Suprim workshop report
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Content

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2. Introduction

This document serves as a deliverable of the Work Package 2 (agreed problem definition and method) of the EU EIT KIC Raw Materials upscaling project SUPRIM. The deliverable (D2.1) includes a report from a two-day workshop held at Leiden University in December 2017. The workshop, "Metal and Mineral Resources in LCIA: What's the problem?", which took place on 7th and 8th December, was attended by 17 representatives from industry, industry associations, academia, research institutes and policy support, including partners from the SUPRIM project and invited project-external stakeholders. The report itself forms the core part of the deliverable, in which the aim of the workshop, the organizational procedures applied during the workshop, and the key findings are summarized and explained. In addition, the material used during the workshop is provided as part of the deliverable as detailed background information (Annex 1 and 2). Furthermore, comments from other stakeholders unable to attend the workshop in person were supplied. Those are provided in an additional annex (Annex 3).

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3. Workshop Metal and Mineral Resources in LCIA: “What’s the problem”? Report from the SUPRIM workshop held at Leiden University, 7/8 December 2017

3.1. Introduction – project context and goal of the workshop

The workshop “Metal and Mineral Resources in LCIA: What’s the problem?” was held at Leiden University on 7th and 8th December. The event was attended by 17 representatives from industry (Boliden, Cobre las Cruces, Rio Tinto for Eurometaux), industry associations (Euromines, International Copper Association), academia (Universities of Leiden, Ghent, Lulea, TU Berlin and ETH for the Life Cycle Initiative hosted by UN Environment), research institutes (Tecnalia) and policy support (JRC), including partners from the SUPRIM project and invited project-external stakeholders. A detailed list of participants is given below:

- Boliden - Mats Lindblom
- Cobre las Cruces - Adrián González, Juan Manuel Escobar Torres
- Rio Tinto for Eurometaux - Ilse Schoeters
- Euromines - Johannes Drielsma
- International Copper Association - Andrea Russell-Vaccari
- Leiden University - Jeroen Guinée, Rita Schulze, Ester van der Voet
- Ghent University - Rodrigo Alvarenga, Jo Dewulf
- Lulea University - Tobias Kampmann, Glenn Bark
- TU Berlin and ETH for the Life Cycle Initiative hosted by UN Environment - Markus Berger, Thomas Sonderegger
- Tecnalia - Aritz Alonso
- JRC – Gian Andrea Blengini

SUPRIM’s starting point was the lack of a broadly accepted method for the assessment of resource use in life cycle assessment (LCA), likely attributable to the lack of a common perspective on resource use, and a common understanding of the potential problem(s) related to the use of

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resources. The aim of the workshop was to address this by creating a common understanding amongst the participants and their stakeholders of the perspectives on resource use and problem(s) that could be associated with it. After the workshop, SUPRIM intends to propose best modelling options for a selection of the perspectives and problems prioritized during the workshop. The goal of the workshop was to discuss and answer the question - "What is the problem with abiotic resource use?" as perceived by the various stakeholders, i.e. the workshop participants as well as the stakeholders they represented. The idea was to go "back to the drawing board" to understand the participants' views on the role(s) of abiotic resources that need protecting, and on the issues they thought needed to be managed. The workshop focused on impacts which occur directly from the use of abiotic resources - more specifically, abiotic resources such as minerals, metals, and natural materials such as sand or natural stone. It concerned impacts such as a reduced future availability of the resources themselves, changes to their ability to provide functions, losses of certain desired properties of materials from within the environment or the technosphere, or an increased difficulty to access the resources. The workshop did not concern impacts associated with resource extraction and processing activities, such as e.g. the potential toxicity of emissions occurring at the mining site itself, energy and water use, or associated impacts on staff at the mine resulting from poor health and safety. These potential impacts are already covered by other impact categories assessed in LCIA or social LCA, and were therefore not discussed during the workshop.

3.2. How was the workshop conducted?

Before the workshop

Approximately one month before the workshop, a background document was sent to workshop participants, explaining the suggested criteria for a structured discussion. The workshop participants were encouraged to circulate the document amongst their stakeholders and asked to formulate their own and their stakeholders' views on the issues with resource use.
Two questions were asked in the background document:

1. What, in your opinion, are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)?
2. Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited?

In the document, it was recommended to initially answer the first question independent of the framework suggested, and independent of existing LCA methods or resource management

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concepts, and regardless of the suitability of the problem definition to be addressed in LCIA. In a next step, participants were then asked to investigate whether the suggested framework and criteria presented in this document could be used to refine their perspectives: which role of resources was addressed by their views, whether they were able to formulate an explicit goal to specify their views, and the scope (time horizon, geographical scope, and types of resources) relevant to their views. Then, they were asked to explain what they thought were the main barriers to achieving the specified goal, i.e. to define the problem with resource use, according to their perspective.

During the workshop

The following section provides an overview of the issues presented and discussed during the workshop. For more details, please refer to the PowerPoint presentations, which have been compiled into two pdf documents ("Day 1"and "Day 2").

Day 1 – Learning and Informing

Before the workshop, a lack of understanding of mining practices and issues on the part of the LCA community, and a lack of understanding of LCA as a method on the part of the mining / raw materials community were identified as barriers to a productive discussion in a multidisciplinary group. For example, terminology issues and various other misconceptions were observed in SUPRIM-internal discussions prior to the workshop. For this reason, it was decided to dedicate the first day of the workshop to an improved understanding of some key issues relevant to the discussions during the workshop. After an introduction to the workshop given by Jo Dewulf, Ghent University, an introduction to LCA was provided for non-LCA practitioners by Jeroen Guinée, Leiden University. The LCA presentation was developed together with Rodrigo Alvarenga, Ghent University. The presentation included an introduction to the method and examples of its application. Then, two presentations on actual mining operations for two copper mines were given by Boliden (Mats Lindblom) and Cobre las Cruces (Juan Manuel Escobar Torres) in order to provide some illustrative examples to those less familiar with mining and metal production. Boliden presented details on a copper mining site (Aitik), and included information on downstream smelter operations and recycling plants run by Boliden (Ronnskar). The presentation given by Cobre las Cruces focused on a copper mining and solvent-extraction/electro-winning site (Las Cruces), its geology and operation. Euromines (Johannes Drielsma) presented further background information on economic issues associated with mining, exploration, metal demand and supply. Each presentation was followed by a Q&A session.

Day 2 – What's the problem? Discussions on issues with resource use

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Introduction – opening presentation and overview of workshop input paper

Day two started again with an introduction by Jo Dewulf, Ghent University, who gave an outline of the presentations and discussions ahead. Then, an overview of the workshop paper "Metal and Mineral Resources in LCIA: What's the problem?" was provided, during which the criteria for a discussion about the "problem definition" were suggested (Rita Schulze, Leiden University). The workshop paper, which had already been distributed to the workshop participants prior to the workshop, was explained again during the meeting to provide an opportunity for questions and discussions. The top level of the suggested framework ("perspective on resources", circled in Figure 1) was suggested as a basis for the discussion during the workshop. The preliminary SUPRIM ideas on perspectives were explained during the presentation. Distinctive criteria were provided to help define the different perspectives on resources. For illustration, they were applied to existing resource management concepts in and beyond the LCA context.

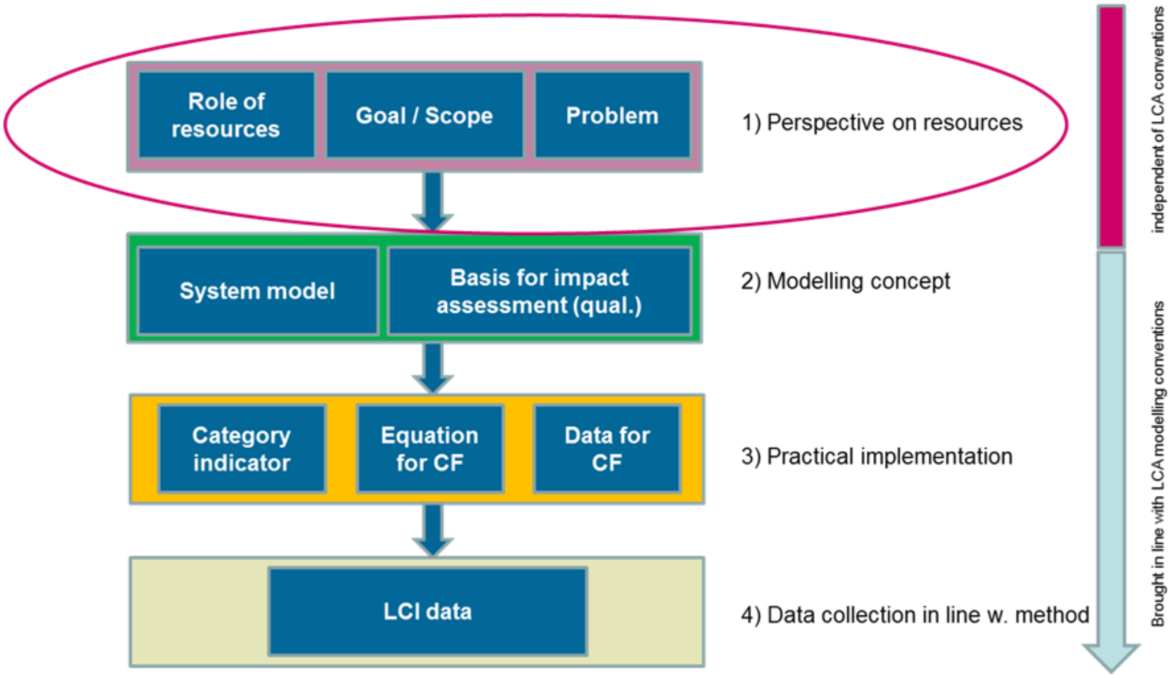

Figure 1: Suggested framework for development and review of LCIA methods on resource use

Stakeholder presentations – feedback on workshop input papers

The presentation was followed by three stakeholder presentations (i.e., project-external workshop participants), in which the stakeholders provided feedback on the workshop input paper, and answers to the key questions to be discussed during the workshop: 1) What, in your opinion, are

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the key issues of concern to be addressed when managing abiotic resources? 2) Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited?
The questions were answered by the workshop participants and their stakeholders, i.e. colleagues from mining & metals companies, members of the Task Force on Natural Resources of the Life Cycle Initiative hosted by UN Environment, and even family members in one case. In the following, a short overview of the stakeholder presentations is given.

Stakeholder presentation 1: Gian Andrea Blengini, JRC

Gian Andrea Blengini presented the feedback on the questions on behalf of JRC. In order to provide a context to the responses provided by him and his colleagues, he also gave an overview of JRC's activities on critical raw materials (CRMs), and life cycle impact assessment.
JRC publishes a method to assess the criticality of raw materials in a EU context, including cut-off criteria used to compile a list of CRM. Criticality has two important components: the economic importance of a material, and its supply risks. The new EU method takes a "non-forward-looking approach" to the evaluation of criticality i.e., the current economic situation is used as a basis to evaluate supply risks rather than demand and supply forecasts, which are more uncertain. Both biotic and abiotic materials are considered, although the majority of materials on the candidate list for the most recent criticality evaluation were abiotic. The EU criticality indicator takes into account both primary and secondary material supply, considers possibilities for material substitution, and accounts for geopolitical factors such as supply concentration, governance, trade restrictions and import dependency. Environmental sustainability issues are not currently considered in the EU criticality calculation, but may be considered in future. For details, the recent EU report on critical raw materials can be consulted (JRC, 2017).
Regarding the life cycle impact assessment of raw materials, JRC's activities are threefold: First, they are supporting the development of the Product Environmental Footprint (PEF) scheme. Secondly, they are currently working on an update of the 2011 guidance document on life cycle impact assessment categories best suited for use in a European context, which will be released in early 2018. Third, a separate JRC project is looking into the idea of evaluating the dissipative use of resources.
For the feedback on the two questions posed in the workshop input paper, inputs from two units were gathered - the Bio Economy Unit (JRC.D1), which hosts the EU Platform on Life Cycle Assessment, and the Land Resources Unit (JRC.D3), which focuses on critical raw materials and the Raw Material Information System. Regarding the first question, two aspects were considered important to JRC: First, the availability of resources for use by current and future generations was considered a key issue from an anthropocentric point of view. The secure and sustainable supply of raw materials to the EU economy is a major concern for EU policymakers currently, both in a re-

industrialization context, and in the context of the circular economy. Second, issues beyond this view, concerning the functions of abiotic resources in the natural environment were also considered important by the JRC colleagues. (The example of phosphorous was given for the latter issue.)

Regarding the second question, a clear message was given in favour of including natural resources in LCA. Explicit mention of resources in ISO 14040 (2006) was cited to back up this position. Furthermore, it was argued that resource use has implications for human wellbeing, which is traditionally included in life cycle impact assessment – for example when assessing impacts on human health, which also lie beyond environmental impacts in a strict sense. The JRC currently believes, though, that elementary flows are not sufficient to inform its preferred perspective on natural resources.

Stakeholder presentation 2: Thomas Sonderegger, Markus Berger (for the Life Cycle Initiative hosted by UN Environment)

Markus and Thomas gave an overview of the activities in the Life Cycle Initiative hosted by UN Environment, Task Force Natural Resources, which is currently aiming towards a consensus for a life cycle impact assessment method on resource use.

Their answer to the first question on the key issue with resource use again concerned the (continued) availability of resources for humans for use in the technosphere. Another member's answer to this question was similar, but more explicitly related to welfare implications, and the distribution of benefits from resource use between and amongst different generations (inter- and intragenerational equity). A third member simply stated that resource availability was to be maintained in both the technosphere and the environment. Furthermore, a more diverse set of answers was provided by another member of the Task Force, ranging from impacts from mining activities on the environment (already covered by other impact assessment methods), a desirable delay of the resources' presence in the technosphere, avoiding an increase in supply risk for abiotic resources, to the avoidance of "quality losses of material stocks in terms of dissipative losses, dilution, concentration decreases, and entropy generation". Thomas and Markus suggested that the latter view was most relevant to LCA.

Regarding the formulation of an explicit goal regarding resource management, the wording of the goal definition Markus and Thomas presented was close to the key issue specified by the description of their perspective, (i.e., the continued availability of resources for humans for use in the technosphere). However, an explicit distinction was made between short- and long term goals, to emphasize that both timeframes were considered relevant. A global geographical scope and a comprehensive inclusion of resource types was favoured by the Life Cycle Initiative hosted by UN Environment in principle (although it was acknowledged that the latter might need some more detailed discussions).

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Markus and Thomas suggested that their views best fit with the Type B perspectives[1] described in the discussion paper for the workshop, (humans are the stakeholders, the technosphere is the system of concern, and both primary and secondary production are considered).
A sub-question related to the barriers associated with resource use and the issue of availability of resources was answered by giving a diversity of potential barriers, which were all seen as relevant:

- Depletion of geologic stocks that can be mined economically
- Degradation of resource quality in the technosphere
- Dissipative loss of resources (from the technosphere and from the environment)
- Short-term/present supply risks (as addressed by "criticality" methods)

Regarding the second question about the suitability of LCA as a tool to assess resource use, Markus and Thomas agreed that the issue was relevant to LCA. However, diverging responses were given regarding the inclusion of different topics into LCIA, which cannot be summarized into a simple conclusion. The detailed responses are therefore provided in the Annex. The diversity of responses given by the group is possibly due to the individual group members of the Life Cycle Initiative hosted by UN Environment each having a concrete life cycle impact assessment method in mind which they consider most suitable for the assessment of resource use.

Stakeholder presentation 3: Ilse Schoeters, Rio Tinto

Ilse Schoeters presented a summary of perspectives given by different teams in her company. The views were summarized into different perspectives. A very interesting finding from this exercise was that the views on the key issues with abiotic resource use were different from different players in the supply chain. Stakeholders consulted included the industrial analysis team supporting the company's decision makers on investments (e.g. types of mines to invest in), the exploration team, the health and environment team, and lastly, family members who do not have a direct link with the raw materials supply chain. Their views, summarized into three perspectives, are summarized below. (More details can be found in the "Day 2" Annex).
Perspective 1 (consumer perspective)
Role of Abiotic Resources: support sustainable development, i.e., ensure the wellbeing of a growing more urbanised population through infrastructure and technology development. This is done by ensuring that the supply meets demand for individual minerals and metals.

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[1] The perspective on resources includes the definition of the role (definition of stakeholder, system of concern, production system), but also the goal and scope, and problem definition (see Figure 1, top level). Depending on the role, the perspectives can be grouped into Type A, B, etc. perspectives. (Type B perspectives share the same "role" of resources (system of concern – technosphere, stakeholder – humans, production system – primary and secondary)).

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Perspective 2 (industry perspective)
Role of Abiotic Resources: support sustainable development, in this case, interpreted as securing reliable and undistorted access to abiotic raw materials in the next 5, or 50 years.
*Perspective 3 (concern for future generations **and** the environment)*
Role of Abiotic Resources: support sustainable development, in this case, interpreted as ensuring minimum extraction (primary production) in order to preserve abiotic resources for future generations, ***and*** to protect the environment. (Here, two different motivations are included in one perspective, and both given as a reason to minimize extraction of primary resources). Contrary to Perspectives 1 and 2, Perspective 3 focuses on primary production only. However, in conclusion, an overall preference for Type B perspectives was highlighted, based on the presented views (stakeholder humans, primary and secondary production, system of concern: technosphere).

Moderated discussion - convergence or consensus on perspectives on resource use

The presentations were followed by a two-hour discussion of the views and perspectives of the workshop participants, moderated by Ester de Voet (Leiden University) and Andrea Russell-Vaccari (International Copper Association). The moderation focused on the two questions that had already been introduced in the workshop input paper:

1. What, in your opinion, are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)?
2. Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited?

The discussion started with a very open question: all workshop participants were asked to formulate their own concerns related to resource use in response to Question 1. The idea was that this question should be answered independent of any pre-defined perspectives, views on existing LCA methods, feasibility of addressing the issues in LCIA, etc. Participants recorded their views on post-it notes, and generally, more than one perspective was recorded per person. The moderators then ordered the thoughts on a whiteboard by common topics in order to identify themes of concern to the participants to be addressed in more detail in sub-group discussions. Ten themes were identified by the moderators. They included

- availability and access
- sociopolitical risks
- economic issues
- resource quality aspects
- policy

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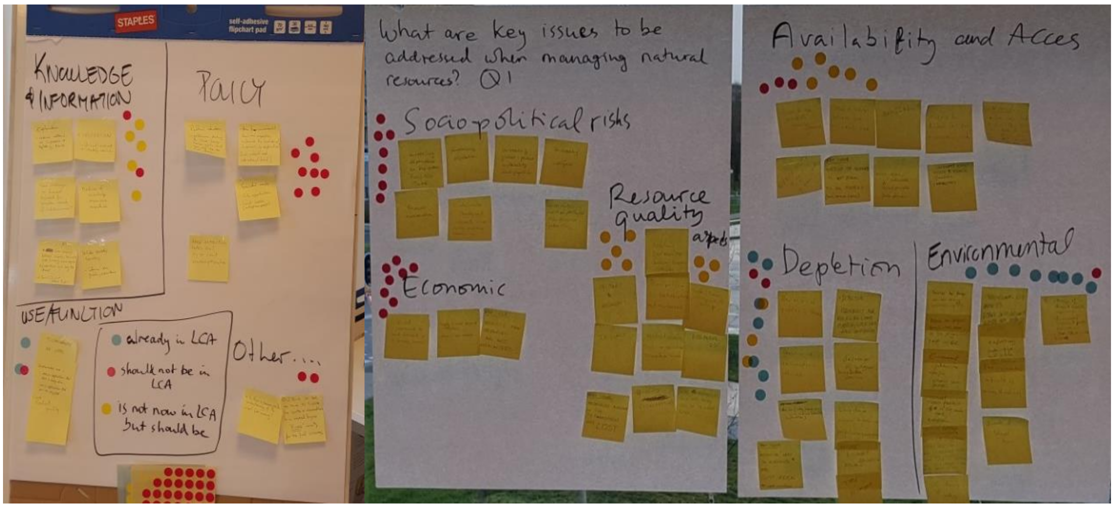
- depletion
- environmental issues
- use/function
- knowledge and information
- other

To identify the themes most relevant for the discussion, the participants were asked to place some “voting stickers” onto the whiteboard. The stickers were coloured and represented three possible votes for each theme: already in LCA (blue stickers), should not be in LCA (red stickers), is not yet in LCA but should be (yellow stickers) (Figure 2).

Figure 2: Voting on topics for discussion with coloured stickers



The list was narrowed down to three themes to be covered during the group discussions: availability and access, depletion, and resource quality aspects. This was broadly based on the number of people who thought a topic was not currently covered in LCA, but should be (i.e., the number of yellow stickers assigned to one topic). However, the topic “knowledge and information” was not selected for the group discussions since it was considered more of a meta issue relevant to different perspectives, although it nevertheless warrants further discussions. The topic “depletion” was chosen instead, due to its high relevance in current discussions around life cycle impact assessment.

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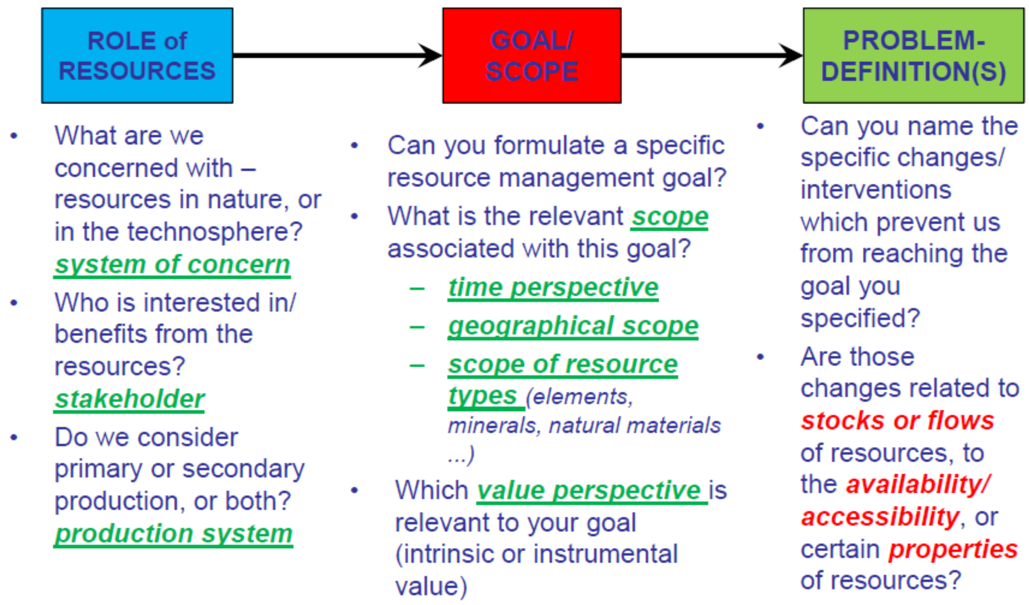
Participants were then split into three groups and asked to reflect on these themes during the group discussion, and to use the evaluation scheme provided in the workshop report to attempt the formulation of a common perspective within each group (Figure 3).

Figure 3: Suggested criteria for the discussion on perspectives



Furthermore, an initial list of five perspectives identified in the workshop report was given as an input to the workshop participants (Figure 4).

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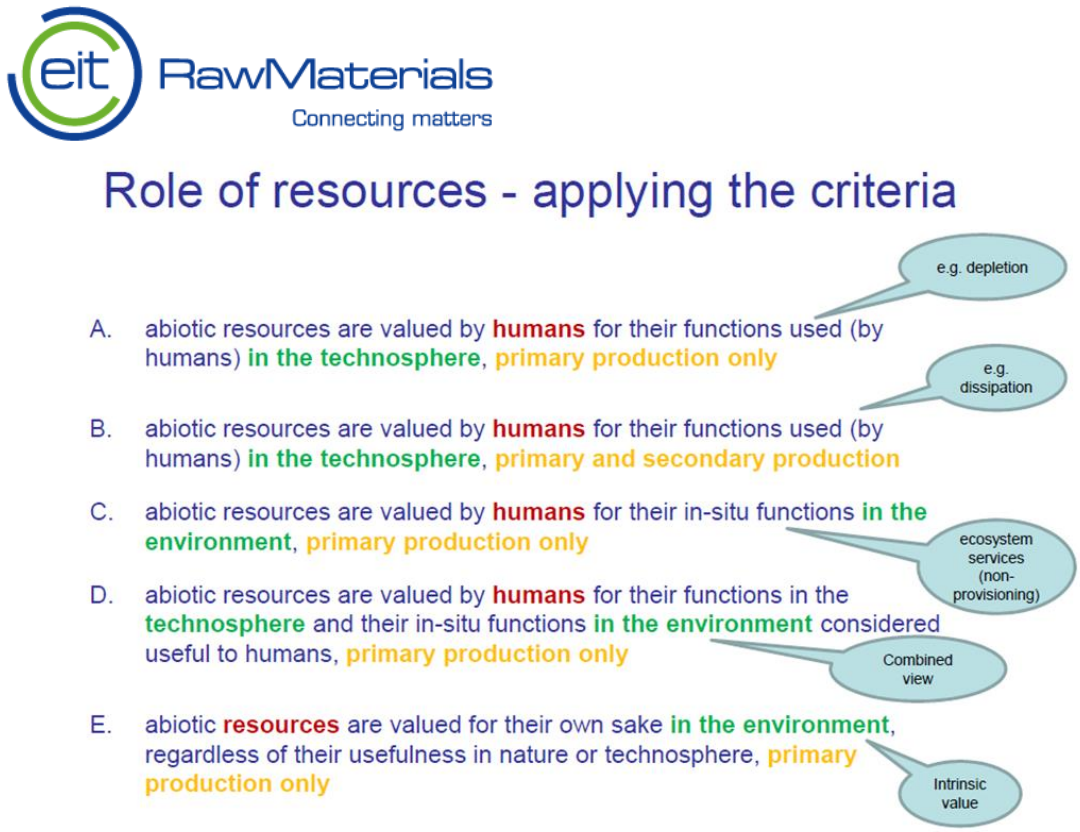

Figure 4: Initial list of perspectives provided as an input at the workshop

Outcome from the group discussions

The overall picture given at the beginning as a result of the "brainstorm session" (i.e. the very open question about peoples' views on the key issues with resource use) provided some very diverse answers from individuals. After some time for discussion, each group presented the outcome of their discussion. The focus of the group discussions varied, but participants all agreed that one of the pre-defined perspective types (Type B perspectives) should be given priority for further analysis, i.e., the Type B perspectives were identified as the perspectives of most common interest to the stakeholders represented at the workshop. Due to a lack of time, fully elaborated goals and problem definitions could not be agreed upon during the workshop.

3.3. Relevant insights from the discussions to be taken up for further development after the workshop

The inputs from the project-external stakeholders who attended the workshop, and the outcomes of the group discussions were valuable and will be reviewed in more detail and used as a basis for

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further development of the research conducted in the SUPRIM project. An initial summary of points for further discussion is provided below. In addition, Type B perspectives, which seemed of most interest to the participants of the workshop, will be discussed and interpreted in more detail. Besides the input given during the workshop, answers were received from other stakeholders who were unable to attend the workshop in person. Those will also be evaluated in preparation of the next SUPRIM WP 2 internal workshop. Besides the input regarding the stakeholder views, the framework and criteria may be further refined, based on the feedback and reactions received during the workshop.

One criterion used as part of the evaluation framework which may be discussed for refinement is the criterion “stakeholder”, which forms part of the definition of the role of resources, since the option to define “humans” as the stakeholder seemed to be very uniformly accepted amongst all workshop participants and their stakeholders, despite the different views on resources. Neither nature nor the resources themselves seemed to play a role in any of the views adopted or presented by the workshop participants. This confirmed the findings from an initial literature review conducted on existing resource management concepts and life cycle impact assessment methods on resource use, which had illustrated that the intrinsic value of resources did not play a role in any of the analyzed methods or concepts[2].

The presentation by Ilse Schoeters gave some interesting insights on how the views on resource management differed depending on the role of “humans” in the supply chain and again supported some initial findings of a review on different resource management concepts and their implications for different supply chain players. Differences could be observed between the perspectives of the industries supplying the raw material for further processing, the downstream industries relying on the materials as inputs, and the consumers.

The criterion “scope of resources”, which is part of the goal definition, was discussed in one of the sub-groups. This criterion asks whether the stakeholder’s concern about resources focusses on the management of elements, minerals or natural materials. This criterion was welcomed/ supported by one of the stakeholders as a very valuable one which had largely been missing from previous discussions, and deserved more detailed attention. It is key in clarifying both the goal of resource management and the problem definition. Within the subgroup (and with the limited time for finding a consensus on a common perspective), this question was answered by stating that the answer depended on whether the original composition of the natural material was relevant in the final product (e.g. natural diamonds, granite kitchen tops, natural stone used as building material, etc.) or a specific *element* was required in the final product, typically extracted from the original natural material, and used e.g. in an alloy required in the final product. Some discussions followed

[2] The intrinsic value of a resource as defined here is a value assigned to the resource entirely for its own sake, and independent of any actual or potential function of the resource in nature or technosphere, independent of human interest, human appreciation, current or potential future use of the resource (see Justus et al., (2009)).

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on the quality of secondary raw materials, direct and indirect recycling (recycling of materials vs. re-extraction of elements from secondary sources). This criterion is also highly relevant for any discussions on dissipation.

Overall, most of the insights gained from the workshop related to stakeholders' views, rather than particular choices of criteria for the formulation of perspectives. Many stakeholders showed interest in resource availability, but over different timeframes. This was an interesting outcome since the intended focus of current LCIA methods addressing abiotic resource use is mainly mid- or long term availability (though often the results do not achieve that focus due to inappropriate use of data). A notable exception is the development of new methods which aim to integrate criticality into life cycle impact assessment. There, a shorter time perspective is taken.

Another very interesting discussion related to the stakeholder question dealt with the goal definition, with no clear-cut preference even if the stakeholders' concerns focus mainly around the Type B perspectives. The challenge was to translate the concerns regarding availability or accessibility into a more specific goal. The key question discussed was whether a goal should be formulated to avoid supply shortages by ensuring supply always meets demand for individual elements / raw materials, or whether the goal should include the option to reduce the demand for certain resources, whilst still meeting the demands in terms of the functions, or final commodities of interest to end-consumers (thereby still ensuring a balanced demand/ supply ratio). The first option reflects more a short-term, economic perspective (of industries requiring resources as input materials for processing), and might rather focus on a certain economic area or material supply chain – or even a specific manufacturer. The narrower the geographical / supply chain focus and the shorter the time focus, the more likely it is that the goal would strictly refer to fulfilling the demand for specific resources. The second option is more related to societal demand for resource functions (consumer perspective) and allows for material substitution, or even the fulfillment of functions with more or less input of commodities (e.g. through lifetime extension of products, product service systems etc.). There, the information on the demand for individual functions cannot be quantified with certainty and coupling of functions with different combinations of resources is difficult. Other ways to specify more open goals within Type B perspectives can be thought of e.g., related to the preservation of a certain state, such as to maintain stocks and/or flows of resources as far as possible to preserve or maximize their value to humans in the technosphere.

One main take-away from the workshop seemed to be that whilst most stakeholder issues & concerns appeared to line up with Type B perspectives, a variety of possible goals (and problem definitions) falls under Type B – each requiring careful scoping in order for a particular LCA to be internally consistent. There appeared to be a clear focus around ensuring supply can meet demand in the technosphere generally. However, it was left open how this balance should ideally be achieved, i.e. whether it should ideally be addressed at the demand or supply level. Furthermore,

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there was not one unified consensus regarding the level of the supply chain at which this should be achieved; i.e. whether demand and supply should be balanced at an element, material, final product or functional level. Different needs were quickly identified and related to short-, mid- or long-term demand for particular functions and how to reliably link each of those to supply of different resources. In some cases it would appear to be most relevant to assess demand & supply for individual elements, for others it would appear more relevant to assess demand & supply for particular minerals or materials meeting minimum quality criteria. Those quality criteria may differ depending on the source of the mineral or material (e.g., primary extraction *versus* secondary processing, but equally extraction of one ore type *versus* extraction of another). The terms "availability" and "accessibility" are frequently used in the context of resource stocks for use in the technosphere. These will be further and more precisely defined.
The next challenge for SUPRIM is to identify and agree upon

- a ***workable*** range of Type B perspectives that clearly define the role of resources
- a goal and problem definition for each Type B perspective

Ultimately, an LCIA method will be developed that reflects the agreed-upon Type B perspectives.

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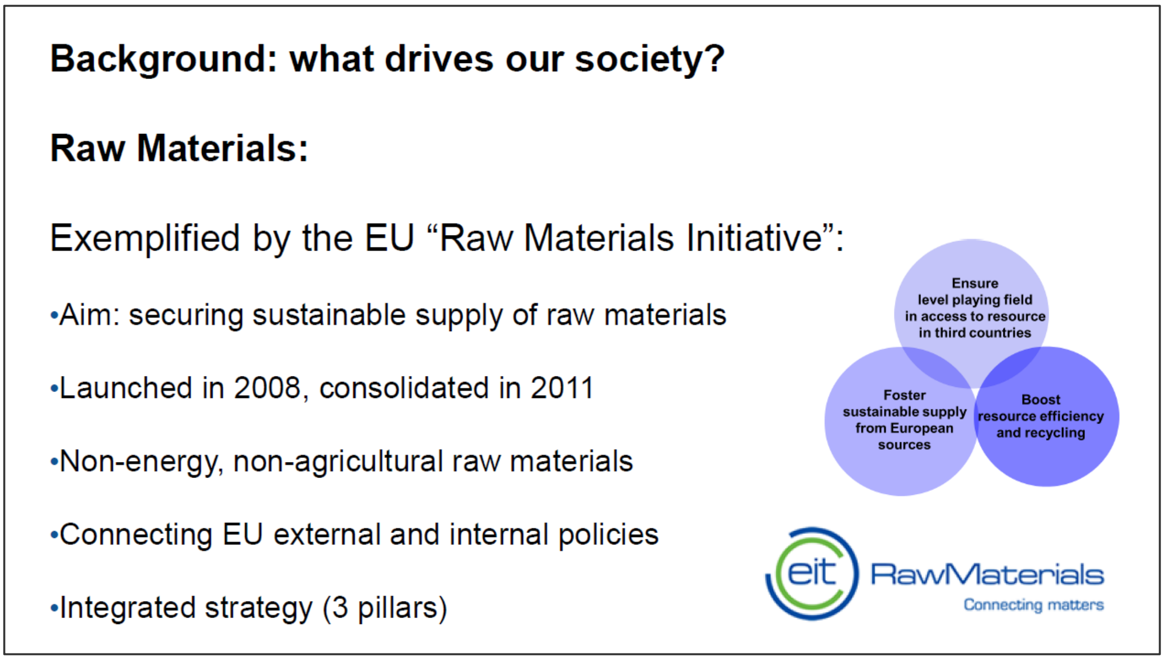
4. Annex 1 – Slides from Day 1



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Background: what drives our society?

Sustainability concerns

What is behind our consumer products?
- Are product supply chains inducing social impacts?
- Are product supply chains impacting the ecosystem quality?
- Are product supply chains depleting resources?

→ Societal request to quantify sustainability

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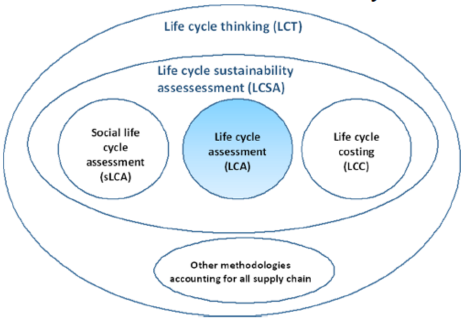
The product sustainability assessment toolbox today:



Life cycle thinking:

Life cycle assessment (LCA):

EC Communication on Integrated Product Policy (COM (2003) 302):
"Life Cycle Assessments provide the best framework for assessing the potential environmental impacts of products currently available"

Policy level: European Platform for LCA (EPLCA)
JRC EUROPEAN COMMISSION

LCA covers multiple potential environmental sustainability impacts of products:
- Some impacts are well understood, modeled and quantified. E.g. Global warming
- Some impacts are less well understood, modeled and quantified. E.g. Resource 'depletion'

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SUPRIM
FOCUS ON RESOURCES:

Agreement on the problem definition and development of an LCIA method → LCI dataset based on case studies and validation of the LCIA method → Bring the service to a broader audience

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PROJECT CONSORTIUM:

eit RawMaterials

GHENT UNIVERSITY

LULEÅ UNIVERSITY OF TECHNOLOGY

NEW BOLIDEN

CLC Cobre Las Cruces, S.A.

euromines

tecnalia Inspiring Business

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Bringing LCA and raw materials specialists together: 1st time !

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EIT RawMaterials
Connecting matters

AGENDA OF TODAY:

As we have brought stakeholders together with different backgrounds:

- Need to understand what LCA is for raw materials experts
  Presentation by Jeroen Guinée

- Need to understand how the raw materials sector works for LCA experts
  Presentation by the raw materials sector

Better understanding can continue at dinner …

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Introduction to LCA

Brief introduction to the basic principles of LCA for the SUPRIM workshop on Metal and Mineral Resources in LCIA: "What's the problem"?, 7-8 December, Leiden, The Netherlands

Universiteit Leiden
The Netherlands

GHENT UNIVERSITY

Discover the world at Leiden University

Content

- LCA in a nutshell; LCA in one slide
- Philosophy behind LCA (life cycle thinking; LCT)
- LCA theory
  - What is LCA?
  - Goal and scope definition
  - Inventory analysis
  - Impact assessment
  - Interpretation

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Content

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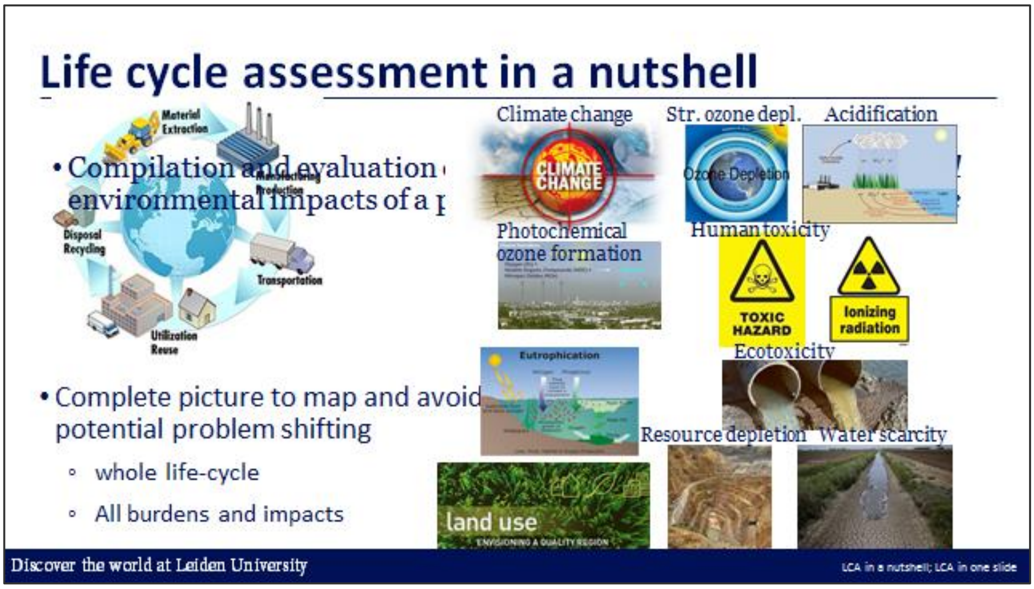

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Recycling plastic (1)

- Recycling is processing used materials (waste) into new products to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from landfilling) by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to virgin production.

Source: http://en.wikipedia.org/wiki/Recycling

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Recycling plastic (2)

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Life Cycle Assessment (LCA)

As WE think it should be done ....

- Science, not ideology
  - is an electric car indeed better ?
  - is recycling always a good idea ?

- Systems analysis
  - technosphere ('economy')
  - nature ('natural environment')

Applied science ....

- Analysis of 'externalities'
  - starts from the assumption that we need, and already value, the product's functions/services
  - aims to map the non-accounted 'externalities' (air pollution, water pollution, etc.)

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Life Cycle Assessment (LCA)

- It's just one method/tool for assessing environmental impacts
  - no 'supertool'
  - only tool taking product functions/services as starting point of analysis, mapping all upstream and downstream environmental burdens

- Complete picture: life cycle & all impacts
  - avoid problem shifting (trade-offs)
  - integral analysis

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Quantitatively mapping trade-offs to:

- Other life cycle phases (zero emission car)
- Other substances (CFC-free fridge)
- Other countries (export of waste)
- Other environmental impacts (unleaded petrol)
- The future (nuclear power)
- …

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The philosophy behind LCA; LCT

Integral analysis of environmental impacts

- Whole life-cycle (any where)
- All substances
- All countries (any place)
- All types of environmental impacts
- Integrated over time (any time)
- …

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The philosophy behind LCA; LCT

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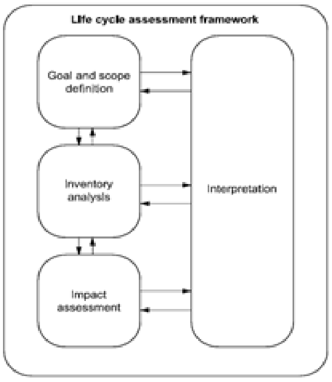
There's no such thing as a free lunch

- Any activity will have a certain environmental impact, direct or indirect
- Think in terms of cause and effect
- Think in terms of life-cycles

Life Cycle Assessment (LCA)

- LCA: science, whole life cycle, all impacts, quantitative, all substances, all countries, integrated over time, mapping trade-offs
- Standardized by ISO 14040 and ISO 14044: only requirements, no specific method
- Four phases (iterative):
  - Goal and Scope definition
  - Inventory analysis *(or Life Cycle Inventory - LCI)*
  - Impact Assessment *(or Life Cycle Impact Assessment – LCIA)*
  - Interpretation



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Goal and scope definition

- "Phase of life cycle assessment in which the aim of the study, and in relation to that, the breadth and depth of the study is established"
  - no formal ISO definition
- Goal definition
  - Goal, application, decision to be supported
- Scope definition
  - functional unit
  - initial choices (system boundaries, temporal and geographical coverage, impact categories, ...)

Functional unit

- What are you comparing ? Functions & services, not products
  - not lamps, but hours of light
  - etc.
- Functional unit: a quantified unit supplied by a product system, used as a basis of comparison in an LCA
  - 1000 hours of light with an intensity of 1250 lumen of white light
  - etc.

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Inventory analysis (LCI)

- ISO 14040: “Phase of life cycle assessment involving the compilation and quantification of inputs and outputs, for a given product system throughout its life cycle”

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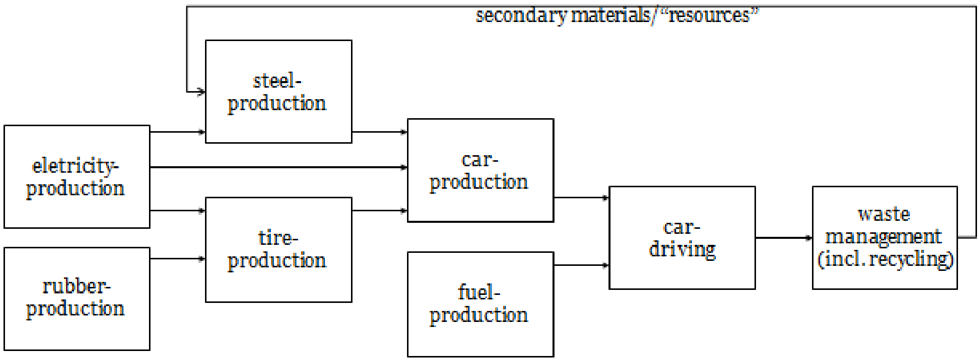
Processes and flows (1)



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LCA theory: Inventory analysis

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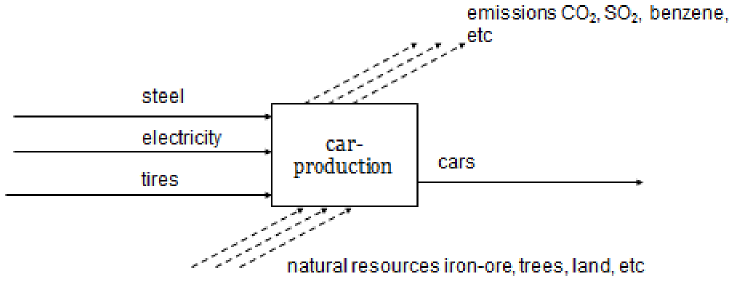
Processes and flows (2)



Processes

- Processes:
  - **extraction of ores and fossil fuels**
  - production of materials and energy carriers
  - production of components and products
  - use and maintenance of products
  - waste processing and **recycling of waste**
  - transport between all lifecycle phases

Recycling is thus modelled as process and all its flows (including secondary materials produced) as part of the inventory analysis

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Flows

- Flows:
  - products and semi-manufactured goods
  - materials and energy
  - waste to be processed
  - **secondary materials**
  - emissions
  - natural resources

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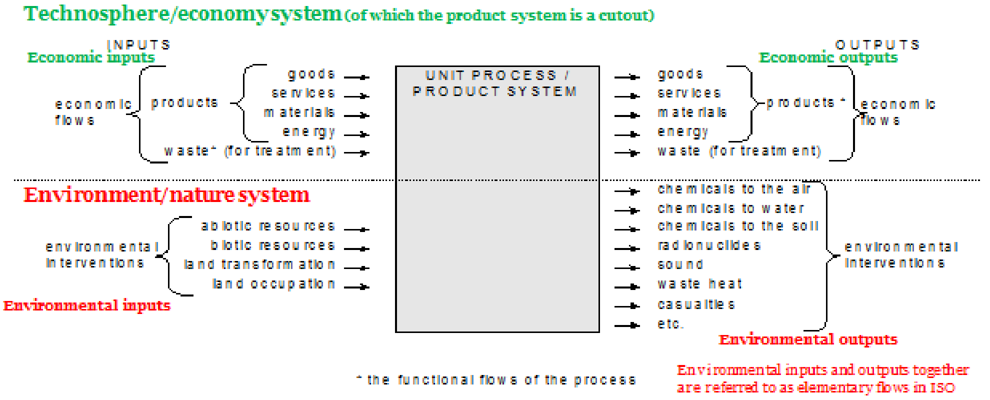
LCA theory: Inventory analysis

Unit process (data)



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LCA theory: Inventory analysis

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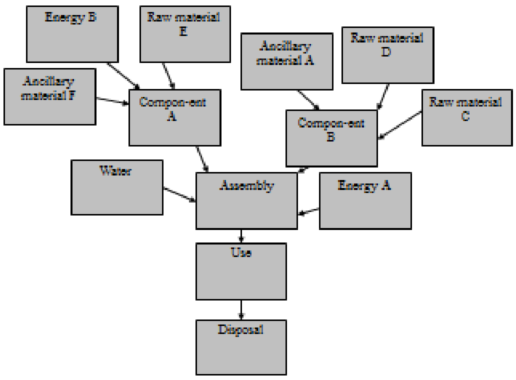
Unit process data from ecoinvent 2.2

Manufactured Resources
(or raw materials)
(from technosphere)

Natural Resources
(from nature)

Process = [P1069] iron ore, 46% Fe, at mine [GLO, 1999-2000]		
Description = ...		
Stage = [S42] metals_extraction		
Region = [R4] GLO		
Author = ecoinvent data v2.2		
Economic inflows	Value	Unit
electricity, medium voltage, production UCTE, at grid[UCTE]	0.00142	kWh
diesel, burned in building machine[GLO]	0.0255	MJ
recultivation, iron mine[GLO]	1.70E-06	m2
blasting[RER]	0.000271	kg
mine, iron[GLO]	8.33E-13	unit
Economic outflows		
iron ore, 46% Fe, at mine[GLO]	1	kg
Environmental resources		
Transformation, from unknown[resource_land]	2.13E-06	m2
Occupation, mineral extraction site[resource_land]	0.00012	m2a
Transformation, to mineral extraction site[resource_land]	2.13E-06	m2
Iron, 46% in ore, 25% in crude ore, in ground[resource_inground]	0.462	kg
Environmental emissions		
Heat, waste[air_low population density]	0.00513	MJ
Particulates, < 2.5 um[air_low population density]	0.000144	kg
Particulates, > 10 um[air_low population density]	0.00144	kg
Particulates, > 2.5 um, and < 10um[air_low population density]	0.0013	kg

Flow diagram or flow chart



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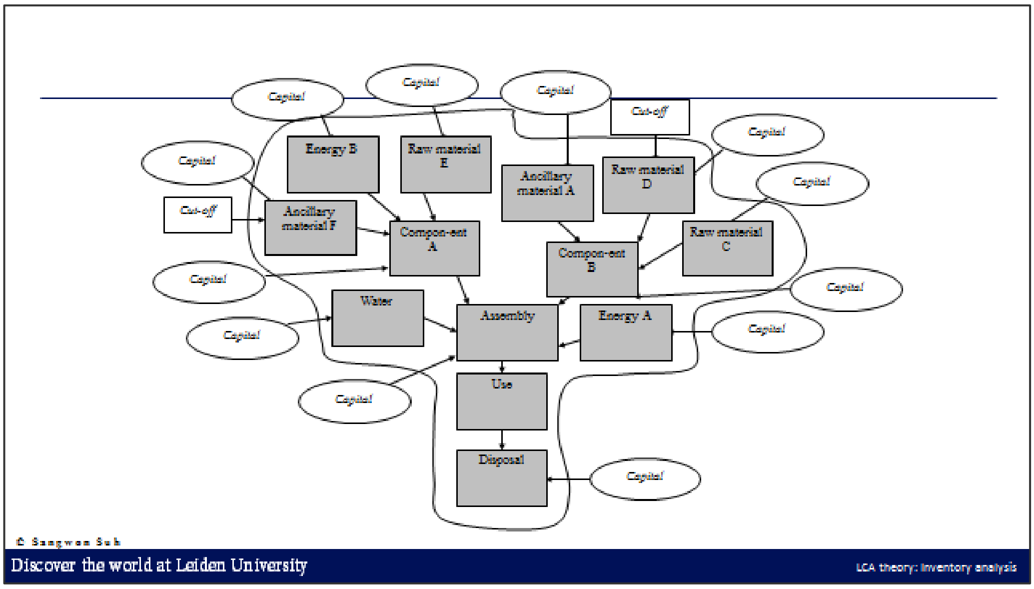

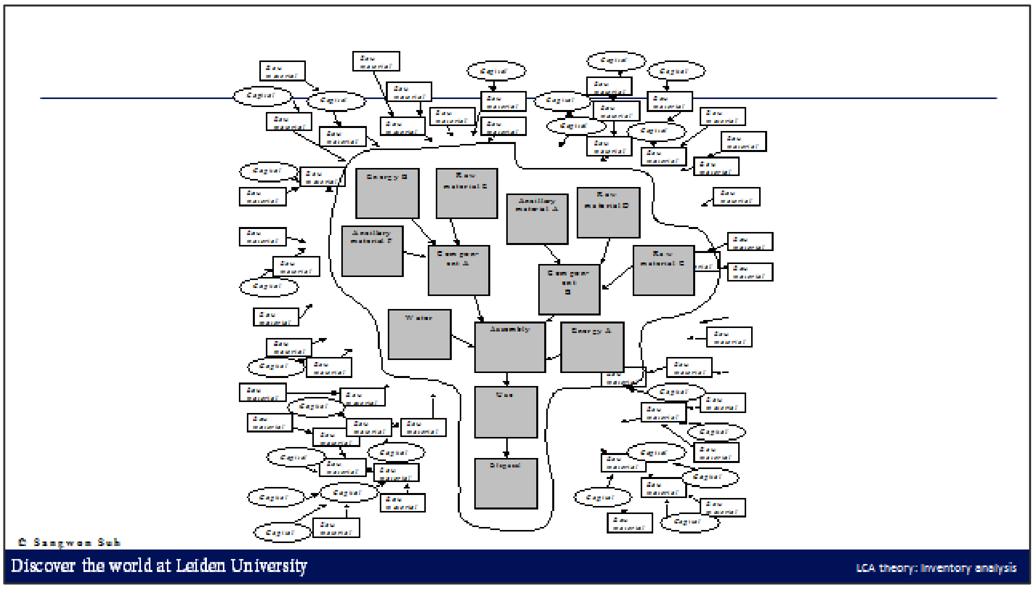

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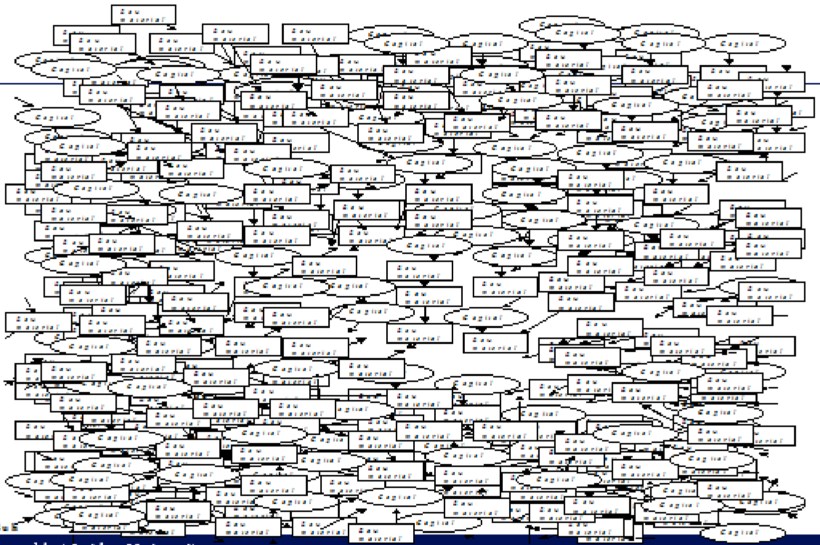

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Example of inventory results: inventory table

Elementary flows	Product 1	Product 2	Unit
NMVOC, non-methane volatile organic compounds, unspecified origin[air_high population density]	1.40E-06	4.57E-07	kg
Carbon dioxide, fossil[air_low population density]	2.85E-01	4.96E-02	kg
Ammonia[air_high population density]	7.82E-07	2.68E-07	kg
Nitrogen oxides[air_high population density]	5.76E-04	6.24E-05	kg
Particulates, < 2.5 um[air_high population density]	5.87E-05	6.88E-06	kg
Particulates, > 10 um[air_high population density]	5.52E-07	1.04E-06	kg
Particulates, > 2.5 um, and < 10um[air_high population density]	6.87E-07	1.02E-06	kg
Zinc, ion[water_river]	4.69E-08	4.57E-08	kg
Lead[water_river]	5.59E-08	2.98E-07	kg
Nickel, ion[water_river]	9.84E-09	5.19E-09	kg
Mercury[water_river]	4.20E-10	4.22E-11	kg
Copper, ion[water_river]	5.97E-09	4.79E-09	kg
Chromium, ion[water_river]	7.10E-09	1.77E-08	kg
Cadmium, ion[water_river]	7.68E-10	1.36E-09	kg
Arsenic, ion[water_river]	5.15E-08	1.47E-08	kg
Phosphate[water_river]	1.83E-08	1.48E-08	kg
Ammonium, ion[water_river]	5.86E-07	2.18E-06	kg
Nitrate[water_river]	6.82E-06	1.02E-06	kg
Nitrate[air_high population density]	1.24E-09	5.42E-10	kg
Calcite, in ground[resource_in ground]	-4.25E-08	-1.34E-08	kg
Sylvite, 25 % in sylvinite, in ground[resource_in ground]	-9.76E-08	-2.53E-08	kg
Water, cooling, unspecified natural origin[resource_in water]	-1.22E-02	-2.65E-05	m3
Water, river[resource_in water]	-2.38E-05	-5.36E-05	m3
Sodium, ion[water_river]	1.48E-04	1.06E-04	kg
Potassium, ion[water_river]	5.21E-06	1.58E-06	kg
Chloride[water_river]	5.45E-04	1.57E-04	kg
Calcium, ion[water_river]	7.74E-05	1.97E-05	kg
Magnesium[water_river]	1.49E-05	3.25E-06	kg
Sulfur[water_river]	[illegible]	[illegible]	kg
[illegible]	[illegible]	[illegible]	kg
[illegible]	[illegible]	[illegible]	kg

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Inventory analysis *summarized*

From unit process data

$\sum_{k=0}^{n}$

Process – [P 1069] Iron ore, 46% Fe, at mine [GLO, 1999-2000]		
Description – The dust emissions are estimated to be the same as in bauxite mining.		
Stage – [S42] metals_extraction		
Region – [R4] GLO		
Author – ecoinvent data v2.2		
Economic inflows	Value	Unit
electricity, medium voltage, production UCTE, at grid [UCTE]	0.00142	kWh
diesel, burned in building machine [GLO]	0.0255	MJ
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blasting [RER]	0.000271	kg
mine, iron [GLO]	8.33E-13	unit
Economic outflows		
Iron ore, 46% Fe, at mine [GLO]	1	kg
Environmental resources		
Transformation, from unknown [resource_land]	2.12E-08	m2
Occupation, mineral extraction site [resource_land]	0.00012	m2a
Transformation, to mineral extraction site [resource_land]	2.12E-08	m2
Iron, 46% in ore, 25% in crude ore, in ground [resource_in ground]	0.462	kg
Environmental emissions		
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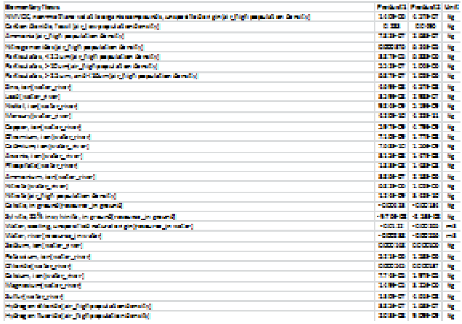
Particulates, < 2.5 um [air_low population density]	0.000144	kg
Particulates, > 10 um [air_low population density]	0.00144	kg
Particulates, > 2.5 um, and < 10um [air_low population density]	0.0012	kg

To inventory table



Life cycle impact assessment (LCIA)

- ISO: "Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system"

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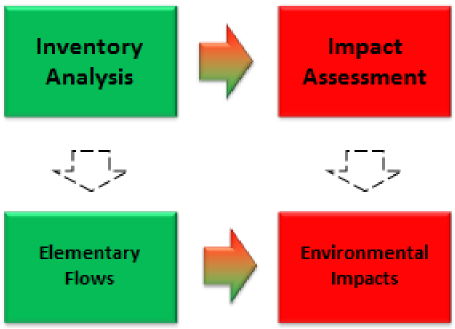
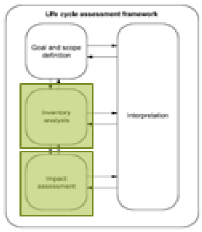
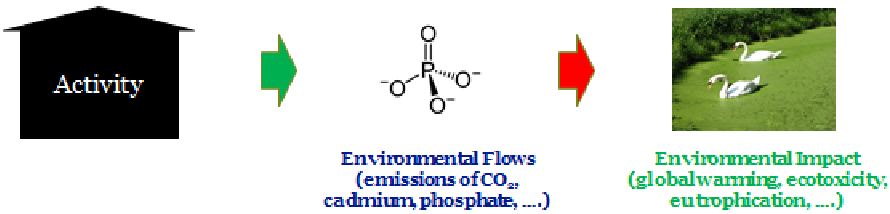
From inventory analysis to impact assessment





Environmental Flow & Impact

- **Elementary Flows** (ISO 14040): "**material or energy entering** the system being studied that has been drawn from the environment **without previous human transformation**, or **material or energy leaving the system** being studied that is released into the environment **without subsequent human transformation**"
- **Environmental Impact** (ISO 14001): "any **change to the environment**, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services"



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From LCI → LCIA: characterisation

- Global Warming (*IPCC*):
  - Global Warming Potential (GWP): measure for Global Warming (Climate Change) in terms of radiative forcing potential (infra-red absorption) of 1 kg of a chemical emission relative to 1 kg of CO_2 emitted
- Example:

  5 kg CO_2 (GWP = 1)

  +

  3 kg CH_4 (GWP = 23)

  =

  1 x 5 + 23 x 3 kg CO_2-equivalent (= 7[illegible] kg CO_2–equivalent)

characterisation factor (CF)

IPCC climate model

characterisation (or category indicator) result

Examples of other impact categories

- Global warming
- Acidification
- Eutrophication
- Energy use
- Biotic resource use
- Marine aquatic ecotoxicity
- Abiotic depletion
- Ozone depletion
- Human toxicity
- Water dependence
- Photochemical oxidant formation
- Freshwater aquatic ecotoxicity
- Terrestrial ecotoxicity
- Surface use
- Respiratory impacts from inorganics
- Carcinogenic effects on humans
- etc.

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Example of characterization results

CML 2001 baseline methods

Impact category	Product 1	Product 2	Unit
CML 2001 baseline, eutrophication	9.59E-04	1.68E-04	kg PO4-Eq
CML 2001 baseline, depletion of abiotic resources	5.26E-05	6.17E-04	kg antimony-Eq
CML 2001 baseline, acidification	9.44E-04	5.21E-04	kg SO2-Eq
CML 2001 baseline, photochemical oxidation	4.02E-05	1.98E-05	kg ethylene-Eq
CML 2001 baseline, climate change	6.77E-01	9.25E-02	kg CO2-Eq
CML 2001 baseline, terrestrial ecotoxicity	5.14E-04	5.29E-04	kg 1,4-DCB-Eq
CML 2001 baseline, freshwater aquatic ecotoxicity	1.40E-01	5.89E-02	kg 1,4-DCB-Eq
CML 2001 baseline, stratospheric ozone depletion	2.62E-08	4.72E-09	kg CFC-11-Eq
CML 2001 baseline, human toxicity	1.71E-01	1.22E-01	kg 1,4-DCB-Eq

PEF recommended methods

Impact category	Product 1	Product 2	Unit
climate change//GWP 100a	6.77E-01	9.22E-02	kg CO2-Eq
ecosystem quality//freshwater and terrestrial acidification	1.22E-03	6.20E-04	mol H+-Eq
ecosystem quality//freshwater ecotoxicity	1.94E+00	6.52E-01	CTUh.m3.yr
ecosystem quality//freshwater eutrophication	2.66E-04	4.20E-05	kg P-Eq
ecosystem quality//ionising radiation	2.74E-07	5.85E-06	mol N-Eq
ecosystem quality//marine eutrophication	3.95E-04	1.06E-04	kg N-Eq
ecosystem quality//terrestrial eutrophication	3.58E-03	1.06E-03	mol N-Eq
human health//carcinogenic effects	2.26E-08	6.52E-09	CTUh
human health//ionising radiation	1.06E-01	1.11E+00	mol N-Eq
human health//non-carcinogenic effects	7.68E-08	4.34E-08	CTUh
human health//ozone layer depletion	2.62E-08	4.72E-09	kg CFC-11-Eq
human health//photochemical ozone creation	9.69E-04	2.87E-04	kg ethylene-Eq
human health//respiratory effects, inorganics	1.72E-04	6.50E-05	kg PM2.5-Eq
resources//land use	3.18E-01	8.19E-02	kg Soil Organic Carbon
resources//mineral, fossils and renewables	8.16E-07	4.26E-06	kg Sb-Eq

Normalization (*optional*)

- ISO 14040: “calculation of the magnitude of category indicator results to reference information”
- Reference information (over a given period of time):
  - area (e.g., France, Europe, the world)
  - person (e.g., a Danish citizen)
  - product (e.g., the most frequently used product)
- Understanding the relative magnitude for characterisation results
  - providing and communicating information on the relative significance of the indicator results
  - preparing for additional procedures

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Calculating normalization values

Substance	cas no.	global emission in 2000 (kg/yr)		GWP100, IPCC 2007 (kg CO₂ eq./kg)		Normalisation reference value (kg CO₂ eq./yr)
1,1,1-trichloroethane	71-55-[illegible]	3.57E+0[illegible]	x	146	=	5.21E+07
Carbon dioxide	[illegible]-38-9	2.85E[illegible]13	x	1	=	2.85E+13
CFC-11	[illegible]-69-4	4.[illegible]E+07	x	4750	=	1.93E+11
CF[illegible]	[illegible]	[illegible].86E+06	x	6130	=	2.37E+10
CF[illegible]	[illegible]	2.07E+06	x	10000	=	2.07E+10
CFC-115	76-15-3	8.73E+05	x	7370	=	6.43E+09
CFC-12	75-71-[illegible]	1.01E+08	x	10900	=	1.10E+12
Dichloromethane	75-[illegible]-2	1.42E+07	x	8.7	=	1.23E+08
Dinitrogen oxide	[illegible]24-97-2	1.15E+10	x	298	=	3.42E+12
HALON-1211	353-59-3	4.82E+06	x	1890	=	9.10E+09
HALON-1301	75-63-8	9.26E+05	x	7140	=	6.61E+09
HCFC-124	2837-89-0	3.93E+06	x	609	=	2.39E+09
HCFC-1[illegible]	[illegible]17-00-6	1.66E+08	x	725	=	1.21E+11
HCFC-14[illegible]	[illegible]5-68-3	5.09E+07	x	2310	=	1.18E+11
HCFC-22	75-45-6	3.00E+08	x	1810	=	5.44E+11
HFC-125	354-33-6	7.40E+06	x	3500	=	2.59E+10
HFC-134[illegible]	[illegible]	1.30E+08	x	1430	=	1.86E+11
HFC-1[illegible]	[illegible]	5.40E+06	x	4470	=	2.41E+10
Methane	[illegible]	2.99E+11	x	25	=	7.47E+12
Methyl Chloride	74-87-3	[illegible]E+07	x	13	=	1.56E+08
Sulphur hexafluoride	2551-62-4	5.22E+0[illegible]	x	22800	=	[illegible].19E+11
Tetrachloromethane	56-23-5	4.17E+05	x	[illegible]	=	5.84E+08
non methane VOC	NMVOC	1.67E+11	x			0.00E+00
					Σ	4.18E+13

$InventoryResult_{i,ref}$

$CharFact_{cat,i}$

$IndicatorResult_{cat,ref}$

Discover the world[illegible] normalization

Example of normalization results

CML 2001 baseline methods

Impact category (CML 2001)	Product 1	Product 2	Unit
CML 2001, eutrophication potential, generic[GLO]	6,47E-15	1,14E-15	year
CML 2001, resources, depletion of abiotic resources[GLO]	2,88E-14	3,38E-15	year
CML 2001, acidification potential, average European[RER]	3,95E-15	2,18E-15	year
CML 2001, photochemical oxidation (summer smog), high NOx POCP[RER]	1,10E-15	5,38E-16	year
CML 2001, climate change, GWP 100a[GLO]	1,60E-14	2,18E-15	year
CML 2001, terrestrial ecotoxicity, TAETP infinite[GLO]	5,09E-16	5,24E-16	year
CML 2001, freshwater aquatic ecotoxicity, FAETP infinite[GLO]	2,55E-13	7,08E-14	year
CML 2001, stratospheric ozone depletion, ODP steady state[GLO]	2,50E-16	4,50E-17	year
CML 2001, human toxicity, HTP infinite[GLO]	7,27E-14	5,21E-14	year

PEF recommended methods

Impact category (PEF)	Product 1	Product 2	Unit
climate change//GWP 100a	1,60E-14	2,17E-15	year
ecosystem quality//freshwater and terrestrial acidification	4,02E-15	2,05E-15	year
ecosystem quality//freshwater ecotoxicity	6,52E-14	2,19E-14	year
ecosystem quality//freshwater eutrophication	1,77E-14	2,80E-15	year
ecosystem quality//ionising radiation	0,00E+00	0,00E+00	year
ecosystem quality//marine eutrophication	8,48E-15	2,26E-15	year
ecosystem quality//terrestrial eutrophication	5,53E-15	1,52E-15	year
human health//carcinogenic effects	5,59E-14	1,61E-14	year
human health//ionising radiation	1,25E-09	1,30E-08	year
human health//non-carcinogenic effects	2,58E-15	1,53E-15	year
human health//ozone layer depletion	2,50E-16	4,50E-17	year
human health//photochemical ozone creation	3,26E-15	9,67E-16	year
human health//respiratory effects, inorganics	4,38E-15	1,66E-15	year
resources//land use	0,00E+00	0,00E+00	year
resources//mineral, fossils and renewables	9,23E-15	4,83E-14	year

Discover the world at Leiden University LCA theory: Impact assessment

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

Weighting (*optional*)

- ISO definition: converting and possibly aggregating indicator results across impact categories using numerical factors
  - based on value-choices
  - ISO: "weighting shall not be used for comparative assertions disclosed to the public"

Example of weighting results

CML 2001 baseline methods

CML 2001	Product 1	Product 2	Unit
weighted index	4,00E-14	1,35E-14	year

PEF recommended methods

PEF	Product 1	Product 2	Unit
weighted index	6,23E-11	6,50E-10	year

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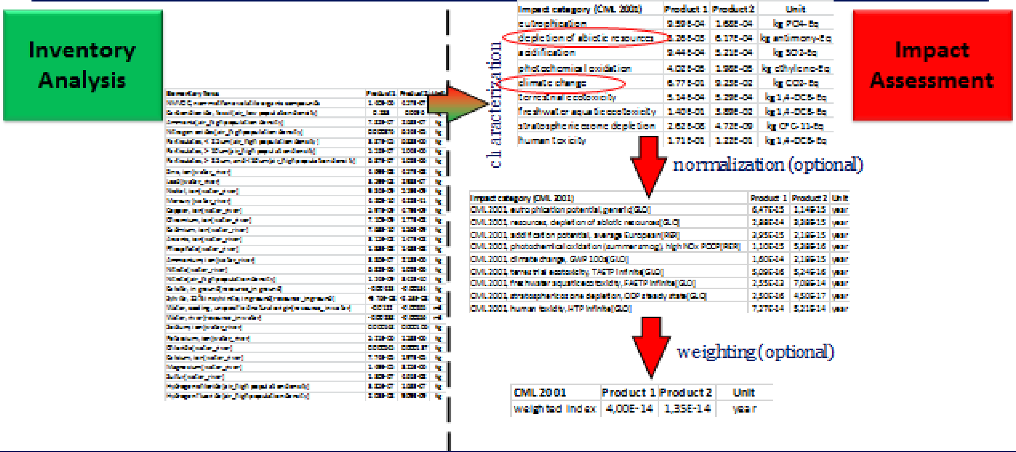
LCI & LCIA *summarized*

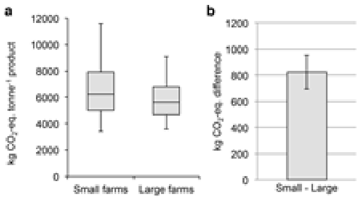


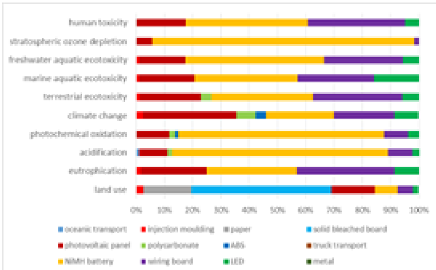
Discover the world at Leiden University — LCA theory: Impact assessment

Interpretation

- Conclusions, recommendations, analyses, all related to goal and scope of the research
  - detailed analysis of results: where are the hot spots ?
    - contribution analysis

Source: Henriksson et al. 2015. PLoS ONE 10(3): e0121221





  - uncertainty analysis etc.

Discover the world at Leiden University — LCA theory: Interpretation

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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

RawMaterials
Connecting matters

Copper
From mineral in the Mine to metal from the Smelter

Mats Lindblom, Boliden Mines
Date: 2017-12-07
Leiden university

This is Boliden

Integrated company with mines and smelters

- Core competence in exploration, mining, smelting and metals recycling.
- The Mines produce concentrates.
- The smelters produce copper, zinc, lead, silver and gold and chemicals such as H_2SO_4, SO_2, $CuSO_4$ etc.
- Some 5 500 employees

● MINES
● SMELTERS
● HEADQUARTER

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But first something about Exploration…

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Exploration at Boliden

- Identify new minable deposits
- Prolonging production life of mines
- Exploration close to our mines is prioritised
- Upgrade deposits from resources to reserves

4 May 2017 BOLIDEN

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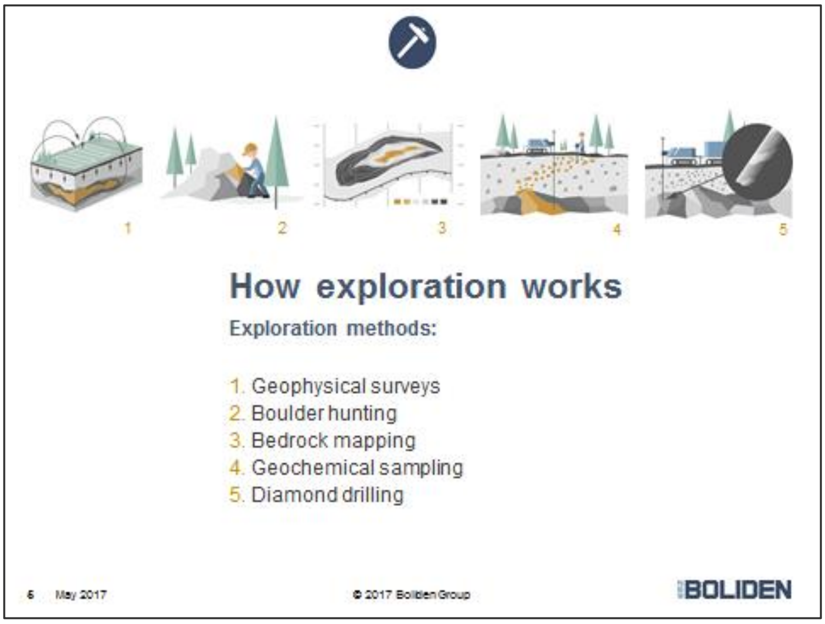

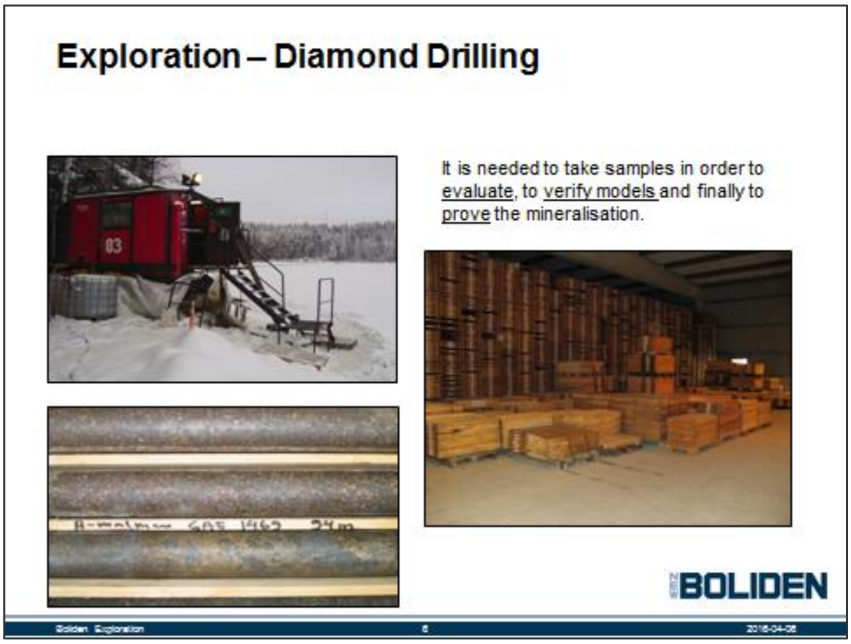

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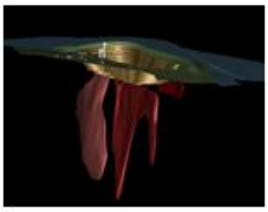
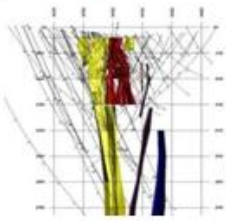
3D modeling and Ore Calculation





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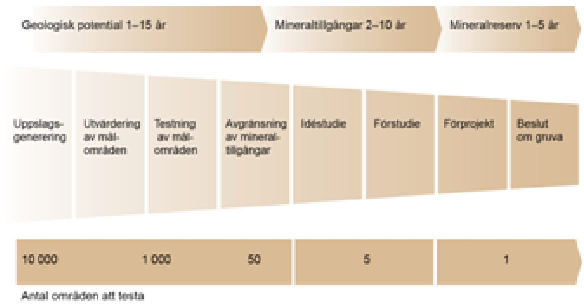
From Exploration to Mine

Statistically, only one object out of 10000 will become a mine. Evaluation is made after each project phase.



The objective is always to discover and develop mines.

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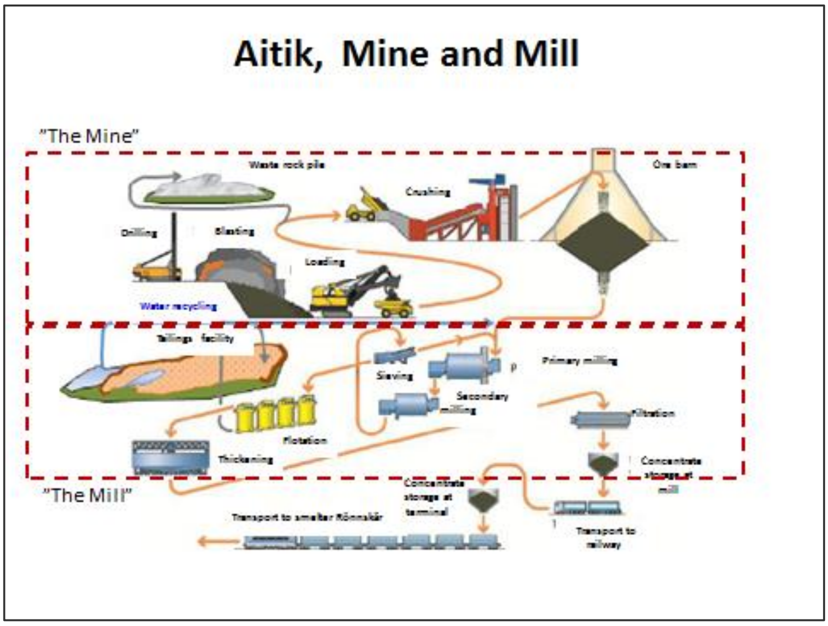

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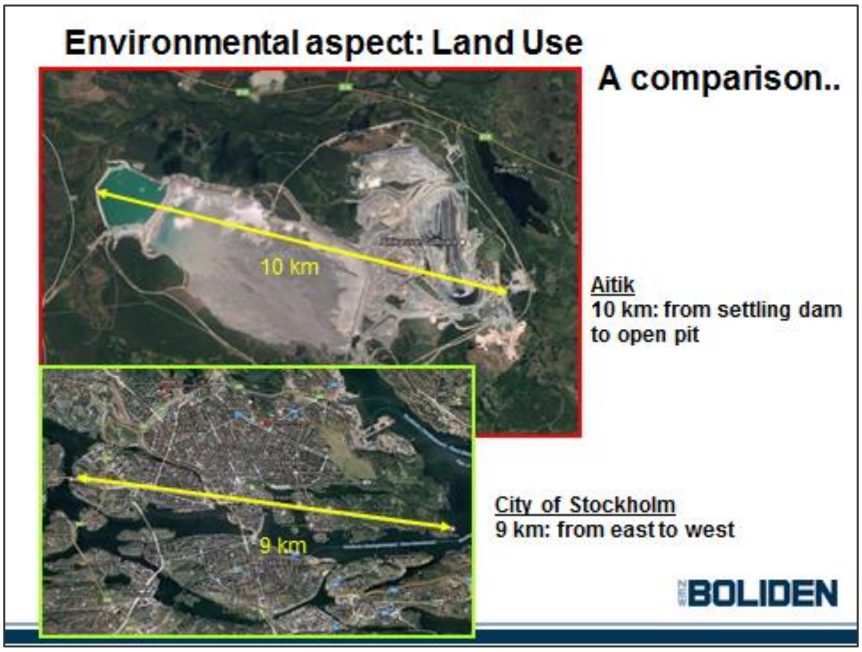

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Boliden Aitik Mine open pit (May 2014)

Drilling in Aitik

- Bore hole diameter is 300mm
- Depth: 5-10 m

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Blasting

Loading

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Excavator

Trucking

- Diesel consumption: 4 m3 per day.

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Aitik Mill Concentrator

How concentrators work

- Crushed ore arrives at concentrator
- The ore is ground to sand and concentrated in the concentrator by…
  1) Grinding
  2) Separation of the metal from the ore by flotation
  3) Dewatering and filtering
- Metal concentrates are shipped to smelters
- Sand is deposited in tailings ponds

20 May 2017 © 2017 Boliden Group BOLIDEN

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Inside the concentrator

Milling, 2 parallell lines, each 25 MWe

Crushed ore is milled to a particle size =< 500µm

Flotation

Flotation uses adsorption technique to concentrate the metal and to separate the *Value mineral* from the tailings (=waste).

Finally the concentrate is transported to the smelter in Skellefteåhamn

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Waste rock

Approx. 50 000 tons of ore is extracted every day.

The same amount of waste rock is also mined in order to access the Ore.

Waste rock does not contain enough valuable metals for being econimically bearable to extract.

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Tailings Facility in Aitik

- Covers 12 km^2 (1200 hectares).

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v

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eit RawMaterials
Connecting matters

CO_2 Aitik (Mine and Mill)

Direct and indirect Emissions of CO2

FOSSIL CO2 SOURCE	UNIT	AITIK MILL	AITIK MINE	AITIK
Gasoline	ton C02	2	-	2
Diesel	ton C02	151	76 259	76 410
Explosives	ton C02	-	380	380
Sum Direct Energy use	ton C02	153	76 639	76 792
Indirect CO2 emissions*	ton C02	8 541	919	9 460

* Purchased electricity** and heat
**) 12 g C02/kWh of electric power in Sweden

Water emissions 2015

- Nitrogen salt emissions (as N): 50480 kg
- Metal emissions*: 307 kg (plus 376 kg Sb)

*) As Cu+Pb+Zn+Hg+Cd+Ni+As
Sb: 376 kg: Since 2016 Antimon (Sb) is included in metal emissions summary.

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Summary of energy use in Aitik

Data to be recalculated to kWh / ton Cu

ENERGY CATEGORY	UNIT	AITIK MILL	AITIK MINE	AITIK
Direct Energy use	MWh	626	311 515	312 141
Purchased electricity	MWh	688 752	74 139	762 891
Purchased heat	MWh	2 441	2 200	4 641

Aitik Data

Key data Aitik	UNIT	Aitik MILL	Aitik MINE	Total Aitik
Gasoline / ton Cu	MJ/t Cu	0,5	0,0	0,5
Diesel /ton Cu	MJ/t Cu	33	16674	16707
Explosives/ton Cu	t/ton Cu	-	0,387	0,000
kWh/ton Cu				

Emissions	UNIT	Total Aitik	Emission kg /ton Cu
N-emissions to recipient	kg	50480	0,751
Metal emissions t recipient	kg	306,7	0,005
Sb to recipient	kg	375,7	0,006

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RawMaterials
Connecting matters

Rönnskär

- One of the world's largest electronic recycling units
- Copper, gold, silver, lead, sulphuric acid and zinc clinker
- Production – copper: 207 ktonnes
- Operating profit: SEK 852 m
- Employees: 775

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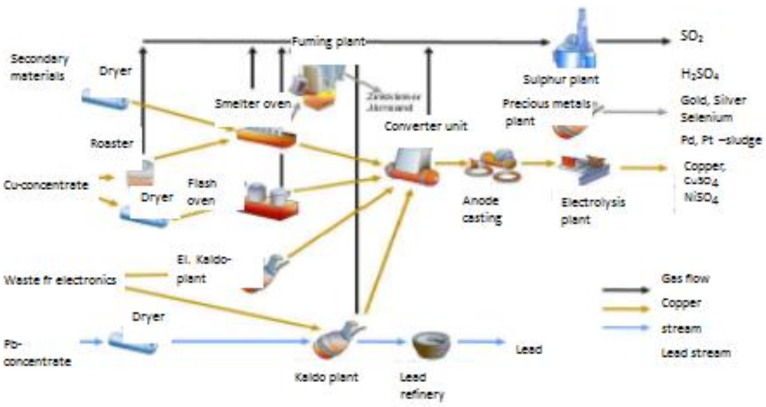
Smelter process Rönnskär



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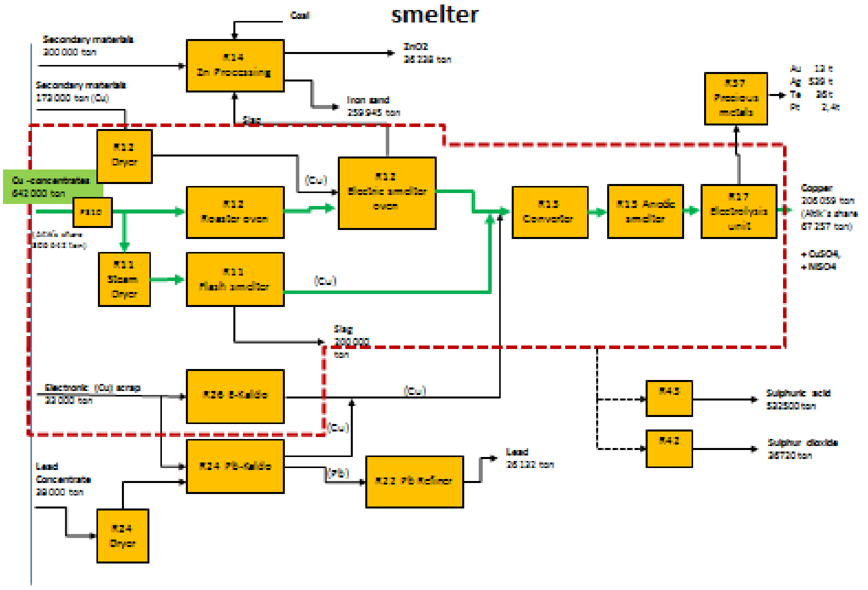
Block flow diagram for Aitik concentrate path through Rönnskär smelter



Rönnskär Energy consumption Cu -part

PRODUCTION		
Total Cu production (100%)	206 059 ton	100%
Aitik share of Cu production:	67259 ton	32,6%

Aitik share of Cu production			
El Power MWh/ton Cu	Fuel oil MWh/ton Cu	LPG MWh/ton Cu	Steam MWh/ton Cu
1,498	0,345	0,018	3,001
GJ/t Cu	GJ/t Cu	GJ/t Cu	GJ/t Cu
5,393	1,242	0,064	10,803

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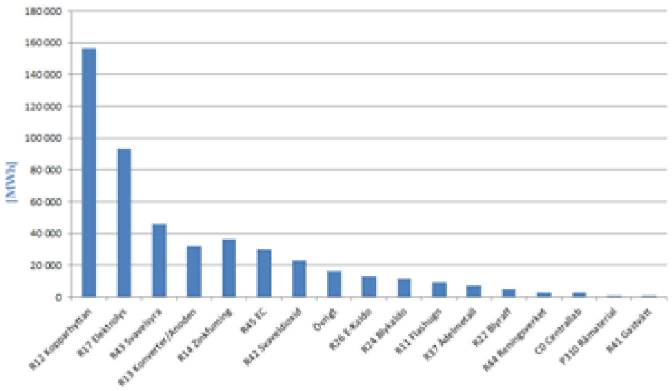
Rönnskär Smelter Emissions to Air and Water Aitik´s share

Component	Air emissions (kg)	Water Emissions (kg)
Metals (As,Cd, Cu, Hg, Ni, Pb, Zn)	3240	739
N-components (as N)	26030	--
SO2	981 180	--
CO2 (fossile origin)	91 920 400	
F		12400
NOx	85519	

Electric Power consumption



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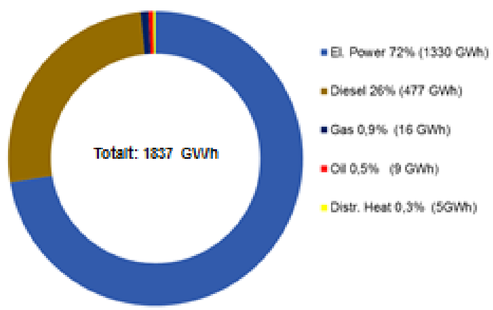
Energy consumption in Boliden Mines 2015

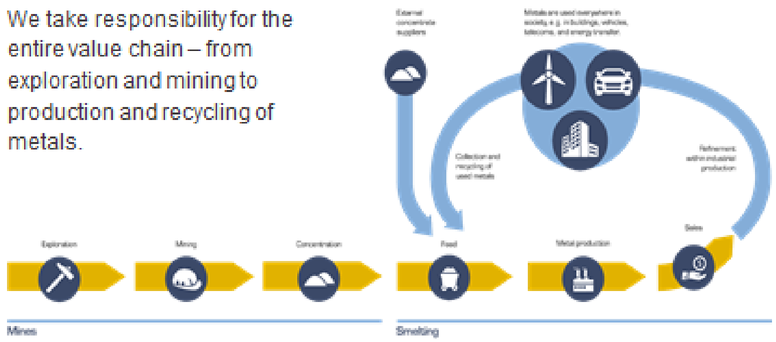
98% of the energy consumed is electric power and diesel fuel.



BOLIDEN

Our business model – part of a circular economy

We take responsibility for the entire value chain – from exploration and mining to production and recycling of metals.



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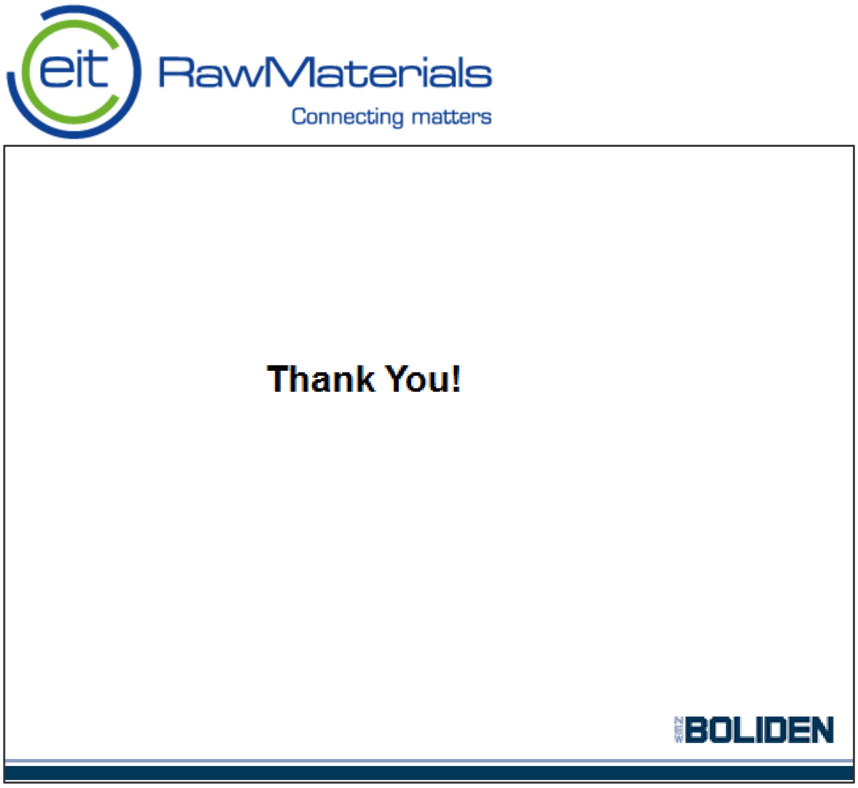

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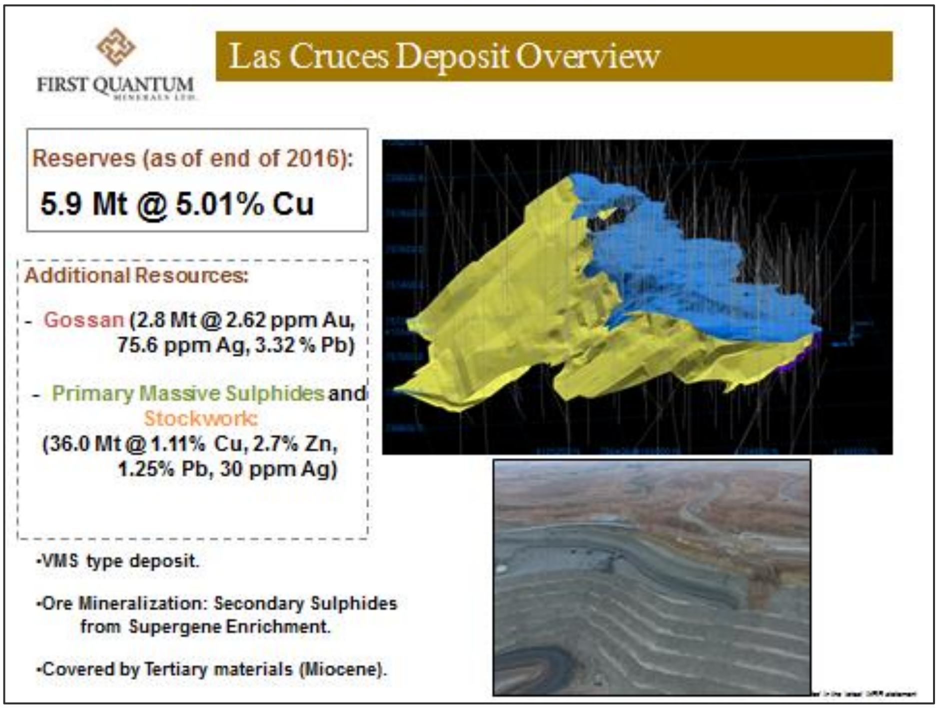

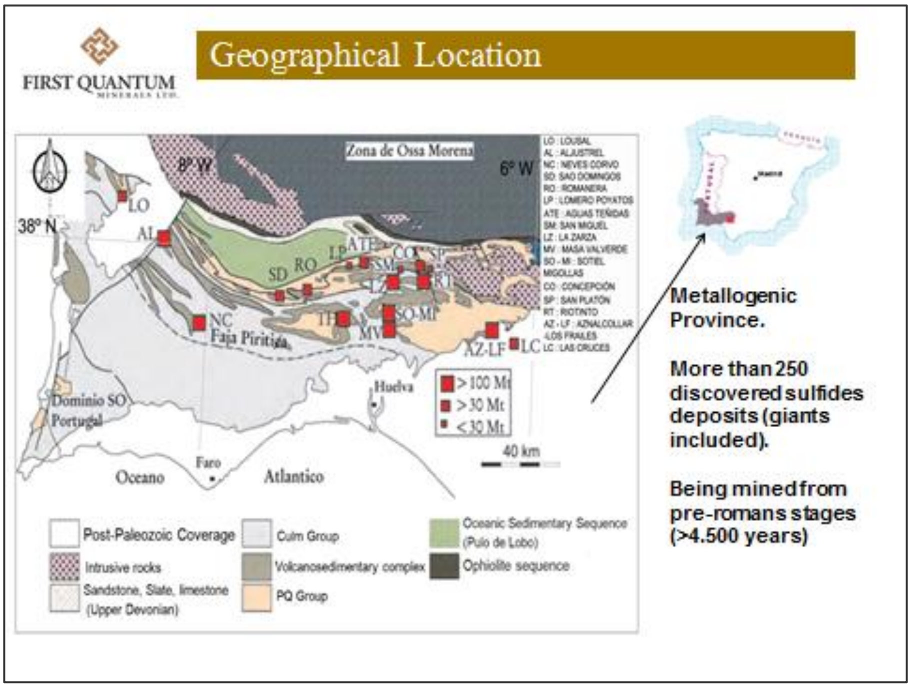

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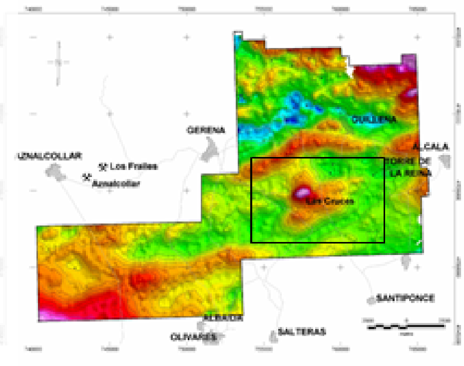
FIRST QUANTUM MINERALS LTD.

Cobre Las Cruces History

Las Cruces Timeline

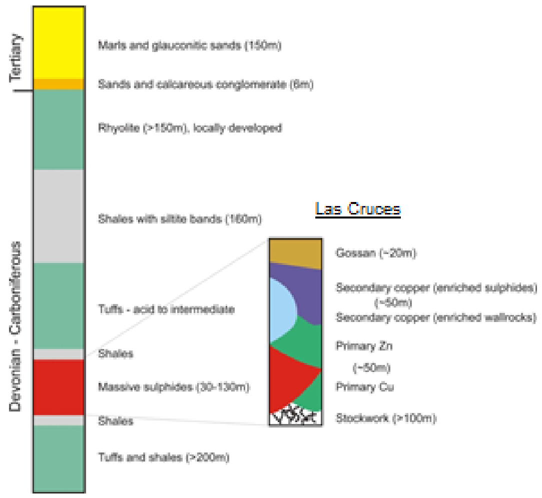
•Exploration commences	1992
•Deposit discovered	1994
•Feasibility study & EIA	1996-2000
•Permit, land acquisition, funding	2001-2005
•INMET 70% acquisition	2005
•Construction	2006-2008
•Initial Production	June 2009
•INMET 100% acquisition	Nov 2010
•FQM 100% acquisition	**Mar 2013**

Residual Gravimetry



FIRST QUANTUM MINERALS LTD.

Geological Profile



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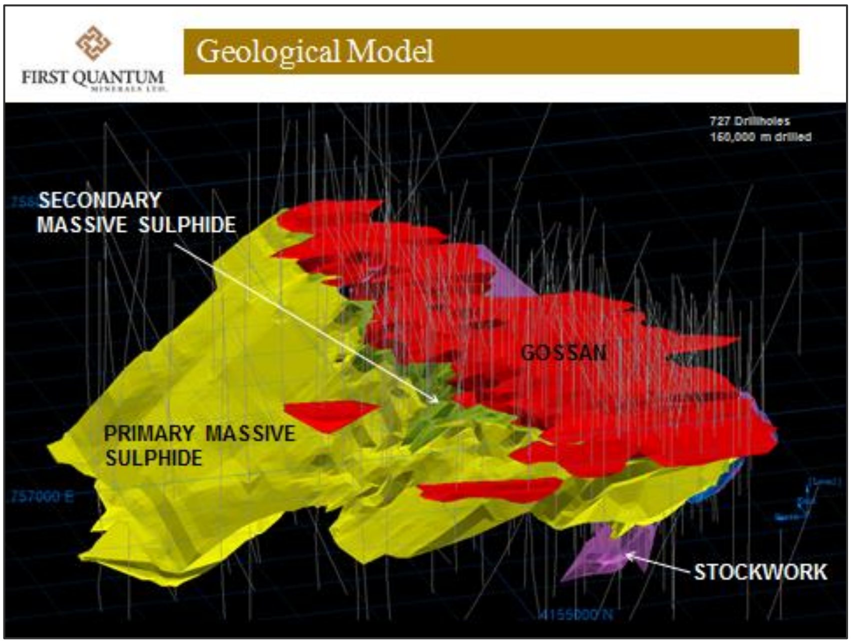

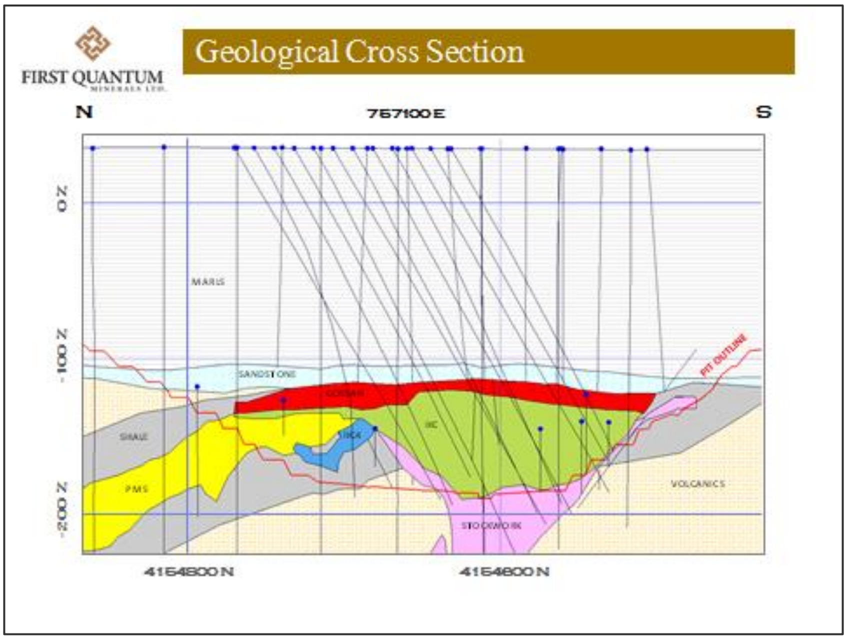

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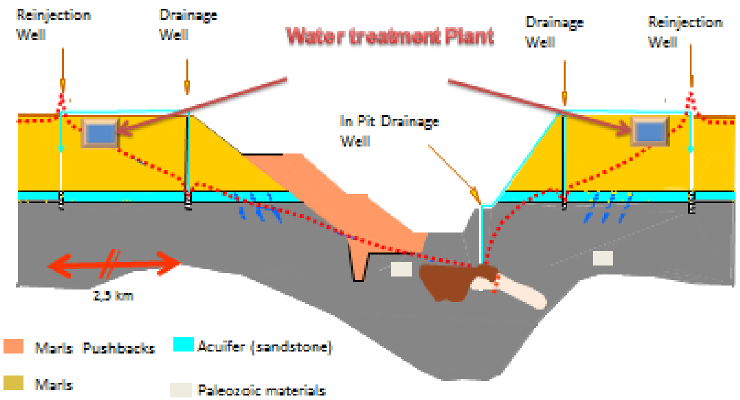
Water Management

Water Management

Reinjection – Drainage System (SDR)



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Hydrometallurgical Plant

Hydrometallurgical Plant

- Atmospheric leach of secondary Cu minerals
- Annual production capacity → 72,000 t of Cu cathode
- Cathode quality ±95% of cathode > 99.999% Cu
- Expected mine life → 2022

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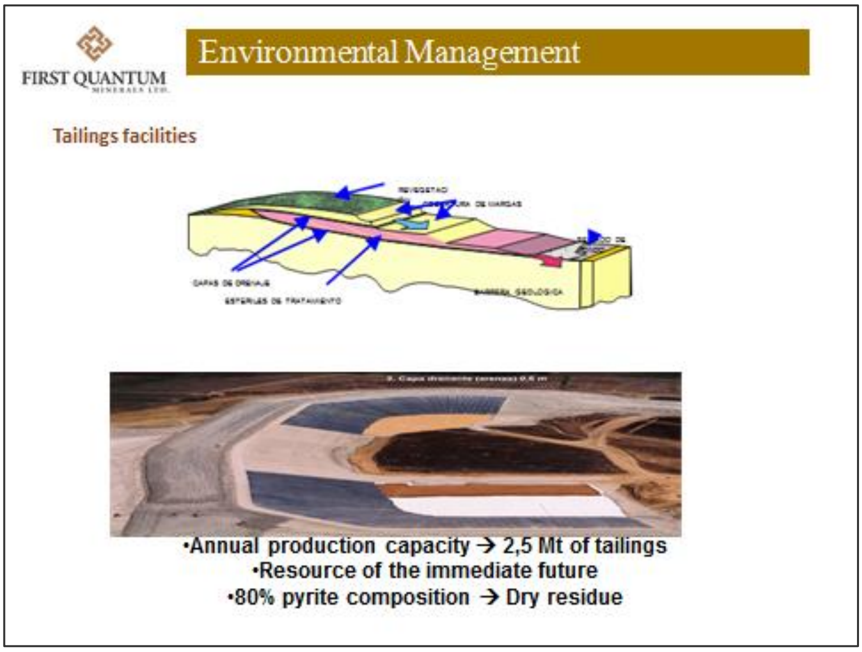

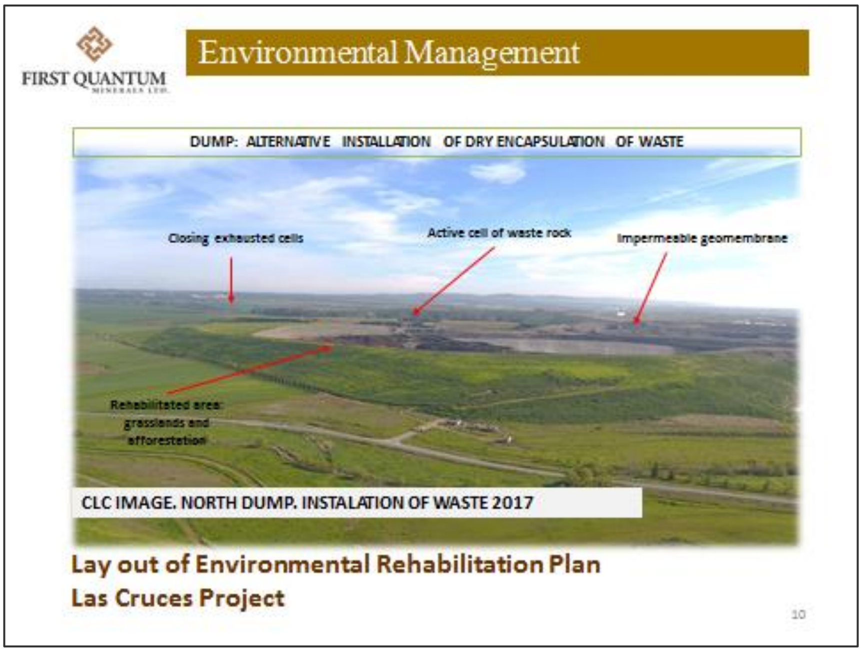

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euromines

When is rock a natural resource? Economics of the mining industry

SUPRIM Information Sessions
Johannes Drielsma – Deputy Director
7 December 2017

OUTLINE

euromines

Health Warning: no single minerals economy – all variations exist

- Recommended References
- Minerals Demand
- Minerals Supply
- Conclusions

European Association of Mining Industries, Metal Ores & Industrial Minerals   www.euromines.org   2

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

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MINERAL DEMAND

euromines

- Demand mostly driven by demand for finished products
  - Typically most volatile segments of overall expenditure
  - Income elastic: demand more volatile than economic activity
  - Volatile prices are a fact of life: hard for policy to influence
- In turn, demand responds to relative prices
  - Big shifts in relative prices trigger process/technology changes
  - Changes in relative prices often drive irreversible substitution
  - Technological change is almost impossible to predict/prevent
- Once the basics are in place, demand per capita eases
  - Emerging economies will not follow the old path that we did

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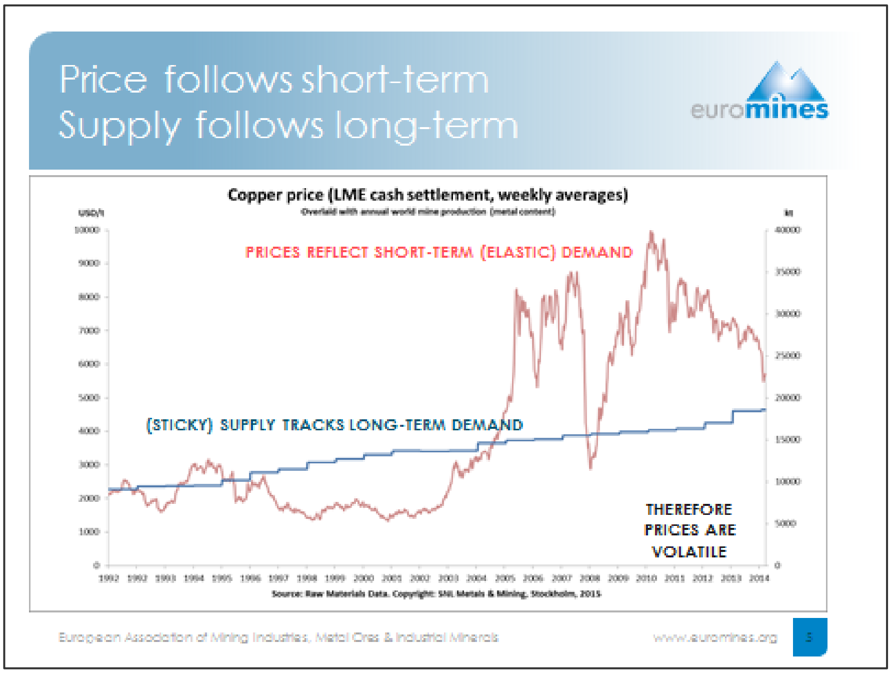

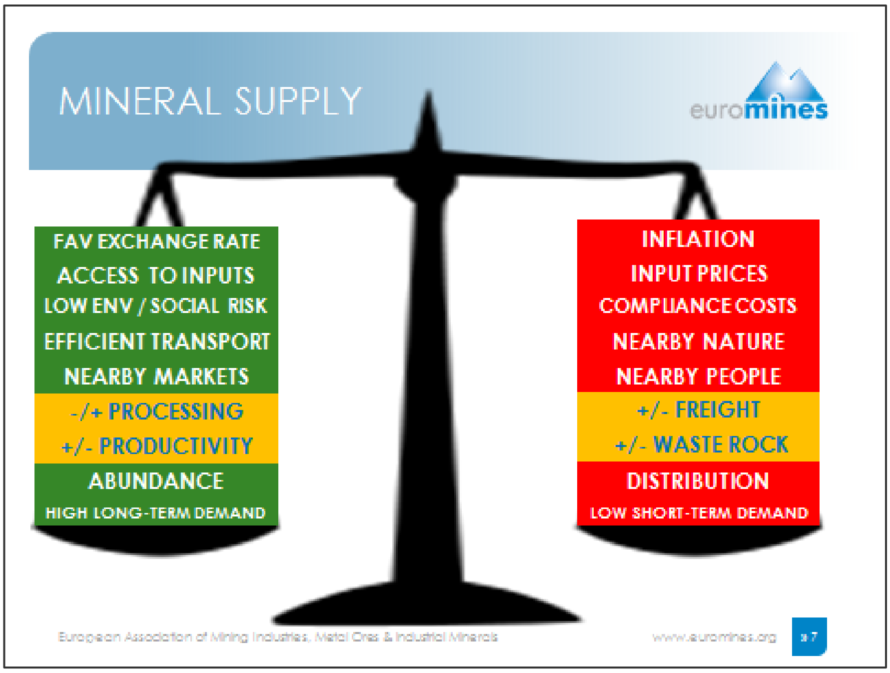

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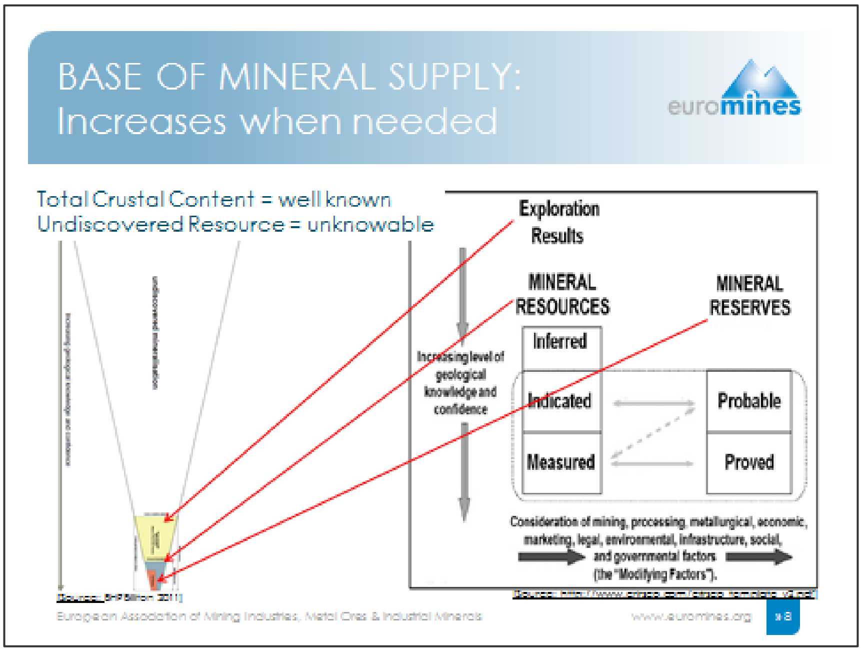

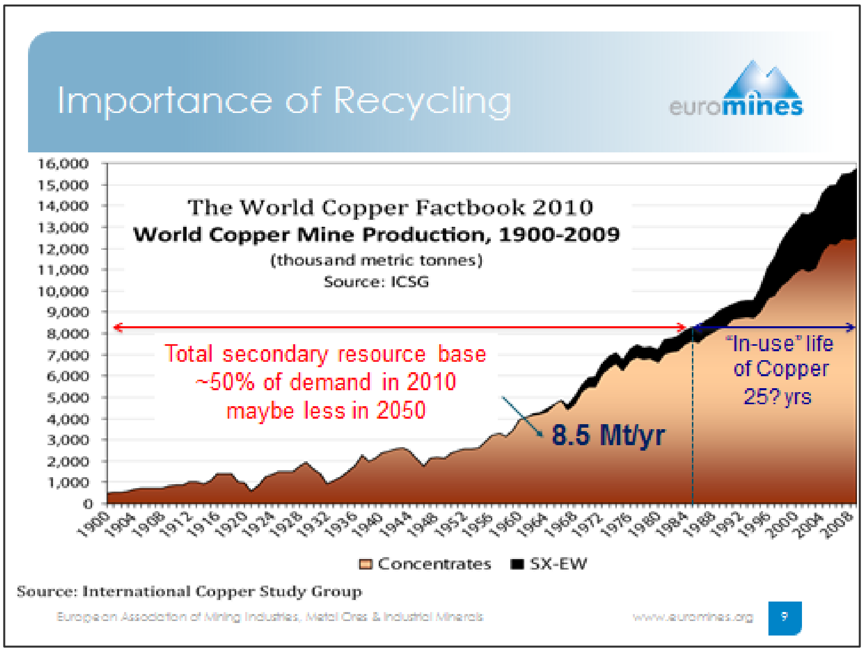

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Assumptions, parameters and baselines

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- Without DEMAND, ores do not exist – only rocks
  - When DEMAND shifts, rocks become ores & ores become rocks
- SUPPLY requires finding mineable deposits through exploration
  - Political change opens & closes opportunities for minerals exploration
  - Guaranteed property rights that can be legally enforced are essential
- Efficient SUPPLY depends on neutral social and political conditions
  - If conditions change, sunk capital cannot be transferred
  - Economically sensible as far as possible to avoid sterilising resources
- Resources are of little or no value to anyone if left underground
  - In future, they can be a treasure chest or just a lost opportunity

European Association of Mining Industries, Metal Ores & Industrial Minerals   www.euromines.org

5. Annex 2 – Slides from Day 2

SUPRIM WORKSHOP LEIDEN DECEMBER 8 2017

Coordinator: Prof. Jo Dewulf, Ghent University, Belgium

UNIVERSITEIT GENT

SUPRIM: PROJECT HISTORY:

- Bringing LCA and raw materials specialists together (1st time)
- Proposal submitted for EIT Raw Materials KAVA call, approved on 1/9/2016
- Start was April 2017, end at end of 2019
- Considered as strategically important for the raw materials sector
  → will be followed closely by EIT Raw Materials

SUPRIM: PROJECT WORK PACKAGES

- WP0: Feasibility study: SoA and value proposition/business model (UGent)
- WP1: Project management (UGent)
- WP2: Depletion model (Leiden)
- WP3: Data inventory (Lulea)
- WP4: Dissemination (Euromines)

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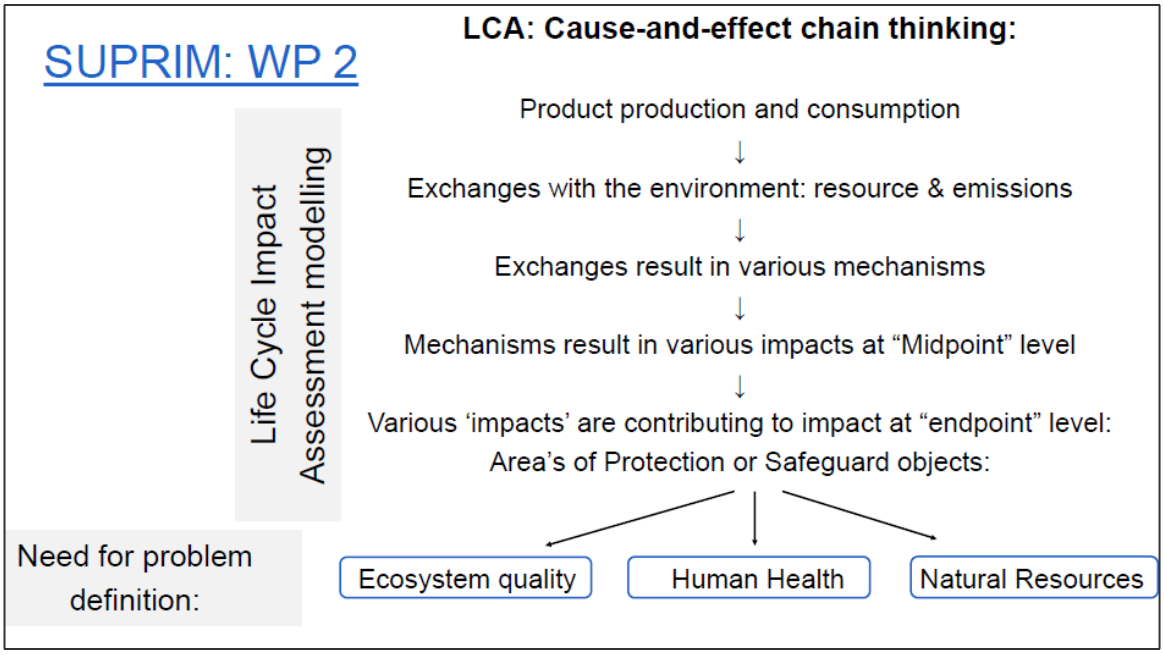

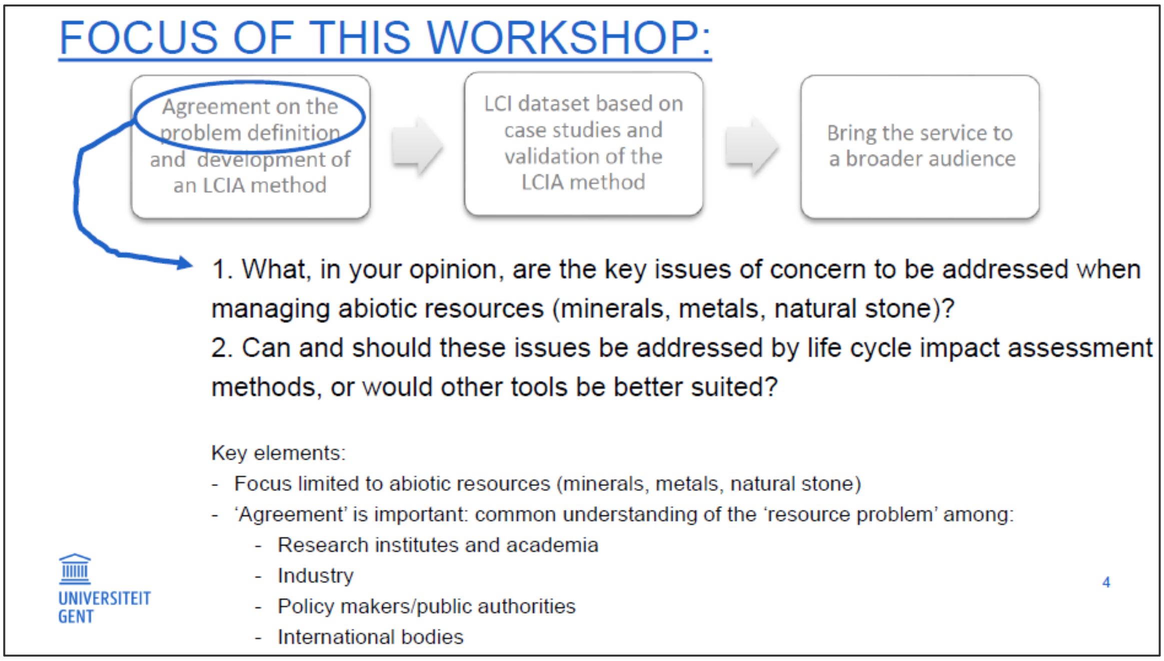

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AGENDA OF TODAY:

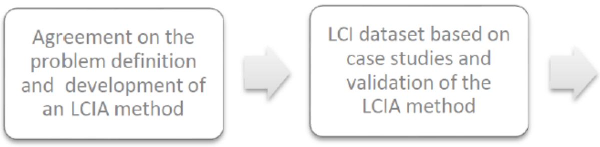
Morning:

- Need to understand how the raw materials sector work
  for LCA experts: **Johannes**
- Presentation of discussion paper: **Rita**
- Comments by institutes on the discussion paper:
  - Public authority: EC-JRC: **Gian Andrea**
  - International organisation: UNEP-SETAC: **Markus/Thomas**
  - Industry: Primary Metals: **Ilse**

Afternoon: in hands of **Andrea and Ester:**

- Further discussion of the paper with all participants
- Can we find a common understanding of the problem/on what to be protected?

PROJECT PROPOSAL OBJECTIVES ON RESOURCES:



1. **Develop a Life Cycle Impact Assessment (LCIA) method to address resource availability ('depletion') in sustainability assessment** - lead to a consensus regarding the problem definition related to resource availability ('depletion') in life cycle assessment.
2. **Develop a Life Cycle Inventory (LCI) dataset through case studies in collaboration with the industrial partners from the mining sector –** to validate LCIA in the sustainable primary production sector with best quality data available
3. **Bring the service to a broader audience –** E.g. the mining sector, policy makers, KIC partners, academic community and LCA community (Development of business model)

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NEXT STEPS:

- Acquiring additional comments on our paper (mainly from industry)
- Processing all insights to define 'the problem' with resources:
  - Meeting in February with SUPRIM partners
  - Second workshop in Spring to conclude 'the problem'
- Next steps later in 2018:
  - Developing a model to characterize the problem
  - Testing the model
- Dissemination of the model, mainly 2019

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Metal and Mineral Resources in LCIA: What's the problem?

Rita Schulze, Jeroen Guinée

Department of Industrial Ecology
Institute of Environmental Sciences
Universiteit Leiden
The Netherlands

Overview

1. Subject of discussion
   → What is the problem with resource use?
2. Suggested framework for discussion
   → How do we best discuss this question?
3. Role of LCA in the context of abiotic resources
   → Which of those problems are relevant to LCA?

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1. Subject of discussion

Key questions for this workshop

- What, in your opinion, are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)?
- Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited?

1. Subject of discussion – 2. Suggested framework for discussion – 3. Role of LCA in the context of abiotic resources

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1. Subject of discussion

Key issues

- What exactly are we talking about (role of resources)?
- What is the goal/ scope?
- What is the problem (impact)?

1. Subject of discussion – 2. Suggested framework for discussion – 3. Role of LCA in the context of abiotic resources

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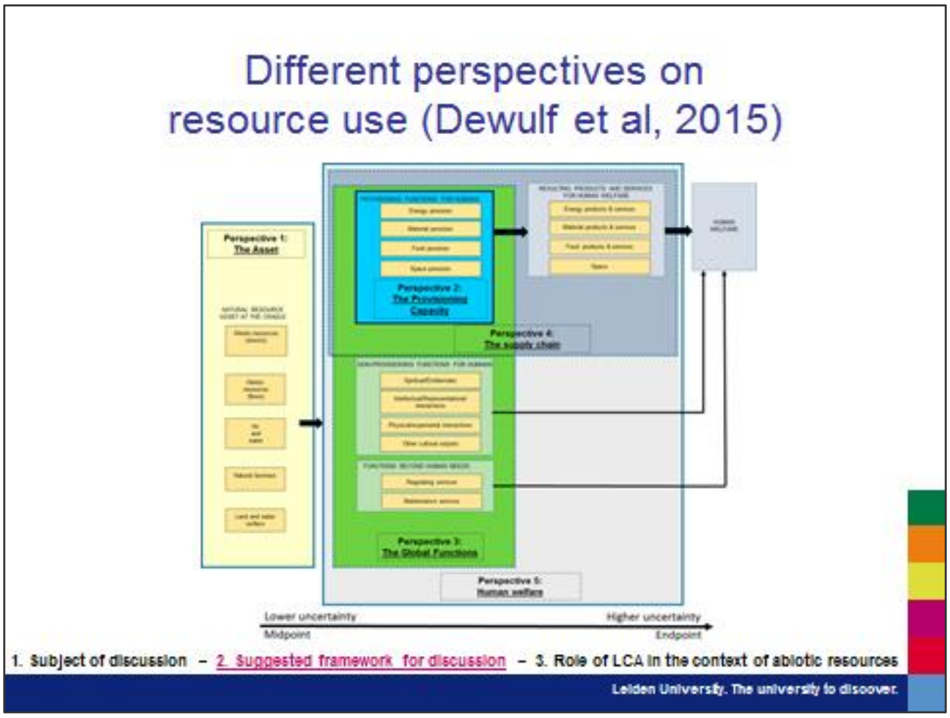

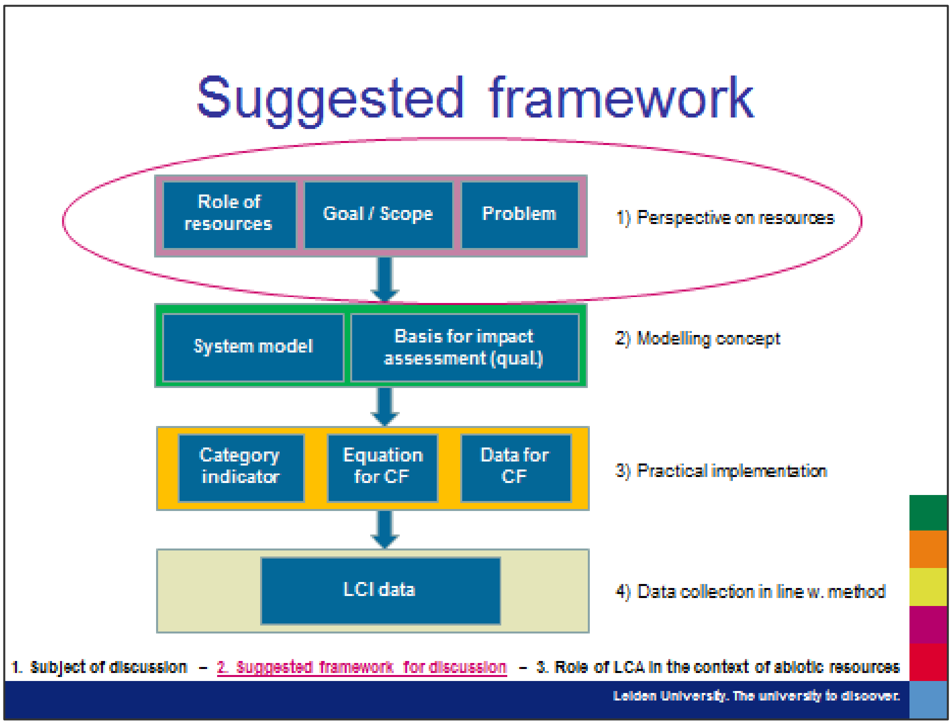

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Which aspects of abiotic resource use are we concerned with? Role of resources

- ...is defined in relation to

Who is interested ?

  - the **stakeholder** interested in/ benefiting from the resources (humans, nature, or the resource itself)

Where are the resources valued ?

  - **system (area) of concern**, in which the resources are valued (nature, technosphere, or both)

Where are they sourced from?

  - the relevant resource **production system (origin)** (primary, or primary *and* secondary production)

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Role of resources - applying the criteria

A. abiotic resources are valued by **humans** for their functions used (by humans) **in the technosphere**, **primary production only** — e.g. depletion

B. abiotic resources are valued by **humans** for their functions used (by humans) **in the technosphere**, **primary and secondary production** — e.g. dissipation

C. abiotic resources are valued by **humans** for their in-situ functions **in the environment**, **primary production only** — ecosystem services (non-provisioning)

D. abiotic resources are valued by **humans** for their functions in the **technosphere** and their in-situ functions **in the environment** considered useful to humans, **primary production only** — Combined view

E. abiotic **resources** are valued for their own sake **in the environment**, regardless of their usefulness in nature or technosphere, **primary production only** — Intrinsic value

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Role of resources – possible combinations

Combination	Stakeholder *Who is interested?*	System of Concern *System where they are valued*	Production system *Source for production*	Perspective types, based on role of resources
1	Human	Environment	Primary	D*
2	Human	Technosphere	Primary	A*
3	Human	Environment & Technosphere	Primary	C*
~~4~~	~~Human~~	~~Environment~~	~~Primary & Secondary~~	~~F*~~
5	Human	Technosphere	Primary & Secondary	B*
6	Human	Environment & Technosphere	Primary & Secondary	G*
7	Resource	Environment	Primary	E*
8	Resource	Technosphere	Primary	H*
9	Resource	Environment & Technosphere	Primary	I*
10	Resource	Environment	Primary & Secondary	J*
11	Resource	Technosphere	Primary & Secondary	E*
12	Resource	Environment & Technosphere	Primary & Secondary	L*
13	Nature	Environment	Primary	M*
14	Nature	Technosphere	Primary	N*
15	Nature	Environment & Technosphere	Primary	O*
16	Nature	Environment	Primary & Secondary	P*
17	Nature	Technosphere	Primary & Secondary	Q*
18	Nature	Environment & Technosphere	Primary & Secondary	R*

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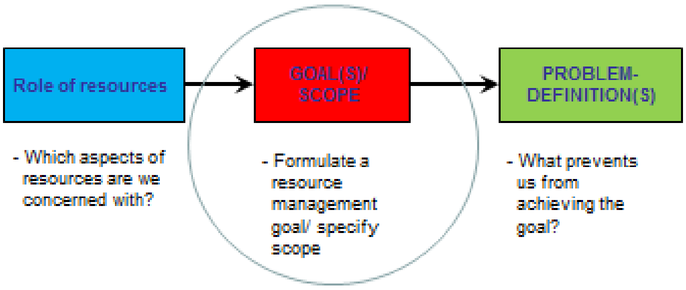
The perspective (top level)



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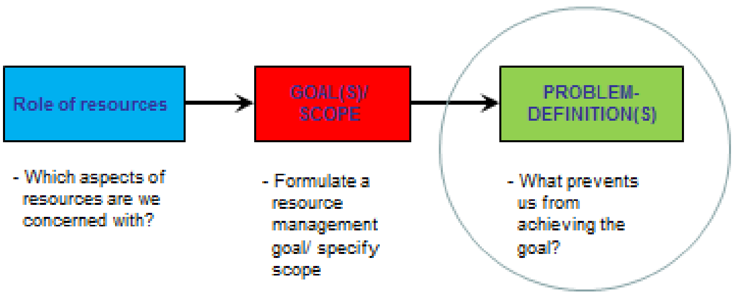
Definition of goal/ scope

- goal builds on role of resources, but is more specific.
  - Example: Perspective A (What is the goal here?)
- to be defined in scope
  - time frame (next 20, 100, 500 years, etc.)
  - geographical scope (global, Europe, etc.)
  - types of resources assessed (e.g. elements, minerals and/ or natural stone/ only currently used elements or all…etc.)
- Which value perspective is relevant to the goal? (see next slide)

The perspective (top level)



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Discussions around resource use – LCA community

"ISO 14042 requests that assigning an emission or resource to an impact category is made on scientific grounds, but the assignment is nevertheless to a large extent a value-laden choice."(Steen 1999)

"From a functional point of view the interest of mankind for abiotic resources is not the resource itself (intrinsic value) but the potential it has to fulfil functions for mankind. The depletion of resources can be defined as follows: Abiotic resource depletion is the decrease of availability of the total reserve of potential functions of resources." (Van Oers et al 2002)

"Whether the resources are extracted from the geologic or the anthropogenic stock is of no concern for society with regard to the provision of the desired function; rather, the loss of a resources' functionality needs to be considered." (Schneider 2015).

"(economic) burden that current resource extraction puts on future situations " (Viera et al 2016)

"From this, it can be deduced that resource extraction is not decisive in the material use of resources, but rather the amount of dissipatively, i.e. irrevocably, extracted and processed resources that are lost and no longer available for future use." (Frischknecht 2014)

- "theoretical energetic usefulness" of mineral resources (Bösch et al. 2006 (CExD)

("limited rate for replenishment" (Frischknecht 2013).

"Therefore, there are indications that the ore grade is of more immediate concern than the abundance of the metal in terms of mass "(Swart and Dewulf, (2013))

1. Subject of discussion – 2. Suggested framework for discussion – 3. Role of LCA in the context of abiotic resources

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Adopting a certain perspective, goal and scope, what is the problem (impact) related to the use of resources?

- use of resource in product system implies that the resource is not available for **something else** (opportunity cost)
- temporary or permanent loss (depending on problem definition)

current state → impact related to resource use → less desirable state

- How do we define this state??

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Starting points for the "problem discussion"

The problems could concern…

- **an absolute loss in availability of the resources**…
  - of potential /currently used functions, or the resource itself
  - related to physical stocks, defined through
    - presence in production system (where resources are sourced)
    - presence of useful properties (e.g. exergy, concentration of target metal in ore)
- a **change in accessibility of the resource**
  - measured through changes in flow properties – physical or other

1. Subject of discussion – 2. Suggested framework for discussion – 3. Role of LCA in the context of abiotic resources

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Summary – Suggested criteria for discussion on perspectives

ROLE of RESOURCES → GOAL/ SCOPE → PROBLEM-DEFINITION(S)

ROLE of RESOURCES

- What are we concerned with – resources in nature, or in the technosphere? ***system of concern***
- Who is interested in/ benefits from the resources? ***stakeholder***
- Do we consider primary or secondary production, or both? ***production system***

GOAL/ SCOPE

- Can you formulate a specific resource management goal?
- What is the relevant ***scope*** associated with this goal?
  - ***time perspective***
  - ***geographical scope***
  - ***scope of resource types*** *(elements, minerals, natural materials …)*
- Which ***value perspective*** is relevant to your goal (intrinsic or instrumental value)

PROBLEM-DEFINITION(S)

- Can you name the specific changes/ interventions which prevent us from reaching the goal you specified?
- Are those changes related to ***stocks or flows*** of resources, to the ***availability/ accessibility***, or certain ***properties*** of resources?

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3.Role of LCA in assessing the impact of using abiotic resources

What issues are typically of concern in LCA?

- AoPs: natural environment, human health, and natural resources
- Alternative categorization (Udo de Haes et al., 1999): natural environment, human health, natural resources *and* the man-made environment
- Discuss – which AoP are relevant to SUPRIM?

Perspective Type	Description – role of resources	AoP in Dewulf et al. (2015)	Alternative AoP (Udo de Haes, 1999)
A	Abiotic resources valued by humans for their functions in the technosphere. Focus is on primary production.	Natural resources (instrumental provisioning value)	Man-made environment
B	Abiotic resources valued by humans for their functions in the technosphere. Primary and secondary production.	Natural resources (part of supply chain perspective)	Man-made environment
C	abiotic resources are valued by humans for their in-situ functions in the environment, primary production only	Natural resources (part of global functions perspective)	Natural environment
E	Natural resources valued for themselves in their natural environment. Focus on primary production.	not represented. All perspectives are concerned with human welfare (stakeholder = humans)	Natural resources

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Role of LCA in assessing the impact of using of abiotic resources

Which flows are typically characterized in (env.) LCA?

- LCI flows from nature to technosphere (primary extraction) for resource availability/ accessibility
- flows from technosphere to nature (emissions) for impacts concerning human or environmental health
- flows generally represent physical movement of mass (exception: LUC)
- flows within the technosphere are not currently characterized

How does LCA consider positive and negative impacts?

- positive impacts which the consumer experiences from owning/ using a product or service are captured by the functional unit
- negative impacts/ externalities (on environment, human health and natural resources) are captured in (environmental) life cycle impact assessment
- positive impacts don't currently play a role in environmental LCIA, but play a role in S-LCA and LCSA (see e.g. Udo de Haes et al., 1999, Sala et al. 2013, Neugebauer et al. 2016)

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The European Commission's science and knowledge service

Joint Research Centre

Contribution from JRC activities on CRMs and LCA

Authors: *JRC Units D1 and D3*
Presenter: *Gian Andrea Blengini (JRC.D3)*

Workshop Metal and Mineral Resources in LCIA:
"What's the problem"?
SUPRIM workshop
December 8th, 2017
Leiden, NL

European Commission

DG JRC's Vision:

"To play a central role in creating, managing and making sense of the collective scientific knowledge for better EU policy."

DG JRC's Mission:

"As the science and knowledge service of the Commission our mission is to support EU policies with independent evidence throughout the whole policy cycle."

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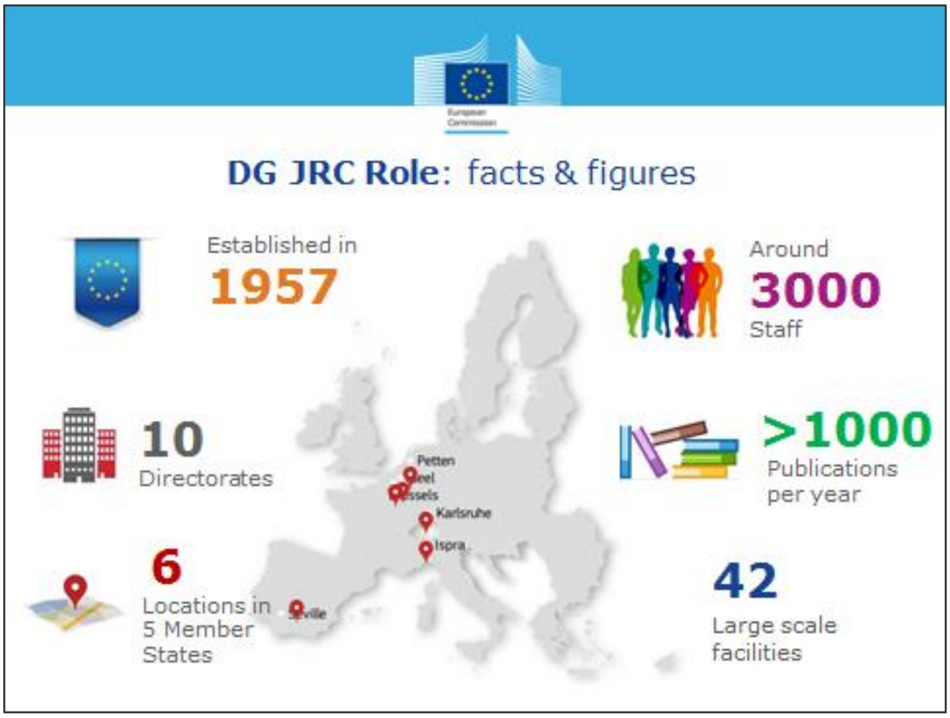

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Questions to the workshops participants:

1. What, in your opinion, are the **key issues of concern** to be addressed when managing **abiotic resources**? **(Q1)**
2. Can and should these issues be addressed by **life cycle impact assessment** methods, or would **other tools be better suited**? **(Q2)**

JRC.D3:
→RMIS/CRMs

Critical Raw Materials

→ **what are CRMs** **(Q1)**

→ **role of JRC**

→ **can criticality inform LCA?** **(Q2)**

→ **can LCA inform criticality?** **(Q2)**

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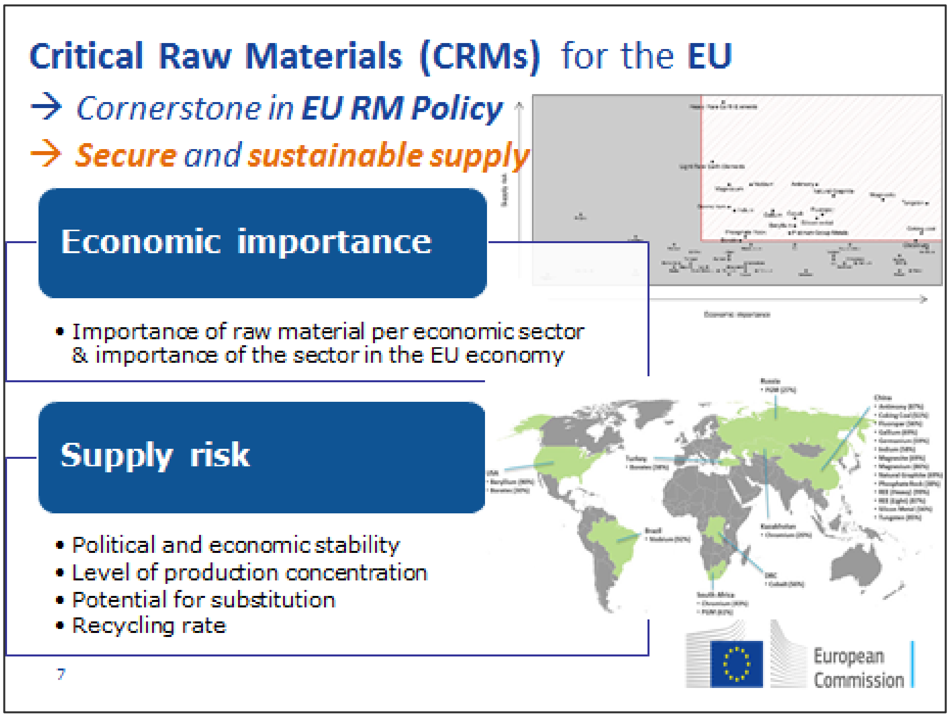

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Revised methodology (Approach)

→ Ensure highest possible level of **comparability** with the 2010 and 2014 lists

→ Intense and **active dialogue with stakeholders** since an early-stage in the revision

→ **Non-forward looking approach** in the assessment, i.e. criticality as a "*snapshot in time*"

→ Best quality data / **average of last 5 years**

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Focus on:
Supply Risk

JRC started from TERP Concept…

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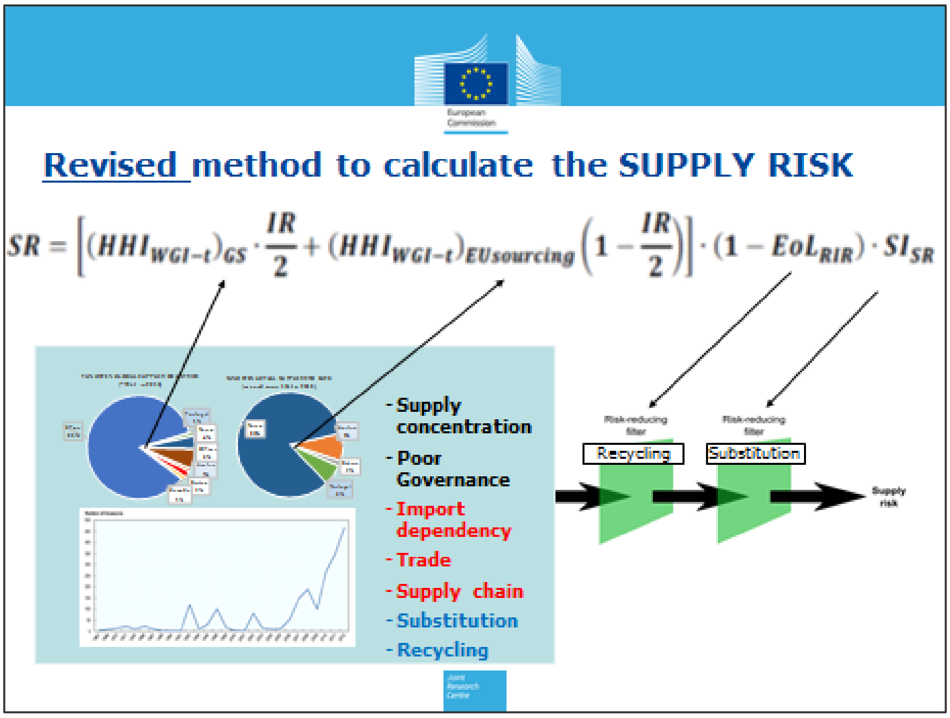

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EU critical raw materials — 2017 criticality assessment

European Commission

Individual abiotic materials		
Aggregates	Hafnium	Rhenium
Aluminium	Helium	Scandium
Antimony	Indium	Selenium
Baryte	Iron Ore	Sulphur
Bauxite	Lead	Potash
Bentonite	Limestone	Silica Sand
Beryllium	Gold	Silicon Metal
Bismuth	Gypsum	Silver
Boron (Borates)	Lithium	Talc
Chromium	Magnesite	Tantalum
Kaolin clay	Magnesium	Tellurium
Cobalt	Manganese	Tin
Coking coal	Molybdenum	Titanium
Copper	Natural Graphite	Tungsten
Diatomite	Nickel	Vanadium
Feldspar	Niobium	Zinc
Fluorspar	Perlite	
Gallium	Phosphorus	
Germanium	Phosphate rock	
Platinum group metals (PGMs)		
Iridium	Platinum	Ruthenium
Palladium	Rhodium	
Rare earth elements (REEs)		
Light rare earth elements (LREEs)	Heavy rare earth elements (HREEs)	
Cerium	Dysprosium	Lutetium
Lanthanum	Erbium	Terbium
Neodymium	Europium	Thulium
Praseodymium	Gadolinium	Ytterbium
Samarium	Holmium	Yttrium
Biotic materials		
Natural Rubber	Natural cork	
Sapele wood	Natural Teak wood	

Study on the review of the list of critical raw materials 2017 (published in September 2017)

78 raw materials under evaluation
(58 individual + 3 grouped materials: HREEs, LREEs and PGMs)

both BIOTIC and ABIOTIC included

Legend:	
Green boxes =	Materials covered in 2014 but not in the 2011 assessments
Orange boxes =	New materials covered in the 2017 assessment

GROW

EU critical raw materials — 2017 list of CRMs for the EU

European Commission

Commission's Communication on the 2017 list of Critical Raw Materials for the EU, COM(2017)490, 13 September 2017

2017 CRMs (27)			
Antimony	Fluorspar	LREEs	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural Rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs	PGMs	Vanadium
Coking coal	Indium	Phosphate rock	

*HREEs=heavy rare earth elements, LREEs=light rare earth elements, PGMs=platinum group metals

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EU critical raw materials

2017 list of CRMs for the EU

Remarks from Criticality:

Why future generations only?
→ *Current generation + short term*

Criticality is different for EU, Japan, US, China...
→ **Criticality in EU is centered on consumption of EU industry**

Primary and Recycled (SRMs) provide the same function
→ **import of final products considered for SRMs**

Large number of candidate RMs (78)
→ **27 CRMs in 2017**
→ **Large number of Criticality parameters (available for 78 RMs)**

Environment / Sustainability not explicitly in the EU list of CRMs
→ **LCA not in the EU list of CRMs (but e.g. in US...?)**

Extraction not in the EU list of CRMs
→ **reserves disregarded?**

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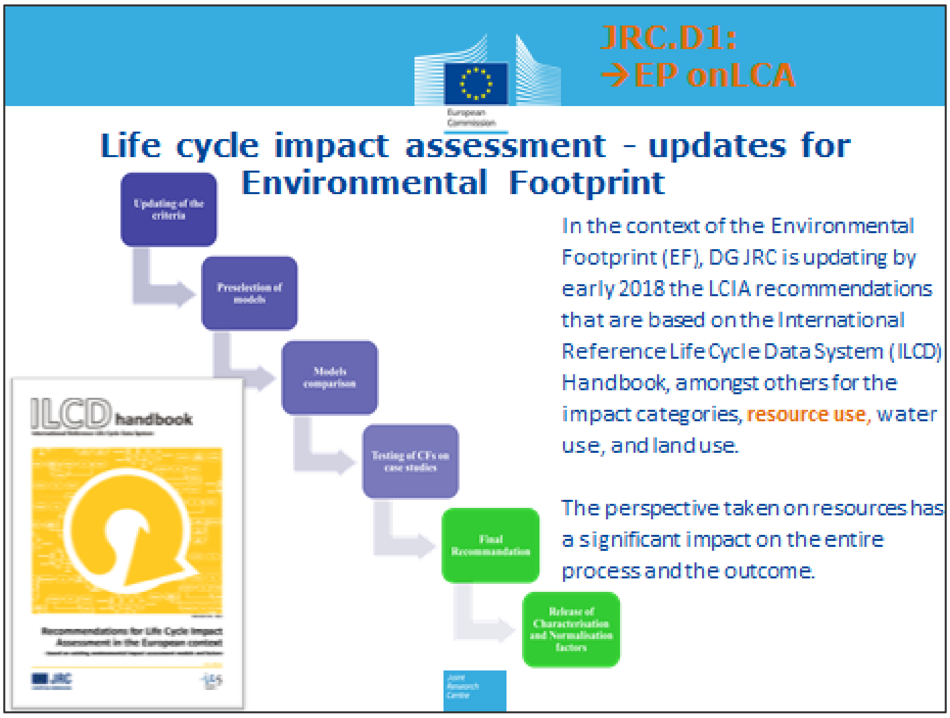

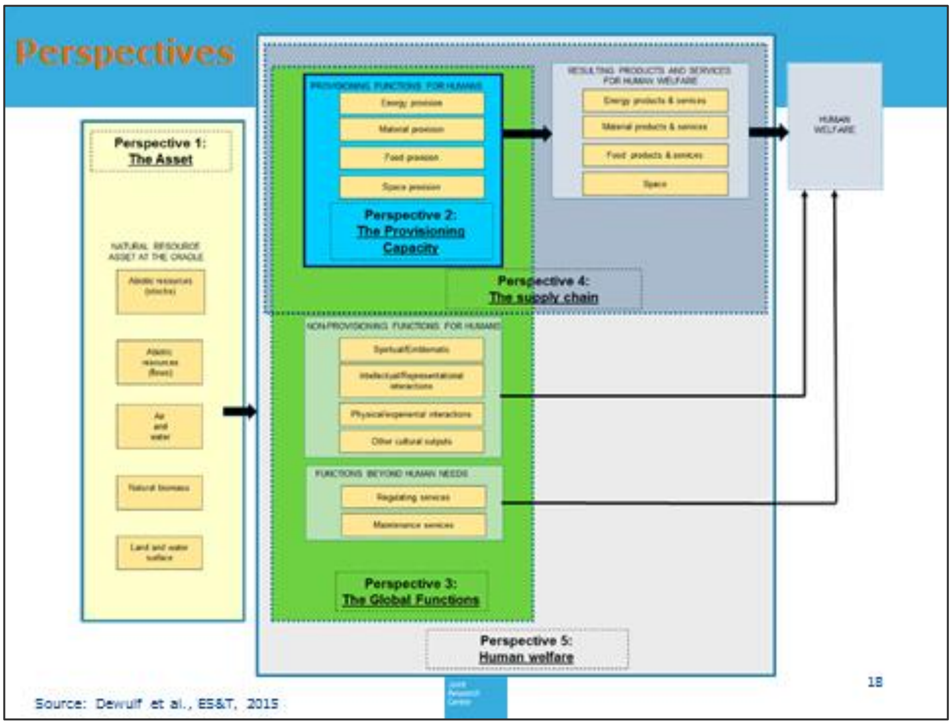

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Reasoning on perspectives for the EF

- **Perspectives 4** and **5** have a clear socio-economic scope
- **Perspective 3** would be the most favorable one, because it refers to the global functions of (abiotic and biotic) natural resources (including the provisioning function). However, none of the models currently available for use in LCA is able to fully cover this perspective.
- **Perspective 2** is chosen as the reference one, because it partially covers the scope of perspective 3.
- Looking at the available methods for covering perspective 2, it became necessary to revert in parts to methods between **perspective 1** and **perspective 2** (e.g. for biotic resources)

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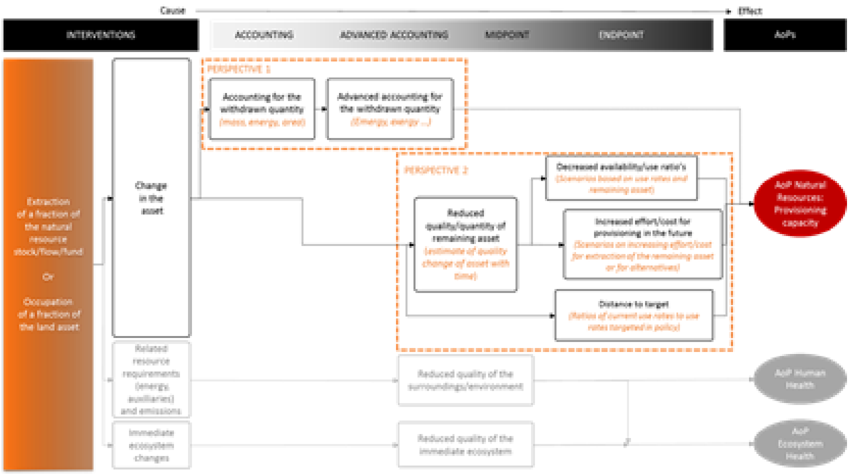
JRC.D1:
→EP onLCA

Impact pathway, referred to the perspective chosen



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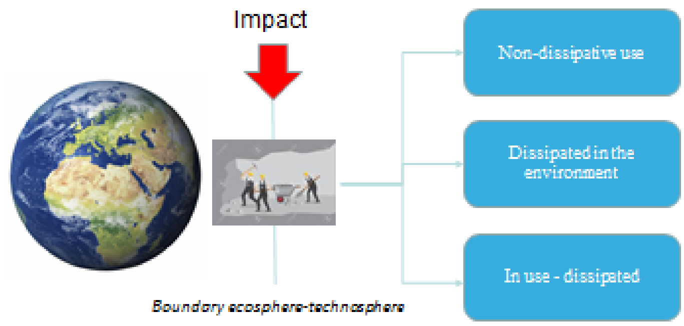
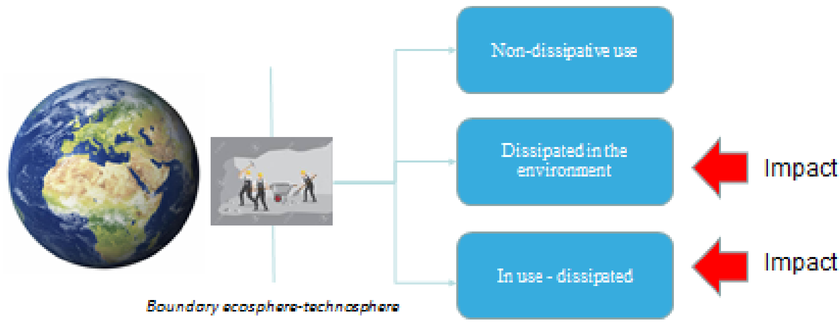
JRC is further exploring resource assessment in LCA – from depletion to dissipation - I



JRC is further exploring resource assessment in LCA – from depletion to dissipation - II



Looking at the interface between nature (litosphere) and technosphere is not enough to identify where dissipation of resources takes place.

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RawMaterials
Connecting matters

1. What, in your opinion, are the **key issues of concern** to be addressed when managing abiotic resources?

- **Anthropocentric view:** The issue of resources seems linked to maintaining current and future availability.
- **Beyond Anthropocentric view:** In some cases, the links to the health of the natural environment are very close, *e.g. for biotic resources but also for abiotic "nutrients" like phosphorous*
- ***Need to cover all resources:*** *the links to fossil resources and biotic resources need to be considered and elaborated from the start, as in real life – e.g. for decision support - you often will need to look into all resource aspects, not only into minerals and metals.*

European Commission

2. Can and should these issues be addressed by **life cycle impact assessment** methods, or would **other tools be better suited**?

- **From a policy perspective:** Resource efficiency is a key policy area that refers to resources in very broad terms (e.g. in COM(2011) 571).
- The Natural Resources Area of Protection (AoP) in LCA has an anthropocentric approach, and tries to address also aspects of human wellbeing (in that case availability of resources) but this is <u>within</u> the scope of LCA and similar to the Human Health AoP that tries to address other aspects of human wellbeing (in that case human health).
- **To sum up:** LCA as a comprehensive assessment method **can** and **<u>should cover</u>** resource aspects, also abiotic ones, to provide a comprehensive picture.
  - **ISO 14040 (2006) states:** "LCA considers all attributes or aspects of natural environment, human health and resources. By considering all attributes and aspects within one study in a cross-media perspective, potential trade-offs can be identified and assessed." (chapter 4.1.7 Comprehensiveness)

European Commission

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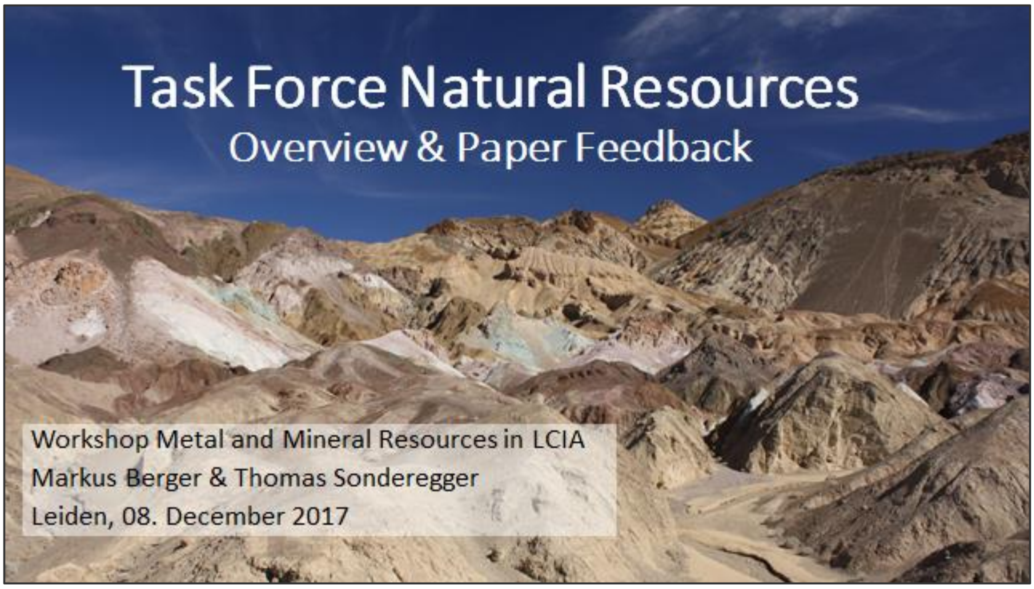
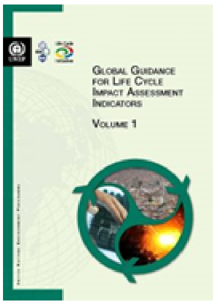


Background

- Life Cycle Initiative
- Flagship activity "Global Guidance for LCIA Indicators"

Life Cycle Initiative UN environment

- Phase 1 (2013-2015):
  - Global warming
  - Fine particulate matter
  - Water use
  - Land use
  - Crosscutting issues



- Phase 2 (2016-2018):
  - Crosscutting issues
  - Acidification-Eutrophication
  - Ecotoxicity
  - Human toxicity
  - Ecosystem services
  - **Natural resources (primary, mineral)**

Task Force Natural Resources 2

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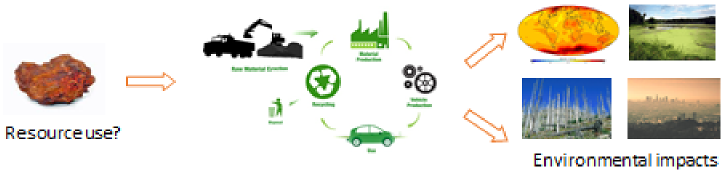
Background

- (Mineral) natural resources are of great relevance for industry, society and future generations
- Environmental impacts caused by emissions from mining and refining are considered in various impact categories (e.g. acidification or ecotoxicity)

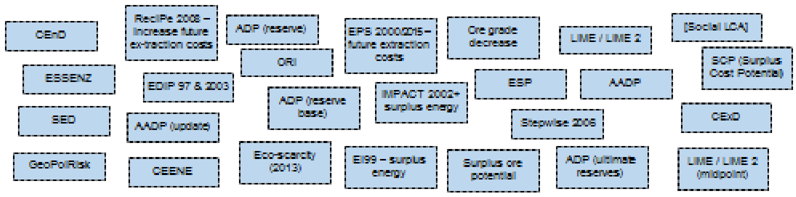


- However, consensus on how the use of resources as such should be considered in LCIA is currently lacking

Task Force Natural Resources 3

Methods to assess resource use in LCA

- The choice is yours…



- Different methods are available describing different impact pathways
- Often the “wrong method” is used to answer the “right question”
- Even the understanding of the Area of Protection “Natural Resources” is controversial

Task Force Natural Resources 4

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Goals

- Overview of existing methods
- Discussion of safeguard subjects
- Description of impact pathways addressed
- Categorize methods
- Describe characteristics and key axioms of methods
- Analyse and compare methods based on evaluation scheme
- Recommend methods
- Harmonize terminology
- Identify research gaps

Task Force Natural Resources 5

The Task Force

- The task force consists of currently 56 members, representing:
  - Academia
  - Geology
  - Mining industry
  - OEMs
  - Consulting
  - LCI database providers
  - Policy
- Members represent 14 countries around the globe

Task Force Natural Resources 6

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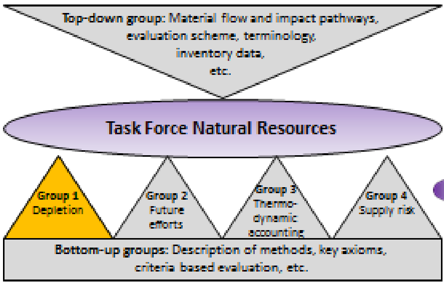
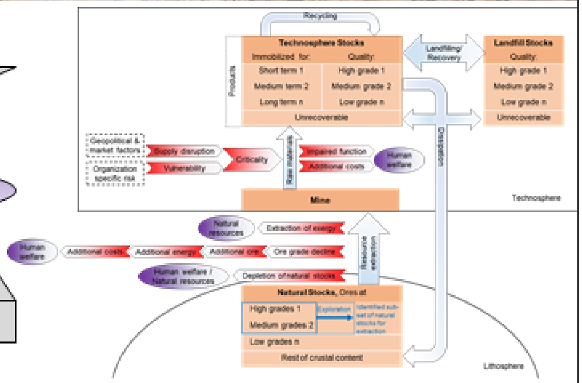
The Task Force - Structure





SUPRIM

Comments on workshop paper 1.1

- *What are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)?*

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Comments on workshop paper 1.2

- In our opinion, the main issue is the availability (in a general sense) of resources for economic use.
- “That the streams of benefits from resource use are equally distributed over the current and future generations (also known as “sustainable development”)”
- “Inter-generational equity (i.e., welfare of future generations)
  Intra-generational equity (i.e., distribution of welfare within generations)
  Resource accessibility – in both the environment (lithosphere) and technosphere”

Task Force Natural Resources 9

Comments on workshop paper 1.4

- “Avoid negative ecosystem and health effects during production (mining, smelting, refining), use and due to dissipative losses.”
- “Increase average time until material leaves technosphere.”
- “Avoid quality losses of material stocks in terms of dissipative losses, dilution, concentration decreases, and entropy generation [...].”
- “Avoid increases in criticality of abiotic resources in terms of supply risk [...].”

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Comments on workshop paper 1.6

Which role of resources best represents your views?

Combination	Stakeholder *Who is interested?*	System of Concern *System where they are valued*	Production system *Source for production*	Perspective types, based on role of resources
1	Human	Environment	Primary	D^{π}
2	Human	Technosphere	Primary	A^{π}
3	Human	Environment & Technosphere	Primary	C^{π}
4	~~Human~~	~~Environment~~	~~Primary & Secondary~~	F^{β}
5	Human	Technosphere	Primary & Secondary	B^{π}
6	Human	Environment & Technosphere	Primary & Secondary	G^{γ}
7	Resource	Environment	Primary	E^{π}

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Comments on workshop paper 1.6

Can you formulate an explicit goal to specify your views, and define the scope (time horizon, geographical scope, and types of resources) relevant to your views?

- Explicit goals:
  - Access to resources for future generations (for economic use)
  - Availability of materials for present economic use
- Time horizon:
  - Long-term (future generations)
  - Short-term (present use)
- Geographical scope: global
- Type of resources: all (?)

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Comments on workshop paper 1.3

What are the main barriers to achieving this goal/what is the key problem with resource use, according to your perspective?

- In our opinion, there are different issues of concern related to the use of abiotic resources and several of them are relevant:
  - Depletion of geologic stocks that can be mined economically
  - Quality degradation in the technosphere
  - Dissipative losses (in technosphere and environment)
  - (Short-term/present: supply risks ➡ "Criticality" methods)

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Comments on workshop paper 2.1

- *Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited?*

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Comments on workshop paper 2.3

- In our opinion, it is useful to consider resource use in combination with other impact categories in order to assess trade-offs between e.g. carbon footprint and use of (scarce/critical) resources in case of electric vehicles.
- Depletion of geologic stocks that can be mined economically.
  - ➡ Yes, depletion and future efforts methods both try to do this.
- Dissipative losses (in technosphere and environment) .
  - ➡ Should be recorded in Life Cycle Inventory.

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Comments on workshop paper 2.2

- "Avoid negative ecosystem and health effects during production (mining, smelting, refining), use and due to dissipative losses."
  - ➡ Yes, "traditional" LCA ecosystem and health impacts.
- "Increase average time until material leaves technosphere."
  - ➡ No, MFA for analysis and "material stewardship".
- "Avoid quality losses of material stocks in terms of dissipative losses, dilution, concentration decreases, and entropy generation […]."
  - ➡ Yes, mainly exergy methods seem to have potential.
- "Avoid increases in criticality of abiotic resources in terms of supply risk […]."
  - ➡ Not really, BUT "knowing the marginal effect of a life cycle inventory onto criticality and the included aspects of criticality within a life cycle inventory is […] very important".

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Comments on 'workshop paper' / stakeholder visions

Some perspectives…

Perspective 1

Role of Abiotic Resources: support sustainable development.

This is: ensure wellbeing of people, while the population is growing. This means: urbanization, infrastructure, technology developments.

Eg steel, aluminium, concrete, glass, zinc, copper.

→ Ensure supply meets demand on minerals/metals.

- Interested stakeholder: people
- System in which they are valued: technosphere
- Origin/sources: environment (primary) and technosphere (secondary)
- Protection goal: supply meets demand
- Indicator?

Perspective 2

Role of Abiotic Resources: support sustainable development.

Securing reliable and undistorted access to abiotic raw materials

-in the next 5 years.

-in the next 50 years

- Interested stakeholder: people
  - Government
  - Mining company
  - Product manufacturer
- System in which they are valued: technosphere
- Origin/sources: environment (primary) and technosphere (secondary)
- Protection goal: undisturbed access
- Indicator?

1-May-18 3

Perspective 3

Role of Abiotic Resources: support sustainable development.

Minimum extraction (primary production) in order to safe abiotic resources for future generations and to protect the environment.

- Interested stakeholder: people
- System in which they are valued: technosphere
- Origin/sources: environment (primary) and technosphere (secondary)
- Protection goal: minimum extraction
- Indicator?

1-May-18 4

Conclusion

Depending the stakeholder, there will be different problems and goals.

LCA is a tool to assess the size of the problem (impact), and to help decision makers to make the right decision.

Problem & goals should be clearly defined so that

-relevant data are collected

-relevant method is developed

→ tool can accurately assess the problem.

Uncertainty assessment! Especially when making predictions over a long time.

6. Annex 3 – Workshop-related comments from non-attendees

6.1. SUPRIM workshop commenting template - Anita Alajoutsijärvi

Name of workshop participant: Anita Alajoutsijärvi
Organisation represented by participant: Agnico Eagle
Date: Nov 30, 2017

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1. What are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)? (See Discussion paper Chapter 5 for further guidance)

- price fluctuation -> economical aspect
- increasing societal aspects to be considered vs. increasing needs for abiotic recourses
- BAT – level technology (process, environmental mgt etc.), developing of new innovative technologies
- increasing demand for replacing materials and reuse/recycling

2. Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited? (See Discussion paper Chapter 5 for further guidance)

LCIA could be a good tool for addressing these issues

- + tool for every phase with related indicators at least with relatively short period of time
- - challenges with long period of time: predictability regarding impacts, future availability; criticality in terms of environmental, economic and social aspects
- what is / how to find and apply ‘the reliable and best model’ to be applied?

6.2. SUPRIM workshop commenting template: Jacques Villeneuve, Stéphanie Muller

Name of workshop participant: Jacques Villeneuve, Stéphanie Muller
Organisation represented by participant: BRGM
Date: 14 December 2017

1. What are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)? (See Discussion paper Chapter 5 for further guidance)

First thanks for the discussion paper and the initiative to come back to the fundamental questions concerning abiotic resources.
The existence of minerals, metals, and natural stone come from a long and energy intensive work done by nature, and this involves all natural forces and resources, including magmatic movements, chemical energy, water, oxygen, sun… The mineral resources, as other resources, are "given" to man. They are "common goods" and have the intrinsic (non-economic) value of a heritage, ie no efforts have been spent to get them. Now the question is: do we use them or not?
If No, the resource is kept and transmitted as such to future generations. The impact of not using the resource is that the resource is preserved for potential future use. Some try to value this impact as the preservation of a "natural capital". This notion of "natural capital" is some kind of an extension of economy that has no meaning in the case of nature. There is no intention from nature to make resources available. They just exist in the state they are given. The mineral resources cannot be used in their natural state. Their use requires work (different physical and organizational energy inputs from man, primary energies) and other resources to obtain a useful function (the function of a metal from the resource of a mineral). So, if any, the value of the "natural capital" is negative and can only be estimated by the amount of "work" necessary to get from it something useful. This is possible to estimate in the present and rather difficult in the future. So I agree with the comments of Type E perspectives in the discussion paper: it seems difficult to develop an indicator on the intrinsic value of not using the abiotic resources (preserving this value for future generations), even if the indicator could be used for example to assess the impact of avoiding "not using" the resource.
If Yes (the resource is used), several questions arise.
On the consumption of resources.
The resources are not evenly distributed and are owned, generally as common goods, at the level of a community, generally a country. The community (its representatives, be it a dictator), generally give "rights" to exploit the resource, often under conditions that the exploitation supplies a "return" to the community: rent, tax on benefits,… The notion of "common goods" speaking about mineral resources is in fact geographically focused: why should Europeans care about mineral resources that in fact, they have no way to manage. These resources do not belong to "humanity", just a part of it. So it is a bit of an appropriation of the problems of the communities to think about a global indicator. There is perhaps a field of social knowledge to integrate: what should prevent me to spend my money as I wish, except having my money managed by others, … so not having MY money ?
Overall, the exploitation of the resource happens once, which means that all extracted matter cannot be extracted another time. So the natural resource "disappears". From an accounting point of view, it is useful to register the quantities of extracted resources at the level of the community for the above

reasons of rights. From an environmental perspective, it is also useful to keep track of the extraction of natural resources when trying to figure out the comparative advantages of products. Nevertheless, this relates to the inherent property of resources that only a part of them is really exploited. The extraction and further exploitation lead to a potentially important part of the extraction being "unused" and remaining at several locations as waste with their specific burdens out of scope here. So when using 1 kg of copper, 100 kg of resource has been extracted. The problem is: what is the problem? Speaking strictly about resources and the way they are exploited, one aspect to consider perhaps is the aspect of co and remaining resources. The mining waste, mineral processing waste, metallurgical waste may be revisited for different reasons linked to their remaining content of valuable resources, being the original for which it was extracted or the accompanying resources not exploited. The impact of the extraction can be the creation of a new resource.

As stated, if only a part of the natural resource is finally used (small part in the case of metals), this part represent the functional part of the resource, its value depending on the quality of the functions made available for the applications. This functional part is being used by different sectors (construction, manufacturing, chemistry,…) to make products that can be stored in the technosphere (like building materials in buildings, metals in infrastructure,…) or dissipated (like paints, chemical products,…).

The part which is stored correspond to a stock of the (functional part of) the natural resources, and is in fact just a displacement from natural resource (of low quality) to anthropogenic resource (of high quality). With other words, the natural resources in this case have not been "consumed", just displaced.

The part which is dissipated corresponds to a real, net, depletion. This could be considered in the first approach of impact assessment in the ILCD (quantity extracted). One part of the resource extracted has really "disappeared" while the other part has been stored.

Nevertheless, the part stored has a lifetime in the technosphere (short compared to the lifetime of mineral deposits). Only one part of the stock can be recycled in a way that the stock is preserved, ie, without altering the quality. Unfortunately, the quality tend to decrease (depending on resource function, applications, mixing and alloying, collection of waste, recycling markets and technologies, etc…) along the successive lifecycles of the resources. One part also disappear during the use of resources (corrosion, breaking,…). On a (very) long term, we could tend to consider that all resources will be consumed (dispersed in the environment). At that point, it appears that the question of TIME seems very important in the appreciation of the depletion. The time during which a resource in the technosphere preserves its "quality", or a quality compatible with a storage in the technosphere, is the time during which resource extraction has no impact (at least for the part of the resource concerned).

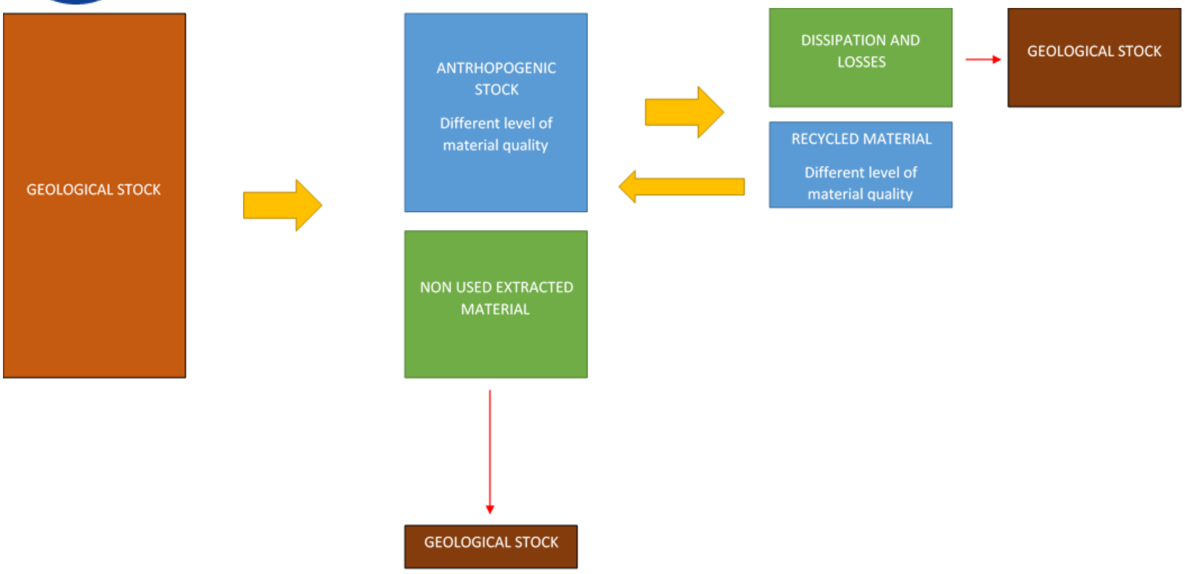
Of course, these considerations must be examined case by case, considering for example the "ultimate quality limit" of Weidema (2004) for each resource/substance.

On the reserves of resources

As long as humanity has lived, there has never appeared a problem of total use of specific geological resources. Problems arise when the exploitation costs are too high, which is the definition of "reserve". These aspects may be better suited in criticality assessments than in environmental impact assessments (case of co-products for example, even if, as already mentioned, co-products not exploited may still exist as a resource in wastes).

So, as a conclusion, strictly speaking about mineral resources and excluding soils and biomass, water, fossil energies, one aspect potentially useful in environmental impacts assessment and which is not covered in present methods, could be some kind of "time before dissipation", all other impacts due to dissipation being captured by other impact categories. This impact category could have a strong effect for industries and governments in their eco-design and sustainability policies…

The attempt of scheme hereunder sumarises the above ideas.



2. Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited? (See Discussion paper Chapter 5 for further guidance)

Sorry for not strictly following the guidance… There are important economic and social issues in the exploitation (or not) of mineral resources. These could probably fit well in a regionalized social life cycle assessment and a criticality assessment more elaborated than presently practiced…???
The concepts here and their link with the resource environmental indicator should be elaborated further.
Some economical thinking on the "real value" of resources tend to compare the earth to a spaceship where all primary resources should come from "elsewhere"…What could be their cost then… interesting?

6.3. SUPRIM workshop commenting template: Damian Kròl

Name of workshop participant: Damian Kròl
Organisation represented by participant: Euromines - KGHM
Date: 7 December 2017

1. What are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)? (See Discussion paper Chapter 5 for further guidance)

Presenting KGHM's point of view I would fill in the proposed standard phrase as below:
LCA should be motivated by human (future generations) concern for value in the Economy and seek to protect it from impacts associated with use of Primary and Secondary resources.
Therefore from all of the proposed perspective in the Workshop Metal and Mineral Resources in LCIA "What's the problem" it corresponds with the perspective B, describing the impact as decreasing availability of functional properties, which could be met by both primary and secondary resources.
However this approach has a specific limitation. At this point in time it is challenging to assess what stocks of resources would be considered reserves for future generations - due to technological advancement (lower cost of mining in difficult conditions and low-grade ores), discoveries of future deposits etc. Furthermore this approach would have to adopt 'importance factors' for certain materials, just assuming (if not guessing) what future technologies will drive the economy and what will be the demand for specific resources.
We believe that recycling potential should also be addressed in this category, as 20kg of copper that you find in a car isn't gone forever. With smart policies (circular economy) and design-for-dismantling solution could keep the materials within the economy as long as their functional properties are maintained.

2. Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited? (See Discussion paper Chapter 5 for further guidance)

Trying to answer the second question - Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited? – we would like to first highlight that this impact category is overwhelming when it comes to LCA studies of mining and processing activities. And it doesn't seem justified as there is no general consensus on what should it address…Maybe a way forward would be trying to diminish it's importance by developing new characterization models?
On the other hand most impact categories focus on environmental impact, as LCA is usually defined as a tool to asses potential environmental impact of all stages of product's life. This particular category seems more as an economical or societal impact than an environmental one. So it could be reasonable argued that abiotic resource depletion doesn't necessarily belong in LCA.

6.4. SUPRIM workshop commenting template: Rolf Frischknecht

Name of workshop participant: Rolf Frischknecht
Organisation represented by participant: treeze Ltd.
Date: 12.12.2017

1. What are the key issues of concern to be addressed when managing abiotic resources (minerals, metals, natural stone)? (See Discussion paper Chapter 5 for further guidance)

The dissipative use of resources today compromises the ability of future generations to meet their needs. Similar to greenhouse gas emissions today which compromise the ability of future generations to meet their needs as they are forced to use (substantial) parts of their resources to fight climate change impacts.
While the impact assessment of greenhouse gas emissions is rather straightforward, it is not when dealing with primary mineral resources. Their production to availability ratio seems an appropriate approach (similar to the AWARE indicator quantifying the water stress impact).
In addition to this, the value of a particular resource for society needs to be quantified somehow. One might need to assess each resource individually or in groups of resources. The value of the resources cannot be reflected by prices because the demand of future generations as well as the ultimate availability of a resource is not reflected in current prices. Hence, the value of resources needs to be assessed differently (suitable approaches to be identified).

2. Can and should these issues be addressed by life cycle impact assessment methods, or would other tools be better suited? (See Discussion paper Chapter 5 for further guidance)

Yes, these issues match perfectly with the LCIA scheme of the ISO standards.