



Teaching Resources on the
Sustainable Management of Critical Raw Materials

Trainer's Manual for
Environmental Aspects

January 2020

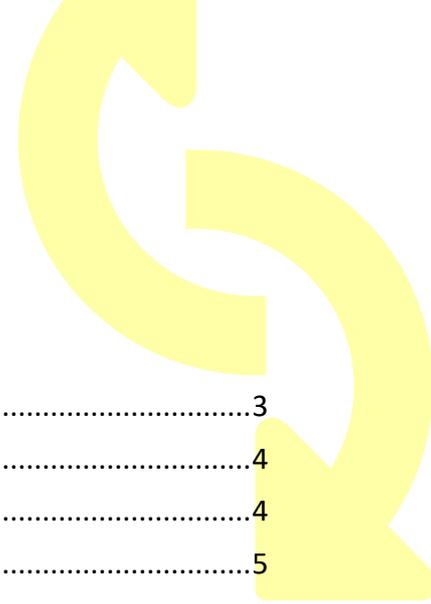


Table of Contents

1	Context and Introduction to Training.....	3
1.1	Training Materials List.....	4
1.2	Suggested timetable	4
1.3	Key Messages.....	5
1.4	Learning Objectives.....	6
1.5	Additional Reading.....	6
2	Slides and Notes	8
3	Examination Questions	20
4	Acknowledgement and Authors.....	21
5	Citation	22



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.

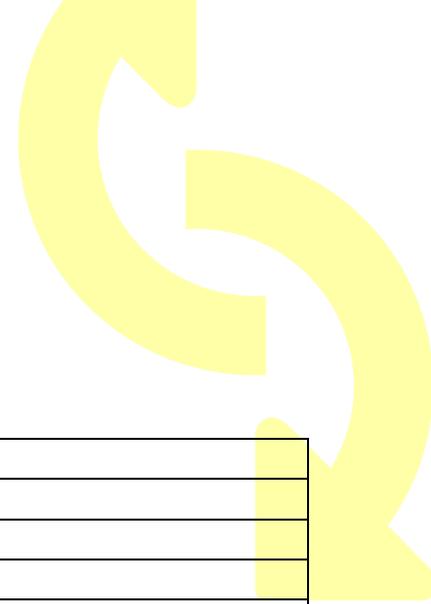
The collection of training manuals presents the key messages related with the sustainable management of critical raw materials in three major sections:

- 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
22	CRM and Sustainable Development
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: 55 minutes

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

1.3 Key Messages

Our lifestyle and economic growth are currently involved with high environmental impacts and a large need for primary resources. According to ISO 14001 related to 'environmental system management', an environmental impact can be described as a change in the environment, negative or positive, resulting partly or totally from human activities, products or services (*i.e.* an anthropogenic cause). In this lecture, two distinct categories of environmental impacts are considered: on the one hand, environmental impacts due to chemical/physical emissions from the technosphere to the ecosphere (see Figure 1); on the other hand, environmental impacts that come from resource extraction, deprivation or depletion for anthropogenic purposes.

Hence, the present lecture aims to present the main environmental impacts considered in environmental evaluations of products, activities or services. For each one, the environmental problem is first described. Then, the underlying environmental mechanisms and fundamental modelling principles are explained. Finally, the main anthropogenic sources causing the problem are highlighted.

This lecture covers nine of the most common environmental impacts: Climate change / Ozone depletion / Photochemical ozone (smog) / Aquatic eutrophication / Acidification / Human toxicity / Eco-toxicity / Resource depletion and Land use. This is a first didactic step allowing to further undertake the measure of these impacts using quantitative assessment methodologies (e.g. Life Cycle Assessment) and then minimise them *via* eco-design practices.

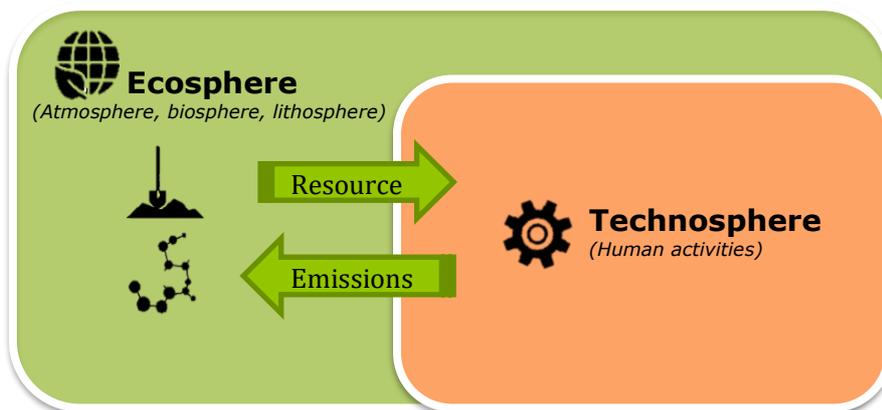
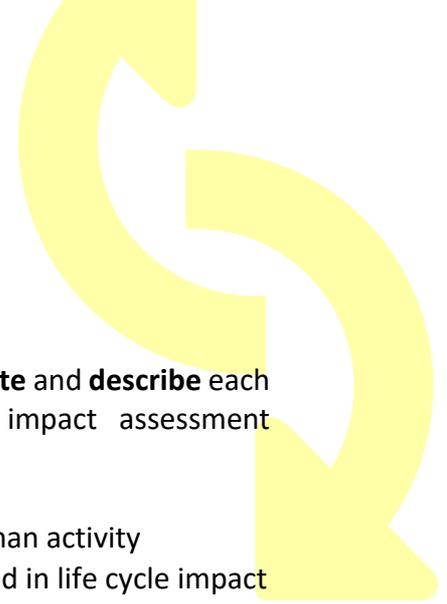


Figure 1 - Potential environmental impacts are due to substance emissions or resource depletion/deprivation



1.4 Learning Objectives

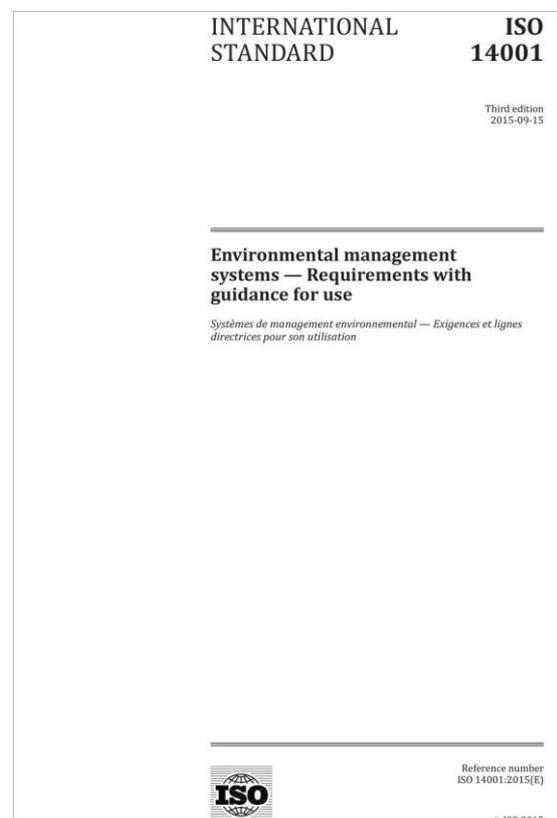
After attending this lecture, the learner should be able to **differentiate** and **describe** each of the main environmental aspects considered in life cycle impact assessment methodologies. Thus, the learning objectives are the following:

- To identify the environmental aspects caused by a given human activity
- To link these aspects to potential environmental impacts used in life cycle impact assessment methodologies
- To understand the environmental mechanisms leading to a particular impact and its fundamental modelling principles
- To determine the main anthropogenic sources causing the targeted environmental impact

1.5 Additional Reading

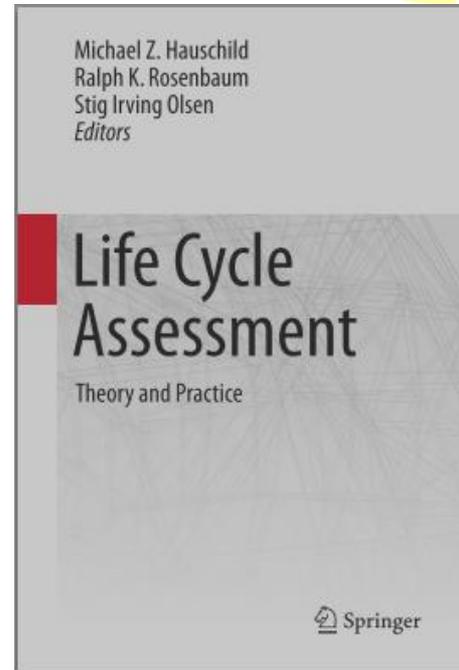
- **ISO 14001:2015** Environmental management systems - Requirements with guidance for use

ISO 14001:2015 specifies the requirements for an environmental management system that an organization can use to enhance its environmental performance.



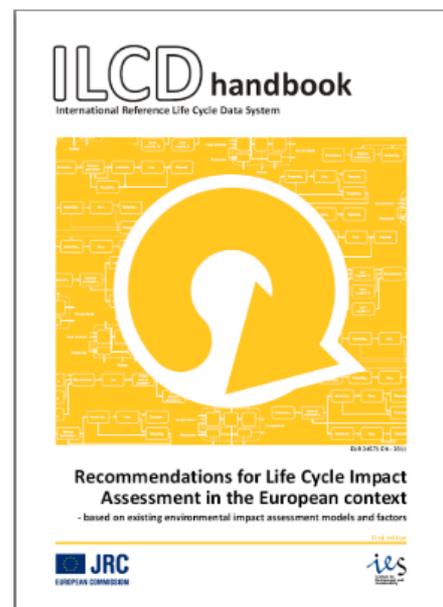
- **LCA Theory & Practice : Chapter 10 – Life Cycle Impact assessment.** Rosenbaum, R. K. *et al.* (2018). pp. 633–959. <https://doi.org/10.1007/978-3-319-56475-3>

Up-to-date and complete LCA textbook that explains, among others, environmental impact mechanisms



- **International Reference Life Cycle Data System (ILCD) Handbook: Recommendations for Life Cycle Impact Assessment in the European context.** European commission-JRC. (2011).. EUR 24571 EN. *European Commission*, 159. <https://doi.org/10.2788/33030>

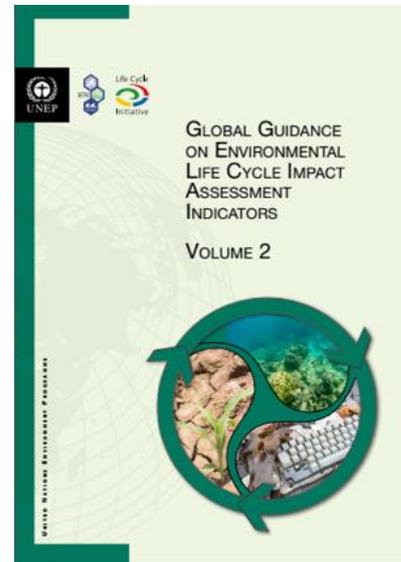
Recommendations of impact assessment methods from the European Commission.





- R. Frischknecht and O. Jolliet, *Global Guidance on Environmental Life Cycle Impact Assessment Indicators Volume 2*, 2019.

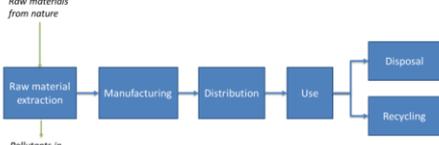
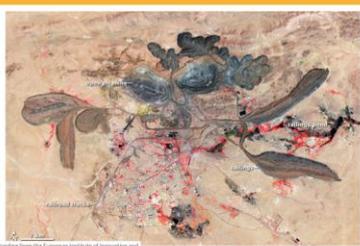
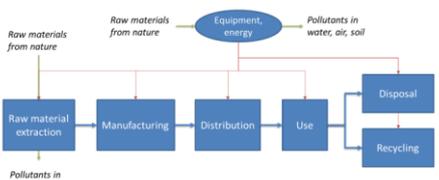
Recent recommendations of the UNEP/SETAC Life Cycle Initiative on method selection and future method development.



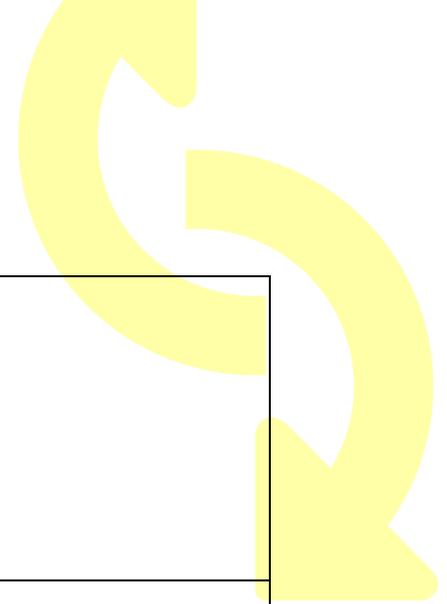
2 Slides and Notes

Include PP slides and notes here.

<p style="text-align: right;">SusMat Crit</p> <p>ENVIRONMENTAL IMPLICATIONS OF MATERIAL USE</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</small></p>	
<p>Introduction</p> <p>Elements widely used in energy pathways</p> <p><small>N.B. Position on the time axis is indicative only</small></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</small></p>	<p>Technologies become more sophisticated, more performant, and more energy efficient. This technology development requires a much larger selection of raw materials than in the past. Materials become also increasingly complex, by mixing raw materials in innovative alloys. On the other hand, these complex mixes are very difficult to recycle due to incompatible combinations of raw materials for separation techniques, or because materials are used in very small fractions. These materials are lost, or dissipated, in other materials that are easier to recycle, such as aluminum, copper, and steel.</p>

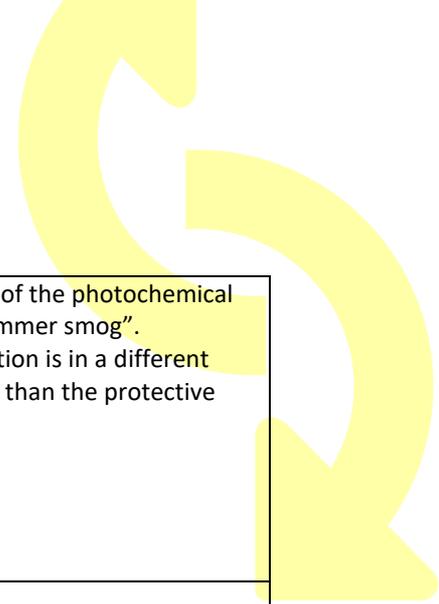
<p>Introduction</p> <p><i>Example: Life cycle of a wind turbine</i></p>  <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small></p> <p><small>© Guido Sonnemann, 2018</small></p>	<p>Take for example the life cycle of a wind turbine. The life cycle starts with raw material extraction. Raw materials are manufactured into components that make the wind turbine. The wind turbine is transported to its final location, where it is taken into use. During use, it will require maintenance to guarantee lifetime operation. Finally, some parts will be recycled, and some parts will be disposed of.</p> <p>Each step in this life cycle will cause interactions with the environment: environmental exchanges. The most obvious step is the “raw material extraction” phase. Metals are taken from the earth’s crust, water is used, and waste streams contain toxic elements, particulate emissions, or simply CO2 that ends up in the atmosphere, and in rivers, lakes, and the soil.</p>
<p>Introduction</p> <p>Rare earth mining in Bayan Obo, China</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</small></p> <p><small>atony.nasa.gov/OTD/view.php?id=77723</small></p> <p><small>© Guido Sonnemann, 2018</small></p>	<p>Examples of raw materials that are used in wind turbines are rare earth elements. The Bayan Obo mine is a large deposit for neodymium, which is produced as a by-product of iron. The satellite image shows the impact of the mining activity on the environment due to large production of wastes and land use.</p>
<p>Introduction</p>  <p>Satellite images of a rare earth mining site in Ganzhou on April 14, 2005, (left) and February 9, 2009 (right)</p> <p><small>Guo, W., 2012. The rare earth development can no longer overdraw ecological cost. China Environment News, July 2.</small></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</small></p> <p><small>131-136</small></p> <p><small>© Guido Sonnemann, 2018</small></p>	<p>This is another rare earth deposit. In this ion-adsorption deposit, more heavy rare earth elements are mined, such as dysprosium. The satellite image shows a high impact on deforestation, with consequences on, among others, soil erosion and biodiversity.</p>
<p>Introduction</p> <p><i>Example: Life cycle of a wind turbine</i></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</small></p> <p><small>© Guido Sonnemann, 2018</small></p>	<p>In fact, in each life cycle stage, equipment and energy are used that cause environmental interactions as well. Energy burnt during raw material extraction will lead to CO2 emissions, use of cleaning products during the maintenance of the wind turbine leads to polluted water and soil, equipment used during manufacturing also require raw material extraction and manufacturing and disposal of the equipment. Furthermore, each life cycle stage can cause direct exchanges with the environment due to inefficiencies and material losses.</p>

<h2>Introduction</h2> <p>The 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</p>	<p>In a Life Cycle Assessment we evaluate to what extent the extraction on resources and the emission of substances have an impact on the environment, where we consider different impact categories. These impact categories contribute to damages in three areas of protection: ecosystems, human health, and/or natural resources.</p>
<h2>Overview</h2> <ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use <p>Main environmental impacts considered in life cycle impact assessment methodologies for the environmental evaluation of products</p> <p>Acknowledgement: The original course material was developed at CIRAG, Canada, and provided by Ralph Rosenbaum, now at IRTA, Spain</p> <p>The 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</p>	
<h2>Climate change</h2> <p>Refers to the phenomenon of the increase, on a global scale and over several years, of the average temperature of the oceans and the atmosphere</p> <p>The majority of scientists acknowledges that this temperature increase is mainly caused by « anthropogenic forcing », namely the increased emission of greenhouse gases to the atmosphere due to human activities</p> <p>The greenhouse effect is a natural process of global warming which intervenes in the radiative balance of the Earth</p> <p>The 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</p>	
<h2>Greenhouse effect: the process</h2> <p>The 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</p>	<p>This figure shows the impact pathway of the greenhouse gas effect. CO₂ emissions contribute to radiative forcing, which results in climate change. Climate change has further an effect on ecosystems and on human health, which are the areas of protection evaluated in LCA.</p>
<h2>Greenhouse effect: the process</h2> <p>The main greenhouse gases are:</p> <ul style="list-style-type: none"> carbon dioxide (CO₂), methane (CH₄), nitrous oxide (a.k.a. laughing gas, N₂O) and ozone (O₃). <p>Industrial greenhouse gases include:</p> <ul style="list-style-type: none"> halocarbons and sulfur hexafluoride (SF₆). <p>Approximate contributions to the greenhouse effect of major gases:</p> <ul style="list-style-type: none"> water vapor: 54,8 % carbon dioxide: 39 % ozone: 2 % methane: 2 % nitrous oxide: 2 % <p>The 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</p>	

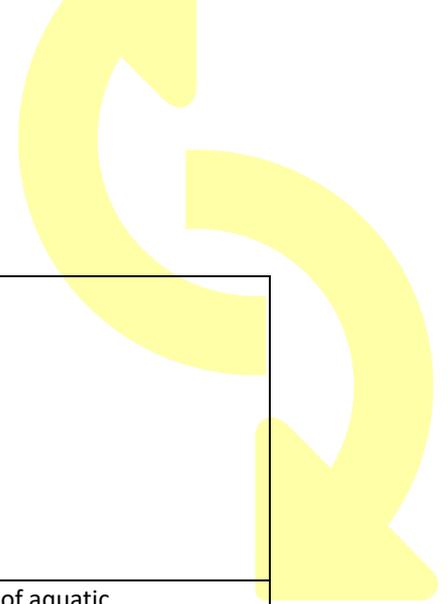


<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3>Hole in the ozone layer: the process</h3> <p>Ozone depleting substances (ODS):</p> <p>Natural ODSs</p> <ul style="list-style-type: none"> • CH₄, N₂O, H₂O, chlorinated or brominated substances <p>Anthropogenic ODSs</p> <ul style="list-style-type: none"> • CFCs, tetrachloromethane, 1,1,1-trichloromethane, HCFCs, halons and methyl bromide. <p>All substances have 2 characteristics in common:</p> <ol style="list-style-type: none"> 1. Chemically very stable in the low altitudes of the atmosphere 2. Ability to release Cl or Br under the influence of UV radiation <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 17</small></p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3>Ozone layer depletion: effects</h3> <p>The ozone layer is essential to life on Earth as it protects it from harmful ultraviolet radiation emitted by the sun.</p> <p>Effects of UV radiation:</p> <ol style="list-style-type: none"> 1. Superficial burns, conjunctivitis, cataracts 2. Increase in cancers and aging of the skin 3. Diseases of the immune system 4. Reduction of photosynthesis: decrease in yields and quality of crops, disappearance of plankton, first link in aquatic food chains ... <p>Effects of UV-B radiation:</p> <ol style="list-style-type: none"> 1. Accelerates the generation of photochemical smog, thus stimulating the production of harmful tropospheric ozone 2. Reduces the lifetime of certain inorganic materials such as paints and plastics <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 18</small></p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3>Ozone layer depletion: effects</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 19</small></p>	<p>Here is the impact pathway of ozone depleting compounds. At the midpoint level, the ozone depleting potential is evaluated, which leads to damage on ecosystems and humans at the end-point level.</p>
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3>Overview</h3> <ul style="list-style-type: none"> • Climate change • Ozone depletion • Photochemical ozone or smog • Aquatic eutrophication • Acidification • Toxicity and eco-toxicity • Resource depletion • Land use <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 20</small></p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3>Photochemical smog formation</h3> <p>Photochemical smog is, unlike stratospheric ozone, located in the troposphere.</p> <p>It is a mixture of harmful air pollutants created when primary pollutants (NO_x and VOCs) interact under the influence of the sun and form chemicals that are toxic to humans, including ozone.</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 21</small></p>	

<p>Climate change</p> <p>Ozone depletion</p> <p>Photochemical ozone or smog</p> <p>Aquatic eutrophication</p> <p>Acidification</p> <p>Toxicity and ecotoxicity</p> <p>Resource depletion</p> <p>Land use</p>	<h3>Sources of photochemical smog</h3> <p>PM – Particulate Matter VOCs – Volatile organic compounds</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 22</small></p>	<p>There are two distinct sources of smog, which are distinguished by “summer smog” and “winter smog”.</p> <p>Summer smog is caused by the photochemical formation of ozone from nitrogen oxides and VOCs.</p> <p>Winter smog is caused by particulate matter, emitted for example by burning of coal.</p>
<p>Climate change</p> <p>Ozone depletion</p> <p>Photochemical ozone or smog</p> <p>Aquatic eutrophication</p> <p>Acidification</p> <p>Toxicity and ecotoxicity</p> <p>Resource depletion</p> <p>Land use</p>	<h3>Smog formation: the process</h3> <div style="display: flex; justify-content: space-around;"> <div style="width: 45%;"> <h4>Summer smog</h4> </div> <div style="width: 45%;"> <h4>Winter smog</h4> </div> </div> <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 23</small></p>	
<p>Climate change</p> <p>Ozone depletion</p> <p>Photochemical ozone or smog</p> <p>Aquatic eutrophication</p> <p>Acidification</p> <p>Toxicity and ecotoxicity</p> <p>Resource depletion</p> <p>Land use</p>	<h3>Smog formation: effects</h3> <h4>Health Effects of Air Pollution</h4> <p>http://courses.dce.harvard.edu/</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 24</small></p>	
<p>Climate change</p> <p>Ozone depletion</p> <p>Photochemical ozone or smog</p> <p>Aquatic eutrophication</p> <p>Acidification</p> <p>Toxicity and ecotoxicity</p> <p>Resource depletion</p> <p>Land use</p>	<h3>Smog formation: effects</h3> <p>Ozone also damages the vegetation and, as a result, reduces the productivity of agriculture.</p> <p>Left: plant damaged by photochemical ozone Right: normal plant</p> <p>Photo courtesy of Gene Daniels/U.S. EPA</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 25</small></p>	
<p>Climate change</p> <p>Ozone depletion</p> <p>Photochemical ozone or smog</p> <p>Aquatic eutrophication</p> <p>Acidification</p> <p>Toxicity and ecotoxicity</p> <p>Resource depletion</p> <p>Land use</p>	<h3>Smog formation: effects</h3> <p>Many elastomers, for example rubber tires, are also strongly attacked by ozone. As well as several building materials</p> <p>Image: https://phys.org/news/2012-10-emission-scoric-st-paul-benefit.html</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 26</small></p>	

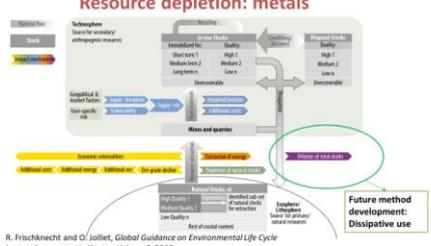


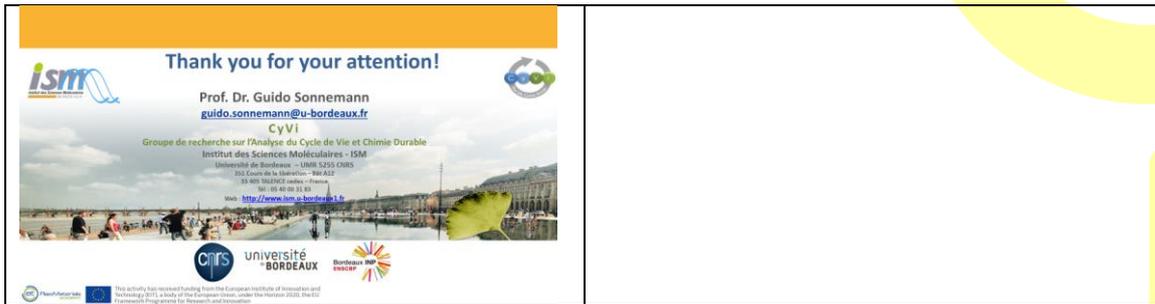
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Smog formation: effects</h3> <p style="font-size: small;">This activity has received 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 28</p>	<p>This is the impact pathway of the photochemical formation of ozone, or “summer smog”. Note that the ozone formation is in a different location in the atmosphere than the protective ozone layer.</p>
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Overview</h3> <ul style="list-style-type: none"> • Climate change • Ozone depletion • Photochemical ozone or smog • Aquatic eutrophication • Acidification • Toxicity and eco-toxicity • Resource depletion • Land use <p style="font-size: 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 28</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Aquatic eutrophication</h3> <p>Eutrophication results from an excessive supply of nutrients which induces the growth of plants, especially algae.</p> <p>Plant growth requires nitrogen, carbon and phosphorus. Phosphorus is generally the limiting element.</p> <p>Eutrophication can take place in both marine and continental environments.</p> <p style="font-size: x-small;">Image: https://en.wikipedia.org/wiki/Eutrophication</p> <p style="font-size: x-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 29</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Aquatic eutrophication</h3> <h4>Affected environments</h4> <p>Eutrophication can take place in both marine and continental environments:</p> <ol style="list-style-type: none"> 1. Still waters, such as lakes and ponds; 2. Watercourses with low flow rates or receiving excessive releases, for example from large agricultural, human or industrial farms; 3. Gulfs, bays and other semi-enclosed areas <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>River</p> </div> <div style="text-align: center;"> <p>Bay</p> </div> </div> <p style="font-size: x-small;">Image: http://environmental-impacts.com/development-of-aquatic-eutrophication-in-lakes-and-ponds/ http://www.environmental-impacts.com/development-of-aquatic-eutrophication-in-lakes-and-ponds/ http://www.environmental-impacts.com/development-of-aquatic-eutrophication-in-lakes-and-ponds/</p> <p style="font-size: x-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 30</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Eutrophication: the process</h3> <h4>Eutrophication of a lake</h4> <p>These steps can be a natural process, transforming a lake into a marsh, into a meadow, then into a forest. This evolution of an aquatic biotope requires however decades, even centuries</p> <p style="font-size: x-small;">Image: https://www.epa.gov/qa/eutrophication/qa-eutrophication.html</p> <p style="font-size: x-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 31</p>	



<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Eutrophication: effects</h3> <p>The main effects of eutrophication are the reduction of biodiversity and the decline in water quality as a resource</p> <p>Other effects:</p> <ul style="list-style-type: none"> • Increase in algal biomass; • Increase in the biomass of gelatinous zooplankton; • Degradation of the organoleptic qualities of water (appearance, colour, odour, flavour); • Development of toxic phytoplankton, cyanobacteria or blue algae; • Decrease in the biotic index; • Decreased dissolved O₂ concentration; • Decreased fishing yield; • Death of the higher organisms (macrophytes, insects, cnidaria, crustaceans, molluscs, fish, etc.). <p style="font-size: 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 32</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Eutrophication: effects</h3> <h4 style="text-align: center;">Aquatic eutrophication</h4> <p style="font-size: x-small;">European Commission, ICED handbook - Recommendations for Life Cycle Impact Assessment on the European context, 2011.</p> <p style="font-size: 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 33</p>	<p>This is the impact pathway of aquatic eutrophication. Emissions of nitrogen and phosphor result in increased growth of algae, which decreases the availability of oxygen for other species, resulting in losses of species.</p>
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Overview</h3> <ul style="list-style-type: none"> • Climate change • Ozone depletion • Photochemical ozone or smog • Aquatic eutrophication • Acidification • Toxicity and eco-toxicity • Resource depletion • Land use <p style="font-size: 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 34</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Acidification</h3> <ul style="list-style-type: none"> • Acid pollution (or acid rain) is linked to acid pollutants (SO₂, NO_x, NH₃, HCl, HF) emitted by human activities that fall partly in the vicinity of the sources, but also hundreds or even thousands of kilometers of their emitting sources. • These pollutants fall down in the form of dry or wet deposition. • Large-scale acid pollution has been demonstrated by acidified lakes and damaged forests. • Some rains have a pH between 3 and 4. <p style="font-size: 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 35</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Acidification: the process</h3> <p>These pollutants are transformed during their transport. SO₂ and NO_x are converted into sulfates (SO₄²⁻) and nitrates (NO₃⁻) in the case of a dry atmosphere, and into sulfuric acid (H₂SO₄) and nitric acid (HNO₃) when the atmosphere is moist.</p> <p style="font-size: x-small;">Source: https://waterresources.ec.europa.eu/infocentre/infocentre_en/2018/2018/02/acid_rain</p> <p style="font-size: 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 36</p>	

<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Eco-toxicity process</h3> <p style="font-size: small;">European Commission, ACQ handbook – Recommendations for LQI-Gate Impact Assessment in the European context, 2011. 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 42</p>	<p>PAF = Potentially Affected Fraction of species (PAF) PDF = Potentially Disappeared Fraction of species</p>
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Overview</h3> <ul style="list-style-type: none"> • Climate change • Ozone depletion • Photochemical ozone or smog • Aquatic eutrophication • Acidification • Toxicity and eco-toxicity • Resource depletion • Land use <p style="font-size: 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 43</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Resource depletion</h3> <h4 style="text-align: center;">Renewable and non-renewable resources</h4> <p>A renewable resource is a natural resource whose stock can be replenished over a short period of time on a human time horizon. This is the case for animal resources (livestock, for example) or plants (forests). However, to be absolutely correct, it is also necessary that the stock can be renewed as fast as it is consumed. Thus, a fish stock may be renewable and yet threatened with extinction if the fishery is intensive and makes it impossible to renew the stock.</p> <p>A natural resource is qualified as non-renewable or exhaustible when the time required for its creation exceeds the time-span of a human life. Oil is a good example.</p> <p style="font-size: 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 44</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Resource depletion: water</h3> <ul style="list-style-type: none"> • 5 to perhaps 25% of the global freshwater use exceeds long-term accessibility (low to medium level of certainty) • 15 to 35% of the water consumption for irrigation exceeds the renewal rates and is therefore unsustainable (low to medium level of certainty) <p style="font-size: x-small;">Voldensky et al., 2004a; Voldensky, C. J., Lobkovsky, C. and Reznicek, C., 2005. "Fresh Water, Ch. 7", in Ecosystems and Human Well-being: Current State and Trends. Edited by Hassan, R. M., Suboshi, R. and Adh, N. Lead Authors, USA: Millennium Ecosystem Assessment. View all references. Fig. T.3, available on line and downloaded from www.millenniumassessment.org/en/GlobalResources.aspx</p> <p style="font-size: 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 45</p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and eco-toxicity Resource depletion Land use 	<h3 style="text-align: center;">Resource depletion: oil</h3> <ul style="list-style-type: none"> • Oil reserves are not infinite • Oil consumption is steadily increasing and is expected to increase by another 50% by 2025 (US Dept. Of Energy) • The discovery of new reserves is falling <p style="text-align: center; font-size: x-small;">Global difference between the discovery of new reserves and consumption (Hirsch et al., 2005)</p> <p style="font-size: 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 46</p>	

<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and ecotoxicity Resource depletion Land use 	<p style="text-align: center;">Resource depletion: metals</p> <ul style="list-style-type: none"> • All the copper in the minerals PLUS all the copper currently in use would be necessary to bring the whole world to the level of developed countries in terms of distribution of electricity and other goods and services • 26% of extractable copper is lost in non-recyclable waste • This figure is as high as 19% for zinc • However, these metals are not in constant danger of exhaustion since the reserves are still large enough to meet demand and extraction techniques are increasingly effective • On the other hand, other, rarer metals, such as platinum, may be depleted in the 21st century <p><small>Source: Tomas Graedel, Proceedings of the National Academy of Sciences, January 2006.</small></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 47</small></p>	<p>Many different impact assessment methods all evaluate something different with regard to metal use:</p> <ul style="list-style-type: none"> - Increased costs due to metal use - Increased energy use - Supply risks due to a high concentration of supply from politically instable countries - Depletion of natural stocks - Dissipative use is considered highly relevant in the impacts of resource use. It considers that no resource depletion takes place as long as the metal is still recoverable, for example by recycling. Only when a metal is used in an irrecoverable way, depletion takes place. However, there are currently no operational impact assessment methods that reflect the dissipative use of metals.
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and ecotoxicity Resource depletion Land use 	<p style="text-align: center;">Resource depletion: metals</p> <ul style="list-style-type: none"> • What is the environmental problem with the use of metals and minerals? <p><i>"Within the Area of Protection 'natural resources,' the safeguard subject for 'mineral resources' is the potential to make use of the value resources, as embedded in a natural or anthropogenic stock, can hold for humans in the technosphere. The damage is quantified as the reduction or loss of this potential caused by human activity. Mineral resources are chemical elements (e.g., copper) or minerals (e.g., gypsum) or aggregates (e.g., sand)."</i></p> <p><small>– R. Frischknecht and O. Joliet, Global Guidance on Environmental Life Cycle Impact Assessment Indicators Volume 2, 2019.</small></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 48</small></p>	
<ul style="list-style-type: none"> Climate change Ozone depletion Photochemical ozone or smog Aquatic eutrophication Acidification Toxicity and ecotoxicity Resource depletion Land use 	<p style="text-align: center;">Resource depletion: metals</p>  <p><small>R. Frischknecht and O. Joliet, Global Guidance on Environmental Life Cycle Impact Assessment Indicators Volume 2, 2019.</small></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 49</small></p>	<p>Many different impact assessment methods all evaluate something different with regard to metal use:</p> <ul style="list-style-type: none"> - Increased costs due to metal use - Increased energy use - Supply risks due to a high concentration of supply from politically instable countries - Depletion of natural stocks - Dissipative use is considered highly relevant in the impacts of resource use. It considers that no resource depletion takes place as long as the metal is still recoverable, for example by recycling. Only when a metal is used in an irrecoverable way, depletion takes place. However, there are currently no operational impact assessment methods that reflect the dissipative use of metals.



3 Examination Questions

What is the Greenhouse effect?

Answer 1: The name of climate change legislation that passed by the European commission

Answer 2: When the gasses in our atmosphere trap heat and block it from escaping our planet (correct)

Answer 3: When you paint your house green to become an environmentalist

Answer 4: When tomatoes grown under controlled greenhouse conditions ensuring a uniform size, shape and colour

What is the most common greenhouse gas?

Answer 1: Water vapour (correct)

Answer 2: Ozone

Answer 3: Carbon dioxide

Answer 4: The noble gases particularly Helium

Why is the ozone layer important?

Answer 1: It absorbs ultraviolet rays from the Sun that can cause cancer (correct)

Answer 2: It slows down global warming

Answer 3: It prevents respiratory diseases

Answer 4: It's not very important anymore

What is the name of the international treaty aiming to cut emissions of CFCs into the atmosphere (avoiding important ozone layer depletion)?

Answer 1: The Paris agreement – 2015

Answer 2: The Rio Earth summit – 1992

Answer 3: The Kyoto protocol – 1997

Answer 4: The Montreal protocol – 1987 (correct)

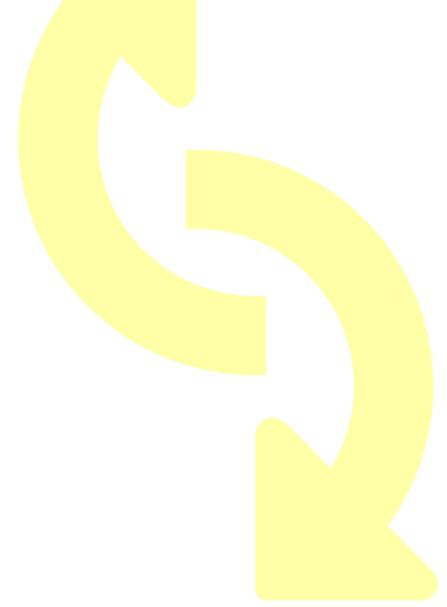
Eutrophication can take place...

Answer 1: in both marine and continental environments (correct)

Answer 2: in coastal areas

Answer 3: in urban areas during heat waves

Answer 4: in warm freshwater basins



What are the main sources of photochemical smog?

Answer 1: Ozone & CFC gases

Answer 2: Carbon dioxide & Nitrogen

Answer 3: Ammonia & Sulfur oxides (SO_x)

Answer 4: Nitrogen oxides (NO_x) & Particulate Matter (correct)

The impact pathway related to toxicity is the following...

Answer 1: Exposure – Severity – Effect – Concentration

Answer 2: Emission – Fate – Exposure – Effect (correct)

Answer 3: Fate – Exposure – Effect – Mortality

Answer 4: Dispersion – Exposure – Effect – Fate

What is 'resource depletion'?

Answer 1: Where humans use a resource at a rate that is not sustainable because it cannot be replenished fast enough. (correct)

Answer 2: Where humans use a resource at a rate that maintains the supply of the resource.

Answer 3: Where humans use a resource at a rate that is not sustainable because the behaviour of wildlife changes.

Answer 4: The use of any resource by humans.

Regarding water supply, which is the percentage of water, both fresh and easily accessible?

Answer 1: 0,014 % of the water volume on the Earth (correct)

Answer 2: 0,14 %

Answer 3: 1,4 %

Answer 4: 14 %

An ecological effect of land use is:

Answer 1: Biodiversity decrease (correct)

Answer 2: Impact on local and regional climate regulation (correct)

Answer 3: Change in the water cycle (correct)

Answer 4: Degradation of arable soils (erosion) (correct)

4 Acknowledgement and Authors

This teaching material was prepared by Guido Sonnemann, University of Bordeaux. The original course material was developed at CIRAIG Montreal (Canada) and provided by Ralph Rosenbaum, now at IRTA (Spain).

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:

Ruud Balkenende, TU Delft
Stefano Cucurachi, Uni Leiden
Andrea Gassmann, Fraunhofer IWKS
James Goddin, Granta Design
Dominique Guyonnet, BRGM
Heinrich Hofmann, EPFL
Alessandra Hool, ESM Foundation
Amund Loevik, Empa
David Peck, TU Delft
Armin Reller, ESM Foundation
Antti Roine, Outotec
Dieuwertje Schrijvers, University of Bordeaux
Guido Sonnemann, University of Bordeaux
Layla van Ellen, TU Delft
Tatiana Vakhitova, Granta Design
Ester van der Voet, Uni Leiden
Patrick Wäger, Empa
Jan-Henk Welink, TU Delft
Steven Young, University of Waterloo

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

5 Citation

Please cite the SusCritMat teaching material as follows when using them for your curriculum:

SusCritMat – Sustainable Management of Critical Raw Materials, funded by EIT RawMaterials, April 2017 – March 2020.