SCORELCA

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INNOVATIVE METHODS OF RESOURCE ACCOUNTING FOR LCA

SYNTHESIS

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The SCORE LCA association is a study and research structure dedicated to the work related to Life Cycle Assessment (LCA) and environmental quantification. It aims to promote and organise collaboration between companies, institutions and scientists in order to encourage a shared and recognised development, at European and international levels, of the Life Cycle Assessment method and its implementation.

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- ✓ The information and conclusions presented in this document have been drawn on the basis of scientific and technical data and of a regulatory and normative framework in force at the time of publication.

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1 Synthesis

This study aims to provide an overview of the impact assessment methods dedicated to resource use in LCA, for renewable and non-renewable resources. Nine methods for characterising the impact of non-renewable resource use were selected for further analysis:

- Abiotic Depletion Potential (ADP) Ultimate Reserve
- Environmental Dissipation Potential (EDP)
- Abiotic Resource Project (ARP)
- Average Dissipation Rate (ADR) (and Lost Potential Service Time, LPST)
- Future Welfare Loss
- GeoPolRisk
- Integrated method to assess resource efficiency (ESSENZ),
- JRC LCI[1] approach
- JRC price-based characterisation approach.

Application cases illustrating the comparison of assessment methods for non-renewable resources are assessed in the full report.

We distinguish four main criteria for evaluating the methods:

- The core concept
- Implementation
- Operationality
- Recommendations by third parties

The core concept of methods is key as it determines the intrinsic relevance of methods.

Implementation is about establishing the link between the core concept of the methods and the operationality. The implementation analysis is divided into two parts: assumptions and underlying data. Assumptions are crucial because they must allow the application of the core concept while respecting it. In most cases, the issue with data is more its accessibility for the method developers than its existence .

Operationality is only a short-term issue because if the method becomes widely used, existing software will adapt and problems of compatibility will be solved.

The third-party recommendation criterion aims to take into account past recommendations (e.g. in the framework of the PEF[2]) or recommendations under discussion (e.g. in the framework of GLAM[3] 3) in the elaboration of the recommendations of this study.

These four main criteria are subdivided into sub-criteria. For each method, and each of these sub-criteria, a "level of satisfaction" is associated: satisfactory, partially satisfactory, partially unsatisfactory, or unsatisfactory. To be recommended, a method must be associated with a minimum "level of satisfaction" depending on each sub-criterion. These thresholds have been defined by expert opinion by the authors of this report and are presented in the following table.

[1] Joint Research Centre Life Cycle Inventory
[2] Product Environmental Footprint
[3] Global Guidance on Environmental Life Cycle Impact Assessment Indicators

Core concept	Threshold level	Comment
Dissipation/loss of accessibility	Partially satisfactory	Unless "Supply shortage" >= "Partially satisfactory"
Value of the function	Partially satisfactory	
Substitutability	Unsatisfactory	
Supply shortage	Partially satisfactory	Unless "Dissipation/loss of accessibility" >= "Partially satisfactory"
Future generations	Unsatisfactory	
Implementation		
Assumptions	Partially unsatisfactory	
Underlying data	Partially unsatisfactory	
Operationality		
Software	Partially satisfactory	
Compatibility with standard LCI databases	Partially satisfactory	
Resource coverage	Partially satisfactory	
Interpretation of results	Partially satisfactory	
Recommendations by third parties		
Existing recommendations or those under discussion for the future (assessment mid-February 2022)	Partially unsatisfactory	

Table 1 Threshold levels by sub-criteria for recommendation

A method rated below the threshold level of satisfaction cannot be recommended.
In the choice of threshold levels, priority was given to:

1) the core concept: "dissipation/loss of accessibility" and "value"; or "supply shortage" (which is a dimension of criticality);
2) the level of operationality.

For these criteria, the threshold is "partially satisfactory".

"Implementation" and "existing recommendations" are also important, but left at a lower threshold level ("partially unsatisfactory") because they are identified, at least in the short term, as less important than the core concept and operationality.

Finally, two sub-criteria ("substitutability" and "future generations") are associated with a non-binding threshold level ("unsatisfactory"). These sub-criteria correspond to an added value of one approach compared to another, but are not necessary for a method to be recommended.

1.1 Core concept

The evaluation of resources can be done from different perspectives: environmental, economic, geopolitical, etc. In this study, we take as our starting point the draft definition of GLAM 3[4] , as of mid-April 2022:

"How can I quantify the consequences of temporal or permanent loss of the functional values of natural resources caused by its use in a product system?"

This definition is based on the temporary or permanent loss of the value of the function as a result of the use of a natural resource in a product system.

To compare the core concept of non-renewable resource methods, we mobilise the following concepts:

- Dissipation/loss of accessibility

  Does the method characterise the loss of accessibility of resources for potential future users, leading eventually to their dissipation, over the life cycle?

- Value of the function

  Does the method take into account the value of the function of resources, for example through their use values or prices?

- Substitutability

  Does the method take into account the substitutability of resources (one resource can possibly substitute for another when it can provide a similar function).

- Supply shortage

  Does the method take into account supply risks (e.g. geopolitical)?

- Future generations

  Does the method take into account the loss of well-being of future generations? If a resource is dissipated or consumed, the value of the function is lost. This may be only in the short term, or it may also be in the longer term (affecting future generations in a more sustainable way).

, The “ADR and LPST” and JRC LCI methods take dissipation/ loss of accessibility into account in a satisfactory way. The price-based methods (Future Welfare Loss and JRC price based) only take dissipation into account through LCA modelling (non-recycled materials are lost). Impact characterisation approaches allow value to be taken into account, though potentially compatible with LCI dissipation approaches[5] (thus allowing *loss* of value to be taken into account). The EDP and ARP methods only consider dissipation to the environment, not into the technosphere. The ADP Ultimate Reserve method does not consider dissipation but rather the contribution of total resource loss (over the life cycle of a product system) to geological stock depletion. GeoPolRisk and ESSENZ do not take dissipation into account at all.

Price-based methods (Future Welfare Loss and JRC price based) cover the value of the function (in particular, the "loss of value" when combined with a method of accounting for dissipation). Up to now, "ADR and LPST" and GeoPolRisk do not cover the value of the function, but proposals for characterisation factors incorporating prices[6] are being suggested. The JRC LCI and ARP methods are potentially compatible with characterisation factors that take into account the value of the function. ADP Ultimate Reserve, EDP and ESSENZ do not take into account the value of the function.

Substitutability is only taken into account in 3 methods: the price-based methods (Future Welfare Loss and JRC price based) and ESSENZ. In CS-ESSENZ, vulnerability is taken into account in a general way. Substitutability is taken into account in prices for the price-based methods.

[4] Global Life Cycle Impact Assessment Method.

[5] Life cycle inventory

[6] This proposal is similar to the one of JRC price based method for ADR and LPST.

Supply shortage risks are only satisfactorily taken into account in GeoPolRisk. The general ESSENZ method analyses these risks on the basis of global data and therefore the regional dimension of the risk of supply shortage is not taken into account. Nevertheless, this regional dimension is taken into account in the CS-ESSENZ version. It should be noted that for ADP Ultimate Reserve, the existing geological stock may be one of the elements for quantifying the supply risk but is not a fundamental element.

The consideration of future generations is only satisfactory in Future Welfare Loss. In EDP and ARP, future generations are partially taken into account under certain assumptions in the long-term approach.

To compare the core concept of renewable resource methods, we mobilise the following concepts:

- Specific criterion on biodiversity
- Ecosystem services
- Time frame
- Geographical coverage

LC Impact and Impact World+ have the same specific criterion on biodiversity: species potentially extinct over time.

Ecosystem services are partially covered by Impact World+ but not at all by LC Impact. The ecosystem services covered by Impact World+ are resistance to erosion, fresh water recharge, mechanical filtration and biotic production.

Impact World+ distinguishes between the short, medium and long term, whereas LC Impact only covers the long term.

In terms of geographical coverage, both methods cover global, continental, country and local. LC Impact also covers regionally unlike Impact World+.

1.2 Implementation

To evaluate the implementation of renewable resource methods, we use the following concepts:

- Assumptions
- Underlying data

The assumptions associated with the impact pathway modelling are partially satisfied in the case of 5 methods:

- Future Welfare Loss and JRC price-based, both based on prices;
- GeoPolRisk and ESSENZ, methods allowing the study of certain dimensions of criticality. To do so, they use a number of acceptable criteria, albeit with different levels of detail (more detailed in ESSENZ);
- JRC-LCI, which considers a relatively short time horizon (25 years) within which the assumptions can be considered relatively robust in the light of the current level of knowledge.

On the contrary, ADP Ultimate Reserve and "ADR and LPST" are partially unsatisfactory in terms of modelling assumptions. For ADP Ultimate Reserve, the "ultimate reserve" does not represent the ultimate extractable reserve (which is unknown), which is problematic both in absolute and relative (between resources) terms. In the "ADR and LPST" method, the assumptions are sometimes too conservative with respect to the inaccessibility of resources, on a long time scale. The CFs[7] were

[7] Characterisation factors

calculated using the dynamic results of MFAs[8] , i.e. based on average values at the global technosphere scale. ADR is based on the observation of a "potential" Service Time according to the current conditions of use and technologies. LPST is based on the introduction of choices of values on an "ideal target", which has no physical reality.
Finally, EDP and ARP are associated with unsatisfactory modelling assumptions. The development of EDP has required a relatively large number of questionable assumptions and simplifications, including:

i) The accessibility of hibernating stocks in the long term,
ii) The use of the continental crust as a proxy for the ultimate extractable reserve, and
iii) Many contradictions in the assumptions made for modelling LCI and CF.

Furthermore, in the ARP approach, Criterion A (which defines whether a resource is accessible or not) is highly questionable. The use of the average concentration in the earth's crust as a threshold for the accessibility of the resource in the future is an assumption for which the level of confidence is extremely low.

The underlying data on which the methods are based is reliable for all non-renewable resource methods except partially for Future Welfare Loss. In the latter method, few specific extraction costs per resource are used.

For the renewable resources methods, Impact World+ is based on a midpoint/damage model. The method gives 4 coherent and complementary points of view to assess the life cycle of impacts:

- Midpoint indicators
- Damage indicators
- Damage to protected areas (human health, quality of ecosystem and ecosystem resources and services).
- Damage to areas of concern (water and carbon)

LC Impact studies 3 types of ecosystems (terrestrial, marine, fresh water). The method focuses on 7 categories of impact to study protection areas.

1.3 Operationality

To assess the operationality of non-renewable resource methods, we use the following concepts:

- Software
- Compatibility with standard LCI databases
- Resource coverage
- Interpretation of results

In terms of the software used by SCORELCA members (Simapro and Gabi), only the ADP Ultimate Reserve method is already implemented. Implementation would be relatively easy for many methods: ARP, ADR and LPST, Future Welfare Loss, JRC price based and GeoPolRisk, but more complicated for the following ones: EDP and JRC LCI.
And finally, for ESSENZ, only an implementation outside the framework of classical LCA software is possible because the calculation of impact is not similar to LCA.

Compatibility with standard LCI databases is satisfactory (or partially satisfactory for GeoPolRisk) for all methods except ESSENZ and JRC LCI. In the case of CS-ESSENZ, company-specific data outside the classical LCI data framework are required. Finally, for JRC LCI, potentially significant efforts are required to compile data using existing LCI databases.

[8] Material Flow Analysis

Resource coverage is satisfactory for the price-based methods (Future Welfare Loss and JRC price based). Resource coverage is partially satisfactory for the following methods: ADP Ultimate Reserve, EDP, ARP, ADR and LPST and GeoPolRisk. For these methods, coverage is generally good for metals but not for minerals. Resource coverage is partially unsatisfactory for ESSENZ as it is only "good" for metals (in comparison, coverage is much wider in the other methods) and partial for minerals. As the JRC LCI method is applied at the LCI scale, the resource coverage criterion is not applicable for this method.

The interpretation of the results is satisfactory for the price-based methods (Future Welfare Loss and JRC price based). It is partially satisfactory for “ADR and LPST”, JRC LCI and GeoPolRisk. The "ADR and LPST” method is easily understandable and communicable, but has little implementation, so there is few feedback. This method is probably particularly useful for identifying hotspots on the dissipation issue, but does not allow the identification of the most contributing life cycle phases (which is problematic in the PEF). For JRC LCI, the concept of dissipation is quite recent, so there is also few feedback. But the approach is a priori easily communicable if translated as "loss". This method allows the identification of the most contributing life cycle phases ("hotspots") to dissipation; this is key for example in the context of the PEF. GeoPolRisk is relatively simple to interpret. There are few published case studies on the use of this method and little feedback for now. The ADP Ultimate Reserve method is partially unsatisfactory because although the implementation is established, the level of difficulty is intermediate for the interpretation. Furthermore, this method does not deal with the "availability" issue (millions of years of resources would be ahead of us). The EDP, ARP and ESSENZ methods are unsatisfactory because for EDP and ARP, there is little hindsight on the use of these methods and a risk of orienting towards bad practices from both a resource and environmental point of view. For ESSENZ, in addition to the lack of feedback, the interpretation is complex due to the number of indicators: 15 indicators to be analysed individually relating to the single issue of "criticality".

For the renewable resources methods, Impact World+ is implemented in Simapro and Brightway 2 while LC Impact is only implemented in Brightway 2.

Compatibility with standard LCI databases is partial for both methods and only at country level.

For the interpretation of the results, specific nuances have to be made to the analysis for LC Impact. The Impact World+ method does not suggest a recommended method for weighting damages (DALY, PDF in m^2*year and $).

1.4 Recommendations by third parties

The criterion of " recommendations by third parties" allows to take into account past and still in progress recommendations. Three of the methods studied were recommended in 2020 by UNEP (Task Force Mineral Resources):

i. ADP Ultimate Reserves to answer the question on the contribution of a product system to mineral resource depletion (level of recommendation: "Recommended");
ii. GeoPolRisk and ESSENZ respectively "suggested" and "interim recommended" on the issue of criticality (i.e. to "quantify the potential problems of accessibility of a product system related to short-term geopolitical and socio-economic aspects (criticality)").

The ADP Ultimate Reserve method is also recommended in the framework of PEF. However, it is expected that none of these three methods will be recommended in the ongoing GLAM 3 work. Indeed, these methods are considered "partially satisfactory" on this criterion in this study.

On the contrary, the ARP, Future Welfare Loss and JRC-LCI methods have not been recommended in the framework of GLAM 2, as they were not yet developed at the time of this work. In the light of today’s discussions (mid-April 2022), it is possible that the ARP and Future Welfare Loss methods will be recommended for the "long-term" assessment of dissipation (consideration of dissipation at the LCI level via ARP, and quantification of the associated loss of value via Future Welfare Loss). Furthermore, it is possible that the JRC-LCI approach will be recommended for the "short-term" assessment of dissipation, in combination with price-based CFs (via an approach yet to be defined). In this context, the ARP, Future Welfare Loss and JRC-LCI methods are considered as "partially satisfactory" in this study.

In addition, the EDP, “ADR and LPST” and JRC price-based methods are currently being discussed in the context of the UNEP GLAM 3 work, but may not be recommended. The JRC price-based approach is excluded from the recommended methods because it has not yet been published in a peer-reviewed article. In this report, these three methods are therefore considered partially unsatisfactory on this criterion.

Finally, none of the methods currently under discussion in the recent work of the PEF on a possible new impact indicator associated with the use of "mineral resources" have been retained to date.

1.5 Summary of the transversal analysis

The

	ADP Ultimate Reserve	EDP	ARP	ADR et LPST	Future Welfare Loss	GeoP
Core concept						
Dissipation/loss of accessibility						
Value of the function						
Substitutability						
Supply shortage						
Future generations						
Implementation						
Assumptions						
Underlying data						
Operationality						
Software						
Compatibility with standard LCI databases						
Resource coverage						
Interpretation of results						
Recommendations by third parties						
Existing recommendations or those under discussion for the future (assessment mid-February 2022)						

Table 2 summarises the transversal analysis for non-renewable resources.

The Table 3 summarises the transversal analysis for renewable resources.

	ADP Ultimate Reserve	EDP	ARP	ADR et LPST	Future Welfare Loss	GeoPolRisk	ESSENZ	JRC LCI	JRC price-based
Core concept									
Dissipation/loss of accessibility	Partially unsatisfactory	Partially unsatisfactory	Partially unsatisfactory	Satisfactory	Partially satisfactory	Unsatisfactory	Unsatisfactory	Satisfactory	Partially satisfactory
Value of the function	Unsatisfactory	Unsatisfactory	Partially satisfactory	Partially satisfactory	Satisfactory	Partially satisfactory	Unsatisfactory	Partially satisfactory	Satisfactory
Substitutability	Unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Satisfactory
Supply shortage	Partially unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory	Satisfactory	Partially satisfactory	Unsatisfactory	Unsatisfactory
Future generations	Unsatisfactory	Partially satisfactory	Partially satisfactory	Unsatisfactory	Satisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory
Implementation									
Assumptions	Partially unsatisfactory	Unsatisfactory	Unsatisfactory	Partially unsatisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory
Underlying data	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Partially satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Operationality									
Software	Satisfactory	Partially unsatisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory	Unsatisfactory	Partially unsatisfactory	Partially satisfactory
Compatibility with standard LCI databases	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Partially satisfactory	Partially unsatisfactory	Partially unsatisfactory	Satisfactory
Resource coverage	Partially satisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory	Satisfactory	Partially satisfactory	Partially unsatisfactory		Satisfactory
Interpretation of results	Partially unsatisfactory	Unsatisfactory	Unsatisfactory	Partially satisfactory	Satisfactory	Partially satisfactory	Unsatisfactory	Partially satisfactory	Satisfactory
Recommendations by third parties									
Existing recommendations or those under discussion for the future (assessment mid-February 2022)	Partially satisfactory	Partially unsatisfactory	Partially satisfactory	Partially unsatisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory	Partially satisfactory	Partially unsatisfactory

Table 2 Summary of the transversal analysis for non-renewable resource methods

- Satisfactory
- Partially satisfactory
- Partially unsatisfactory
- Unsatisfactory

	LC Impact	Impact World +
Core concept		
Specific criterion on biodiversity		
Ecosystem services		
Time frame		
Geographical coverage		
Implementation		
Underlying data		
Operationality		
Software		
Compatibility with standard LCI databases		
Interpretation of results		

Table 3 Summary of the transversal analysis for renewable resource methods

Satisfactory
Partially satisfactory
Partially unsatisfactory
Unsatisfactory

1.6 Conclusions and recommendations

A method is recommended if :

- It meets the minimum threshold established for each of the sub-criteria (thresholds defined in the Table 1) ;
- It obtains a good overall evaluation score, based on the evaluation of the sub-criteria (see the summary tables of the transversal analysis).

Three methods are recommended:

- **two that assess the loss of value of mineral resources**. They calculate a conventional LCA impact indicator.

  One method is recommended in the short term: it is usable with current databases and software.

  Another method is recommended for the medium term: it is more satisfactory in terms of robustness and decision support, but not sufficiently operational for now.
- **one that calculates the risk of supply shortage** to which a system is subject; it is a **complementary indicator** to the LCA indicators, not reflecting the impact of a system on its environment but rather a risk to which the system is subject**.**

Question: quantification of the loss of value induced by the use of mineral resources by a product system over its life cycle (i.e. the current GLAM 3 question: *"How can I quantify the consequences of temporal or permanent loss of the functional values of natural resources caused by its use in a product system*?)

“Loss of value" is the key concept that the recommended approach should capture. To do this, a combination of two methods is recommended:

- a method for capturing the "loss" of mineral resources induced by a system over its life cycle. Some[9] "dissipation" methods allow to explain at which stages of the life cycle (e.g. for eco-design) resource losses occur, calculated in LCA by resource mass balance. In the classical LCI approach, the net consumption of a resource in LCA is the difference between the consumption of raw material and the saving of raw material through recycling. It is this amount of material that is then considered to be "dissipated".
- a method for capturing the 'value' of the material lost.

Recommended methods:

- ***Ad interim***: **ADR method combined with the Future Welfare Loss method;** unfortunately, no case studies test this combination and there is a risk of unidentified practical difficulties; tests are therefore still needed to confirm this recommendation
- **In the future** (when JRC-LCI will be implemented in the LCI databases)**: JRC-LCI method[10] combined with the Future Welfare Loss method**

The characterisation factors of the ADR method are recommended rather than those of the LPST method. Both methods were developed by Charpentier-Poncelet et al. and have a common methodological base. However, the LPST method is a "distance to target" method based on the introduction of choices of values on an "ideal target" (hypothetical absence of dissipation over a given time perspective). Instead, ADR is based on the observation of a "potential" Service Time according to the current conditions of use and technologies. Its use is recommended.
The JRC-LCI approach is inherently more satisfactory than the ADR because the choices and assumptions supporting the model are more satisfactory. The JRC-LCI method considers a relatively

[9] Not ADR and LPST.
[10] Joint Research Centre Life Cycle Inventory

short time horizon (25 years) within which the assumptions can be considered relatively robust with regard to the current level of knowledge. For ADR, the assumptions are sometimes too conservative with respect to the inaccessibility of resources on a long time scale. The Characterisation Factors were calculated using the dynamic results of MFAs, i.e. based on average values at the global technosphere scale. The JRC-LCI method also allows for a more detailed interpretation of the results; in contrast, the ADR approach allows for a better identification of hotspots. In practice, as the JRC-LCI approach is not implemented in the LCI software and databases, it cannot be recommended. When this loophole will befilled, its application will be recommended (and not only "suggested").
The Future Welfare Loss method is preferred to the JRC price-based method because it takes into account future generations. The ADP Ultimate Reserve, EDP and ARP methods are excluded from this recommendation as they do not allow for a satisfactory quantification of the "loss of value". The EDP and ARP methods are insufficient with regard to the criteria Assumptions and Interpretation of results ("unsatisfactory" methods for these criteria). The development of EDP required a relatively large number of questionable assumptions and simplifications, including:

i. The accessibility of hibernating stocks in the long term,
ii. The use of the continental crust as a proxy for the ultimate extractable reserve, and
iii. Many contradictions in the assumptions made for modelling LCI and CF.

Furthermore, in the ARP approach, Criterion A (which defines whether a resource is accessible or not) is highly questionable. The use of the average concentration in the earth's crust (as a threshold for the accessibility of the resource in the future) is an assumption for which the level of confidence is extremely low.

Question: "Quantify the potential problems of accessibility of a product system related to short term geopolitical and socio-economic aspects(criticality)".

Recommended approach: GeoPolRisk method
Level of recommendation: suggested

The GeoPolRisk approach is preferred over the ESSENZ approach, as the latter does not reach a sufficient level of satisfaction with regard to the sub-criteria Software, Compatibility with standard LCI databases and Interpretation of results. To date, ESSENZ can only be implemented outside the framework of conventional LCA software because the calculation of impact is not similar to LCA. In addition, company-specific data outside the classical LCI data framework is required. The CFs of GeoPolRisk are currently being finalised (expected in late 2022 - early 2023) and will allow the method to be applied relatively easily.

Suggestions for future research

Currently, dissipation methods are on/off methods: either a resource is dissipated or it is not. However, dissipation is more of a continuous concept.

The societal added value of a resource is the difference between the use value of a resource and the societal cost (economic, environmental and social) of making it usable from its initial source (e.g. ore) or final location (e.g. waste). The market value (or its long-term value when fully dissipated) is a lower bound of the use value of a directly usable material. If the societal cost is higher than the use value of the resource, it is dissipated. If the use value is higher than the societal cost, the resource is not dissipated. This is not a Boolean function (on/off) but rather a continuous function of the extent of dissipation or non-dissipation.

The loss of value due to dissipation is capped by the use value of the resource because the societal cost of making the resource usable would result in an adverse societal impact. There is a link between the societal cost of making the resource usable and quality, which can be seen as a generic term covering the quality, quantity, chemical status, etc. of a resource.

This approach of assessing the degradability of accessibility would allow to:

- Develop the approach to dissipation, as it becomes a continuous assessment of dissipation (societal cost of processing to return to a ready for use form) instead of the on/off analysis (there is dissipation or not) as it is the case in current 'dissipation' methodologies
- Take into account the importance (added value) of the material because, in case of permanent loss (dissipation), the loss is capped by the market value of the material
- Take into account substitutability since the long-term use value (with future generations) is considered

The value added to or destroyed from the material by the product during its life cycle is the difference between:

- The societal cost of making it usable from its original source (e.g. an ore)
- The societal cost of making it usable from its final location (e.g. waste, emission)

Note that the use of the resource can create value in some cases (e.g. bauxite transformed into aluminium reduces dissipation because the societal cost of using aluminium metal post use is lower than the societal cost of using bauxite).

In practice, for resources that are dissipated today, the societal cost is higher than the use value and the loss of value is capped by the use value. However, for non-dissipated resources, the societal cost of making these resources usable should be modelled. The economic cost is known (at least by the actors using these resources) and the environmental and social costs can be modelled.

Moreover, the notion of occupation-in-use is not considered by any method at present. In particular, Beylot et al (2021)[11] discuss this topic in a dedicated section *("3.3.3 Occupation-in-use is not a form of dissipation").* The authors acknowledge that occupation-in-use poses a resource accessibility issue for current and future users. At the same time, however, by definition of occupation-in-use, resources that are "occupied" are functional for users; hence not "dissipated".

There is still a need to think about the modelling of the inventory to address this issue. For example, it could be considered to address the subject in the context of dynamic LCI modelling.

[11] Beylot, A., et al. 2021. Mineral resource dissipation in life cycle inventories. Int J Life Cycle Assess 26, 497-510. https://doi.org/10.1007/s11367-021-01875-4