Teaching Resources on the Sustainable Management of Critical Raw Materials

Trainer's Manual for Supply Risk Factors

March 2020

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

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1 Context and Introduction to Training

This booklet is supplementing the teaching materials and the set of further supporting booklets that have been developed to support teachers in conducting training courses related to the sustainable management of critical raw materials.

SusCritMat aims to educate people from Master's student level up, both in industry and academia about important aspects of sustainable critical raw materials. In a novel concept, it introduces courses on these complex and interdisciplinary topics in a modular structure, adaptable to a variety of different formats and accessible to both students and managers in industry. These courses will develop new skills, which will help participants to better understand the impact and role of critical raw materials in the whole value chain; enabling them to identify and mitigate risks. Understanding the bigger picture and the interconnected nature of global business and society is increasingly necessary to and valued by industry.

SusCritMat is an EU-funded project that brings together the technical and pedagogical expertise of leading educational institutions and business partners. It uses and creates teaching materials which can be combined into different course formats.

This training kit presents the key messages related with the sustainable management of critical raw materials in three major sections:

- Introduction to criticality (including criticality assessment, global resource supply chains, geopolitical factors, and economics of metals)
- Analysis of criticality (including material flows, scenario planning, and life cycle assessment)
- Solutions (including responsible sourcing, circularity indicators, circular product design, and good practice examples)

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1.1 Training Materials List

The *SusCritMat project* developed the following teaching materials:

Basics
Critical Resources for Emerging Technologies
Criticality
Supply Chain Resilience
Supply Risk Factors
Circularity
Circular Economy
Characterizing the Urban Mine
Circular Business Models
Waste Management and Recycling Potential
Closing Loops on Product Level
Governance
Geopolitical Aspects
Metals & CRM Scenarios
Restricted Substances Legislation
Impact on Society and the Environment
Sustainability Assessment
Responsible Mining
Responsible Sourcing / Certification
Environmental Aspects
Sustainable Materials Usage
CRM and Sustainable Development
Tools
MFA - Material Flow Management
Good Use of Data
LCA – Life Cycle Assessment
Process Models based on LCA

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1.2 Description of teaching materials

Supply risk is one of the aspects taken into account in criticality assessments. The purpose of the lecture was to discuss some important choices to be made, indicate a number of existing approaches, and highlight the importance of paying more attention to secondary materials in criticality assessments.

The training material for the Supply risk lecture consists of the following:

- a powerpoint presentation.
- A clip containing a lecture, with an abbreviated powerpoint presentation on the side.

1.3 Key Messages

The lecture contains an overview of generally taken approaches for assessing supply risk in criticality assessments, and mainly focuses on two: the EU criticality assessment and the criticality assessment method developed at the Center of Industrial Ecology at Yale University. It treats the aspects that are relevant for supply risk situations. It then goes on to apply those same aspects on the secondary supply of critical materials. The conclusion is that there is a great necessity to include secondary production in criticality assessment, especially if the transition towards a circular economy is taken seriously.

1.4 Learning Objectives

The learning outcomes for the Supply risk lecture is the following:

- Understanding which aspects are important for assessing supply risk related to individual (critical) materials
- Obtaining information on how such aspects are included, or not included, in criticality assessments

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- Understanding the importance of secondary production from the point of view of criticality assessments
- Getting some starting points for thinking about including secondary production in criticality assessment.

1.5 Additional Reading

European Commission, 2017. COMMISSION STAFF WORKING DOCUMENT. Report on Critical Raw Materials and the Circular Economy. Brussels,16.1.2018. SWD(2018) 36 final.

Gian Andrea Blengini, Philip Nuss, Jo Dewulf, Viorel Nita, Laura Talens Peirò, Beatriz Vidal-Legaz, Cynthia Latunussa, Lucia Mancini, Darina Blagoeva, David Pennington, Mattia Pellegrini, Alexis Van Maercke, Slavko Solar, Milan Grohol, Constantin Ciupagea, 2017. EU methodology for critical raw materials assessment: Policy needs and proposed solutions for incremental improvements. Resources Policy 53 (2017) 12–19.

Lorenz Erdmann & Thomas E Graedel, 2011. Criticality of Non-Fuel Minerals: A Review of Major Approaches and Analyses. Environ. Sci. Technol. 2011, 45, 18, 7620-7630.

Dieuwertje Schrijvers, Alessandra Hool, Gian Andrea Blengini, Wei-Qiang Chen, Jo Dewulf, Roderick Eggert, Layla van Ellen, Roland Gauss, James Goddin, Komal Habib, Christian Hagelüken, Atsufumi Hirohata, Margarethe Hofmann-Amtenbrink, Jan Kosmol, Maïté Le Gleuher, Milan Grohol, Anthony Ku, Min-Ha Lee, Gang Liu, Keisuke Nansai, Philip Nuss, David Peck, Armin Reller, Guido Sonnemann, Luis Tercero, Andrea Thorenz, Patrick A. Wäger. A review of methods and data to determine raw material criticality. Resources, Conservation and Recycling 2020, 155, 104617. DOI: 10.1016/j.resconrec.2019.104617.

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2 Slides and Notes

The slides for the supply risk lecture show different methodologies for criticality assessment, and how these include supply risk. Mainly the EU method and the Yale method are treated. Other criticality assessments exist as well but their treatment of supply risk is not very different. It is interesting to also see how businesses develop their own assessments, with a different angle on supply risk.

In the lecture, a number of aspects related to criticality are distinguished:

- Restricted access to the resource
- Unstable markets
- Global economic optimisation

These same aspects are then treated for the urban mine, the source of secondary materials. They differ in some respects from primary materials, but they could be made operational for secondary materials as well. At first glance it seems that exploiting urban mines could solve some criticality aspects, but there are still challenges to overcome.

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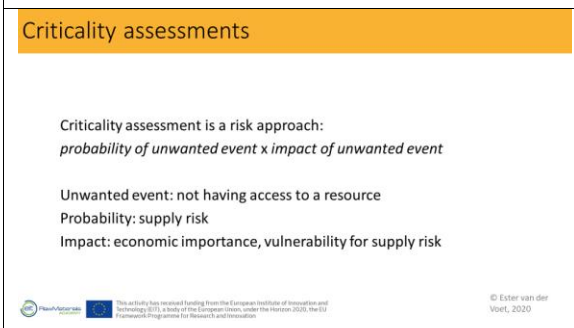
<td>
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<td>Criticality assessment is generally understood to be a risk analysis: some unwanted event is specified, and the risk is then determined as the probability of the unwanted event multiplied by the impact of that unwanted event in case it would actually happen. In the case of critical materials, the unwanted effect clearly is defined as: not having access to a resource. The probability of such an event is then defined as supply risk, and the impact is called “economic importance” or “vulnerability to supply risk”– the</td>
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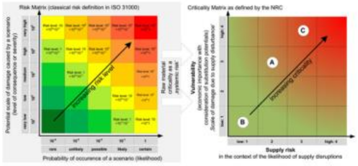
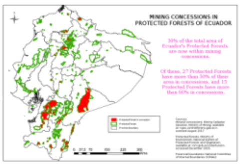
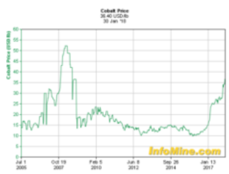
	more important a resource is, the worse it is when access is restricted. Both supply risk and economic importance are different for different actors (consumers, companies, countries) and different functionalities (energy, communication etc.)
Criticality assessments • Depicting criticality (source: Glöser et al., 2015)  © Ester van der Voet, 2020	Criticality is often depicted as a matrix, with supply risk on one axis and the economic importance on the other. Top right means high criticality. We will further focus just on the supply risk side of criticality assessment. There are several factors that contribute to the supply risk, the risk that the supply of a particular material will be disrupted. In the following slides we will go through several of those.

Supply risk factors
• Restricted access
  • geologically scarce resource
  • restricted access to site
  • site located in risky area
  • few mines
  • low possibility for secondary production

© Ester van der Voet, 2020
	First factor: restricted access. This means that physically we can’t get at deposits we need. This can be because such deposits are rare, but also refers to deposits that are actually there but there are reasons we cannot access them. One of these is that deposits may be located in protected areas, where mining is not allowed. Another that they belong to states that restrict access, that are at war, or that have governments we don’t like to do business with or that won’t do business with us: geopolitical reasons, in short.

Supply risk factors
• Restricted access
• Unstable markets
  • Disconnect between supply and demand
    • co- or by-production
    • production from scrap
  • Unpredictable / rapidly changing demand

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	A second factor is unstable markets. Mining companies do not want to engage in production of a commodity when they are afraid it won’t make a profit. Mining is a long-term activity, and stable markets are very important for the decision of a mining company to start up the whole process.

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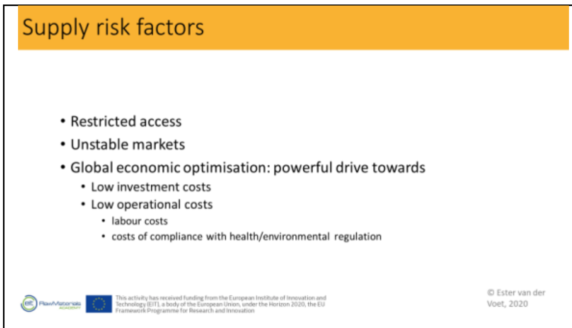
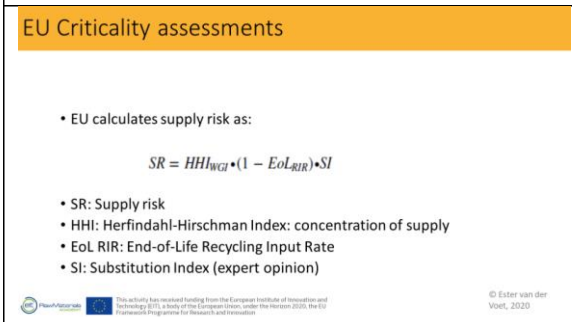
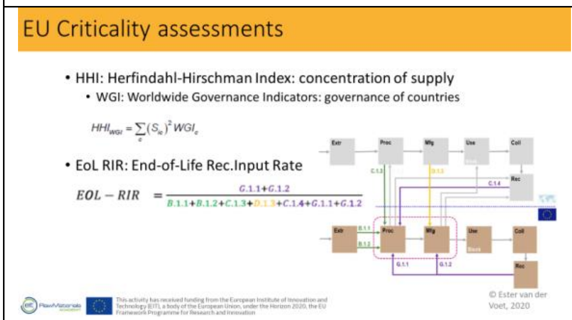


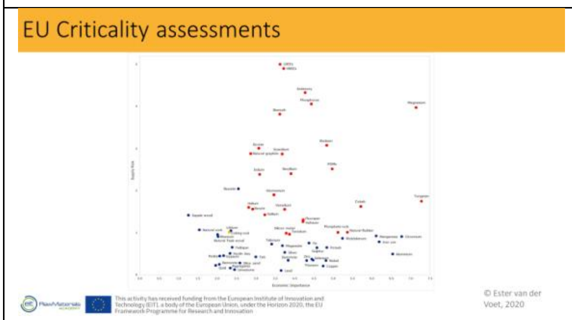
A third factor is global economic optimisation, which means resources are produced at the locations that can do so at lowest costs. Often China and REE are mentioned as a case – the issue is not that REE cannot be produced in Europe – plenty of deposits available – but that they cannot be produced at such low costs as China is able to.



The way the EU does criticality assessments is depicted in this slide. The HHI is a measure of geopolitical scarcity, and is calculated based on the number of countries that produce the material in question. The fewer countries, the higher the supply risk. Supply risk is lower when a significant part of the supply can come from recycling. And finally, when it is easy to substitute with another material, the supply risk is lower.



Note the way the EoL RIR is calculated. It must not be confused with the EoL RR, the end-of-life recycling rate, which is the percentage of scrap that is recycled. The EoL RIR refers to the fraction of the input that comes from recycling. This can be very different in a situation where demand is still growing, as is the case for metals in general and CRM in particular.



This is the 2017 list of critical materials of the EU, as calculated by the above method. Upper right is most critical. A lot of materials score high on economic importance (x-axis), but are still not critical because of their low supply risk (y-axis).

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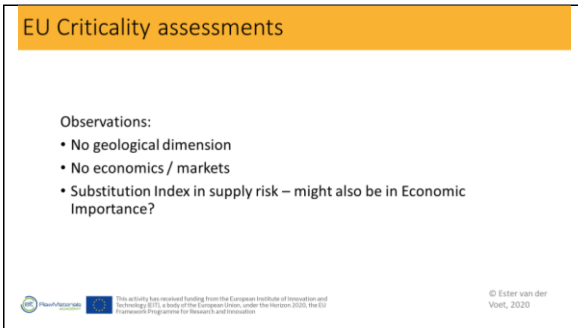
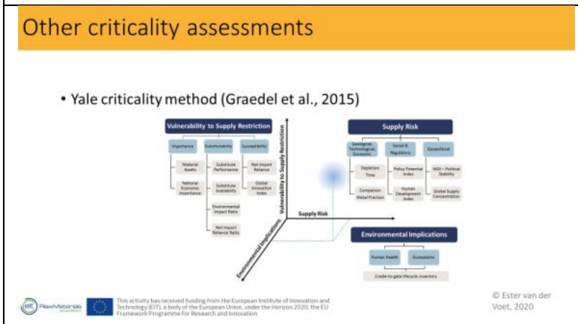
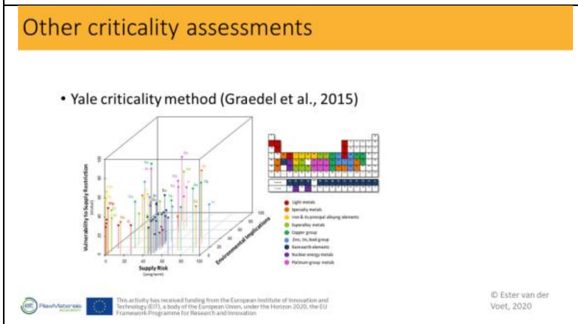
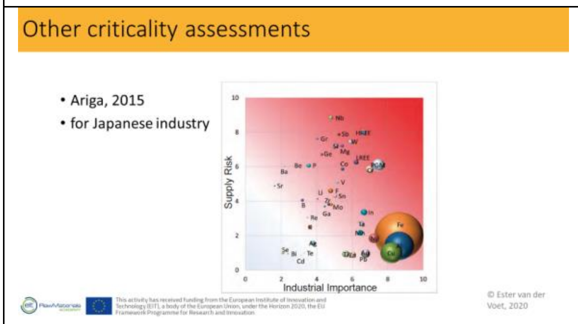
	The EU criticality assessment is rather limited in its scope. It does contain geopolitics but not economics and markets, and not geological or other physical restrictions to access. The substitution index may be something that rather belongs in Economic importance: if it can be easily replaced, it may be less important for that reason.
	The method used mostly in the USA is the Yale criticality method. This method has an additional axis, the Environmental implications axis. This is a debated issue: do the environmental impacts related to the materials' life cycles belong in criticality, or is this an important, but nevertheless different topic? Both in Supply risk and in Economic importance (here named Vulnerability to Supply restriction) the number of factors taken into account is considerably larger than in the EU criticality method.
	This is the result of applying the Yale criticality method to a number of elements. Far top right is most critical. None of these elements score highly on the Environmental implications axis. This makes it a bit futile to include such an axis, at least in this way. The USA criticality list overlaps with the EU, but is certainly not identical.
	This picture is company based. Here, the supply risk is defined as "their" supply risk, dependent on the general supply risk factors as mentioned before, but also on their specific supply chain. The economic importance is interpreted here as "industrial importance", not from the point of view of the needs of society, but of the business needs of this particular industry. In the suggested

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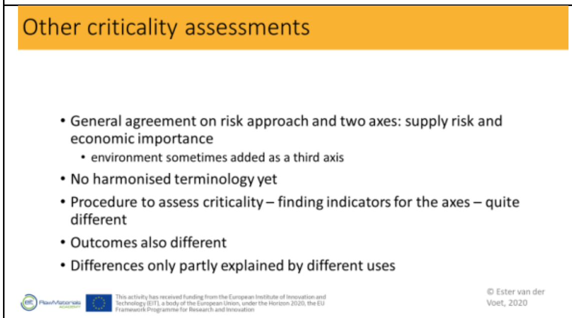
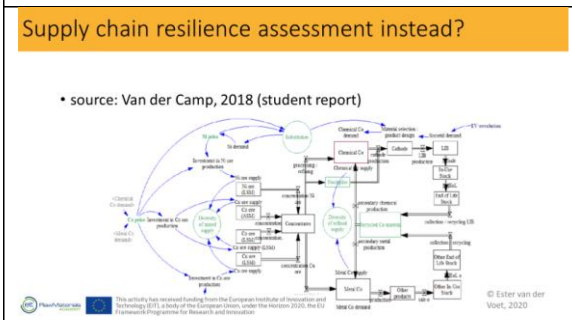
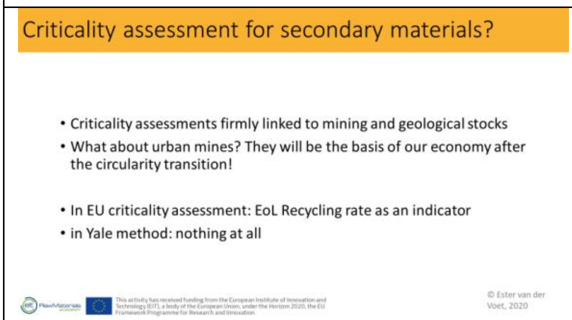
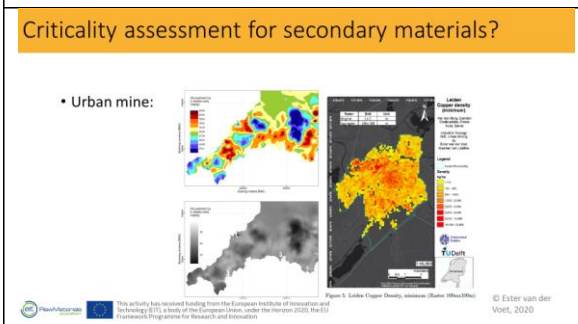
	readings there are many examples of company-based criticality assessment.
	Also important to mention: these criticality assessments change over time as the global situation, the industrial situation, and other factors may also change over time. This is why governments as well as industries update their list of critical materials from time to time.
	Some suggest, because of the multitude of criticality assessments and especially because these assessments change over time, that it may be more robust to assess the resilience of supply chains instead of coming up with numbers. That would provide more insight and would enable to react to changes in an early stage. This idea is further elaborated in the “Supply chain resilience” package.
	So far, criticality assessments refer to mining and geological stocks. The present recycled input is part of the EU criticality assessment. But wouldn’t it be better to treat secondary resources as we do the primary resources, and develop a specific criticality assessment for those?
	This links to the idea of urban mining: considering stocks-in-use in our societies as a potential future deposit, from where “new” materials can be produced. Presently, the urban mine is being prospected in different places. So far the question is: how much is there, where is it, and when will it become available? There is a specific package in the SusCritMat teaching materials on urban mining.

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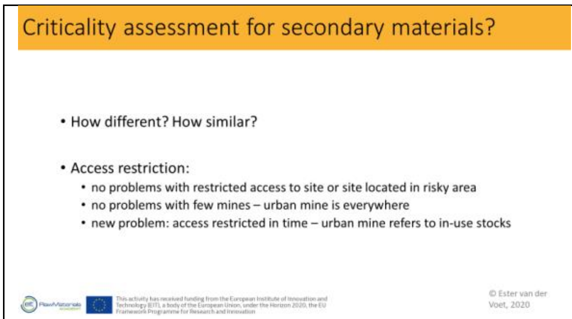
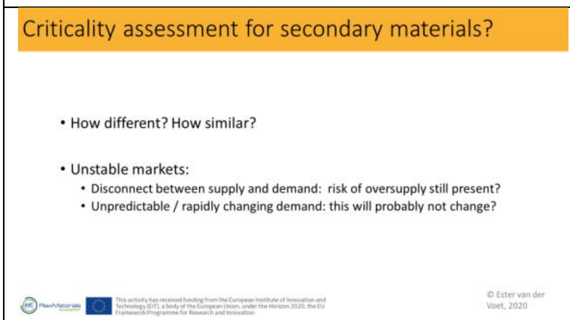
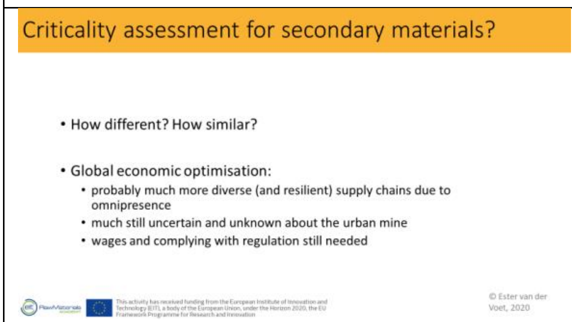
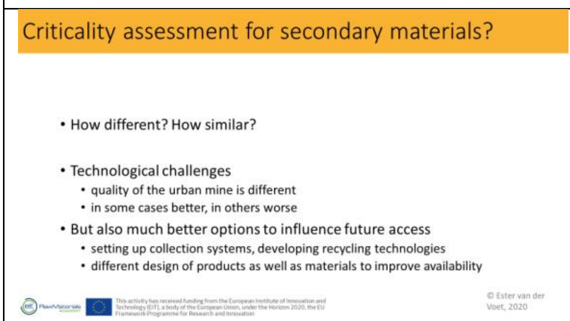
 	The urban mine can be assessed just as the geological mine. There are, of course, also many differences that are interesting to explore. How about the factors that determine supply risk, that we have mentioned earlier for primary production? Access restriction already looks quite different. Some issues are suddenly not at all problematic. But a new problem is the access restriction in time: as long as these stocks are actually in use, they can't be accessed.
 	Unstable markets may not really be different for these secondary materials. There will still be a risk of over- or undersupply, and there will still be situations of unpredictable demand.
 	For the global economics, the urban mine may actually be better, since it is omnipresent. However we don't really know how this will work out. A lot still needs to be explored.
 	There are other factors that may be different between urban and geological mines. But it does seem worthwhile to start including urban mines in criticality assessments. Especially when societies start to move more and more in the direction of circular economies, the urban mine becomes more and more important and will have a powerful influence on the whole idea of criticality assessments.

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Criticality assessment for secondary materials?

- Urban mine increasingly important, presently ignored
- Urban mine really different from geological mine
- Developing criticality approach for secondary materials seems therefore a reasonable idea
- How to proceed?
  - Where to use existing indicators, where to develop new ones?
  - What data needed? What calculation steps?
  - Integrate with existing criticality assessment or keep separate?
- Really interesting challenge for the future!

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- European Commission, 2017. Methodology for establishing the EU list of critical raw materials. Published: 2017-07-11. ISBN 978-92-79-68051-9, DOI 10.2873/769526
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Criticality assessment for secondary materials?

Thank you!!!

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3 Exercises

There are no exercises related to this presentation.

However there is a separate exercise developed by Dominique Guyonnet of BRGM on criticality assessments and how they operate.

4 Assessment questions

1. Criticality assessment is coined as a risk approach. What does that mean? (answer b is correct)
    a. This means that criticality is a problem we have to assess in order to prevent it from happening

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b. This means that criticality assessment relies on two aspects: the chance an unwanted event may happen, and the effect this unwanted event would have if it would happen
c. This means that criticality assessment should be integrated with environmental risk assessment to enable a sound judgment on potentially critical materials
d. This doesn't mean a lot, it is just an attempt to squeeze a subjective concept into an objective jacket.

2. Criticality assessment is most commonly made up from two concepts. Which are they? (answer c is correct)
    a. Supply risk and environmental impact
    b. Economic importance and environmental impact
    c. Supply risk and economic importance
    d. Economic importance and vulnerability for supply risk

3. Supply risk contains the following aspects (answer c is the correct answer)
    a. Supply risk refers to scarcity in a geological and geopolitical sense
    b. Supply risk refers to primary and secondary production
    c. It depends on the exact criticality assessment method what is included in supply risk
    d. It is not possible to give an exact definition of supply risk

4. In the lecture, it is stated that three aspects contribute to supply risk: (1) access restrictions, (2) volatile markets, and (3) global optimisation. Which of the statements below is true (can be more than one correct answer)? (answers a and b are both correct)
    a. These three aspects are applicable to urban mines as well as geological mines
    b. For urban mines, these three aspects work out differently than for geological mines
    c. These three aspects are irrelevant for urban mines
    d. Criticality assessment does not apply to urban mines, therefore, we don't know whether these aspects are relevant or not.

5. The Herfindahl-Hirschmann index (HHI) is used to calculate geopolitical supply risk. The number of countries where a material is mined is used to indicate this risk. What else is used to calculate HHI? (answer d is correct)
    a. The price of the material per kg
    b. The labour conditions in the countries where the material is mined
    c. The End-of-Life Recycling Input Rate
    d. The stability of the governments of the countries where the material is mined

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5 Acknowledgements and Authors

The slides on supply risk were developed by Ester van der Voet of Leiden University for the SusCritMat autumn school in Delft, the Netherlands, October 2018.

The following authors have prepared the complete teaching material kit for the SusCritMat Summer School for Educators and intend to provide an overview of major topics surrounding the sustainable management of critical raw materials:

Ruud Balkenende, TU Delft
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James Goddin, Granta Design
Gus Gunn, BGS
Dominique Guyonnet, BRGM
Alessandra Hool, ESM Foundation
Amund Løvik, Empa
Thibaut Maury, University of Bordeaux
David Peck, TU Delft
Dieuwertje Schrijvers, University of Bordeaux
Layla van Ellen, TU Delft
Tatiana Vakhitova, Granta Design
Ester van der Voet, Uni Leiden
Patrick Wäger, Empa
Steven Young, University of Waterloo

Besides, many others invested their time and expertise to discuss and review the teaching materials.

6 Citation

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7 Disclaimer

The teaching materials within the SusCritMat project have been prepared with great care and experienced several revisions. Nevertheless, the consortium assumes no liability for the topicality, completeness and correctness of the content provided.

In case you have suggestions or other feedback how to improve the materials, we value your opinion: Please contact us via the project webpage https://suscritmat.eu/contact/.

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