

10. The requirements of the pollution and emissions legislation (such as the Industrial Emissions legislation, the Integrated Pollution Prevention and Control Directive and the Large Combustion Plants Directive) have encouraged refineries to switch towards low-sulphur (which is generally more expensive) fuel oil for refinery energy needs.

11. The impacts of the market demand for refining products in the EU exhibited by the Renewable Energy Directive, Energy Taxation Directive, and the Industrial Emissions legislation have partially contributed to reducing refineries' utilisation rate (as indicated by OURSE modelling), which can negatively affect refineries' energy and operating efficiency.

The impact of EU legislation on competitiveness of EU refineries
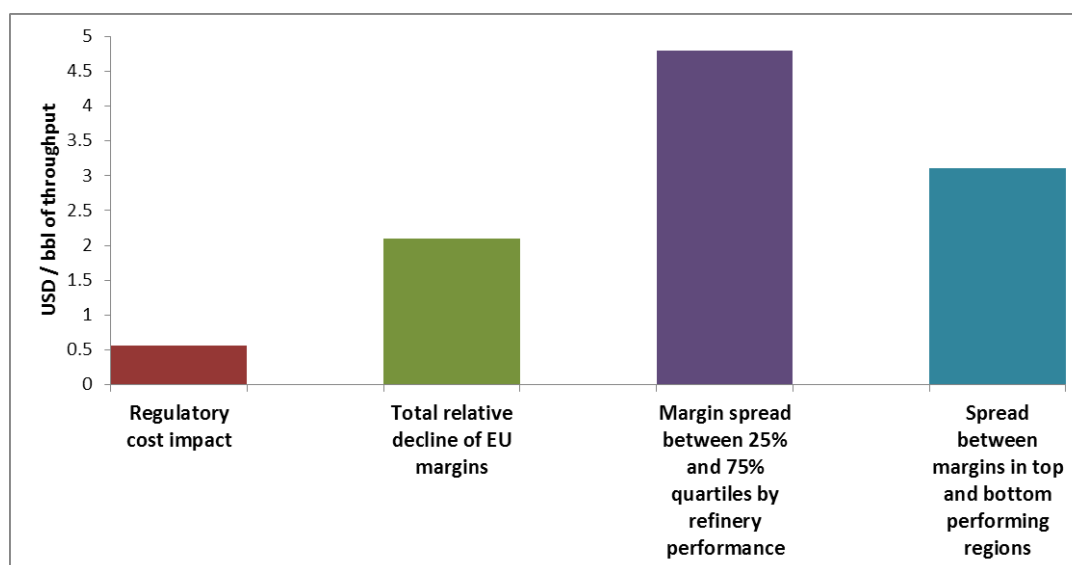
Figure 5.3.1: Comparison of the quantified total cost effect of legislation with other performance parameters of EU refineries
Source: IHS (2014), Solomon Associates (2014a,c), and own calculations with OURSE model.

12. The cumulative quantified cost impact per barrel of processed throughput from the investigated regulation packages is significant. The regulatory cost effect has been increasing from 2000 to 2008 and appears to stabilise afterwards until 2012.

13. The identified cost impacts of regulation on refineries' performance primarily imply the diversion of revenues towards regulatory compliance investments and operating costs rather than making other investments and operation adjustments that improve competitiveness.

14. For comparison, this quantified average regulatory cost impact corresponds to, at most, 25 % of EU refineries' observed net margin decline relative to competitor regions during 2000-2012, which indicates at presence of other factors that had a stronger influence on the refineries' economic performance. Among such factors, we can name the refinery's configuration, size and location which are associated with the large variability in EU refineries' input costs, product slates, revenues, operating costs, and, therefore, net margins (as shown in Figure 5.3.1).

Has EU legislation affected EU refineries in a coherent manner?

15. It has been observed that the effects of more horizontal (initially cross-industry) pieces of legislation (such as the Air Quality Directive and Energy Efficiency Directive) are likely to be implicitly covered within the impact of more focused regulation which establishes tangible norms and limits (such as, for example, the fuel quality legislation and Industrial Emissions legislation) which can be directly linked to particular changes in investment and operating expenditures.

16. The efforts made by the EU refineries to meet the requirements of the Industrial Emissions legislation and Renewable Energy Directive during the analysed period have also contributed to

meeting the objectives of the Air Quality Directive and Energy Efficiency Directive which do not address the refining sector specifically.

17. In terms of general and focused regulations' objectives with regard to GHG emissions, the analysis shows that the requirements imposed by EU legislation that lead to increased energy consumption create tensions between the objectives of higher fuel quality and lower industrial emissions on one hand and the objectives of decreasing GHG emissions on the other (such as those specified in the EU Emissions Trading System and fuel quality legislation). At the same time it should be noted that the increasing energy costs create additional incentives for refineries to make efforts to improve their own energy efficiency, which is the main objective of the Energy Efficiency Directive.

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7. <u>Annex</u>

7.1. Refining Margin Estimates: Reviewed sources

1. IEA

IEA Global Indicator Refining Margins are calculated for various complexity configurations, each optimised for processing the specific crude(s) in a specific refining centre. Margins include energy costs, but exclude other variable costs, depreciation and amortisation. Consequently, reported margins should be taken as an indication, or proxy, of changes in profitability for a given refining centre. The refinery margins are based on indicator refinery yields derived from KBC's Petro-SIM simulation. These yields are used by both the IEA and KBC to generate indicative refining margins for these main product markets, to be referenced as 'KBC/IEA Global Indicator Refinery Margins'. The IEA uses Argus Media Ltd price input for all refinery margin calculations.

2. BP

The refining margins presented are benchmark margins for three major global refining centres: the US Gulf Coast (USGC), North-West Europe (NWE - Rotterdam) and Singapore. Thus, the margin estimates considered correspond to the average of refineries in North-West Europe.

They are based on a single crude oil appropriate for that region and have optimised product yields based on a generic refinery configuration (cracking, hydrocracking or coking) appropriate for the corresponding region. The margins are on a semi-variable basis, i.e. the margin after all variable costs and fixed energy costs.

3. ENI-Platts

The margin estimates produced by ENI are based on the product prices published by Platts. The margin estimate considered is the difference between the average selling price and the direct acquisition cost of a finished product or raw material excluding other production costs (e.g. refining margin, margin on distribution of natural gas and petroleum products or margin of petrochemical products).

4. Wood Mackenzie

Net Cash Margins of individual European refineries. The values were approximated by fitting a polygonal curve to the published diagrams of individual refineries' margin comparisons and calculating the corresponding mean as a proxy for the actual mean of the underlying data.

Net Cash Margin (USD/bbl) = Gross Margin (USD/bbl) – Cash Operating Expenses (USD/bbl),

where:

Gross Margin = Gross Product Worth + Location Benefit – Delivered Crude Cost.

5. Solomon Associates

Net Cash Margins indexed relative to the EU-28 Net Cash Margin in 2000 as 100.

Net Earnings = Gross Earnings (including own produced fuel) – (Fixed + Variable costs)

Net Margin = Net Earnings / (Total Raw material input).

Variable costs include Refinery Consumed Energy. Fixed costs exclude depreciation, but include all overhead costs related to the Fuel Refining business only (excluding marketing, lubes, chemicals, trading etc.).

6. IHS

In the database, estimated revenues, gross margins and net cash margins are provided at the refinery level for European refineries, and by region for other regions. The NCM was calculated as follows:

Net Earnings = Gross Earnings – (Fixed + Variable costs)

Net Margin = Net Earnings / (Crude and Feedstock input).

It has to be noted that the net cash margin does not include depreciation or overhead costs.

Table 7.1.1: Correlation coefficients between different refining margin estimates

	Solomon Associates	IHS	BP	IEA	ENI-Platts	Wood Mackenzie (approximated)
Solomon Associates	1.000					
IHS	0.955	1.000				
BP	0.788	0.802	1.000			
IEA	0.863	0.814	0.838	1.000		
ENI-Platts	0.883	0.883	0.894	0.996	1.000	
Wood Mackenzie (approximated)	0.732	0.775	0.421	0.595	0.700	1.000

7.2. Intervention Logic

This fitness check has considered the following pieces of legislation:

- the Renewable Energy Directive[336];
- the Energy Taxation Directive[337];
- the EU Emissions Trading System[338];
- the Fuel Quality Directive[339];

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[336] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

[337] Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity.

[338] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC and subsequent amendments.

- the Directive on Clean and Energy-Efficient Vehicles[340];
- the Industrial Emissions Legislation[341];
- the Strategic Oil Stocks Directive[342];
- the Marine Fuels Directive[343];
- the Energy Efficiency Directive[344];
- the Air Quality Directive[345].

Among others, the fitness check has assessed how these legislative acts work together, whether they are relevant and coherent, and whether they achieve their objectives effectively and efficiently. In order to structure the discussion of these issues, the intervention logic of the above

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[339] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.

[340] Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles.

[341] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

[342] Council Directive 2009/119/EC of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products.

[343] Directive 2012/33/EU of the European Parliament and of the Council of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels.

[344] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[345] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

legislative measures is presented in a joint diagram (Figure 7.2.1 and

MEASURES

Energy Efficiency Dir.
- Set EU and national energy efficiency targets
- Ensure access to energy data for consumers
- Introduce energy audits for large enterprises
- Encourage public sector to lead by example

Clean and Efficient Vehicles Dir.
- Incorporate environmental and efficiency considerations as criteria in public procurement of transport

Strategic Oil Stocks Dir.
- Specify minimum MS stockholding obligations and related procedures

Renewable Energy Dir.
- Set 20% target for share of renewables in EU by 2020; specific 10% target for transport

Energy Taxation Dir.
- Harmonized energy tax rates across MS

Fuels Quality Dir.
- Ensure min/max specifications for transport fuels
- Establish GHG emission reduction targets (per unit of fuel consumed)

Marine Fuels Dir.
- Specify max sulphur content for marine fuels

Air Quality Dir.
- Specify max ambient concentrations of pollutants

Industrial Emissions Dir.
- Specify emission limits for SO_2, NO_x, CO_x, PM, VOC, other pollutants

EU ETS
- Introduce tradable GHG emission permits
- Distribute permits in line with established emission reduction targets

OUTPUTS

- MS set indicative national energy efficiency targets and achieve certain amount of final energy savings
- MS ensure efficient and free-of-charge access to data on real-time and historical energy consumption
- Large enterprises carry out energy audits at least every four years
- MS perform monitoring and assessments of potential of new energy generation capacities
- MS include energy efficiency considerations in public procurement (incl. transport vehicles)
- MS implement provisions for holding, monitoring and reporting of emergency oil stocks; ensure their correct composition and accessibility at all times
- MS regularly prepare National Renewable Actions Plans (NREAP) with annual trajectory of renewables shares in electricity, heating (incl. cooling) and transport
- MS adapt national taxation in line with EU-wide minimum rates for a range of energy products
- Sufficient capacities and production processes in place for meeting fuel specifications (sulphur, aromatics, metallic additives, FAME, etc.)
- Sufficient capacities and processes for blending of refined products
- Effective product quality control and standard enforcement practices
- MS introduce measures to ensure compliance with max ambient concentration of air pollutants
- Affected installations take preventive measures against pollution and accidents; apply the Best Available Techniques (BAT); reduce waste; remediate sites when activities come to an end
- Affected installations ensure energy efficiency is maximised
- MS ensure that affected installations hold permits for air pollution-resulting activities
- Industry has incentives to implement GHG emission reduction measures
- MS prepare national allocation plans in line with GHG emission reduction targets
- Well-functioning market for GHG emissions is created

EXPECTED RESULTS
for the oil refining sector
in short and medium term

(+)

- Harmonized and simplified emergency stockholding rules; increased reliability of crude oil supply
- Harmonized and modernized product specifications and taxation rules in the internal market
- Potential for providing emergency stockholding services and renting out industry storage facilities
- Potential benefits from emission trading
- Improved environmental performance of the industry
- Additional incentives for improving energy efficiency

(-)

- Potential reduction in demand for refined oil products due to improved energy efficiency and increased use of biofuels
- Costs of emergency stockholding partly born by the industry
- Capital and operating costs increase due to efforts towards meeting fuel quality specifications
- Capital and operating costs increase due to efforts towards emission abatement
- Potential increase in the costs of inputs (e.g. electricity, bio-blendstock)
- Potential increase in the costs for compliance, control and reporting

EXPECTED IMPACTS
on the oil refining sector

Effective internal market for refined petroleum products. Improved industrial competitiveness and environmental performance of the EU oil refining sector.

Figure 7.2.2)

OBJECTIVES and MEASURES

Energy Efficiency Dir.
- **Promote energy efficiency to reduce energy demand, thereby increasing energy security, lowering carbon emissions and contributing to sustainable economic growth**

Set EU and national energy efficiency targets

Ensure access to energy data for consumers

Introduce energy audits for large enterprises

Encourage public sector to lead by example

Clean and Efficient Vehicles Dir.
- **Promote the market for clean and energy-efficient vehicles**

Incorporate environmental and efficiency considerations as criteria in public procurement of transport

Strategic Oil Stocks Dir.
- **Secure a sufficient supply of crude oil and/or oil products in case of a temporary disruption**

Specify MS stockholding obligations and related procedures

Renewable Energy Dir.
- **Promote the use of energy from renewable sources**

Set 20% target for share of renewables in EU by 2020; specific 10% target for transport

Energy Taxation Dir.
- **Improve the functioning of the internal market for refined products**

Harmonized energy tax rates across MS

Fuels Quality Dir.
- **Ensure a single market in the fuels covered by setting the minimum specifications based on environmental and health grounds**

Ensure min/max specifications for transport fuels

Establish GHG emission reduction targets (per unit of fuel used)

Marine Fuels Dir.
- **Reduce local, regional and international SOX air pollution from the combustion of liquid fuels on ships**

Specify max sulphur content for marine fuels

Air Quality Dir.
- **Reduce to acceptable levels the emissions of air pollutants**

Specify max ambient concentrations of pollutants

Industrial Emissions Dir.
- **Minimise pollution from industrial processes and its associated negative impact on air, soil, and water**

Specify emission limits for SO_2, NO_x, CO_x, PM, VOC, other pollutants

EU ETS
- **Ensure a cost-effective compliance with commitments for reductions of CO_2 and other GHG emissions**

Introduce tradable GHG emission permits

Distribute permits in line with established emission reduction targets

OUTPUTS

MS set indicative national energy efficiency targets and achieve certain amount of final energy savings

MS ensure efficient and free-of-charge access to data on real-time and historical energy consumption

Large enterprises carry out energy audits at least every four years

MS perform monitoring and assessments of potential of new energy generation capacities

MS include environment and energy considerations in public procurement (incl. transport vehicles)

MS implement provisions for holding, monitoring and reporting of emergency oil stocks; ensure their correct composition and accessibility at all times

MS regularly prepare National Renewable Actions Plans (NREAP) with annual trajectory of renewables shares in electricity, heating (incl. cooling) and transport

MS adapt national taxation in line with EU-wide minimum rates for a range of energy products

Sufficient capacities and production processes in place for meeting fuel specifications (sulphur, aromatics, metallic additives, FAME, etc.)

Sufficient capacities and processes for blending of refined products

Effective product quality control and standard enforcement practices

MS introduce measures to ensure compliance with max ambient concentration of air pollutants

Affected installations take preventive measures against pollution and accidents; apply the Best Available Techniques (BAT); reduce waste; remediate sites when activities come to an end

Affected installations ensure energy efficiency is maximised

MS ensure that affected installations hold permits for air pollution-resulting activities

Industry has incentives to implement GHG emission reduction measures

MS prepare national allocation plans in line with GHG emission reduction targets

Well-functioning market for GHG emissions is created

SHORT-TERM RESULTS

Encourage use of energy-efficient technologies and processes

Minimise negative impacts of an energy supply disruption on the EU economy; increase credibility and security of the emergency stockholding system

Guarantee sustainable use of biomass for energy purposes

Harmonize and modernize product specifications and taxation rules in the internal market

Ensure levels of environmental pollutants within health and safety norms

Provide a framework for monetizing and penalizing greenhouse emissions

MEDIUM-TERM RESULTS

Reduce the gap to EU's climate and energy '20-20-20' targets (more resource efficient and greener economy)

Security and diversification of the EU energy supply

Employment and sustainable economic growth

Meeting the international climate change commitments

Technological development and innovation

Health and safety of the EU citizens

Smooth functioning of the internal market

Reduce unnecessary administrative burden, simplify compliance

IMPACTS

Green, sustainable, and inclusive economic growth

Effective internal market and improved industrial competitiveness

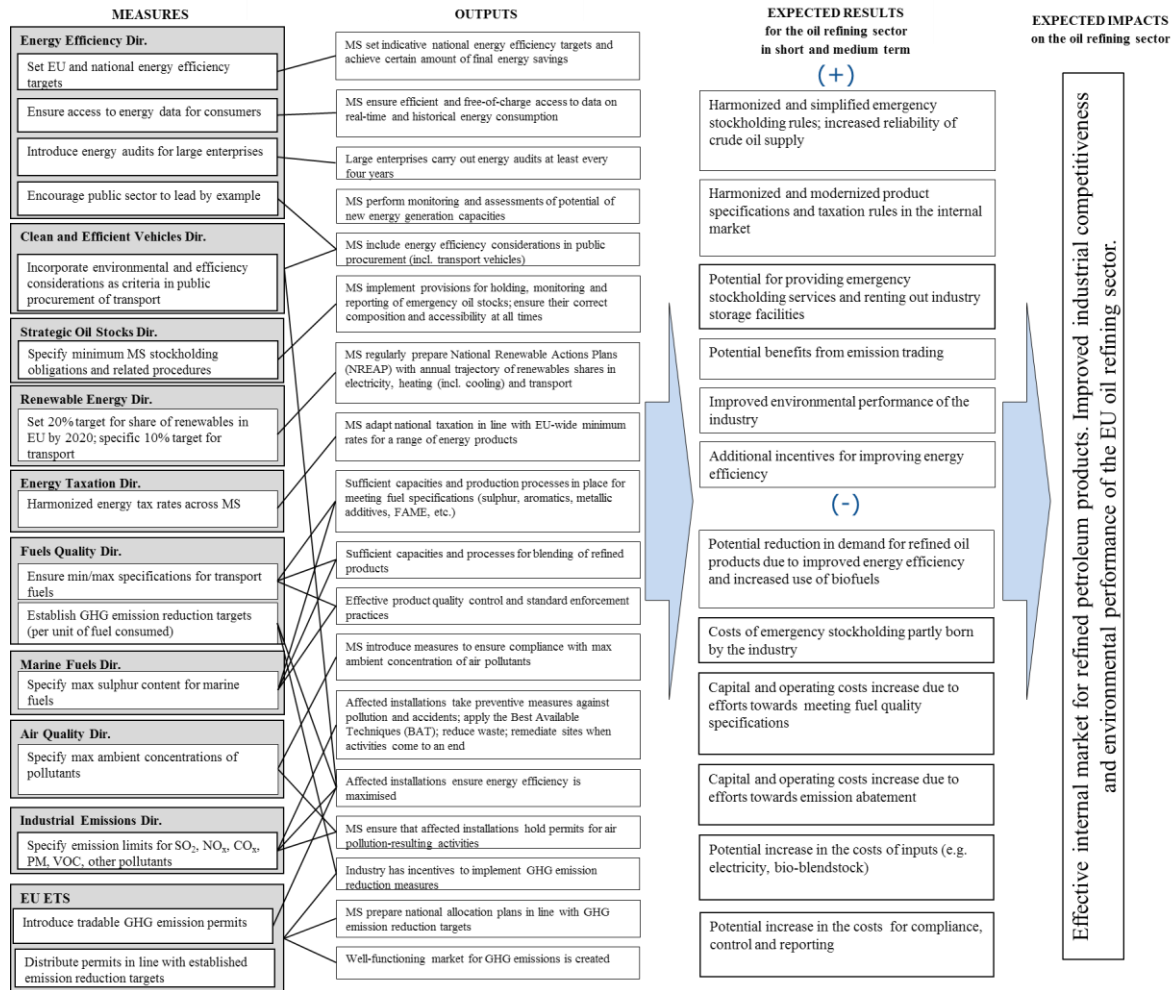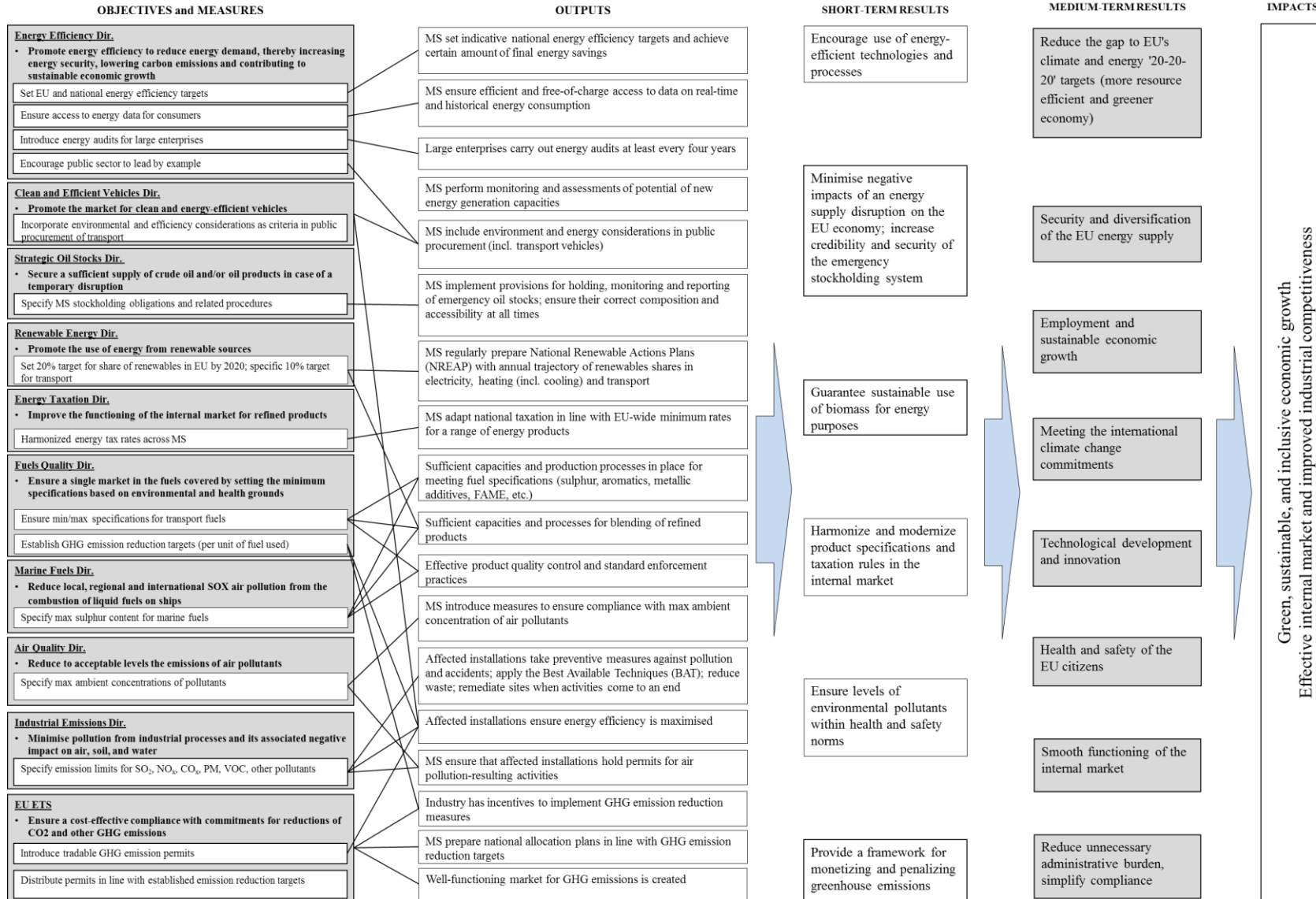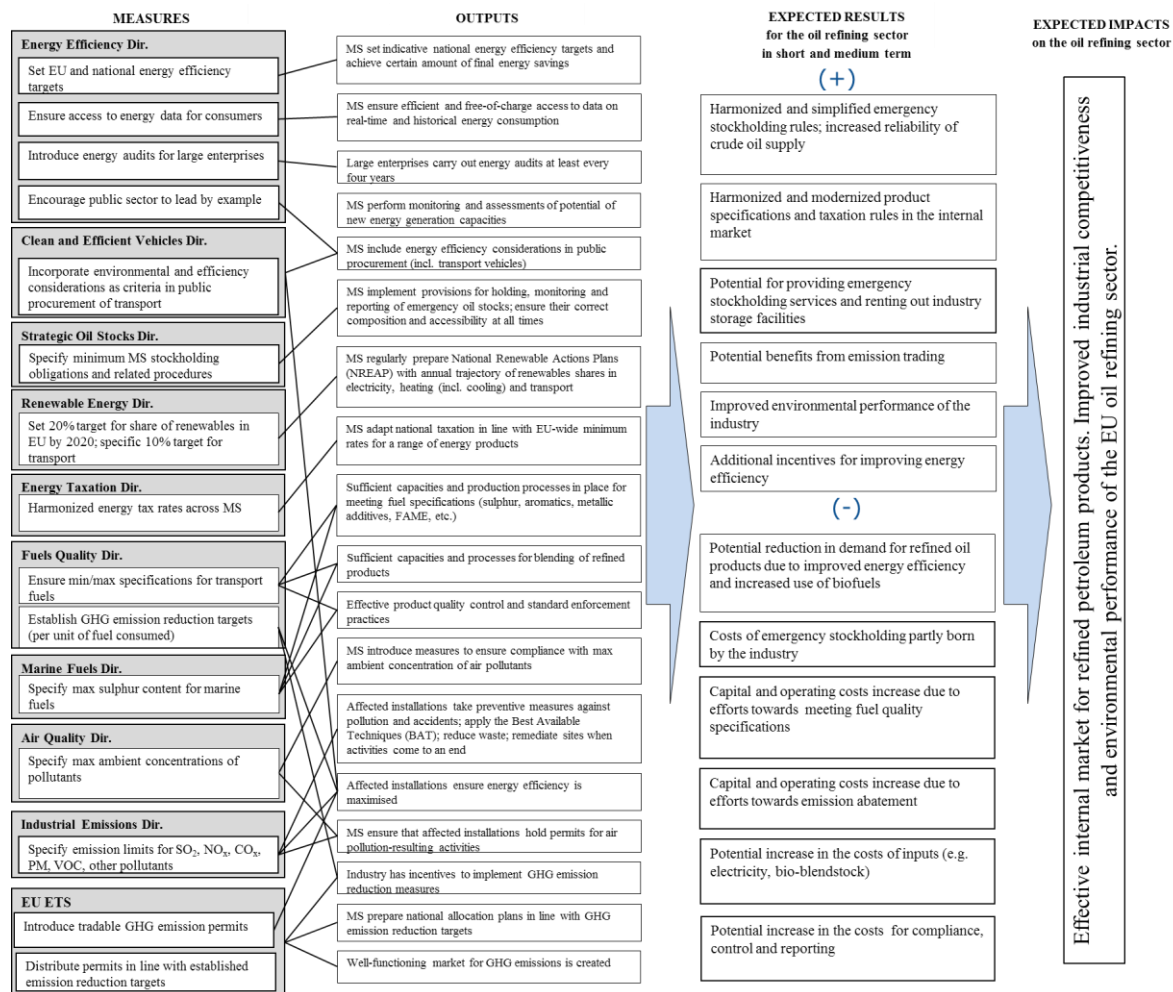**Figure 7.2.1: Integrated Intervention Logic of EU regulation in the context of the Refining Industry Fitness Check**

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Figure 7.2.2:. Intervention logic of the different EU regulation assessed with regards to their effects on the refining sector.

As the diagram shows, by addressing various environmental, energy security and market harmonisation issues, the 10 directives considered in the fitness check contribute through different channels to the long-term goals of green, sustainable and inclusive economic growth, effective internal market, and improved industrial competitiveness in the EU. Below we consider specific measures introduced by each of the directives and their respective contribution to the above long-term objectives in more detail.

The main objective pursued by the Energy Efficiency Directive is the promotion of energy efficiency in order to ensure the achievement of the Union's 2020 headline target on energy savings and for further energy efficiency improvements. The main contribution of the Directive has been to reinforce and consolidate previous regulatory efforts to improve energy efficiency. While providing a common framework for improving energy efficiency at the EU level, the Directive leaves significant flexibility to Member States with respect to the specific measures to be implemented.

As a result, the following main outputs could be expected from the implementation of this Directive: MS set indicative national energy efficiency targets and achieve a certain amount of final energy savings; MS ensure efficient and free-of-charge access to data on real-time and historical energy consumption; large enterprises carry out energy audits at least every four years; MS perform monitoring and assessments of the potential of new energy generation capacities; MS include environmental and energy considerations in public procurement, with respect to the

procurement of road transport vehicles, is also targeted by the Directive on Clean and Energy-Efficient Vehicles).

These outputs, by introducing additional incentives for using more energy-efficient technologies and processes, contribute to reducing the gap to the EU 2020 energy efficiency goals, technological developments and innovation, increased security of energy supply, and, in the long-term, to the green and sustainable growth of the EU economy and improved international competitiveness of the EU industry.

The Directive on Clean and Energy-Efficient Vehicles states that its main objective is to promote and stimulate the market for clean and energy-efficient vehicles, and to improve the contribution of the transport sector to the EU's environmental, climate and energy policies. To this end, the Directive applies specific requirements with respect to the public procurement procedures in order to incentivise production of vehicles with low levels of energy consumption and emissions. Namely, the Directive requires 'contracting authorities, contracting entities as well as certain operators to take into account lifetime energy and environmental impacts ... when purchasing road transport vehicles'. Energy and environmental impacts to be taken into account include: energy consumption; emissions of CO_2; and emissions of NO_X, NMHC and particulate matter (purchasers may also consider other environmental impacts).

The direct output expected from the implementation of this Directive is the inclusion of environmental and energy considerations in the public procurement of road transport vehicles at the MS level. In the long run, general culture shifts towards prioritising energy efficiency concerns and environmental awareness in public procurement can be expected to lead to energy efficiency and environmental performance improvements. This would, in the longer term, contribute to green and sustainable economic growth in the EU.

The Strategic Oil Stocks Directive imposes an obligation on Member States to maintain specified minimum stocks of crude oil and/or petroleum products. Its immediate expected output is that at the Member State level provisions for holding, monitoring and reporting of emergency oil stocks are implemented, and that their correct composition and accessibility are ensured at all times. The Directive also provides EU-wide harmonised emergency reaction procedures to ensure smooth release of the stocks in case of a disruption. It thus aims at minimising the negative impacts of an energy supply disruption on the EU economy and at increasing the credibility and security of the emergency stockholding system. In addition, the Directive aims at simplifying compliance by harmonising the EU strategic stockholding rules with those of the International Energy Agency, which obliges its members (including the majority of EU MS) to hold emergency oil stocks. In turn, the above measures in the long run contribute, through the increased security of energy supply, to green and sustainable economic growth and industrial competitiveness in the EU.

The Renewable Energy Directive's overarching objective is to contribute to the European Union's climate and energy '20-20-20' package. To achieve this target in a dynamically efficient manner, new – and in particular renewable – energy technologies have to be developed. In particular, the Directive prescribes a 20 % minimum share for renewables in EU-wide final energy consumption by 2020, as well as a specific 10 % target for renewable energy in transport (RES-T), where the latter has to be achieved in every Member State.

As a result, the following main short-term outputs are expected: MS regularly prepare National Renewable Action Plans (NREAP) outlining the planned annual trajectory of the renewables' shares in the electricity, heating (including cooling) and transport sectors; sufficient capacities and processes for the blending of refined oil products with renewable-source fuels are ensured. In turn, by enabling the sustainable use of biomass for energy purposes, this becomes an additional

channel for increasing the security of the EU energy supply, as well as stimulating technological developments and innovation. In addition, these measures are directly aimed at achieving the EU 2020 renewable energy goals (more resource-efficient and greener economy). In the long term, these outputs are expected to add to the green and sustainable economic growth and industrial competitiveness in the EU.

The Energy Taxation Directive establishes the EU-wide minimum rates of energy taxation, with the objective of providing a framework for aligning the energy excise tax systems in the new EU Member States with the overall EU practice. As a result of its implementation, Member States were expected to adapt national taxation in line with EU-wide minimum rates for a range of energy products. Through harmonising taxation rules, the Directive has contributed to the smooth functioning of the internal market for energy products, reduced the administrative burden and simplified compliance and thus, in the long run, contributed to effective internal market and to improved competitiveness of the EU industry.

The Fuel Quality Directive and the Marine Fuels Directive regulate EU-wide specifications for transport fuels, such as the maximum sulphur content. They thus lead to the following immediate outcomes: sufficient capacities and production processes for meeting fuel specifications (sulphur, aromatics, metallic additives, FAME, etc.); sufficient capacities and processes for the blending of refined products; effective product quality control and standard enforcement practices. In addition, the Fuel Quality Directive contains provisions establishing GHG emission reduction targets (per unit of fuel consumed), contributing to the goals of reducing GHG emissions and improving energy efficiency.

Overall, in the long run these Directives are instrumental for ensuring that the levels of environmental pollutants are within those permitted by health and safety norms, as well as for harmonisation of product specifications in the internal market, which enables the smooth functioning of the market and simplifies compliance. Through these channels, they contribute to the long-term objectives of green, sustainable and inclusive economic growth, effective internal market, and improved competitiveness of the EU oil refining industry.

The Air Quality Directive, which sets maximum ambient concentrations for a range of parameters and defines the standards for assessing and managing air quality, is an important component of the current EU air quality policy. By specifying maximum ambient concentrations of certain pollutants (PM, SO_2, NO_X, NH_3, VOC, O_3), the Directive ensures that measures for compliance with these concentrations are put in place at the Member State level and that affected installations hold permits for activities that result in air pollution. This ensures that the levels of environmental pollutants in the EU are within those permitted by health and safety norms and contributes to the overall health and safety of EU citizens, making it part of the green, sustainable and inclusive economy.

In a similar way, the Industrial Emissions legislation specifies emission limits for SO_2, NO_X, CO_2, PM, VOCs and other pollutants from industrial installations. It is thus expected to ensure the following short-term outcomes: affected installations take preventive measures against pollution and accidents, apply the Best Available Techniques (BAT), reduce waste, and remediate sites when activities come to an end; affected installations that ensure energy efficiency is maximised; MS ensure that affected installations hold permits for activities that result in air pollution.

By ensuring that the levels of environmental pollutants in the EU are within those permitted by health and safety norms and by improving energy efficiency, these measures can be expected to contribute to the health and safety of EU citizens (in a similar, albeit more targeted, way to the Air

Quality Directive), as well as the security of the EU energy supply and, in the long run, to become important channels for green, sustainable and inclusive economic growth.

The EU Emissions Trading System employs market-based mechanisms to reduce GHG emissions in line with the Europe 2020 climate and energy goals. It does so through introducing tradable GHG emission permits and distributing these permits among the affected installations in accordance with the established emission reduction targets. The following immediate outcomes can be expected: MS prepare National Allocation Plans in line with GHG emission reduction targets; a well-functioning market for GHG emissions is created; industry has incentives to implement GHG emission reduction measures, including improved energy efficiency.

By establishing a framework for monetising and penalising greenhouse gas emissions, and encouraging the use of energy-efficient technologies and processes, the Directive contributes to the achievement of the EU 2020 climate and energy goals, security of energy supply, meeting the international climate change commitments, technological development and innovation and, in the long term, to green, sustainable and inclusive economic growth and improved industrial competitiveness.

## 7.3. EU Petroleum Refining Fitness Check: OURSE modelling and results

We use the OURSE (Oil is Used in Refineries to Supply Energy) model to assess *ex post* the likely impact on the performance and international competitiveness of the EU refineries of the main EU legislation included in the EU Petroleum Refining Fitness Check (REFIT) study. Given the (dis)similar nature of the immediate (i.e. direct) impact mechanisms of the legislative acts on the refining industry, the directives considered were grouped into the following three (broader) categories for modelling purposes:

1. fuel quality specification changes due to the Fuel Quality Directive (FQD) and Marine Fuels Directive (MFD);
2. demand level and composition changes due to the requirements of the Renewable Energy Directive (RED) and Energy Taxation Directive (ETD); and
3. sulphur dioxide emission limit changes implied by the requirements of the Large Combustion Plants Directive (LCPD), Integrated Pollution Prevention and Control Directive (IPPCD) and Air Quality Directive (AQD).

The summary of the main results (for full details on modelling see Temurshoev et. al (2015)) in terms of costs incurred by the EU refineries are presented in the following table, where all the cost figures are given in *mln USD per year expressed in constant 2008 prices*:

	Lower average estimate	Upper average estimate	Upper bound estimate
Overall costs of the directives considered			
-- Total costs	416.7	753.1	940.3
Costs due to FQD and MFD			
-- Total costs	154.3	464.0	550.4
---- CapEx	102.5	408.3	475.2
---- OpEx	51.8	55.6	75.1
Costs due to RED and ETD			
-- Net forgone earnings	200.1	204.6	297.8
Costs due to SO_2 regulations (LCPD, IPPCD and AQD)			
-- Total costs	62.3	84.5	92.1
---- CapEx	33.0	33.3	38.7
---- Low-sulphur crude/feedstock switching costs	29.3	51.1	53.4

The details of these results are explained thoroughly in the text. The figure below shows the equivalent *total cost* estimates in terms of *euro cents per barrel of processed crude oil* (again in 2008 prices). If we consider the upper bound estimates, the individual contributions of each group of directives to the estimated *total costs of 18.3 euro cents per barrel of processed crude* have the following distribution: FQD/MFD – 56 %, RED/ETD – 34 %, and LCPD/IPPCD/AQD (SO_2 only) – 10 %. The average of these contributions over the three reported estimates (i.e. lower average, upper average, and upper bound) is similar and gives FQD/MFD – 51 %, RED/ETD – 36 %, and LCPD/IPPCD/AQD (SO_2 only) – 12 %. Thus, it can be concluded that the FQD/MFD are the directives with the largest cost implications for the EU refineries.
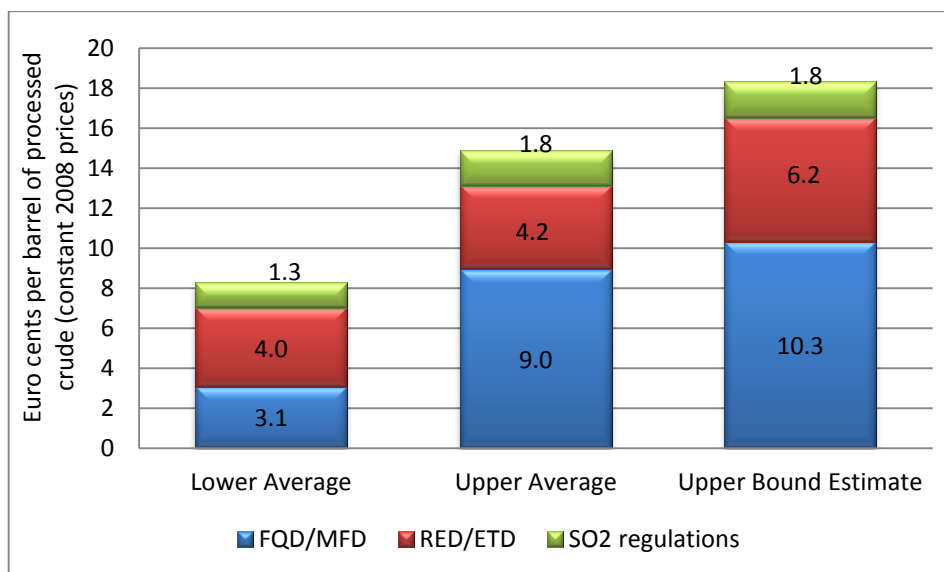
The RED/ETD-related costs, which quantify the forgone profits due to the lower fuel demand caused by these Directives, are driven mainly by the RED, which accounts for about 89 % of these costs. In the case of SO₂ regulation-related costs, however, it should be noted that our estimates of the CapEx costs are most likely underestimated as the model does not capture all the relevant SO₂ emissions abatement measures adopted by the refineries in practice.

Using the so-called relative trade balance (RTB) indicator, it is found that the European refining industry would have been somewhat more internationally competitive in a counterfactual situation where tighter fuel quality specifications had not been imposed in Europe. This result, however, is not exclusively about the external competitive strength of Europe, but also reflects the resulting trade structure of domestic and foreign demand for refined products as implied by the optimal reaction of all refineries worldwide to the new counterfactual European circumstances without the FQD and MFD requirements.

The RED and ETD are assessed to cause a reduction in the EU refineries' crude distillation unit (CDU) utilisation rates, on average, of 0.9 % to 1.9 % over the entire 2000-2010 period. These reductions are larger in northern Europe (NE) than in southern Europe (SE) by an average factor of 1.8 to 2.2, caused mainly by the higher penetration of biofuels in NE than in SE and also the larger demand changes in NE caused by the ETD. The maximum reduction (3.1 %) in the CDU utilisation rate is observed in the second sub-period of 2005-2010 in NE, which is due to larger relevant changes in demand.

Furthermore, it is assessed that in the counterfactual situation without the RED and ETD in place, European imports of diesel oil (from Russia) would have increased, on average over the 2000-2010 period, by 1-6.3 %, with an upper bound of 8.9 %. Thus, if one focuses on the trade dependency issues, a reduction in the diesel imports dependency of the EU (from Russia) can be considered the most noticeable EU-wide benefit that the RED and ETD have brought about.

Finally, the overall benefits of legislative acts on SO₂ emissions regulation, notably the LCPD, IPPCD and AQD, are assessed to be reductions of 12.7-32.5 % in the SO₂ emissions generated by the EU refineries in northern and southern Europe over the period covered. The overall European figures show SO₂ emissions reductions of 18.4-28.2 % over the entire 2000-2010 period. The benefits produced in southern Europe are larger than those in northern Europe by factor of 1.3 to 2.3.

REFERENCES TO RELEVANT SOURCES

Temurshoev, U., Mraz, M., Delgado Sancho, L. and P. Eder (2015), An Analysis of the EU Refining Industry: OURSE Modelling and Results, JRC Research Report.

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