



Teaching Resources on the  
Sustainable Management of Critical Raw Materials

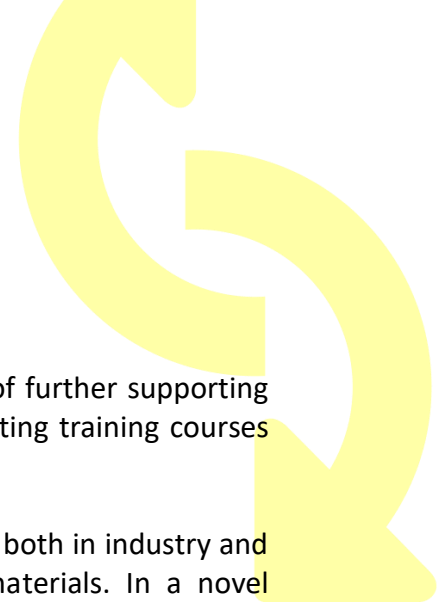
*Trainer's Manual for*  
***Critical Raw Materials and  
Sustainable Development***

January 2020



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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.

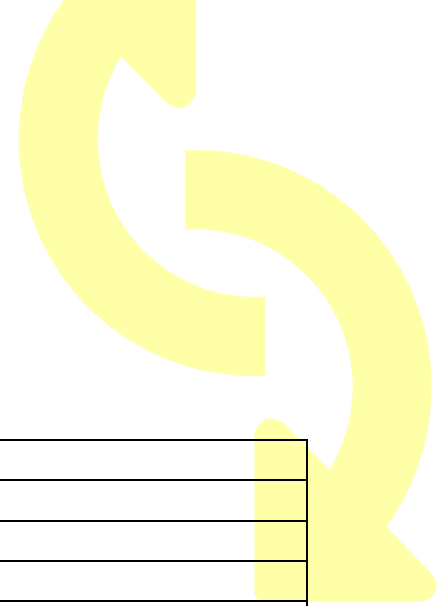
The collection of training manuals presents the key messages related with the sustainable management of critical raw materials in three major sections:

- Introduction to criticality
- Analysis of criticality
- Solutions for sustainable management

In particular, the solutions part will be in the focus. The intention is to underline the possibilities that are available to approach and implement a circular economy for critical raw materials and the products bearing these. Doing so the concrete actions, i.e. the things that can be done, are highlighted, instead of only mentioning all sorts of associated problems or barriers in the context of CRMs.

The overall goal of the SusCritMat project is to qualify lecturers to teach the topics themselves. Therefore, the teaching resources do not only provide an introduction and improved insight into selected thematic issues, but also deliver a set of teaching materials "ready-to-use".

- Learning targets that will be reached after having taught the courses
- Presentations on the specific topics including also notes on how to present the slides and key messages.
- Group work exercises including the task or question to work on, if applicable further reading on the methodology and the solutions in case of tasks requiring calculations.
- Assessment questions and the correct answers for each specific topic.
- Additional reading for each topic.



## 1.1 Training Materials List

The *SusCritMat* project developed the following teaching materials:

1	Critical Resources for emerging technologies
2	Circular Economy
3	Criticality
4	LCA
5	Responsible Mining
6	Responsible Sourcing/Certification
7	Closing Loops on Product Level
8	MFA
9	Geopolitical aspects
10	Metals & CRM scenarios
11	Sustainability Assessment
12	Waste Management
13	Simulation-based Design for Recycling
14	Restricted Substances Legislation
15	Historical solutions for CRM
16	Characterizing the Urban Mine
17	Environmental Aspects
18	Process Models based on LCA
19	Responsible Business Practices
20	Supply chain resilience
21	Sustainable materials usage
<b>22</b>	<b>CRM and Sustainable Development</b>
23	Circular Business Models
24	Economy of rare metals
25	Supply Risk factors
26	Recycling
27	Good Use of Data

## 1.2 Suggested timetable

The agenda contains a recommended timing for the lecture and exercises. However, depending on the pre-existing knowledge or group size the time can be extended.

Estimated time for the lecture: 45 minutes

Estimated time for the quiz and discussion of the answers: 10 minutes



## 1.3 Key Messages

Our lifestyle and economic growth are currently involved with high environmental impacts (including climate change), a large need for primary resources, and global inequality. This is a challenge for a sustainable development. Although investments in cleaner production and resource efficiency have shown progress with the use of CRMs, much work is still needed to make other product life cycle phases (such as the end-of-life treatment of products) and current consumption patterns more sustainable. Therefore, a double decoupling is needed between economic growth, resource use, and environmental impacts. Whereas increased resource efficiency could be obtained by moving to a more circular economy, a challenge lies in aligning this transition with globally agreed targets: abating climate change and achieving the Sustainable Development Goals. Critical Raw Materials are currently most often defined as materials that are important for the economic growth (of developed countries) or for clean technologies, with a risk of supply disruption due to socio-economic issues in supplying countries. Identifying which materials are critical for achieving the sustainable development goals related to social functions (e.g. access to clean energy and housing), the creation of jobs and infrastructure in developing countries is an area that needs further consideration.

## 1.4 Learning Objectives

This session will provide learners....

- An overview of current issues of global consumption patterns with regard to planetary boundaries and inequality
- Understanding of the need to decouple economic growth from resource use and environmental impacts in absolute terms and the role that CRMs play in this
- Understanding of the relevance of the Circular Economy to achieve resource efficiency
- Familiarity with the Sustainable Development Goals
- The ability to relate the current discourse on CRMs to the Sustainable Development Goals
- A critical reflection on the potential role of CRMs in achieving the SDGs and the roles that governments and private actors could or should take
- The perspective to reframe Critical Raw Materials in the context of Sustainable Development and its Goals

## 1.5 Additional Reading

Agenda 21 (and the consumption challenge)

<https://sustainabledevelopment.un.org/outcomedocuments/agenda21>

[https://sustainabledevelopment.un.org/content/dsd/agenda21/res\\_agenda21\\_04.shtml](https://sustainabledevelopment.un.org/content/dsd/agenda21/res_agenda21_04.shtml)

Brundtland-Report (and Johannesburg Plan of Implementation)

<https://www.britannica.com/topic/Brundtland-Report>

<https://www.sustainabledevelopment2015.org/AdvocacyToolkit/index.php/earth-summit-history/historical-documents/94-jpoi>

Ecological Footprint (and UN Human Development Index)

<https://www.footprintnetwork.org/our-work/ecological-footprint/>

<https://www.footprintnetwork.org/our-work/sustainable-development/>

Decoupling Natural Resource Use and Environmental Impacts from Economic Growth

<https://www.resourcepanel.org/reports/decoupling-natural-resource-use-and-environmental-impacts-economic-growth>

Circular Economy

<https://www.ellenmacarthurfoundation.org/circular-economy/concept/>

Sustainable Development Goals (and their clustering)

<https://sustainabledevelopment.un.org/?menu=1300>

<https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html>

Environmental sustainability indicator typology (and indicators for abiotic resources)

<https://www.eea.europa.eu/publications/TEC25>

UNE (2019) Global Guidance on Environmental Impact Assessment indicators – Volume 2

Raw material criticality (and the Circular Economy)

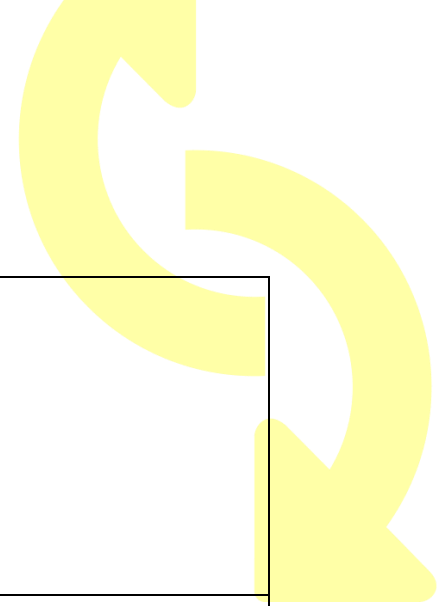
Schrijvers D, Hool A, Blengini GA, Chen W-Q, Dewulf J, Eggert R et al. (2019) A review of methods and data to determine raw material criticality. Resource Conservation and Recycling

European Commission. Report on Critical Raw Materials and the Circular Economy; 2018

## 2 Slides and Notes


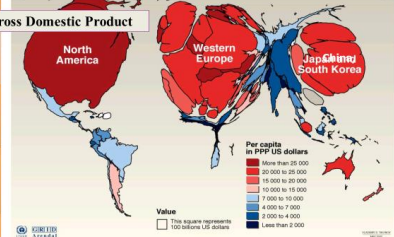


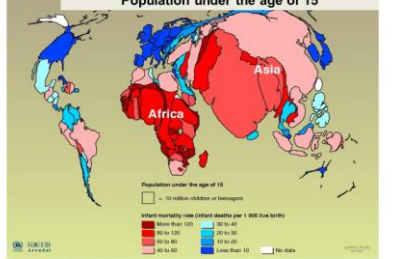


Include PP slides and notes here.

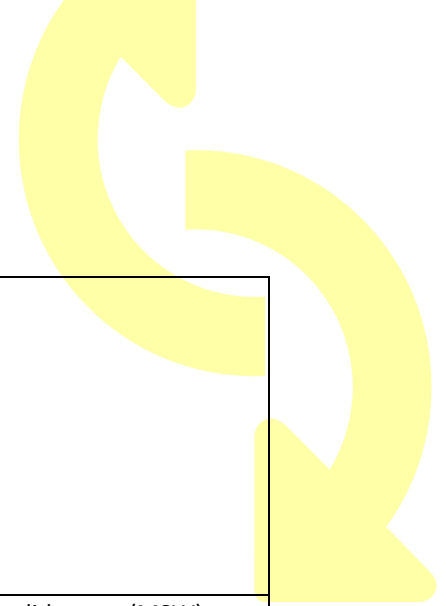
 <p><b>CRM AND SUSTAINABLE DEVELOPMENT:</b> CRITICAL RAW MATERIALS IN THE GLOBAL CONTEXT OF THE NEED FOR RESOURCE EFFICIENCY AND THE SUSTAINABLE DEVELOPMENT GOALS (SDGs)</p> <p>GUIDO SONNEMANN FULL PROFESSOR, UNIVERSITY OF BORDEAUX GUIDO.SONNEMANN@U-BORDEAUX.FR</p> <p><small>This activity has received 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. © Guido Sonnemann, 2018</small></p>	
<p><b>Problem-setting</b> - Outline -</p> <ul style="list-style-type: none"> <li>• Problem-setting</li> <li>• Global consumption patterns</li> <li>• Interrelation of consumption and production: The need for resource efficiency</li> <li>• Sustainable Development Goals</li> <li>• Role of critical raw materials</li> </ul> <p>Acknowledgement: Parts of the course material was developed at UNEP DTIE</p> <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p><b>Problem-setting</b> What is the problem? (1)</p> <p>“The major cause of the continued deterioration of the global environment is the <b>unsustainable patterns of consumption and production</b>, particularly in industrialized countries, which is a matter of grave concern, aggravating poverty and imbalances.”</p> <p>Agenda 21 (Chap. 4.3), Earth Summit, Rio 1992</p> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information: <a href="https://sustainabledevelopment.un.org/outcom edocuments/agenda21">https://sustainabledevelopment.un.org/outcom edocuments/agenda21</a></p>
<p><b>Problem-setting</b> What is the Magnitude?</p> <p>“It is simply impossible for the world as a whole to sustain a Western level of consumption for all. In fact, if 7 billion people were to consume as much energy and resources as we do in the West today we will need more than one planet to satisfy all our needs.”</p> <p>Gro Harlem Brundtland, 1994</p> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information <a href="https://www.britannica.com/topic/Brundtland-Report">https://www.britannica.com/topic/Brundtland-Report</a></p>
<p><b>Problem-setting</b> Sustainable Development: a long-term issue</p> <p>If we go on with current production and consumption patterns, <b>Two planets are needed by 2050</b></p>  <p>1900 2002 2050 2100 Source: Footprint Network</p> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information <a href="https://www.footprintnetwork.org/our-work/ecological-footprint/">https://www.footprintnetwork.org/our-work/ecological-footprint/</a></p>



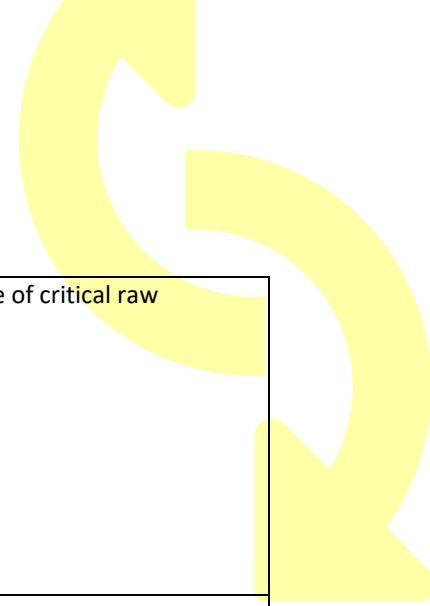
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Sustainable Development: Examples of long-term issues</h3> <p>Source: UNEP DTIE</p> <p>© Guido Sonnemann, 2019</p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Problem setting - Twin Challenge for Sustainable Development</h3> <p>Source: The Ecological Wealth of Nations (Earth's Biocapacity as a New Framework for International Cooperation). Global Footprint Network (2018), p. 13. Human Development Index data from Human Development Report 2018 - Charting the Way: Human Mobility and Development. UNDP (2018).</p> <p>© Guido Sonnemann, 2019</p>	<p>For more information  <a href="https://www.footprintnetwork.org/our-work/sustainable-development/">https://www.footprintnetwork.org/our-work/sustainable-development/</a>          CRM needed to achieve sustainable development within the « magic square »</p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Examples of the deterioration</h3> <ul style="list-style-type: none"> <li>• Between 1990 and 1995, <b>65 million hectares of forest</b> (the size of 130 million football fields) were lost.</li> <li>• In 1996, <b>25% of the world's mammal species</b> and <b>11% bird species</b> were at a significant risk of total extinction.</li> <li>• <b>The global marine fish catch almost doubled</b> between 1975-1995 and now an estimated <b>60%</b> of fisheries are at or near the point at which yields decline.</li> <li>• <b>400 million tons of hazardous waste</b> is created from chemicals each year, with 75% of the use and waste generation attributed to the industrial countries.</li> </ul> <p>Source: UNEP DTIE</p> <p>© Guido Sonnemann, 2019</p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>The case of critical metals from the Congo Basin</h3> <ul style="list-style-type: none"> <li>• Coltan, an ore that contains tantalum and niobium used for electronics and car manufacture, is resourced from one of the most conflict-ridden countries in the world.</li> </ul> <p>Source of photos: Pinterest</p> <p>© Guido Sonnemann, 2019</p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>The Case of Phosphate Mining in Nauru</h3> <h4>It was politically correct...but has proven unsustainable</h4> <ul style="list-style-type: none"> <li>• Phosphate mining begins in 1840's</li> <li>• Brings important influx of wealth and opportunity, but tailings gray coral reefs</li> <li>• Today, no phosphate remains and few additional resources left to exploit</li> <li>• Result: 9,000 people in poverty, struggling to restart their economy</li> </ul> <p>© Guido Sonnemann, 2018</p>	



<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Implementation Gap since 2002</h3> <p><i>Fundamental changes in the way societies produce and consume are indispensable for achieving global sustainable development. <b>All countries should promote sustainable consumption and production patterns...</b> Governments, relevant international organizations, the private sector and all major groups should play an active role in changing unsustainable consumption and production patterns.</i></p> <p>WSSD Johannesburg Plan of Implementation, Sept. 2002</p>  <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information  <a href="https://www.sustainabledevelopment2015.org/AdvocacyToolkit/index.php/earth-summit-history/historical-documents/94-jpoi">https://www.sustainabledevelopment2015.org/AdvocacyToolkit/index.php/earth-summit-history/historical-documents/94-jpoi</a></p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Global Consumption Patterns</h3> <p><b>Gross Domestic Product</b></p>   <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information:  <a href="https://sustainabledevelopment.un.org/content/dsd/agenda21/res_agenda21_04.shtml">https://sustainabledevelopment.un.org/content/dsd/agenda21/res_agenda21_04.shtml</a></p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Examples of inequalities in Consumption</h3> <ul style="list-style-type: none"> <li>◆ 1.3 billion people live on less than 1 US dollar a day.</li> <li>◆ The overall consumption of the richest fifth of the world's population is 16 times that of the poorest fifth.</li> <li>◆ Nearly 160 million children are malnourished.</li> <li>◆ More than 880 million people lack access to health services.</li> <li>◆ 1.5 billion lack access to sanitation and clean water.</li> </ul>  <p><small>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. © Guido Sonnemann, 2019</small></p>	<ul style="list-style-type: none"> <li>• 1.3 billion people live on less than 1 US dollar a day and close to 1 billion cannot meet their basic consumption requirements.</li> <li>• The overall consumption of the richest fifth of the world's population is 16 times that of the poorest fifth;</li> <li>• Nearly 160 million children are malnourished.</li> <li>• More than 880 million people lack access to health services ·</li> <li>• 1.5 billion lack access to sanitation and clean water, 1 billion do not have adequate housing.</li> </ul>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Population under the age of 15</h3>   <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Population, Consumption &amp; Environment</h3> <ul style="list-style-type: none"> <li>• Population is not the main problem of environmental degradation, but rather the consumption and production patterns.</li> <li>• Need for inter- and intra-generation equity.</li> <li>• Need to <b>meet the basic needs</b> of the whole population (food, shelter, health, education, clothing).</li> </ul>  <p><small>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. © Guido Sonnemann, 2019</small></p>	

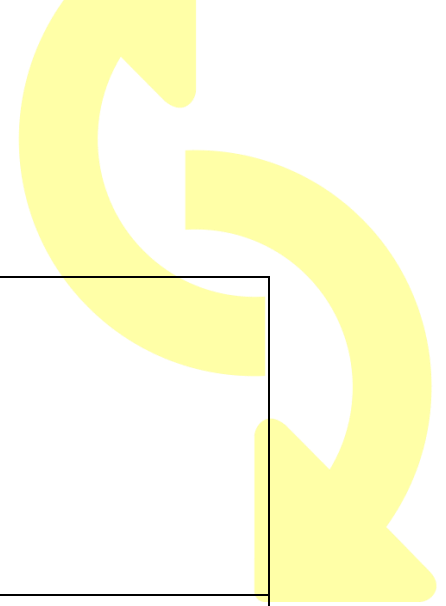


<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Interrelation of Cleaner Production and Sustainable Consumption</h3> <ul style="list-style-type: none"> <li>Over the last decade, we have seen significant improvements in <b>Cleaner Production</b> (pollution prevention, waste minimization mainly at the production level).</li> <li>However, changes in consumption patterns have offset the environmental gains achieved through Cleaner Production.</li> </ul> <p><small>© Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>GDP per capita vs. municipal solid waste per capita</h3> <p><small>© Guido Sonnemann, 2019</small></p>	<p>The amount of municipal solid waste (MSW) per capita is half in Japan than US although both half a similar level of GDP. That means the Japanese economy is more resource-efficient with regard to MSW. Some European countries on the one or the other side of the curve but less extreme.</p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Figure 1. Resource and material intensity of OECD economies, total use and intensity of use relative to GDP, 1980-2020</h3> <p><small>Source: OECD</small></p> <p><small>© Guido Sonnemann, 2019</small></p>	<p>The resource and material intensity is improving, while the absolute resource use is still increasing. The situation is much better for water than for MSW.</p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Global relative decoupling trends (1980-2007)</h3> <p><small>Source: Sustainable European Research Institute (SEMI), 2010. **Note: This figure illustrates global trends in resource extraction, GDP, population and material intensity in indexed form (1980 equals a value of 100).</small></p> <p><small>© Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Absolute and relative decoupling of environmental impact from economic growth.</h3> <p>The upper growth line represents economic growth. The middle (dotted) line shows an annual growth of environmental impacts related to resource use. The lower (dashed) line shows a decrease in environmental impact.</p> <p><small>Source: UNEP DTIE</small></p> <p><small>© Guido Sonnemann, 2019</small></p>	

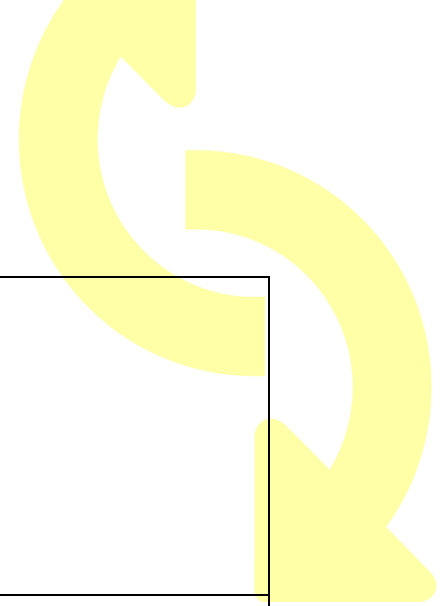


<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Decoupling Equation</h3> $I = P * A * T$ <p>Total environmental impact = Population * per capita Affluence * Technology</p> <table border="1"> <tr> <td><math>I</math></td> <td>=</td> <td><math>i</math></td> <td>x</td> <td><math>m</math></td> <td>x</td> <td><math>u</math></td> <td>x</td> <td><math>P</math></td> </tr> <tr> <td>(Total impact)</td> <td></td> <td>(impact / kg)</td> <td></td> <td>(kg / utility)</td> <td></td> <td>(utility / capita)</td> <td></td> <td>(capita)</td> </tr> <tr> <td>Strategies:</td> <td></td> <td>Transmaterialisation</td> <td></td> <td>Dematerialisation</td> <td></td> <td>Structural Changes</td> <td></td> <td></td> </tr> </table> <h4>Role of critical raw materials</h4> <p>Source: Holdren and Ehrlich (1974)</p> <p><small>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. © Guido Sonnemann, 2019</small></p>	$I$	=	$i$	x	$m$	x	$u$	x	$P$	(Total impact)		(impact / kg)		(kg / utility)		(utility / capita)		(capita)	Strategies:		Transmaterialisation		Dematerialisation		Structural Changes			<p>What is meant with « role of critical raw materials »?</p>
$I$	=	$i$	x	$m$	x	$u$	x	$P$																					
(Total impact)		(impact / kg)		(kg / utility)		(utility / capita)		(capita)																					
Strategies:		Transmaterialisation		Dematerialisation		Structural Changes																							
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Activities at the international level</p> <p>Role of critical raw materials</p>	<h3>Two aspects of decoupling</h3> <p>Source: International Resource Panel</p> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information:  <a href="https://www.resourcepanel.org/reports/decoupling-natural-resource-use-and-environmental-impacts-economic-growth">https://www.resourcepanel.org/reports/decoupling-natural-resource-use-and-environmental-impacts-economic-growth</a></p>																											
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Environmental Kuznets Curve</h3> <ul style="list-style-type: none"> <li>Largely, this trend can be seen in the history of developed economies, particularly for air pollution.</li> <li>Two main exceptions to this trend tend to be CO2 and municipal solid waste.</li> <li>The impacts of both of these tend to be too far removed in space and time from those responsible to elicit any change in behavior.</li> </ul> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information:  <a href="https://www.intellegenteconomist.com/environmental-kuznets-curve/">https://www.intellegenteconomist.com/environmental-kuznets-curve/</a></p>																											
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Current Situation</h3> <ul style="list-style-type: none"> <li><b>Rebound effects:</b> productivity/efficiency gains stimulating consumption and being overtaken by production increases (Jevon' s paradox)</li> <li>Problems of production process understood but <b>gap of understanding consumption</b> (use) and disposal of products.</li> <li><b>Digitalization</b> provides new opportunities</li> <li>Environmental concerns <b>not integrated</b> into economic and social programmes and vice versa</li> </ul> <p><small>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. © Guido Sonnemann, 2019</small></p>																												
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>The need for resource efficiency</h3> <h4>Promoting sustainable consumption and production patterns</h4> <ul style="list-style-type: none"> <li>New product-oriented strategies (life cycle perspective, design and manufacture)</li> <li>Understanding consumption</li> <li>Integrated approach of sustainable consumption and production.</li> </ul> <p>→ De-linking resource use and environmental impacts from economic growth</p> <p>→ And striving towards resource-efficiency</p> <p><small>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. © Guido Sonnemann, 2019</small></p>																												

<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Resource Efficiency</h3> <ul style="list-style-type: none"> <li>Efficiency at economic level</li> <li>Environmental dimension</li> <li>Resource efficiency (raw materials, including CRM, energy, water, biomass, land &amp; waste)</li> </ul> <div style="border: 1px solid green; padding: 5px; text-align: center;"> <p>Reducing the environmental impact of consumption and production of goods and services over their full life cycles</p> </div> <ul style="list-style-type: none"> <li>By producing more wellbeing with less material consumption, RE enhances the means to meet human needs while respecting the ecological carrying capacity of the Earth.</li> </ul> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>Resource efficiency means a win-win situation at the economic level by cost savings and at the same time environmental benefits. This is because raw materials have to be purchased and all emission and waste flows mean losses. Moreover, these losses need to be treated (for instance air filter and wastewater treatment) which has a cost, similar to taxes such as for landfill or carbon emissions.</p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Spotlight on global systems of production and consumption</h3> <p><b>Including CRM</b> <span style="float: right;">Source: CSCP</span></p> <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Activities at the international level</p> <p>Role of critical raw materials</p>	<h3>Increasing evidence for burden shifting</h3> <p><b>Data from Wuppertal Institute for European situation</b></p> <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Understanding supply chain and use-phase issues</h3> <p><b>Mining of CRM</b> <b>Substitution of CRM</b> <b>Design for a Circular Economy</b> <b>Recycling of CRM</b></p> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>80% of overall effort to reduce environmental impact have focused in the past on 20% of the total risk. The hotspot of the environmental impacts of a product is not always in the manufacturing stage, where most efforts are traditionally positioned, but it can be the mining for instance. The environmental impact of mining CRM can be reduced by recycling. And CRM can help to reduce the environmental in the use phase of cars for example.</p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Activities at the international level</p> <p>Role of critical raw materials</p>	<h3>Moving towards a Circular Economy (CE)</h3> <p><b>Aim: Circular CRM</b></p> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information:  <a href="https://www.ellenmacarthurfoundation.org/circular-economy/concept/">https://www.ellenmacarthurfoundation.org/circular-economy/concept/</a></p>

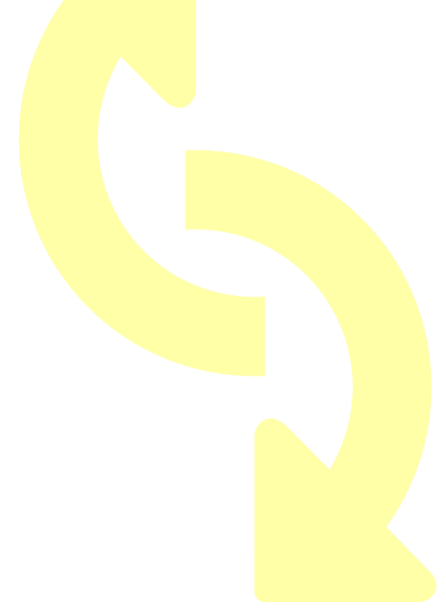


<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>Achievements in 2015 (1):</b> Paris agreement aims to strengthen:</p> <ul style="list-style-type: none"> <li>The global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.</li> <li>The ability of countries to deal with the impacts of climate change.</li> </ul> <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>Achievements in 2015 (2):</b> The 2030 agenda</p>  <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information: <a href="https://sustainabledevelopment.un.org/?menu=1300">https://sustainabledevelopment.un.org/?menu=1300</a></p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>Clustering of SDGs</b></p>  <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information: <a href="https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html">https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html</a></p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>The role of the Circular Economy (CE)</b></p>  <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>The key role of Goal 12 in the SDGs</b></p>  <p><small>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. © Guido Sonnemann, 2019</small></p>	



<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>Goal 12 targets (1):</b> Ensure sustainable consumption and production patterns</p> <ul style="list-style-type: none"> <li>Implement the <b>10-year framework of programmes on sustainable consumption and production</b>, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries</li> <li>By 2030, achieve the sustainable management and <b>efficient use of natural resources</b></li> </ul> <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>Goal 12 targets (2):</b> Ensure sustainable consumption and production patterns</p> <ul style="list-style-type: none"> <li>By 2030, substantially <b>reduce waste generation through prevention, reduction, recycling and reuse</b></li> <li>By 2030, halve per capita global <b>food waste</b> at the retail and consumer levels</li> <li>Promote <b>public procurement</b> practices that are sustainable, in accordance with national policies and priorities</li> </ul> <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>Goal 12 targets (3):</b> Ensure sustainable consumption and production patterns</p> <ul style="list-style-type: none"> <li>By 2020, achieve the <b>environmentally sound management of chemicals and all wastes throughout their life cycle</b>, in accordance with agreed international frameworks, and significantly <b>reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment</b></li> </ul> <p><small>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. © Guido Sonnemann, 2019</small></p>	
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>DPSIR framework for key indicator areas for environmental sustainability assessment</b></p> <p><small>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. © Guido Sonnemann, 2019</small></p>	<p>For more information on the DPSIR framework <a href="https://www.eea.europa.eu/publications/TEC25">https://www.eea.europa.eu/publications/TEC25</a> In this figure CRM are positioned in the indicator framework of DPSIR /Drivers, Pressures, State, Impacts, Responses). Pressures on the environment come from resource use (materials, including CRM, land, water and energy). These pressures are changing the status of various safeguard subjects: Climate, biodiversity, health and supply security, particular relevant for CRM and not an environmental parameter. The use of CRMs is often done with the aim to mitigate climate change.</p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<p><b>Supporting role of input-output based industrial ecology assessment tools</b></p> <p><b>Need to include CRM in the assessment tools</b></p> <p><small>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. © Guido Sonnemann, 2019</small></p>	

<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>UNE Life Cycle Initiative's recommendations on impact indicators for abiotic resources</h3> <p>How can I quantify the...</p> <p><b>Minority statement!</b></p> <p>...changing opportunities of future generations to use resources due to a current resource use? (intended: LCA)</p> <p>...potential resource availability (related to a product system)? (intended: LCA)</p> <p>...potential resource availability (related to a product system related to mid-term geo-political and socio-economic aspects)?</p> <p>Way how CRM are part of the life cycle impact assessment</p> <p>Source: UNE (2019)</p> <p>© Guido Sonnemann, 2019</p>	<p>For more information UNE (2019) Global Guidance on Environmental Impact Assessment indicators – Volume 2</p>
<p>Problem-setting</p> <p>Global consumption patterns</p> <p>Interrelation of consumption and production</p> <p>Sustainable Development Goals</p> <p>Role of critical raw materials</p>	<h3>Which Raw Materials are critical in line with the SDGs and what is the link to CE?</h3> <p>Economic growth</p> <p>Raw Materials for</p> <p>Low carbon and RE technologies</p> <p>with Supply Risk</p> <p>© Guido Sonnemann, 2019</p>	<p>The Supply Risk of CRM includes the risk of conflict (i.e. conflict metals) in relation to the social SDG 16 Peace.</p> <p>CRM are needed for the economic SDGs 8, 9 and 12, that is economic growth, industry &amp; innovation and responsible consumption &amp; production.</p> <p>The latter is the one that focuses and resource efficiency and hence is the link to the circular economy.</p> <p>Evidently, CRMs most “noble” role is the support in mitigation technologies for climate change (SDG 13 – Climate Action).</p> <p>The open question is whether this clean tech role is the most strategic use or rather the general contribution to economic growth or security needs.</p>
<p>Conclusions</p>	<ul style="list-style-type: none"> <li>• Sustainable development is from a resource efficiency point of view about double-decoupling resource use and environmental impacts from economic growth and human well-being.</li> <li>• CRMs have a key role to play in order to allow for resource efficient technologies and decoupling.</li> <li>• The circular economy is a mitigation strategy for CRMs.</li> <li>• SDGs can be classified in economic, social and environmental cluster. The open question is whether CRMs are mostly contributing to economic growth or through its use in cleantech to climate action.</li> <li>• Identifying which materials are critical for achieving social SDGs (e.g. access to clean energy and housing), the creation of jobs and infrastructure in developing countries is an area that needs further consideration.</li> </ul> <p>© Guido Sonnemann, 2019</p>	
<p>ism</p>	<p>Thank you for your attention!</p> <p>Pr. Guido Sonnemann guido.sonnemann@u-bordeaux.fr</p> <p>CyVI Groupe de recherche sur l'Analyse du Cycle de Vie et Chimie Durable Institut des Sciences Moléculaires - ISM Université de Bordeaux – UMR 5255 CNRS 113 Avenue de la Médiathèque – BP A12 33 405 76303 CEDEX – France Tel : 05 40 00 12 83 Web : <a href="http://www.ism.u-bordeaux.fr">http://www.ism.u-bordeaux.fr</a></p> <p>© Université de Bordeaux</p>	



## 3 Exercises

This course does not contain exercises.

## 4 Examination Questions

Include 10 multiple choice quiz questions and 4 possible answers here. Mark the correct answer(s) by putting “correct” in brackets behind it.

**How many planets do we need in 2050 if we continue with current production and consumption patterns according to the Ecological Footprint approach?**

Answer 1: 1,2

Answer 2: 1,5

Answer 3: 2 (correct)

Answer 4: 10

**Why resource efficiency is of economic interest?**

Answer 1: Losses are costly because they need to be treated (correct)

Answer 2: No taxes are paid for emissions

Answer 3: Wastewater is directly emitted into rivers in most OECD countries

Answer 4: Resource efficiency is only of environmental interest

**Which element of the following is part of the decoupling equation?**

Answer 1: Input

Answer 2: Policy

Answer 3: Age

Answer 4: Technology (correct)

**What decoupling is necessary for sustainable development?**

Answer 1: Decoupling of economic growth from human welfare

Answer 2: Decoupling of economic growth from the increase of environmental impacts

Answer 3: Decoupling of economic growth from resource use

Answer 4: Decoupling of economic growth from resource use and total environmental impacts (correct)

**What area still requires most improvement in order to decouple economic growth from environmental deterioration?**

Answer 1: Make production activities cleaner

Answer 2: Change consumption patterns and decrease the production of waste (correct)

Answer 3: Minimize population growth

Answer 4: Decrease standards of welfare





## **What is the role of CRMs in the decoupling of economic growth from environmental deterioration?**

Answer 1: CRMs are used in innovative technologies with lower environmental impacts over their whole life cycle (correct)

Answer 2: CRMs prevent the production of waste

Answer 3: CRMs are easily recyclable

Answer 4: CRMs can be supplied with low environmental impacts

## **How can the Circular Economy aid in sustainable development?**

Answer 1: The Circular Economy makes mining in developing countries less impactful

Answer 2: The Circular Economy leads to lower economic activity

Answer 3: The Circular Economy decreases the demand for the utility provided by products

Answer 4: Resources are used more efficiently, hence more value can be extracted from primary material use (correct)

## **Which of the following is *not* a Sustainable Development Goal?**

Answer 1: Circular Economy (correct)

Answer 2: Gender equality

Answer 3: Good health and well-being

Answer 4: Responsible production and consumption

## **For which SDG do we often consider material criticality at the moment?**

Answer 1: Education

Answer 2: Health

Answer 3: Economic growth (correct)

Answer 4: Life below water

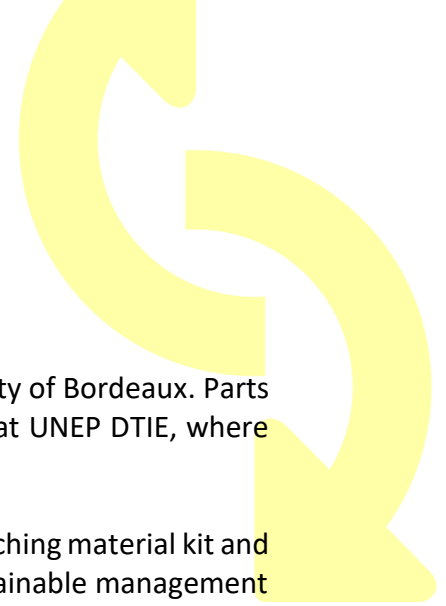
## **(How) could achieving the SDGs make materials less critical for the European Union (according to the current European method to evaluate criticality)?**

Answer 1: Improving social circumstances in mining countries decreases social-economic risk of material supply (correct)

Answer 2: The SDGs do not contribute to decreasing criticality for the European economy, as European countries already have high human development standards

Answer 3: Climate action decreases risks related to environmental impacts

Answer 4: Reduced inequality makes the European Union more stable



## 5 Acknowledgements and Authors

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The following authors have contributed to prepare the complete teaching material kit and intend to provide an overview of major topics surrounding the sustainable management of critical raw materials:

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Besides, many others invested their time and expertise to discuss and review this teaching material.

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