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METHODOLOGY FOR ESTABLISHING THE EU LIST OF CRITICAL RAW MATERIALS

• Guidelines •

Raw
materials

EUROPEAN COMMISSION

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European Commission
B-1049 Brussels

Luxembourg: Publications Office of the European Union, 2017

PDF:	ISBN 978-92-79-68051-9	doi:10.2873/769526	ET-01-17-370-EN-N
Print:	ISBN 978-92-79-70212-9	doi:10.2873/040300	ET-01-17-370-EN-C

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Contents

INTRODUCTION

This is a prescriptive document containing the guidelines and the 'ready-to-apply' methodology for the EU criticality assessment and the revision of the list of critical raw materials (CRM) for the EU.

These synthesised guidelines build on the methodology used to establish the lists of CRM in 2011 ([1]) and 2014 ([2]) and integrate the methodological improvements identified by the European Commission in the project 'Assessment of the methodology on the list of critical raw materials', in close consultation with the ad hoc working group 'Defining critical raw materials'.

Additional information regarding the methodology, including justification and discussion, can be found in the background report ([3]) developed by the Directorate General Joint Research Centre (JRC) and in related annexes.

These guidelines also contain recommendations on how to reorganise and improve the single fact sheets of the assessed raw materials.

([1]) COM(2011) 25 final, Tackling the challenges in commodity markets and on raw materials

([2]) COM(2014) 297 final, On the review of the list of critical raw materials for the EU and the implementation of the Raw Materials Initiative

([3]) JRC technical report (2017): Assessment of the Methodology for Establishing the EU List of Critical Raw Materials, Publications Office of the European Union, Luxemburg, 2017, 978-92-79-69611-4, doi:10.2760/130462, JRC106997

1. CRITICALITY METHODOLOGY

1.1. Overview

Critical raw materials (CRM) are raw materials of high importance to the economy of the EU and whose supply is associated with high risk. The two main parameters, economic importance (EI) and supply risk (SR), are used to determine the criticality of the material for the EU. The list of critical raw materials is established on the basis of the assessed raw materials which reach or exceed the thresholds for both parameters defined by the European Commission. There is no ranking order of the raw materials in terms of criticality.

Calculations are based on an average of the data from over the last 5 years. For different parameters, priority, quality and availability of data are taken into account. Any exceptions or deviations from the methodology must be reported and duly justified in the raw materials fact sheets produced within the criticality assessment.

The following data priority for the calculations is to be used. General data priority order: the official EU data; Member State authorities' public data; public data from international organisations and non-EU authorities (e.g. the United States Geological Survey (USGS)); and exceptionally, as a last option, and if duly justified, trade/industry associations' public data and expert judgement. The data priority order for the end-of-life recycling input rate (EOL_{RIR}) is: raw material system analysis (MSA) data; the United Nations Environment Programme's (UNEP) report 'Recycling rate of metals'; rates from the previous European Commission (EC) criticality reports or sectorial reports; and finally an expert judgement.

Economic importance (EI)

The parameter on economic importance (EI) aims at providing insight on the importance of a material for the EU economy in terms of end-use applications and the value added (VA) of corresponding EU manufacturing sectors at the NACE Rev.2 (2-digit level). The economic importance is corrected by the substitution index (SI_{EI}) related to technical and cost performance of the substitutes for individual applications.

The EI formula (see chapter 2.1) of the revised criticality methodology is as follows:

$$\boldsymbol{EI} = \sum\nolimits_{\boldsymbol{s}} (\boldsymbol{A_s} * \boldsymbol{Q_s}) * \boldsymbol{SI_{EI}}$$

where:

- *EI = economic importance;*
- *As = the share of end use of a raw material in a NACE Rev. 2 (2-digit level) sector;*
- *Qs = the sector's VA at the NACE Rev. 2 (2-digit level);*
- *SI_{EI} = the substitution index of a raw material related to economic importance;*
- *s denotes sector.*

The EI specific substitution index (SI_{EI}) for a given candidate material (see chapter 2.2.2) is calculated using the substitute cost-performance (SCP) parameters assigned to each substitute material, multiplied by the sub-share of each substitute in a given application, and in turn to the share of the end-use application.

$$SI_{EI} = \sum_{i}\sum_{a} SCP_{i,a} * Sub\text{-}share_{i,a} * Share_{a}$$

where:

- *i denotes an individual substitute material;*
- *a denotes an individual application of the candidate material;*
- *SCP = substitute cost performance parameter;*
- *Share = the share of the raw materials in an end-use application;*
- *Sub-share = the sub-share of each substitute within each application.*

Supply risk (SR)

The parameter on SR (see chapter 3.1) reflects the risk of a disruption in the EU supply of the material. It is based on the concentration of primary supply from raw materials producing countries, considering their governance performance and trade aspects. Depending on the EU import reliance (IR), proportionally the two sets of the producing countries are taken into account — the global suppliers and the countries from which the EU is sourcing the raw materials. SR is measured at the 'bottleneck' stage of the material (extraction or processing), which presents the highest supply risk for the EU. Substitution and recycling are considered risk-reducing measures.

The revised methodology proposes the following SR formula:

$$SR = \left[\left(HHI_{WGI,t}\right)_{GS} \cdot \frac{IR}{2} + \left(HHI_{WGI,t}\right)_{EUsourcing}\left(1 - \frac{IR}{2}\right)\right] \cdot (1 - EoL_{RIR}) \cdot SI_{SR}$$

Where:

- *SR = supply risk;*
- *GS = global supply, i.e. global suppliers countries mix;*
- *$EU_{sourcing}$ = actual sourcing of the supply to the EU, i.e. EU domestic production plus other countries importing to the EU;*
- *HHI = Herfindahl-Hirschman Index (used as a proxy for country concentration);*
- *WGI = scaled World Governance Index (used as a proxy for country governance);*
- *t = trade parameter adjusting WGI;*
- *IR = import reliance;*
- *EOL_{RIR} = end-of-life recycling input rate;*
- *SI_{SR} = substitution index related to supply risk.*

The import reliance (IR) of a candidate material (see chapter 3.2) is calculated as follows:

$$Import\ Reliance\ (IR) = \frac{Import - Export}{Domestic\ production + Import - Export}$$

The HHI_{WGI} for global supplier country concentration and EU-28 actual sourcing country concentration is adjusted by a trade parameter and calculated as follows:

$$(HHI_{WGI,t})_{GS\ or\ EUsourcing} = \sum_c (S_c)^2 WGI_c * t_c$$

where:

- *S_c = the share of country c in the global supply (or EU sourcing) of the raw material;*
- *WGI_c = scaled World Governance Index of country c;*
- *Export restrictions types (source: OECD's Inventory of Restrictions on Exports of Raw Materials).*

Variable *t* (see chapter 3.3) is constructed as follows:

$$t_c = (ET\text{-}TA_c \text{ or } EQ_c \text{ or } EP_c \text{ or } EU_c)$$

where:

- *t_c = the trade-related variable of country c for a candidate raw material (RM);*
- *$ET\text{-}TA_c$ = parameter reflecting an export tax imposed (%) by country c, possibly mitigated by trade agreement (TA) in force;*
- *EQ_c = parameter reflecting an export physical quota imposed by country c (physical units, e.g. tonnes);*
- *EP_c = parameter reflecting an export prohibition introduced by country c for a candidate RM;*
- *EU_c = EU countries parameter c for a candidate RM equal to 0.8.*

The end-of-life recycling input rate (EOL_{RIR}) (see chapter 3.4) is understood as 'the ratio of recycling from old scrap to European demand of a candidate raw material (equal to primary and secondary material inputs)':

$$EOL_{RIR} = \frac{\text{Input of secondary material to EU [from old scrap]}}{\text{Input of primary material to EU} + \text{Input of secondary material to EU}}$$

The specific substitution index (SI_{SR}) of a candidate material (see chapter 3.5) is calculated as a geometric average of the three parameters (SP, SCr and SCo) assigned to each substitute material, multiplied by the sub-share of each substitute in a given application, and by the share of the end-use:

$$SI_{SR} = \sum_i [(SP_i * SCr_i * SCo_i)^{1/3} * \sum_a (Sub-share_{i,a} * Share_a)]$$

where:

- *i denotes an individual substitute material;*
- *a denotes an individual application of the candidate material;*
- *SP = substitute production reflects global production of the substitute and the material as an indicator of whether sufficient amounts of substitute material are available;*
- *SCr = substitute criticality takes into account whether the substitute was critical in the previous EU list;*
- *SCo = substitute co-production takes into account whether the substitute is a primary product or mined as a co-/by-product;*
- *Share = the share of the candidate materials in an end-use application;*
- *Sub-share = the sub-share of each substitute within each application.*

1.2. Comparison with the previous methodology

Similar to the previous assessments done in 2011 and 2014, both main parameters: economic importance (EI) and supply risk (SR) are used to determine the criticality of the material to ensure comparability of results.

The following parameters are similar to the previous assessments: HHI = Herfindahl-Hirschman Index (used as a proxy for country concentration); WGI = scaled World Governance Index (used as a proxy for country governance); GS = global supply; EOL_{RIR} = end-of-life recycling input rate; substitution index.

However, there are several new and revised elements in the presented criticality methodology that are important to highlight:

- An average of the data from over the last 5 years is used in calculations. In the previous criticality assessments, only the last available year was used.

- Introducing an initial 'bottleneck' screening to determine which stage of the material (extraction or processing) presents the highest supply risk for the EU, taking into account the availability and quality of data.

- More transparent estimation of the substitution through formulas, also introducing the substitution index into the EI parameter and refinement of the substitution index in SR, while only proven and readily available substitutes are considered. The rationale for introducing substitution under EI is that when considering a raw material and its end-use applications, the EU industry may be able to use other alternative materials as a potential substitute on the basis of their cost and the technical performance/functionality. In the previous criticality assessments, substitution was a single number estimated as a forward-looking parameter (substitutability) by an expert judgement only within the SR.

- Refined allocation of raw materials to economic sectors based on the material-specific applications and their corresponding NACE Rev. 2 sectors at the 2-digit level. In previous criticality assessments, EI was evaluated by accounting for the fraction of each material associated with industrial mega-sectors at the EU level and their gross value added (GVA).

- Considering both the set of global supplier countries of the material and the countries where the EU is sourcing from in the supply risk parameter. The previous criticality assessments estimated the supply risk based on the mix of global supplier countries only. In the case of unavailability and/or low quality of data, only global supply or production capacity for specific cases is taken into account.

- Refining methodology and introducing data priority for the calculations. General data priority order: first, the official EU data, then Member State authorities' public data, public data from international organisations and non-EU authorities (e.g. USGS), and exceptionally, as a last option and if duly justified, trade/industry associations' public data and expert judgement. The data priority order for the end-of-life recycling input rate (EOL_{RIR}) in SR: EU raw material system analysis (MSA) data [4]; UNEP's report 'recycling rate of metals' [5]; rates from the previous EC criticality reports or sectorial reports; and finally an expert judgement.

- Introducing an import reliance (dependency) parameter in SR, to balance the risk linked to the global supply mix and the actual EU sourcing mix (domestic production plus imports).

- Introducing trade aspects (export restrictions and trade agreements) in SR.

([4]) DG Internal Market, Industry, Entrepreneurship and SMEs (2015), Study on Data Inventory for a Raw Material System Analysis: Roadmap and Test of the Fully Operational MSA for Raw Materials

([5]) United Nations Environment Programme (2011), *Recycling rates of metals — A status report*

2. ECONOMIC IMPORTANCE

2.1. Calculation of economic importance

I. Scope: Raw material (RM) end-use applications are assigned to the EU's manufacturing sectors at NACE Rev.2 (2-digit level). The reference period is an average of the data from the last 5 years.

II. Formula: The following formula is used to calculate EI:

$$\boldsymbol{EI = \sum_s (A_s * Q_s) * SI_{EI}}$$

where:

- *EI is economic importance;*
- *A_s is the share of end use of a raw material in a NACE Rev. 2 2-digit level sector;*
- *Q_s is the NACE Rev. 2 2-digit level sector's VA;*
- *SI_{EI} is the substitution index (SI) of a RM (to be used in economic importance);*
- *s denotes sector.*

III. Approach: It is proposed that the potential consequences associated with a potential supply disruption in terms of the economic importance (EI) that can be attributed to a candidate raw material (RM), be calculated in six steps as follows:

Step 1: Identification of RM end-use applications in PRODCOM and 5-/6-digit CPA categories (where possible) and their corresponding shares.

Step 2: Allocation of each end-use application to the corresponding manufacturing sector of a category C, defined by NACE Rev. 2 (2-digit level) classification provided by Eurostat. As a general approach, first the end uses at CPA level and/or NACE 3-/4-digit should be identified, and then they should be allocated to the corresponding sectors at NACE 2-digit level.

Step 3: Calculation of substitution index related to the economic importance component (SI_{EI}) for the RM uses identified at Step 1.

Step 4: Compilation of sectorial value added (VA) data for the NACE Rev. 2 sectors at the 2-digit level. Most data is provided by Eurostat's Structural Business Statistics.

Step 5: Calculating the EI score by multiplication of RM end-use shares by industrial sectors' VA and by substitution indexes.

Step 6: Scaling the results by dividing the calculated EI score by the value of the largest manufacturing sector NACE Rev. 2 at the 2-digit level and multiplied by 10, in order to reach the value in the scale between 0-10.

2.2. Calculation and use of substitution index in criticality assessment

In the revised methodology for criticality assessment, the availability of substitutes is considered a reducing element in both the economic importance (SI_{EI}) and the supply risk (SI_{SR}) dimensions. The assessment only takes into account the proven substitutes that are readily available today and able to reduce the consequences of a disruption and/or influence the risk of a disruption. Commercial information and published patents are only used to identify proven substitute alternatives readily available and applicable at the market today. Neither 'substitutability' nor 'potential future substitution' is considered in this methodology.

The following factors and influences are taken into account in the assessment:

- technical performance (extent to which the substitute can replace the functionality of a candidate raw material in an application, e.g. it is very unlikely that a tantalum capacitor would be substituted with an aluminium capacitor because a mobile phone would weigh 1 kg);
- cost performance (costs often drive decisions in business);
- substitute production (availability of substitutes in sufficient quantities needs to be considered);
- substitute criticality (substituting one critical material with another is unlikely to decrease the RM supply risk in a given application);
- substitute by-/co-production (if the proposed substitute is mainly obtained as a by- or co-product, its supply is dependent on a demand for another raw material).

The components of SI_{EI} and SI_{SR} are estimated based on the following subcomponents:

Substitution calculation within EI component (SI_{EI}):

- Substitute cost-performance (SCP)

Substitution calculation within SR component (SI_{SR}):

- Substitute production (SP)
- Substitute criticality (SCr)
- Substitute co-production (SCo)

2.2.1.Guidance for calculating the substitution index components

The calculation of the SI_{EI} and SI_{SR} components is done in three steps:

Step 1: Identifying the end-use applications' shares of the candidate material; should be the same shares as used in the calculation of the EI.

> *Example of how to search for available substitutes: the following key words can be used to do a first search: name of the materials to be substituted + end-use application + substitution/alternatives/replacement. In addition, more specific keywords can be used for each application, e.g. if the material to be substituted is used as a coating, the name 'coating' can be added to the search.*
>
> *If no information can be found on the internet, the same combination of keywords can be used in the freely available patents databases, such as Espacenet, EPO, OECD patent databases, etc.*

Step 2: Determining the 'sub-shares' of the substitute materials within each end-use application. In case information on the sub-shares is known or can be deduced from the commercial sources, the exact sub-shares are used in the calculations.

> *Example 1: information is available for the end-use application labelled 'batteries', where aluminium, nickel, zinc, lead and sodium can substitute for lithium (Source: SignumBox 2015).*
>
> *Example 2: it is known that 4 % of tungsten is used for incandescent lamps. The product 'wires' belongs to 'mill products' end-use application of tungsten with a share of 14 %. Therefore, the substitute materials for incandescent tungsten wires, namely germanium, silicon, gallium, indium, europium, terbium and yttrium (LED technology as a substitution possibility), are each participating with a very marginal share of around 0.3 % in the final calculations. This is also an example of a product/technology for product/technology substitution.*
>
> *Example 3: indium can be substituted with tin (fluorine doped tin oxide — FTO) or zinc (aluminium doped zinc oxide — AZO) in flat panel displays application. However, this is scarcely done due to reduced performance of the displays. Therefore, it is assumed that only 10 % of the produced displays are using tin or zinc and 90 % still employ indium, i.e. practically non-substituted in this end-use application.*

If the sub-shares of the different substitutes within one end-use application are not known, the following approach is adopted: it is conservatively assumed that the candidate material is still used (not substituted) in 50 % of the cases; the other 50 % is divided equally between the existing substitutes.

> *Example 1: it is assumed that half of the 8 % of indium used in solar components is not substitutable, i.e. 50 %*8 % = 4 %. The other half of the 8 % indium is substitutable by silicon and zinc, both of them contributing with 2 % to the final SI.*
>
> *Example 2: titanium, silicon, zirconium and aluminium are viable substitutes of tungsten in hard metals (cemented carbides) application with 60 % share of tungsten usage. In the calculations, 12.5 % is assumed for each of the substitutes (50 % divided equally by 4 substitutes) and 50 % for tungsten within the hard metals application. The final contributions of the different substitute materials will thus be as follows: titanium (7.5 %), silicon (7.5 %), zirconium (7.5 %), aluminium (7.5 %) and tungsten (30 %).*

Step 3: Calculating the substitution subcomponents: substitute cost-performance (SCP), substitute production (SP), substitute criticality (SCr), substitute co-production (SCo) and calculating the components of SI_{EI} and SI_{SR} as defined in chapters 2.2.2 and 3.5.

2.2.2. Substitution component in the economic importance

Furthermore, the addition of the SCP parameters assigned to each substitute material multiplied by the sub-share of each substitute, and in turn to the share of the end-use application, is used to determine the SI_{EI} for a given candidate material:

$$\boldsymbol{SI_{EI}} = \sum_{i}\sum_{a} \boldsymbol{SCP_{i,a}} * \boldsymbol{Sub\text{-}share_{i,a}} * \boldsymbol{Share_{a}}$$

where:

- *i denotes an individual substitute material;*
- *a denotes an individual application of the candidate material;*
- *SCP = substitute cost performance parameter;*
- *Share = the share of the raw materials in an end-use application;*
- *Sub-share = the sub-share of each substitute within each application.*

Substitute cost performance (SCP)

Substitute cost performance (SCP) is used to calculate the substitution component (SI_{EI}). The rationale behind it is that the market decision to adopt a substitute material is taken on the basis of its cost and the technical performance and functionality it offers.

The following elements are used for estimating the SCP subcomponent using the evaluation matrix (Table 1):

- **substitute material technical performance** and functionality in comparison to that of the candidate material within given application;
- **substitute material cost** in comparison to the cost of the candidate material within given application.

Table 1: **Substitute cost performance (SCP)** evaluation matrix (based on current costs)

Substitute material technical performance / *Substitute material cost*	*Similar performance*	*Reduced performance*	*Performance in case of no substitute*
Very high costs (more than 2 times)	*0.9*	*1*	*1*
Slightly higher costs (up to 2 times)	*0.8*	*0.9*	*1*
Similar or lower costs	*0.7*	*0.8*	*1*

This matrix is to be applied for each substitute material within the given application. A maximum 30 % reduction of the economic importance (EI) is assumed if all substitute materials offer similar performance at a similar cost, which would be the ideal case. If all substitute materials offer reduced performance at very high cost (more than 2 times) it is unlikely that they would be adopted by the market even though they are available. Therefore, in this case no reduction of the EI is anticipated.

3. SUPPLY RISK

3.1. Calculation of supply risk

I. Scope: The reference period is an average of the data of the last 5 years. By default, the extraction stage of raw materials is used for the calculation of the supply risk, unless the processing stage is proved to be the most critical point in the supply chain or data for the extraction stage are unavailable or of insufficient quality.

II. Formula: The following formula is used to calculate SR:

$$SR = \left[\left(HHI_{WGI,t}\right)_{GS} \cdot \frac{IR}{2} + \left(HHI_{WGI,t}\right)_{EUsourcing} \left(1 - \frac{IR}{2}\right) \right] \cdot (1 - EoL_{RIR}) \cdot SI_{SR}$$

where:

- *SR = supply risk;*
- *GS = global supply;*
- *$EU_{sourcing}$ = actual sourcing of the supply to the EU, i.e. EU domestic production plus other countries importing to the EU;*
- *HHI = Herfindahl-Hirschman Index (used as a proxy for country concentration);*
- *WGI = scaled World Governance Index (used as a proxy for country governance);*
- *t = trade parameter adjusting WGI;*
- *IR = import reliance;*
- *EOL_{RIR} = end-of-life recycling input rate;*
- *SI_{SR} = substitution index related to supply risk.*

The import reliance (IR) of a candidate material is calculated as follows (see chapter 3.2):

$$Import\ Reliance\ (IR) = \frac{Import - Export}{Domestic\ production + Import - Export}$$

The HHI_{WGI} for global supplier country concentration and EU-28 actual sourcing country concentration is adjusted by a trade parameter and calculated as follows:

$$(HHI_{WGI,t})_{GS\ or\ EUsourcing} = \sum_c (S_c)^2 WGI_c * t_c$$

where:

- *S_c = the share of country c in the global supply mix or in the EU sourcing mix of the raw material considered;*
- *WGI_c = the scaled World Governance Indicators of country c;*
- *t_c = the trade-related variable of country c for a candidate raw material (RM).*

Trade component t of a country for a candidate raw material is constructed as follows:

$$t_c = (ET\text{-}TA_c \text{ or } EQ_c \text{ or } EP_c \text{ or } EU_c)$$

where:

- *t_c = the trade-related variable of country c for a candidate raw material (RM) (6);*
- *$ET\text{-}TA_c$ = parameter reflecting an export tax imposed (%) by country c, possibly mitigated by trade agreement (TA) in force;*
- *EQ_c = parameter reflecting an export physical quota imposed by country c (physical units, e.g. tonnes);*
- *EP_c = parameter reflecting an export prohibition introduced by country c for a candidate RM;*
- *EU_c = EU countries parameter c for a candidate RM equal to 0.8.*

The SR-specific substitution index (SI_{SR}) of a candidate material (see chapter 3.5) is calculated as a geometric average of the three parameters — SP, SCr and SCo — assigned to each substitute material, multiplied by the sub-share of each substitute, and by the share of the end-use:

$$\boldsymbol{SI_{SR}} = \sum_{\boldsymbol{i}} [(\boldsymbol{SP_i} * \boldsymbol{SCr_i} * \boldsymbol{SCo_i})^{\boldsymbol{1/3}} * \sum_{\boldsymbol{a}} (\boldsymbol{Sub-share_{i,a}} * \boldsymbol{Share_a})]$$

where:

- *substitute production (SP) reflects global production of the substitute and the material as an indicator of whether sufficient amounts of substitute material are available;*
- *substitute criticality (SCr) takes into account whether the substitute was critical in the previous EU list;*
- *substitute co-production (SCo) takes into account whether the substitute is a primary product or is produced as a co-/by-product;*
- *i denotes an individual substitute material;*
- *a denotes an individual application of the candidate material.*

III. Approach. It is proposed that the potential consequences associated with a potential supply disruption in terms of the economic importance (EI) that can be attributed to a candidate raw material (RM), be calculated in 6 steps as follows:

<u>Step 1</u>: Identify the most critical point in the supply chain 'bottleneck' for the calculation of the supply risk, i.e. extraction or processing stage.

<u>Step 2:</u> Calculate the import reliance (IR) based on the data on global supply and actual EU sourcing used in the first step. For the metal ores, if available in sufficient quality the metal content data shall be used, otherwise the gross weight of ores should be used. In any case,

(6) Export restriction types source: OECD's Inventory of Restrictions on Exports of Industrial Raw Materials.

the same type of data (metal content vs gross weight) has to be used for both the global supply and the EU sourcing mixes.

Step 3: Calculate a Herfindahl-Hirschman Index (HHI) used as a proxy for country concentration based on the scaled World Governance Index (WGI). In the SR formula, HHI_{WGI} is calculated and used twice, once using global suppliers mix data and once using the mix of the actual suppliers to the EU, called EU sourcing.

Step 4: Calculate the trade (t) component, as described in chapter 3.3. The parameter 't' takes into account the contribution of trade to the supply risk.

Step 5: Calculate a corrected HHI_{WGI} both for the global suppliers mix and EU sourcing by the trade component.

Step 6: Calculate the end-of-life recycling input rate (EOL_{RIR}), a filter reducing the primary supply risk, as described in chapter 3.4. Recycling is, for the purpose of the methodology, considered a risk-free supply, due to lack of acceptable data on secondary raw materials production and trade for the materials in the scope of the assessments.

Step 7: Calculate the substitution component of the supply risk (SI_{SR}), a filter reducing the primary supply risk, as described in chapter 3.5.

Step 8: Integrate all components in the SR formula. SR is then divided by 10 000 in order to fit between 0 and 10. As for the calculation of HHI the shares of global supply and EU sourcing are typically in the range 0-100, instead of 0-1.

3.2. 'Bottleneck' screening

The screening covers all candidate raw materials.

In principle the mining/harvesting stage of a candidate raw material should be considered, unless there are duly documented arguments to make the assessment at the processing/refining stage, e.g. lack of quality data (to be reported in the raw materials fact sheets).

The calculation of the supply risk should be performed at both stages if quality data for global supply and EU sourcing countries is available for both stages, and if there is a significant difference in the country distribution of mining/harvesting versus processing/refining. The stage with a higher SR score should be selected.

Data on global supply and on import/export to/from the EU-28 are to be used.

3.3. Import reliance and its use in connection with global suppliers mix and actual sourcing

In the revised methodology, in order to calculate a more representative measure of the risk for the EU, the global supply (global suppliers mix) is used in combination with EU sourcing (the mix of suppliers to the EU, i.e. the mix of domestic production plus import).

Two examples are reported in Figures 1a-b to clarify the difference between global supply and actual EU sourcing.

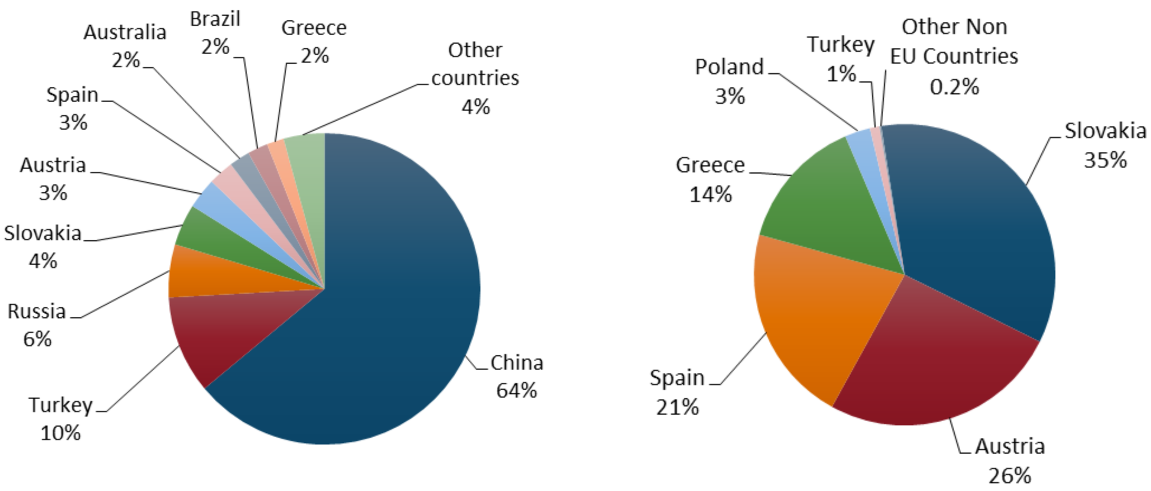


Figure 1a: Example: global supply of magnesite (left) and actual EU sourcing (right).

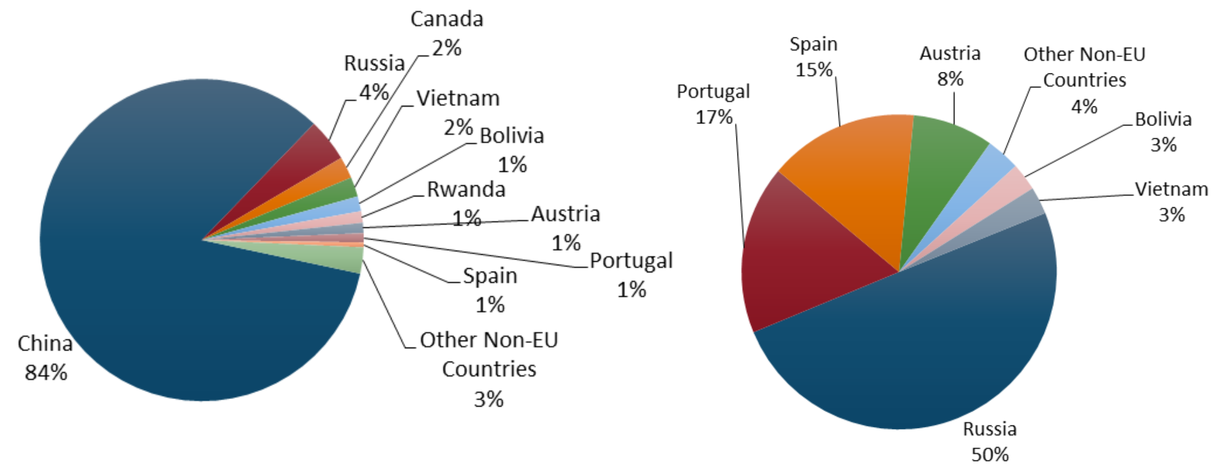


Figure 1b: Example: global supply of tungsten (left) and actual EU sourcing (right).

Import reliance (IR) is a parameter used to balance the risk linked to the global supply mix and the actual EU sourcing:

$$\boldsymbol{Import\ Reliance\ (IR)\ =\ \frac{Net\ Import}{Apparent\ Consumption}}$$

where:

$$\boldsymbol{Net\ import\ =\ Import - Export}$$

$$\boldsymbol{Apparent\ consumption\ =\ Domestic\ production\ +\ Import - Export}$$

The simplified formula to be used in the calculation is the following:

$$\boldsymbol{Import\ Reliance\ (IR)\ =\ \frac{Import - Export}{Domestic\ production\ +\ Import - Export}}$$

The IR is incorporated into the comprehensive formula as follows:

$$\boldsymbol{SR = \left[(HHI_{WGI-t})_{GS} \cdot \frac{IR}{2} + (HHI_{WGI-t})_{EUsourcing}\left(1 - \frac{IR}{2}\right)\right] \cdot (1 - EoL_{RIR}) \cdot SI_{SR}}$$

In the revised methodology, when IR is 100 %, the risk is the average of the two measures, i.e. 50 % based on global supply and 50 % based on actual EU sourcing.

In those cases where the EU is independent from imports (i.e. IR=0), the global supply mix is disregarded and the risk is entirely calculated based on the actual sourcing.

When the EU is a net exporter (i.e. IR<0), IR is made equal to zero for the calculation of the SR, but the actual IR is reported in the fact sheet.

The above formula and underlying approach are to be systematically adopted, except for cases where the data are not available, or not of sufficiently high quality. Data unavailability and/or low quality might imply estimating the risk based on global supply only (previous methodology) or production capacity (specific cases e.g. indium).

Example: in the case of gallium (IR=0) or indium (IR=100) the calculation of supply risk is likely to remain based on global production capacities, unless sufficiently high-quality data are found.

3.4. Trade parameter

Trade parameter '*t*' is used for quantifying the trade contribution to increasing or diminishing the supply risk related to a specific country for a candidate raw material (RM). Influence of export restrictions and trade agreements is thereby taken into account.

Restrictions (7) considered are export taxes, physical export quotas and export prohibitions. Licensing requirements are left aside due to the difficulty of quantifying them.

There is a distinction between the export taxes and the export quotas in the methodology. The case of export quotas remains a separate element of supply risk as the EU trade agreements cannot guarantee their removal. Mirroring the legal provisions of the World Trade Organisation (WTO), EU trade agreements make reference to the General Agreement on Tariffs and Trade (GATT) exceptions that may be invoked to justify their use (even though their use is in principle ruled out). Trading partners may use these exceptions and only long WTO dispute settlement proceedings may possibly end up in the removal of the quotas. Therefore, for all practical reasons, the impact of quotas cannot be mitigated by the existence of EU trade agreements.

For the purpose of the methodology, only bilateral trade agreements with the EU are taken into account.

The trade parameter t_c (ranging from 0.8 to 2) for a candidate raw material for any of the EU countries equals to 0.8, while for the non-EU countries it is equal to the highest score of the restrictions parameters ($ET\text{-}TA_c$ or EQ_c or EP_c):

$$t_c = (ET\text{-}TA_c \text{ or } EQ_c \text{ or } EP_c \text{ or } EU_c)$$

where:

- t_c = *the trade-related variable of country c for a candidate raw material (RM);*
- $ET\text{-}TA_c$ = *parameter reflecting an export tax imposed (%) by country c, possibly mitigated by trade agreement (TA) in force;*
- EQ_c = *parameter reflecting an export physical quota imposed by country c (physical units, e.g. tonnes);*
- EP_c = *parameter reflecting an export prohibition introduced by country c for a candidate RM;*
- EU_c = *EU countries parameter c for a candidate RM equal to 0.8.*

EU countries parameter (EU_c)

The supply by the EU countries is considered to represent the lowest supply risk for the EU, as a single trading block. Therefore the associated value of the trade component is lower than 1 and is equal to the EU countries parameter:

$$EU_c = t_c = 0.8$$

(7) Export restriction types source: OECD's Inventory of Restrictions on Exports of Industrial Raw Materials.

Export taxes/trade agreements parameter ($ET\text{-}TA_c$)

The contribution of export taxes (ET) or trade agreements (TA) of a non-EU country c for a candidate RM to the increased supply risk is assigned in two steps. First, the existence of an ET is identified, and if positive the existence of a relevant TA is verified, and finally ET-TAc is assigned as follows:

$$ET = 1 + 0.1\ (0 < TAX \leq 25\ \%)$$

$$ET = 1 + 0.2\ (25\ \% < TAX \leq 75\ \%)$$

$$ET = 1 + 0.3\ (TAX > 75\ \%))$$

The risk mitigating effect of the bilateral trade agreement of a candidate RM might be conditional on the concerned RM's coverage by the provisions on export duty in the agreement. Thus, the mitigation effect of the bilateral trade agreements concluded with country c supplying a candidate RM might need further investigation on a case-by-case basis. Only bilateral trade agreements concluded by the EU with the RM supplying countries (listed in the table below) are assumed to have a risk mitigation effect. When in force, the supply risk of the concerned country goes back to the level as if no export tax was applied to the RM.

EU preferential trade agreements in force			
Customs Union	**European Economic Area (EEA)**	**Bilateral or regional agreements**	**Economic Partnership Agreements (EPA)**
Andorra, Monaco, San Marino, Turkey	Iceland, Liechtenstein, Norway	Albania, Algeria, Bosnia and Herzegovina, Chile, Colombia, Costa Rica, Ecuador, Egypt, El Salvador, Faroes, Iraq, Israel, Jordan, Lebanon, Macedonia, Mexico, Montenegro, Morocco, Nicaragua, Occupied Palestinian Territory, Panama, Peru, Serbia, South Africa, South Korea, Switzerland, Syria, Tunisia	Antigua and Barbuda, Bahamas, Barbados, Belize, Cameroon, Dominica, Dominican Republic, Fiji, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Madagascar, Mauritius, Papua New Guinea, Saint Kitts and Nevis, Saint Lucia, Seychelles, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Zimbabwe

Source: DG Trade, overview of trade agreements: http://ec.europa.eu/trade/policy/countries-and-regions/agreements

Export quotas parameter (EQ_c)

Export quotas of non-EU country c for candidate RM contribute to the increased supply risk:

$$EQc = 1 + \frac{country\ c\ production\ of\ a\ candidate\ RM - physical\ quota\ imposed}{total\ world\ production}$$

Export prohibition parameter (EP_c)

Export prohibition by non-EU country c for candidate RM represents an extreme version of export quota (i.e. quota = 0):

$$\boldsymbol{EPc = 1 + \frac{country\ c\ production\ of\ a\ candidate\ RM}{total\ world\ production}}$$

Data sources to be used are:

i. For export restrictions: OECD's inventory of restrictions on exports of raw materials, http://qdd.oecd.org/subject.aspx?Subject=ExportRestrictions_IndustrialRawMaterials
ii. For EU bilateral trade agreements: DG Trade, overview of trade agreements, http://ec.europa.eu/trade/policy/countries-and-regions/agreements

3.5. Secondary raw materials (recycling)

Due to a lack of acceptable data on secondary raw materials production and trade for the materials in the scope of the assessment, in this methodology, the supply of secondary raw materials is represented by a recycling parameter 'end-of-life recycling input rate' (EOL_{RIR}). EOL_{RIR} is used as a primary supply risk reducing factor/filter. No correction is applied for the risk of supply of secondary raw materials. EOL_{RIR} is understood as 'the ratio of recycling from old scrap to European demand of a candidate raw material (equal to primary and secondary material inputs)':

$$\boldsymbol{EOL_{RIR}} = \frac{\boldsymbol{Input\ of\ secondary\ material\ to\ EU}\ [\boldsymbol{from\ old\ scrap}]}{\boldsymbol{Input\ of\ primary\ material\ to\ EU}\ +\ \boldsymbol{Input\ of\ secondary\ material\ to\ EU}}$$

In the methodology, the EOL_{RIR} parameter is assigned according to the following rules in the order of priority:

i. Calculate EOL_{RIR} according to the EU raw material system analysis (MSA) methodology when data is available, or use the MSA results if available. In such cases, the system boundaries include 'processing' and 'manufacture'. Figure 2 illustrates flows of material inputs and outputs to be considered for the calculation of EOL_{RIR}.

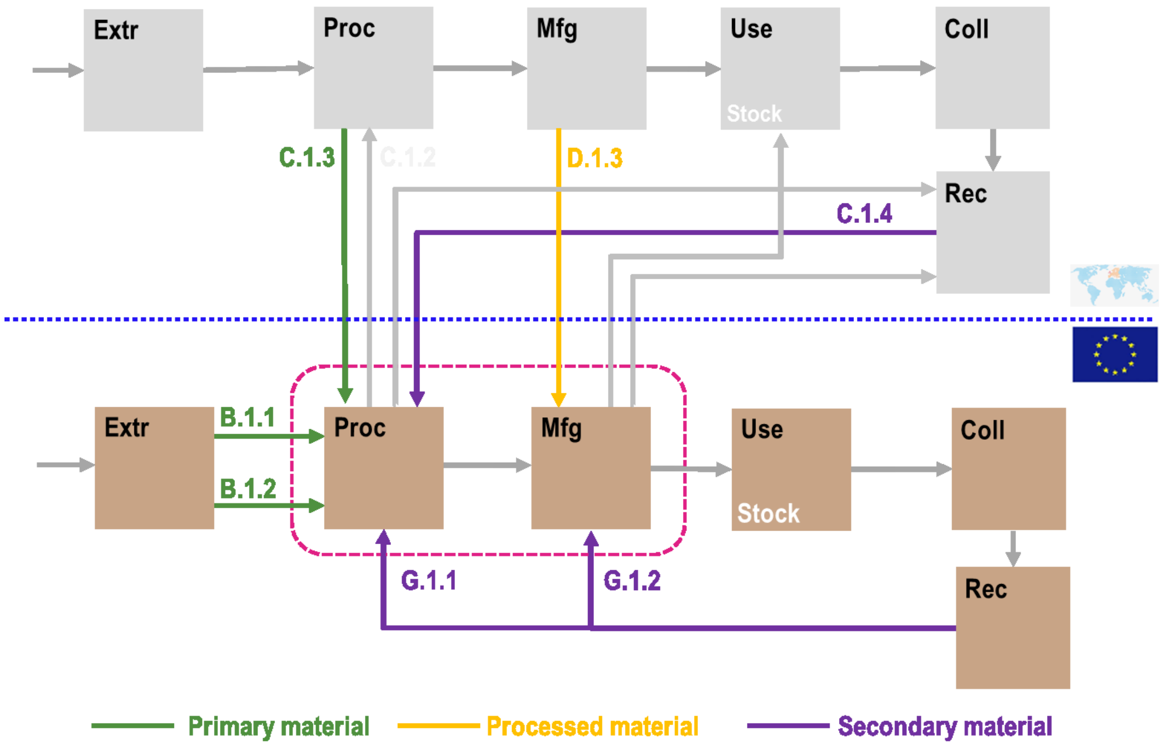


Figure 2: Flow diagram extracted from the MSA study for the calculation of EoL_{RIR}

The first part of the figure represents the life cycle stages of a raw material in the rest of world (ROW) while the life cycle stages of a raw material in Europe are represented by the brown boxes. The system boundary is represented in pink dashes. Flows included for the 'end of life recycling input rate' calculations are represented in green (primary material), yellow (processed material), and purple (secondary material).

Based on Figure 2 extracted from the MSA study ([8]), EOL_{RIR} should be calculated with the following formula:

$$\boldsymbol{EOL_{RIR}} = \frac{\boldsymbol{G.1.1 + G.1.2}}{\boldsymbol{B.1.1 + B.1.2 + C.1.3 + D.1.3 + C.1.4 + G.1.1 + G.1.2}}$$

where:

- ***B.1.1.*** *production of primary material as main product in the EU sent for processing in the EU;*
- ***B.1.2.*** *production of primary material as by-product in the EU sent for manufacturing in the EU;*
- ***C.1.3.*** *imports to the EU of primary material;*
- ***D.1.3.*** *imports to the EU of processed material;*
- ***C.1.4.*** *imports to the EU of secondary materials;*
- ***G.1.1.*** *production of secondary material from post-consumer functional recycling in the EU sent for processing in the EU;*
- ***G.1.2.*** *production of secondary material from post-consumer functional recycling in the EU sent for manufacturing in the EU.*

ii. Use UNEP's report 'recycling rate of metals' ([9]), if data from the MSA is not available.

UNEP global recycling data are used as a proxy of the fraction of secondary material generated in the EU if no MSA data are available. UNEP definitions of old scrap ratio (OSR) and recycled content (RC) could be used to estimate the 'end of life recycling input rate' as defined by the EC criticality methodology; this means including only the contribution of old scrap to the total production of a material. Figure 3 illustrates the system boundaries and flows taken into account for estimating the OSR and RC.

EOL_{RIR} values can be deducted from the UNEP equations as follows:

$$\boldsymbol{EOL_{RIR} = OSR \times RC}$$

$$\boldsymbol{EOL_{RIR}} = \frac{\boldsymbol{Input\ of\ secondary\ material\ (only\ old\ scrap)}}{\boldsymbol{Input\ of\ primary\ maerial\ +\ Input\ of\ secondary\ material\ \ (new\ and\ old\ scraps)}}$$

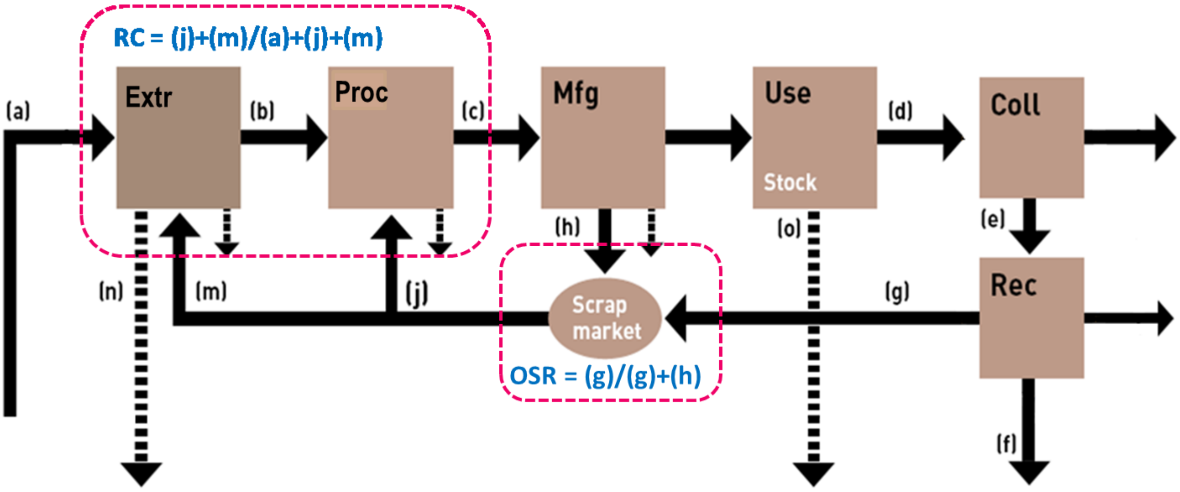
where:

$$\boldsymbol{Old\ scrap\ ratio\ (OSR)} = \frac{\boldsymbol{Input\ of\ secondary\ material\ (only\ old\ scrap)}}{\boldsymbol{Total\ of\ secondary\ material\ (new\ and\ old\ scraps)}} = \frac{\boldsymbol{(g)}}{\boldsymbol{(g)+(h)}}$$

$$\boldsymbol{Recycled\ content\ (RC)} =$$
$$\frac{\boldsymbol{Input\ of\ secondary\ material\ (new\ and\ old\ scraps)}}{\boldsymbol{Input\ of\ primary\ material\ +\ Input\ of\ secondary\ mat.(new\ and\ old\ scraps)}} = \frac{\boldsymbol{(j) + (m)}}{\boldsymbol{(j) + (m) + (a)}}$$

(8) https://ec.europa.eu/jrc/en/scientific-tool/msa
(9) UNEP (2011), Recycling rates of metals — A status report

$$\textit{Secondary material (new and old scrap)} = (j) + (m) = (g) + (h)$$



(a): primary metal input; (b): refined metal; (c): intermediate products (e.g. alloys, semis); (d): EOL products (metal content); (e): EOL metal collected for recycling; (f): EOL metal separated for non-functional recycling; (g): recycled EOL metal (old scrap); (h): scrap from manufacturing (new scrap); (j) scrap used in fabrication (new and old scraps); (m): scrap used in production (new and old scrap); (n): tailings and slag); (o): in-use dissipation.

Extr: *Extraction*; **Proc:** *Processing;* **Fab:** *Fabrication;* **Mfg:** *manufacturing;* **Coll:** *collection;* **Rec:** *recycling*

Figure 3: System boundaries and flows to estimate diverse recycling indicators for a metal life cycle by UNEP. Modified from (Graedel, Allwood et al., 2011).

iii. **Use recycling rates from the previous EC criticality report, or sectorial reports or expert judgement only when MSA and UNEP data are not available.**

For some materials, recycling figures might be available in sectorial reports, or might also be provided by expert judgement. In such cases, a detailed justification about the use of sources other than the MSA study and UNEP shall be given. Such justification shall include information about the system boundaries and flows accounted for the EOL_{RIR} calculations; a description about the number of end-uses accounted for; and detail on whether EOL_{RIR} refers to the complete recycling stage or partially to pre-processing and end-processing stages.

3.6. Substitution component of the supply risk

As presented in section 2.2, in this methodology, substitution (SI) is considered a reducing element in both the economic importance (EI) and the supply risk (SR) dimensions.

The existence of available substitutes could influence supply risk inherent in the current supply mix of the candidate material and is therefore included in the SR calculation.

It is considered that physical availability of a substitute in the required quantities is an important factor in decreasing the SR. If a substitute material is already critical and highly demanded by other technologies and sectors, it may not be able to reduce risk of supply of the candidate material. The substitute's SR can also be influenced by the way it is produced, as a main product or a by-/co-product depending on other products.

For determining the substitution component of the supply risk (SI_{SR}) the geometric averages of the three parameters (SP, SCr and SCo) assigned to each substitute material are multiplied by the sub-share of each substitute within each application of the candidate material, and by the share of the candidate raw materials in a given application:

$$\boldsymbol{SI_{SR}} = \sum_{\boldsymbol{i}} [(\boldsymbol{SP_i} * \boldsymbol{SCr_i} * \boldsymbol{SCo_i})^{\boldsymbol{1/3}} * \sum_{\boldsymbol{a}} (\boldsymbol{Sub - share_{i,a}} * \boldsymbol{Share_a})\,]$$

where*:*

- *i denotes an individual substitute material;*
- *a denotes an individual application of the candidate material;*
- *SP = substitute production reflects global production of the substitute and the material as an indicator of whether sufficient amounts of substitute material are available;*
- *SCr = substitute criticality takes into account whether the substitute was critical in the previous EU list;*
- *SCo = substitute co-production takes into account whether the substitute is a primary product or mined as a co-/by-product;*
- *Share = the share of the candidate raw materials in the application 'a';*
- *Sub-share = the sub-share of a substitute 'i' within each application 'a' of the raw material.*

The SP, SCr and SCo parameters are to be determined for each substitute of the relevant candidate material.

Substitute production (SP) assessment

The substitute production (SP) parameter reflects the market size (global production data) of the candidate material compared to that of the substitute material. In this methodology, only substitutes that are available in sufficient quantities in terms of annual production are considered a potential reducing factor for the supply risk of the candidate material. Substitutes produced in lower quantities will not affect the SR. If a material with high annual production of e.g. hundreds of thousands of tonnes has to be substituted by a material with limited annual production (e.g. hundreds of tonnes) then it is very unlikely that substitution will take place, at least not on a large scale, due to the physical scarcity of the substitute material.

Therefore, the following approach is adopted for the SP:

SP = 0.8	*if the annual global production of the substitute material is higher than that of the candidate material;*
SP = 1	*if the annual global production of the substitute material is similar or lower than that of the candidate material.*

Substitute criticality (SCr) assessment

It is important to assess the criticality of the substitute itself. If a substitute material is already critical, it might not be readily available as a substitute option.

SCr is assigned for each substitute material according to the system below:

Substitute criticality (SCr)	Rationale
SCr = 1	*If the **substitute material was on the last EU list of CRM**, this material is not expected to contribute to the reduction of the SR of the candidate material.*
SCr = 0.8	*If the **substitute material was not critical** in the last EU assessment **or was not screened in the previous exercise**, this material is expected to contribute to the reduction of the SR of the candidate material.*
SCr = 1	*If **no substitute material is available**, no reduction of the SR is assumed.*

Substitute co-/by-production (SCo) assessment

Co-/by-production of the substitute materials is a new element that is considered in this methodology. For candidate materials, such as minor metals (REE, In, Ga, Ge, etc.) it could be a significant constraint on the immediate supply of these materials. Co-production dynamics are also considered in the criticality methodologies of the USA (US Critical Materials Institute) as one of the risk factors, as well as in Japan (Japan Oil, Gas and Metals National Corporation) in the supply risk component.

For the present methodology a simple approach is used to estimate the influence of the substitute co-production or by-production:

Substitute co-production (SCo)	Rationale
SCo = 1	*If the substitute material is mined **only as a by-product or co-product** — no reduction of the SR of the candidate material is assumed.*
SCo = 0.8	*If the substitute material is mined as a **primary material** — up to 20 % reduction of the SR is assumed.*
SCo = 0.9	*If the substitute material is mined both **as a primary material, but also as a by-/co-product** (e.g. the case of Molybdenum) — up to 10 % reduction of the SR is assumed.*
SCo = 1	*If **no substitute material is available,** no reduction of the SR is assumed.*

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ET-01-17-370-EN-N

ISBN 978-92-79-68051-9

doi:10.2873/769526