Social Extension Task Force report, Task III and IV

Modeling, assessment, and aggregation of social indicators along the life cycle

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1 Introduction

Task III and IV develop an approach for modeling social indicators over the entire life cycle (task III) and for aggregating the modeled indicator information across the life cycle (task IV). Both are obviously strongly connected, and will be dealt with in conjunction, in this text.

The proposed solutions obviously need to recognize the social indicators that are currently selected and discussed in PROSUITE,[1] but at the same time they should also be able to work with other indicator sets, thereby being to some extent independent from PROSUITE's current social indicator lists.[2]

For sake of simplicity, this text will address modeling life cycle for a product. This is not exactly the task of the PROSUITE project (which deals with technology assessment) but modeling product life cycles is much more common, at least for economic and environmental issues. A special task will deal with the technology perspective of PROSUITE.

This is justified since also the environmental and economic assessment follow the same approach; for example, for the economic assessment, WPs 2.2 is focusing on microeconomic impacts, while WP 2.4 until WP 2.6 are dealing with technology scenarios.

Evidently, this approach may overlook solutions that fit only for technology assessment, and not for product assessment. Therefore, a special consideration may make sense to "purely technology-related" solutions (the dotted line in Figure 1).

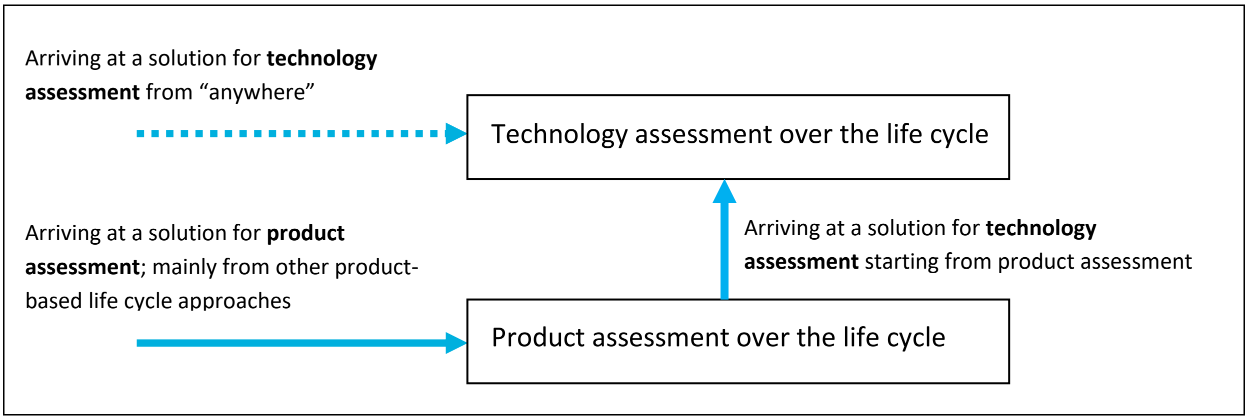

Figure 1: developing an approach for technology assessment via product assessment. Further explanation see text

Similarly, the current tasks III and IV do neither deal with prospective assessment nor with normalization. These questions will be addressed in separate tasks.

This is very similar to treating these additional requirements as "complications" for clocks[3].

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[1] http://www.prosuite.org/c/document_library/get_file?uuid=d1b91384-d89b-4988-8f87-5806020b8874&groupId=12772 and Table 1

[2] Minutes conference call January 16 2013

[3] "In horology (study of clocks), complication refers to any feature in a timepiece beyond the simple display of hours, minutes, and seconds.", http://en.wikipedia.org/wiki/Complication_%28horology%29, February 5 2013.

Figure 2: Prague, astronomical clock; photo: Antony Dodd

The current set of indicators in PROSUITE is provided in Table 1.[4] However, this is to some extent still work in progress.

Criterion / impact category	List of indicators
Safety, security and tranquillity	• Decrease in knowledge-intensive jobs • Decrease in total employment • Increased risk perception • Possibility of misuse, e.g. terrorism • Other
Autonomy	• Increased child labour • Increased forced labour • Other
Participation and influence[5]	• Decrease in trust in risk information • Limited involvement of stakeholders in decision making processes • Decrease of trust that long-term control will is safeguarded • Other
Equal opportunities	• Increase of income inequalities (Gini-index, i.e. within countries) • Increased in global inequalities (between countries, e.g. developing versus developed countries) • Other

Table 1: Current indicator list in PROSUITE
Source: PROSUITE Case study Meeting Minutes June 5, 2012

[4] PROSUITE Case study Meeting Minutes June 5, 2012

[5] With focus on impacts that are technology-implicit

For the social assessment in this task III, goal is to find a procedure to obtain reasonable information concerning the indicators listed in Table 1 for different parts of the life cycle, and ideally on a basis of every process in the life cycle. The life cycle itself needs to be modeled to meet this goal. Then, information obtained needs to be aggregated over the entire life cycle in order to come to conclusions.

2 Objectives of the social assessment

In PROSUITE, the social assessment is performed in a life cycle perspective, and in parallel to an economic and environmental assessment. This has some implications on a desirable social assessment approach for PROSUITE.

Leaving for the moment the additional PROSUITE requirements of prospective assessment and technology relation aside, following the "complication" approach (see chapter 1), the following objectives can be set for the social assessment approach in PROSUITE:

As overall goal, the PROSUITE statement of work demands "a coherent, life-cycle oriented environmental, economic and social impact methodology"[6]. This can be translated into the following, overarching goals for the method development in this task:

1. A life cycle perspective needs to be applied.
2. The approach needs to be consistent with the economic and environmental approach, and consistent in itself, i.e. not contradictory in its own ("coherence" criterion).
3. Not stated in the quote, the approach needs to be comprehensive, meaning it should be able to assess what is supposed to be assessed.
4. Also not stated in the quote but certainly required, the approach needs to be feasible.
5. In addition, it is desirable for the method to meet general scientific requirements; it needs to be transparent.

These goals need to be met both by the modeling and also by the assessment procedure (that is applied based on a model).

2.1 Life cycle perspective

Life cycle assessments allow a holistic consideration of impacts caused by products and services in raw material extraction, production, distribution, use, and end of life. This comprehensive view avoids burden shifting, by choosing alternatives due to apparent improvements in one life cycle stage at the expense of other life cycle stages.

In dependence on the ISO norms 14040 and 14044 for LCA the method should distinguish between goal & scope, inventory, impact assessment, and interpretation as modelling phases. Further, a functional unit and boundaries of the considered system need to be precisely specified.

2.2 Consistency

Consistency is a basic requirement that all scientific methods have to fulfill. Therefore, first, the developed social assessment method should be consistent in itself. This means the method needs to be unambiguous. Same issues should be solved with the same procedures to have a balanced and symmetric method.

[6] PROSUITE (2009), p. 11

Moreover, the developed social assessment approach should be consistent to the environmental and economic assessments to allow a comparison between the three dimensions. This requires identical and equivalent starting points (definition of goal and scope), identical and equivalent approaches for same methodological aspects (for instance regarding aggregation), identical and equivalent assumptions, etc. for all three assessments, whereas applicable.

2.3 Comprehensiveness

The term comprehensiveness here means that the method should be able to assess what it aims to assess. This sounds trivial, but it is not. Already the goal and scope definition, especially the definition of indicators, plays here a key role. It needs to be ensured that sufficient information is gathered by the selected indicators to assess a specific theme.

For example, an S-LCA case study may aim to assess the theme “changes in land ownership” by the indicator “publicly owned forest” in %.[7] First, changes in land ownership cannot really be captured by a static indicator (percentage). Rather, a change over time, a trend, should be captured by the indicator that fits for the assessment of this theme. Second, there are different land types. For the example case study, it is not clear why forests were chosen and for example agricultural land was ignored.

2.4 Feasibility

Feasibility addresses several characteristics of the method. First, the method should be technically feasible, i.e. generally applicable and without methodological gaps. Second, the application of the method should be possible with manageable time and budget.

For example, the UNEP/SETAC guidelines for S-LCA do not provide any approach for assessing the social impacts over the life cycle in a “social LCIA” method. Also, no guidance is provided on how to aggregate the indicators over the life cycle.

2.5 Transparency

The criterion transparency refers to the entire S-LCA model. For one thing, conducted case studies should be transparent in a way that third parties are able to reconstruct inventory and impact assessment results.

Then, the method will be used by outsiders, i.e. persons not involved in the project, who need to understand each of the technical steps within the method.

3 Modeling the social life cycle

Modeling social impacts related to a product over its entire life cycle means to be able to determine the product life cycle, consisting of multiple, up to several thousand, processes linked together by material and energy flows exchanges. Such a life cycle may start from resource extraction, where raw materials are then passed to refining and processing processes, and continue to various production processes, to product use and then finally to disposal.

[7] Ekener-Petersen, Finnveden (2013)

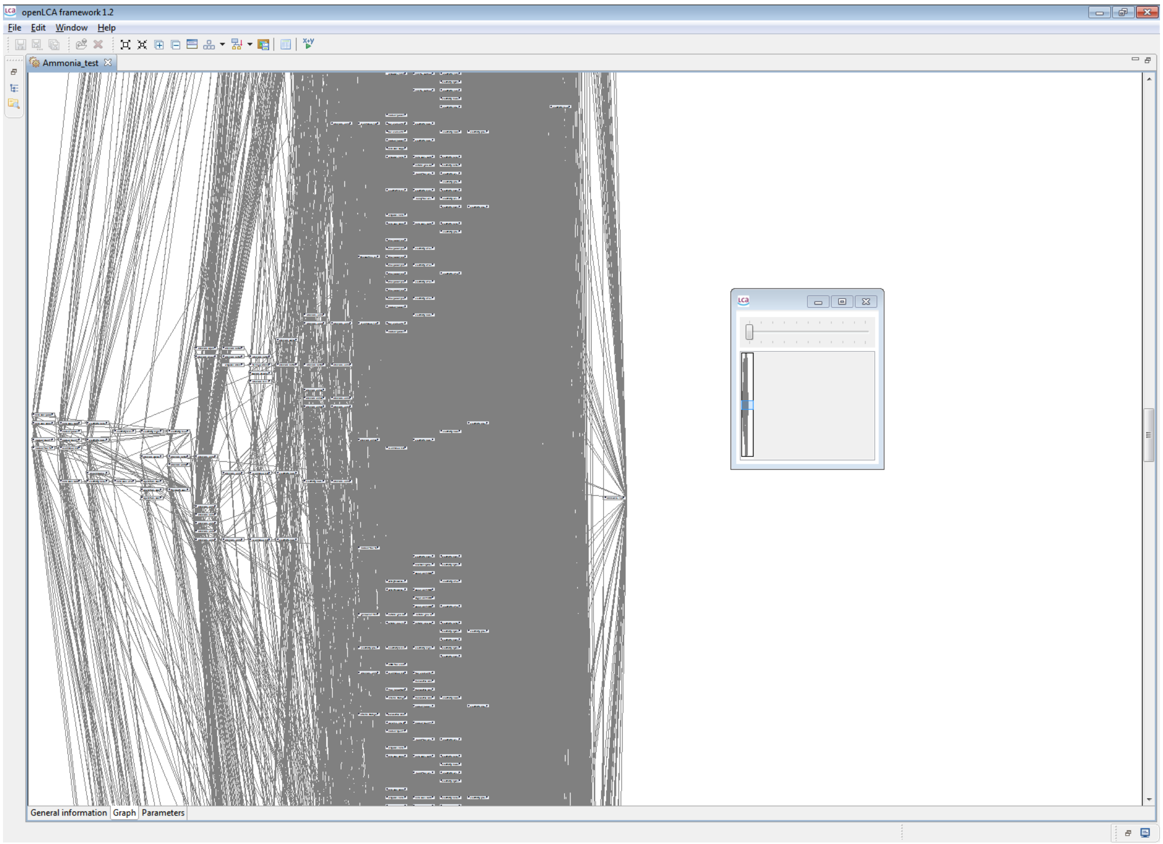

Figure 3: Example for a graphical display of a product life cycle (ecoinvent 2.2 database, ammonia production, displayed in the openLCA software; one box represents one process)

Strictly speaking, every life cycle is infinite[8], but in practice, limits need to be set somewhere. This is done by the scope definition. Here, first, the functional unit is defined which is strongly related to the reference output of the system. In a second step, the life cycle of the considered product must be identified (which processes are necessary, where are the processes located, etc.). In a third step, the identified life cycle is narrowed down; the system boundaries are set.

3.1 The concept of a functional unit – is this useful in the context of social assessment?

The functional unit is one of the core principles of the LCA approach. Defining the functional unit has direct and strong impacts on the overall result of an assessment[9] and should therefore be done with great care. Recall the fundamental role the ISO 14040 standard puts on the functional unit:

> "LCA is a relative approach, which is structured around a functional unit. This functional unit defines what is being studied. All subsequent analyses are then relative to that functional unit, as all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit."[10]

The ISO standards for LCA provide guidance on how to define a functional unit, for example in ISO 14040, 5.2.2:

[8] An investigation of the German electricity mix in 2006 revealed that for gas from Russia, needed for gas-fired power plants in Germany, gas is transported in Siberia through pipelines where pumps are in parts operated with electricity from the Chinese electricity grid (Viehbahn et al. (2007)).

[9] e.g. Ciroth, Srocka (2008)

[10] ISO 14040, 4.1.4

> "The functional unit defines the quantification of the identified functions (performance characteristics) of the product. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results. Comparability of LCA results is particularly critical when different systems are being assessed, to ensure that such comparisons are made on a common basis".

So, the more fundamental reason for a functional unit is comparability. In the ISO 10404 sense, the functional unit specifies the performance characteristics of a product; products with comparable performance characteristics can be assessed over the life cycle, and their environmental (usually negative) performance shows then the overall preferable product (Figure 4).

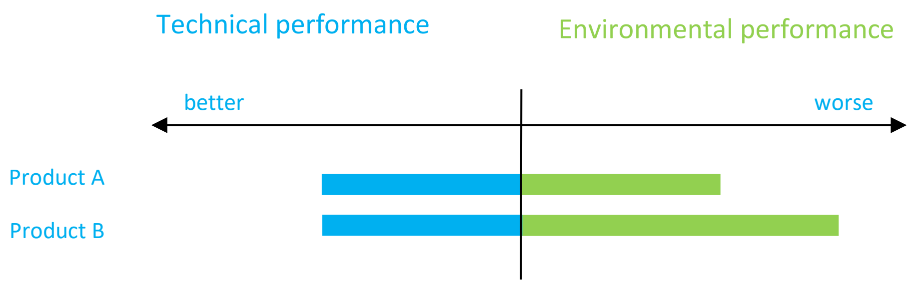

Figure 4: The principle of a functional unit in LCA: with identical technical performance, the environmental performance of products can be reasonably compared in order to identify the best alternative (here: product A)

For the social assessment in PROSUITE, the situation is slightly more complicated, for several reasons:

a) In PROSUITE, there is always a parallel assessment of social, environmental, and economic aspects; trade-offs will exist between these different assessment types, which is implicitly a comparison even if only one product / technology is analysed.
b) Social impacts and thus also social impact assessments are not linear, in contrast to common environmental assessment models (as they are used in the "classic", attributional LCA). Therefore, a simple functional unit concept may be too narrow for the social assessment.
c) Social assessment results can also reveal positive social impacts related to a product or technology. For example, products can lead to an increase in knowledge-intensive jobs.
d) Finally, PROSUITE does not analyse products but technologies.

These points will be addressed more in detail in the following. Point d) will be dealt with in a separate document (Haaster Ramirez 2013). Especially regarding the functional unit, it is possible that our "complication approach" (see section 1) may be misleading, since it is common practice and straightforward to define functional units for products, but quite novel to define a functional unit or "technical performance in a quantitative way" for a technology.

3.1.1 Parallel assessment of social, environmental and economic aspects

In an assessment of social, environmental and economic aspects, results for each of these "dimensions" depend on what exactly is assessed and investigated. A comparison of social effects of apples and economic effects of oranges is probably rather useless; social vs. economic effects of a clearly defined apple are probably much more interesting.

Therefore, in an assessment, it should be very clear "what is being studied" (ISO). This is exactly the concept of a functional unit, when also a quantification of the benefit, specifically the "technical performance" is provided.

Further, in a comparative assessment and also in a parallel assessment of social and economic and/or environmental aspects, the functional unit needs to be identical.

3.1.2 Non-linearity of social assessments

Social effects are often non-linear. However, this does not speak against a functional unit. Very much comparable to consequential LCA, which is also non-linear, non-linearity puts more emphasis on the amount of the functional unit. For a fully linear, attributional LCA, the specific amount that is selected for a functional unit is unimportant, and may be varied from e.g. '1 kWh electricity at grid' to '1 TWh electricity at grid' without changing the relative result. This is very different in consequential LCA, since the electricity market will probably change when a huge additional demand needs to be satisfied. More precisely, the market will change depending on the production conditions and the demand, including the demand induced by the functional.[11] As a consequence, the amount of the functional unit needs also be carefully defined, for consequential LCA.

The same can be done for social assessment, for the same reasons: Since social assessment results are non-linear, they depend on the specific amount of "technical performance" defined in the functional unit.

3.1.3 Positive social impacts and functional unit definition

Strictly speaking, the functional unit tries to capture the technical performance of the product, but in common day practice, this is often translated into the benefit a product may provide (which is then contrasted to its negative environmental performance).

With potentially positive social impacts, a product can have additional benefit besides its technical performance. The UNEP/SETAC guidelines require that the "social utility" of a product is integrated into the definition of the functional unit.[12]

Social impacts of an investigated product are an assessment result however; they are available, evidently, *after* the assessment, that should in turn be based on the functional unit. Considering social impacts in the functional unit thus introduces circular reasoning, which is maybe even tolerable (LCA often refers to iterative approaches) but makes the application at least more complicated.

But such an iterative approach in defining the functional unit for social assessment is not really necessary. Also environmental life cycle assessments may show positive environmental performance, for example when multi-output processes can credibly avoid comparable products with high environmental impacts. In these cases, the functional unit is not adjusted (in the sense: this product has a technical performance of xyz and in addition avoids environmental impacts of abc). Frequently, though, the overall environmental performance is still negative, even if several aspects are positive (see Figure 5 for an example).

[11] Wesnæ*s,* Weidema (2006)

[12] Benoît, Mazijn (2009), p. 53

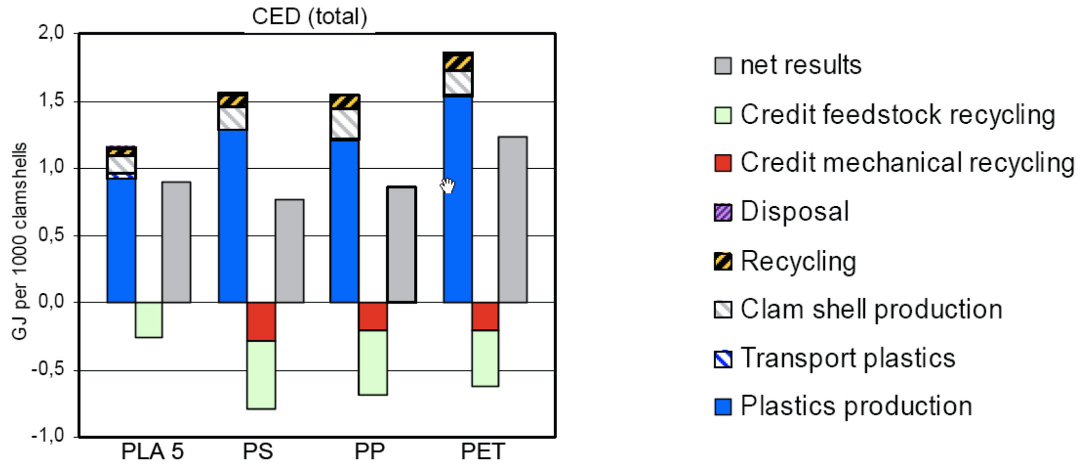

Figure 5: Cumulative energy demand as result of an (environmental) LCA study with negative demand for some parts of the life cycle due to system expansion (avoided product) calculations
Source: Detzel, Krüger (2006), p. 50

It seems reasonable to follow a similar approach also for social assessments in PROSUITE: Should the investigated product have positive social impacts, these are mentioned, and may disappear in the overall net results, but they are not used to adjust the functional unit which strictly reflects the technical performance.

3.1.4 Conclusion

A functional unit is useful also for the social assessment in PROSUITE.

It defines, for a product assessment over the life cycle, the technical performance the product delivers, including a quantification of a reference flow just as it is currently applied in LCA. This quantification is especially important to take into account potential non-linear social impact effects.

In case of positive social impacts related to a product, the functional unit is not "enlarged" to also include the positive social impacts, but still refers to the technical performance only, to avoid circular reasoning.

The functional unit needs to be identical in comparisons, and also in parallel assessments of social, environmental, and/or economic impacts of a product over its life cycle.

3.2 How to identify the life cycle of a product

If a generic product, as for instance a smart phone, should be investigated, a generic life cycle needs to be determined; this generic life cycle describes in which regions and with what kind of technologies and processes are the phone and its components typically produced, and in which amounts. In contrast, the analysis of a specific product, as for instance the iPhone5 from Apple, requires the identification of a specific life cycle, i.e. which components are produced by which company in which site. Also here, the amounts of exchanged products need to be quantified.

Starting point for both kinds of life cycles can be the process network from the (environmental) LCA that is obtained by the following procedure:[13]

- Starting point is the product under investigation, typically in the form as it is described in the functional unit. A first process is modeled that produces the product in the desired amount,

[13] e.g. SETAC (1991) or Baumann, Tillman (2004)

location, and quality.
Example: 10 new iPhone5 at point of sale in Germany; process: representative Apple store in Germany.

- The first process is modeled as an input/output balance; it will usually have inputs of other products, basic materials, electricity, and output of the analysed product and also maybe waste, emissions, and possibly also other products.
- These material and energy flows are “followed up”, new processes are created, again as input/output balances, products on the input side are again followed up, and so forth.

This is a well-established procedure for environmental LCA; for generic supply chains and for background processes, the information can often be taken from publicly available databases which reduces the effort required for the modeling to a very large extent.

Since social assessment and environmental assessment start from the identical functional unit, and assess the same product in a life cycle perspective, it is logical to use the environmental life cycle as a template for the social assessment life cycle. Additional information is needed for the social assessment, however, therefore both life cycles are usually not identical: For S-LCAs it is very important to know where, i.e. in which country and region, and for specific products also in which organisation and site, processes are located. This is due to the fact that social impacts depend decisively on the behaviour of companies (payment of workers, employment of forced labourers, provision of appropriate protection clothes, etc.) and local living conditions (access to infrastructure, access to drinking water, etc.) and not that much on the technical process itself. A similar process in different regions can have very different social effects.

For determining generic life cycles, global production, export, and trade statistics are very useful. They reveal countries with highest production and export rates as well as trade relations between countries.

For specific life cycles, first step is to find the process locations (country and/or region). Second step is to identify involved organisations and sites. This can of course be difficult and at times impossible without insider information. In the latter case processes can be considered on sector level. The example below shows some tricks for obtaining required data.

Example

For electronic products, a disassembly reveals at least most 1st tier suppliers, as almost all components have labels with serial number, name of manufacturer or identification number, and give often hints to the production location. Combined with information on the corporate website or reports it is often possible to obtain all required data.

Further, bar codes provide information about the country of origin and the manufacturer. In the case of GTIN codes (EAN-13), the first two digits identify the country of origin (e.g. 40-44 for Germany) and the next five digits represent the company code. The following five digits code the specific item, while the last one is a check digit. There are online search tools to identify manufacturers with barcodes, for instance www.gepir.de.

3.3 How to define system boundaries

As the PROSUITE sustainability assessment method performs several parallel life cycle analyses (environmental, economic, social; maybe even more since five sustainability endpoints are defined in the sustainability method of PROSUITE[14]), basically two options for the definition of system boundaries exist which are in line with the requirements of the method:

a) **Identical** system boundaries are used;
b) **Equivalent** system boundaries are used.

Both options are discussed in the following subchapters.

3.3.1 Identical system boundaries

The definition of identical system boundaries means that all three life cycle assessments include the same processes, i.e. one system boundary is set for all assessments (see Figure 6). The advantage of this approach is that a full comparison can be done for all processes over all three perspectives. However, it is likely that processes which are relevant for only one analysis are not considered, for practicality reasons, as they are not relevant for the other analyses. For example, research and design are usually not relevant for the environmental assessment but can be highly relevant for the economic assessment, especially for innovative and novel products. Thus severe impacts can be overlooked and conclusions are possibly not reliable. Of course, one could determine that if a process is relevant at least for on perspective it has to be included in the system boundaries, but as result the system would be very broad and likely not feasible anymore.

If really all processes relevant for any of the assessments are taken into account (see Figure 7), then the approach is not efficient as information needs to be collected and analysed that is not relevant for some of the assessments. For example, information on the environmental impact of a three year research and test phase, including environmental impacts due to patent rights specification, would need to be collected and analysed, for a smart phone case study.

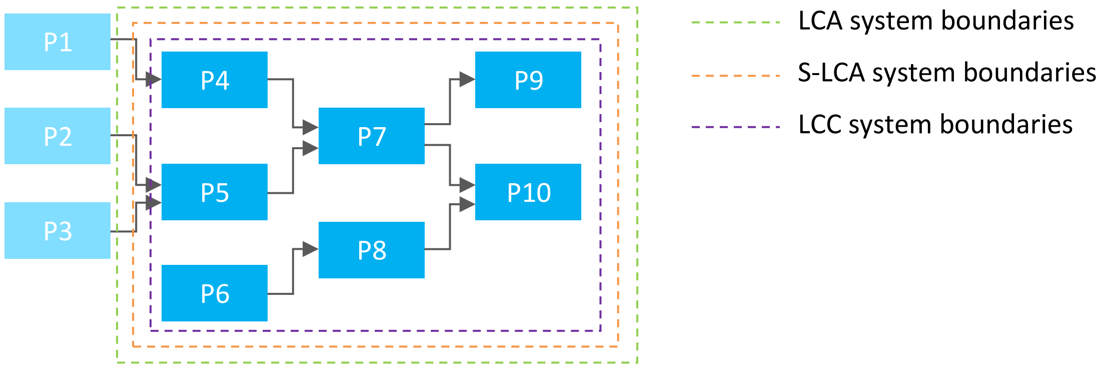

Figure 6: Identical system boundaries, case a: practical approach

[14] www.prosuite.org

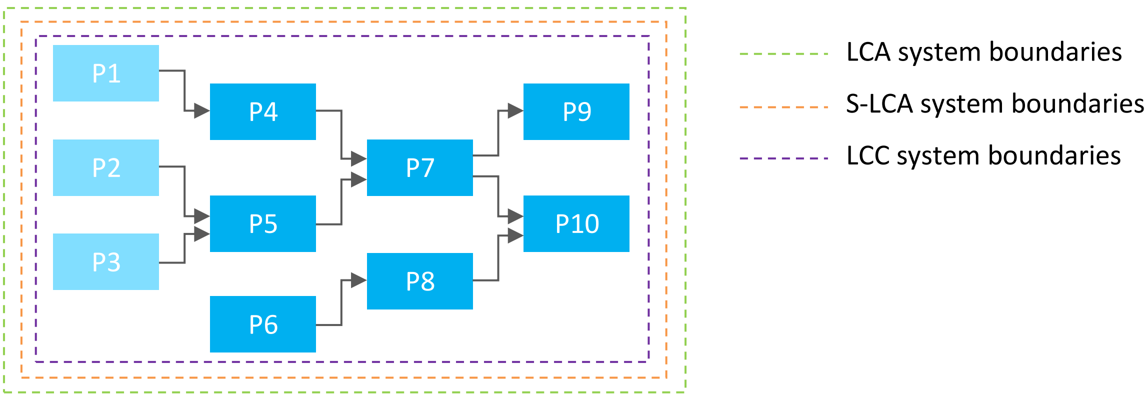

Figure 7: Identical system boundaries, case b: strict approach

3.3.2 Equivalent system boundaries

The application of equivalent system boundaries means that the same principles and cut-off criteria are used to define the system boundaries for all three sustainability dimensions. Thus, the system boundaries for the S-LCA, LCA, and LCC part can differ from each other (see Figure 8), as processes do not necessarily have the same relevance for all the sustainability assessments. Equivalent system boundaries ensure that all relevant processes in the life cycle are covered.

This approach critically depends on how the relevance and the system boundaries are set for each of the assessments. If good relevance criteria can be found, then this approach is more efficient than the “strict identical life cycle approach” and yet not biased, as the pragmatic identical life cycle approach.

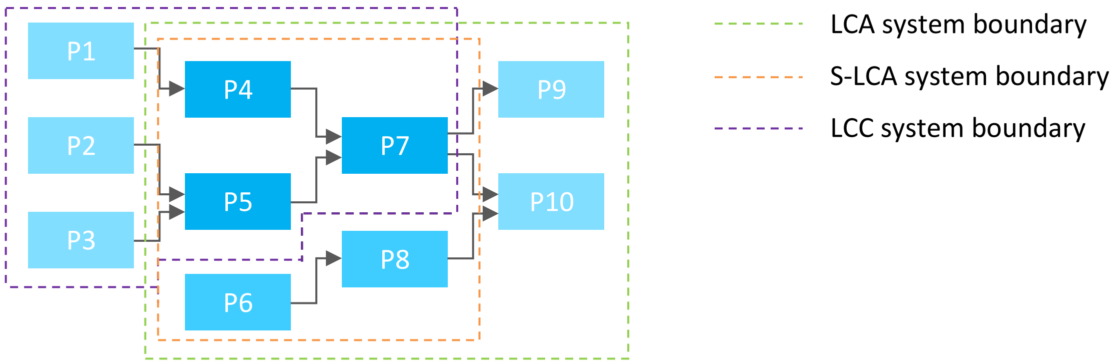

Figure 8: Equivalent system boundaries

3.3.3 Conclusion

Based on the discussion above, equivalent system boundaries are recommended in order to ensure that all relevant processes are considered while keeping the life cycle model relatively small.

The system boundary for the social assessment is recommended to be determined considering the set of social indicators, using a qualitative assessment of relevant processes.

As an option, results from the Social Hot Spot Database can in addition be used for determining system boundaries.

3.4 Definition of background and foreground processes

Conventional LCA process networks include usually hundreds to thousands of processes (see Figure 3), which is feasible due to the use of comprehensive background databases as ecoinvent. Someone who tried to model each process within the system boundaries on site level, with a broad social indicator set, would be occupied for years. To ensure feasibility of the PROSUITE social assessment method, the complexity of the S-LCA has to be reduced, even more so as S-LCA databases can only be applied to a limited extent.

To reduce complexity it is recommended to divide all processes within the system boundaries into foreground and background processes. First, for background processes a less comprehensive indicator system should be applied. Second, data for background processes should be considered on country-specific sector level, i.e. on a more general level. Whether data for foreground processes should be more specific depends on the goal of the study. If a specific product is analysed, i.e. product a of company b produced in site c, it is necessary to collect site- and product-specific data. If, in contrast, a general product d available in country e is object of the analysis, collected data should be on a more general level.

For the classification of processes in foreground or background processes different criteria can be applied, as for example:

- **Number of actors in a life cycle stage**: It is not practicable to contact hundreds of actors in one life cycle stage, so all actors in these phases should be considered as one unit in a background process, for example farmers, mines, or consumers.
- **Fluctuation of actors in a life cycle stage**: If there is a high fluctuation concerning the actors in a life cycle stage, it is also not feasible to consider all specific actors.
- **Relevance of the life cycle stage regarding social issues**: Background processes are considered with a different, less comprehensive indicator system, so relevant aspects might be overlooked. It should be assured that all relevant themes are regarded in the analysis.

For example in the notebook case study the first two criteria were applied. Thus, the production of raw materials and basic materials, as well as the disposal processes were classified as background processes. The design of the laptop, the production of intermediate products, and the laptop assembly were considered as foreground processes.

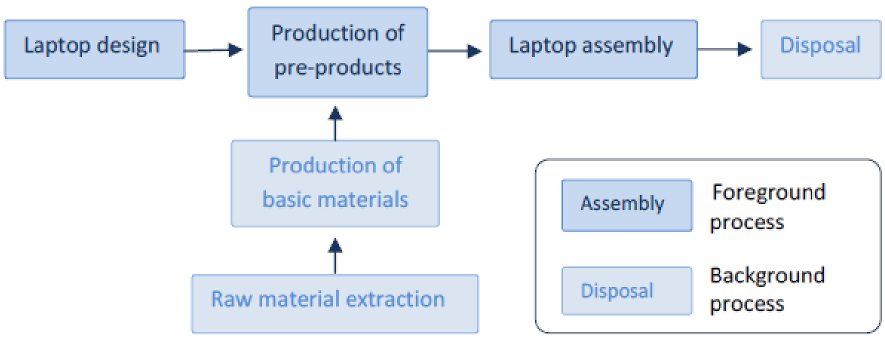

Figure 9: Foreground and background processes in the S-LCA part of the notebook study
Source: Ciroth, Franze (2011), p. 45

4 Types of indicators for the social assessment and their implications on the life cycle model

There are two types of indicators for social life cycle assessment which need to be handled in a different way[15]:

- ***extensive* indicators: These indicators are process-specific** and can be attributed to processes in the life cycle of the analysed product (e.g. salary of workers, employment of child laborers, etc.), and can also be assessed on a process basis.
- ***intensive* indicators: These indicators are not process-specific.** They can only be attributed to the considered product (e.g. possibilities of misuse for terroristic purposes, health effects during use, etc.).

4.1 Modeling of extensive indicators

Modeling the process-specific indicators is more straightforward: Data for defined indicators is collected for each process within the system boundaries. It is possible to apply different indicator sets for different process types (see chapter 3.4).

There are different types of process-specific indicators: Some indicators can be seen as **input or output of a process** (e.g. working hours, salary, or occupational accidents). They can be scaled to the process output which is in turn scaled to the functional unit (FU) of the entire process network. Some indicators can be understood as characteristic or **attribute of a process**, site, company, sector, region, or country (e.g. presence of an anti-corruption policy, respect of indigenous rights, etc.). It is not possible to scale them to process output directly. In order to relate them to the process output, so called activity variables can be applied.[16]

4.2 Modeling of intensive indicators

Intensive indicators cannot be scaled to the functional unit; they describe general characteristics of a product. For example, they answer if there is any possibility to misuse the product for terroristic purposes. Intensive indicators are by definition not specific for each process; they do not relate to specific processes, and thus, it is also not necessary to consider them on the process level. Instead, these indicators should be analysed on the level of life cycle stages. The PROSUITE case studies of mobile phones and carbon capture follow a similar approach.[17] Typical life cycle stages are raw material extraction (RME), production, distribution, use, and end of life (EoL). For some products additional life cycle stages might be necessary, e.g. whole sale or retail.

Further, in each life cycle stage, usually infrastructure will be used, which in turn has on own life cycle, with similar life cycle stages. Evidently, also the infrastructure needs products and infrastructure which again have life cycles.

As a result, all life cycle stages that are relevant for an investigated product can be drawn, and the created picture resembles usually one obtained in the first rounds of a scrabble game.

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[15] Extensive and intensive are taken from terminology used in thermodynamics.

[16] Benoît, Mazijn (2009)

[17] Kautto et al. (2012) and Ramirez, Schakel (2010)

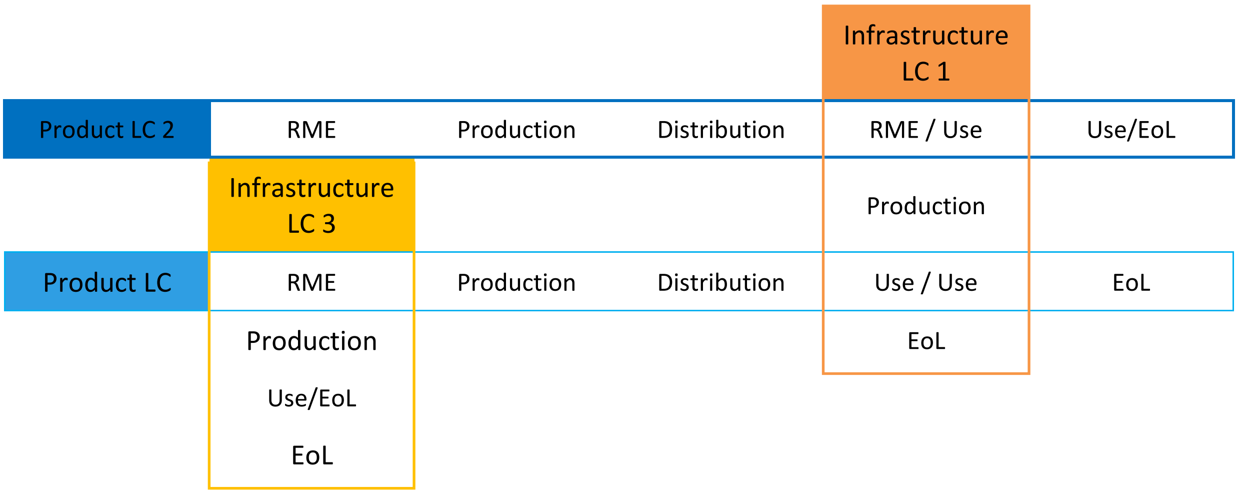

Figure 10: Scrabble-like diagram of the horizontal, product-based life cycles, and vertical, crossing life cycle for infrastructure

Note that in the cross-sections, e.g. 'RME / Use', two different life cycle stages need to be investigated, one for the product and one for the respective infrastructure.

Note further that there may be none or several relevant infrastructure life cycles in each product life cycle stage, and hence also here, the question of system boundary setting comes up.

Usually, though, a second order of a product life cycle (LC2 in the figure above) and related infrastructure (LC3 in the figure above) will not be necessary.

Example

Indicator: Possibility of misuse of the technology for terroristic purposes
Possible indicator values: no risk, low risk, medium risk and high risk
Product: electricity generated by nuclear power plant

	Uranium mine	Plutonium mine	Nuclear power plant	Power distribution network	(Use, without life cycle)	Waste treatment plant
	No risk	No risk	No risk	No risk		No risk
	No risk	No risk	No risk	No risk		No risk
Nuclear electricity	Medium risk		High risk	Low risk	Low risk	Low risk
	No risk	No risk	Medium risk	No risk		No risk

Table 2: Example matrix scheme for intensive indicators; indicator: possible misuse of technology for terroristic purposes

For the product nuclear electricity the possibility of misuse for terroristic purposes is assessed for its life cycle stages raw material production, production, distribution, use, and end of life using the indicator values no risk, low risk, medium risk, and high risk. In addition, related and relevant infrastructure which is needed in the specific life cycle stages of the product is also analysed in the same way. Of course you need more than uranium and plutonium as raw material to produce electricity with a nuclear power plant, but they seem to be the most relevant in respect to the used indicator.

The matrix can be read in this way:

During the extraction of uranium and plutonium there is a medium risk that uranium and plutonium are misused for terroristic purposes, while there is no risk during the raw material extraction for the mines, their construction phase, and their end of life.

During the production of the electricity in the nuclear power plant there is a high risk for misuse. For instance, the nuclear material can be used to build bombs, or the power plant can be used as attack target. Nuclear power plants pose in their disposal phase a medium risk, as nuclear material is still remains.

5 Assessing indicators

Assessment of indicators is the most crucial step in life cycle assessments since only after the assessment, a result is usually available in a way that is aggregated enough to allow for decision support and also for further analysis of most contributing elements in the life cycle. Common procedure in LCAs is to aggregate, in a first step, the inventory indicators, i.e. needed inputs and emitted as well as produced outputs, over all processes in the life cycle; this result is called Life Cycle Inventory, LCI (see Figure 11 for an example, obtained from the European ELCD database using openLCA).

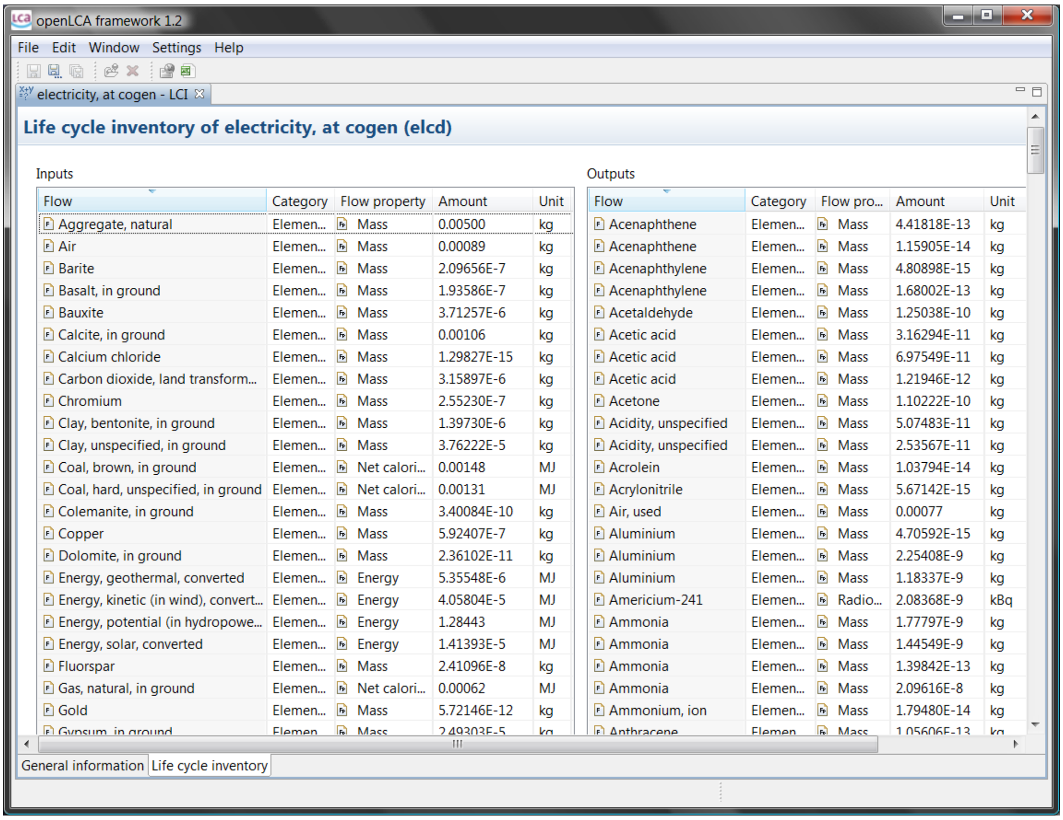

Figure 11: (parts of the) LCI result for the production of 1kWh electricity from hydroelectric power plant, data source: ELCD database, calculated with openLCA

This LCI result is input into the Life Cycle Impact Assessment (LCIA) phase. LCIA methods assign impacts to each flow (classification) and characterisation factors expressing the relative impact of a flow compared to a reference flow for each impact category (characterization) (see Figure 12).

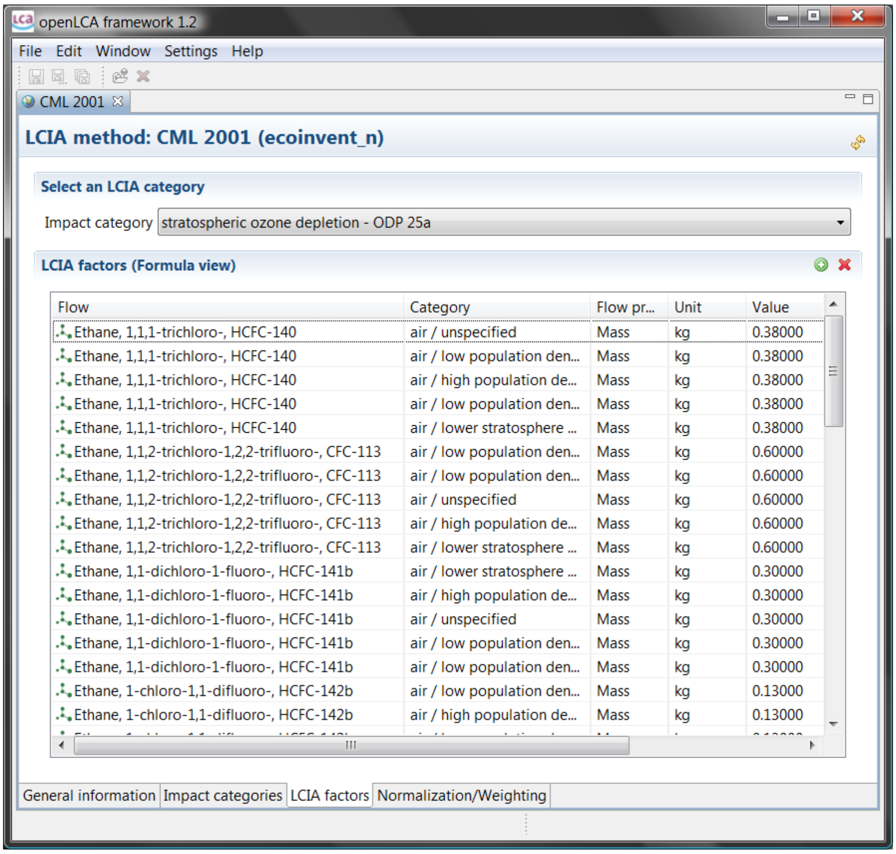

Figure 12: CML 2001 LCIA method, screenshot from openLCA

This procedure is linear, and very convenient in (environmental) LCA and is there applied for many different impact categories. It is also applied in the environmental assessment in PROSUITE.

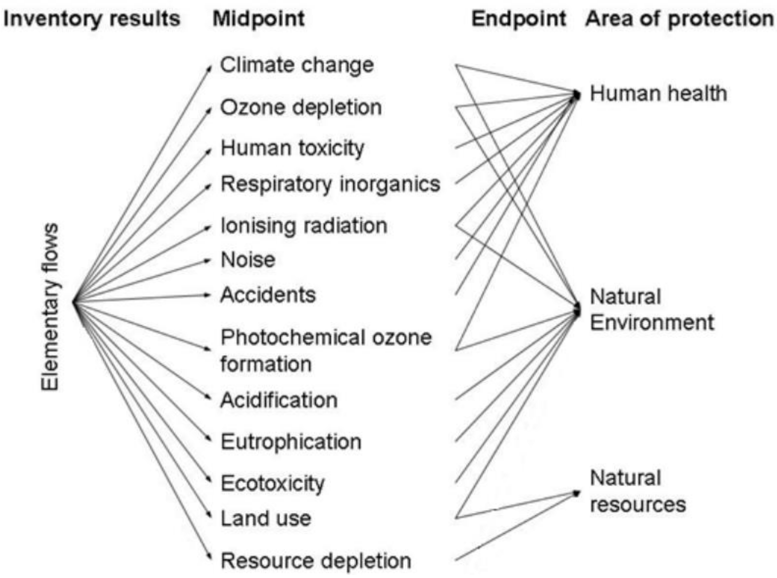

Figure 13: Framework of impact categories for characterization modeling at midpoint and endpoint levels
Source: Dong, Hauschild (2011), p. 9

This procedure can be directly applied for extensive indicators as they are used for example in the Social Hotspots Database.

It is, however, not possible in social LCAs that apply qualitative indicators, or quantitative indicators that cannot be scaled to the process output. Therefore, the impact assessment needs at least in parts be done on the process level.

For the PROSUITE S-LCA method a twofold assessment procedure is proposed: In a first step, the performance of the analysed sector or site is evaluated on indicator level based on performance reference points (PRP). These PRPs define a benchmark and are essential for the assessment; in contrast to environmental LCIA, where the "reference" for each indicator is always unanimously clear (less resource depletion is good; less greenhouse gas emissions are good) this can be more complicated for social indicators; this will be explained later in the text on working time as one example.

5.1 Performance assessment

The performance assessment aims to rate the indicator value on process level to be able to identify good and poor practices without taken into account the impact of this practice. The PROSUITE case study of biorefineries applies the same approach.[18] An analogues procedure does not exist in LCA.

5.1.1 The assessment scale

Many different assessment scales are applied in the field of S-LCA. For example, the Life Cycle Sustainability Dashboard uses a score from 0 to 1000,[19] the PROSA method applies 10 different graduations,[20] while the SEEBALANCE approach scales its fingerprints from 0 to 1.[21] Very common is a range of 5 scores[22] which is usually declared to be based on the Likert scale[23]. It is also common to focus on negative social impacts. In the following two different scales are compared applying this 5 shades approach:

- performance assessment scale A: a scale ranging from 1 (best) to 5 (worst)

performance assessment scale B: a scale from -2 (worst) to +2 (best)

Table 3 shows how the different performance assessment scores can be interpreted. To highlight negative conditions, only one assessment score for positive conditions is provided in this example. Further, one score is provided to express neutral conditions. To assess negative conditions three different scores are in the scale.

[18] De Meester et al. (2012)

[19] Finkbeiner et al. (2010)

[20] Öko-Institut (2007)

[21] Müller, Saling (2011)

[22] e.g. Franze, Ciroth (2011)

[23] Main characteristic of the Likert scale is to provide a symmetrical score, with one neutral assessment in the middle of the available options, with the aim to, in the end, represent the scale model of Thorndike which in turn is based on the normal probability distribution (Diekmann (2003), p. 209). It is an "attudinal" scale, meant to capture human attitudes towards given topics or questions – and was tested by Likert in 1934 in a study on: attitudes towards birth control; the Chinese; Communism; Evolution; the Germans; God/ reality of God, and so forth (Edmondson (2005)). This is often not observed in S-LCA literature even if it is declared that the scores are based on the Likert scale.

Scale A	Scale B	Interpretation
1	+2	Good conditions
2	+1	Neutral conditions
3	0	Light negative conditions
4	-1	Negative conditions
5	-2	Very negative conditions

Table 3: Examples of rating scales

5.1.2 Performance reference points

Performance reference points (PRPs) are target values for indicators that are specified in goal and scope of a study. They have been introduced to S-LCA modeling in the course of the notebook study of Ciroth & Franze[24] with the motivation to make the assessment consistent, transparent, and reproducible. The target values can be qualitative or quantitative; qualitative indicators should have qualitative PRPs, while quantitative indicators should have quantitative PRPs.

PRPs must be defined in a way that they allow a clear assessment of each indicator value to the available assessment scores, i.e. from 1 to 5 with scale A or from -2 to +2 applying scale B. International conventions, goals, or laws can be used to define target values. The PRPs can be agreed with experts or other external stakeholders. It is recommended to discuss and finally decide the PRPs in goal and scope of every case study.

For some indicators it might be necessary to define different target values for different regions. For example, the costs of living differ a lot between different regions, so it does not make sense to define a global target value for salaries.

Example

For the indicator "average working hours per month" a PRP needs to be defined. The ILO conventions no. 1 and no. 30 set the regular working hours per week at max. 48h. This value can be used as minimum standard, i.e. 48h are acceptable and stand for a medium performance. On the other hand, the average working time in Europe for full time workers is around 40h which is used as target value for the best performance. Based on both values (≤40h = good performance, max. 48h = neutral performance), the rest of the table is filled out. For example like this:

Indicator	PRP	Scale A	Scale B
Average working hours per week	≤40h	1	+2
	41 - 48h	2	+1
	49 - 52h	3	0
	53 - 56h	4	-1
	>57h	5	-2

Table 4: Example for Performance Reference Points, PRPs

[24] Ciroth, Franze (2011), Annex VII pp. 403

5.1.3 Conducting the performance assessment

The performance assessment is conducted on process level for each indicator based on the defined PRP. Its task is to assess the performance of the process concerning a social indicator; the PRP should provide guidance for this assessment and should especially clearly state what a desirable, good performance for this indicator and for this process is.

Example

In the following example the performance assessment is conducted with the two assessment scales proposed in 5.1 for the same, fictitious, process. Both scales are very similar; a scale from -2 to 2 may easier suggest that the '0' assessment score is neutral which is a disadvantage since 0 is not neutral but slightly negative in the qualitative assessment explanation.

Category	Subcategory	PA
Safety, security & tranquillity	knowledge-intensive jobs	5
	total employment	1
	risk perception	1
	Misuse	3
Autonomy	child labour	4
	forced labour	5
Participation & influence	trust in risk information	5
	involvement of stakeholders in decision making process	2
	trust that long-term control will is safeguarded	5
Equal opportunities	income inequalities	3
	global inequalities	3

Table 5: Example for a performance assessment (PA) with scale A

Category	Subcategory	PA
Safety, security & tranquillity	knowledge-intensive jobs	-2
	total employment	+2
	risk perception	+2
	Misuse	0
Autonomy	child labour	-1
	forced labour	-2
Participation & influence	trust in risk information	-2
	involvement of stakeholders in decision making process	+1
	trust that long-term control will is safeguarded	-2
Equal opportunities	income inequalities	0
	global inequalities	0

Table 6: Example for a performance assessment (PA) with scale B

5.2 Impact assessment

After the performance assessment, assessment scores are available for all selected indicators,

- on the level of processes for the extensive indicators,
- on the level of life cycle stages for the intensive and qualitative indicators.

These performance results are not directly linked to an impact though, which is similar to environmental performance and the environmental impacts: emitting non-toxic, inorganic dust in a sandy desert (=bad performance) probably causes less environmental impact than when the same emission takes place in high populated areas with a lot of green vegetation.

For the social assessment, creation of knowledge intense jobs (=good social performance) has higher (positive) impact if it happens in an area where these jobs are scarce; it may even have a negative effect if lot of knowledge-intense jobs are already available.

Therefore, after the performance assessment, an additional impact assessment step is necessary.

Let us take again environmental LCA as an example; here, characterization factors are used to calculate the LCIA indicators from the inventory results, using so called characterization models. Characterization factors are often different from 1 and are used to aggregate the inventory results in a linear, simple equation: The products of the amounts of all inventory result and their characterization factor are added up, per impact category. The mathematical function is thus identical to a weighting, but the intent is very different. Aim is here to model, in characterization models, the relevance of each inventory result (i.e. elementary flow) based on scientific findings, excluding subjective evaluation as far as possible.

Distinguishing subjective from objective assessment results is of course also relevant for the social assessment in PROSUITE. Therefore it is desirable to separate characterization and weighting also in PROSUITE. In difference to the environmental LCIA approach, however, the social assessment always involves subjective elements. Also, impact pathway and "social impact assessment characterization" models are not really available. As a consequence, many of the available approaches combine impact assessment, value-based weighting, and "mere" mathematical aggregation. Therefore, all different approaches to further aggregate the performance assessment in social assessment will be dealt with in the next section, under the common term "aggregation".

5.3 Aggregation

After the performance assessment, assessment scores are available for all selected indicators, on the level of processes for the extensive indicators, and on less detailed levels for the other indicators.

In PROSUITE, the social assessment provides input into a sustainability assessment module where results for all different life cycle assessments are combined (

Figure 14). It is also direct output of the social assessment and of the PROSUITE methodology. As any other life cycle assessment approach, also the social assessment requires aggregation of the initial performance assessment information in order to be meaningful for decision support and further analyses. This aggregation will be discussed here in this section.

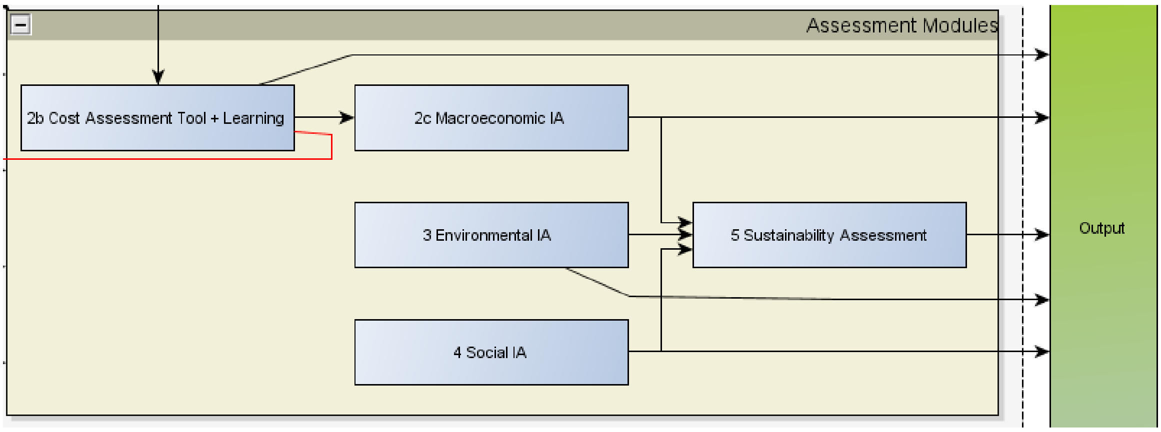

Figure 14: Social Impact Assessment (IA) module in connection with other life cycle impact assessment modules in the PROSUITE DSS
Source: Ciroth (2012), p. 5

The aggregation is for the social assessment probably more challenging than in other life cycle approaches:

- information in S-LCA is more diverse, less homogenous (partly qualitative, potentially biased, …)
- the assessment results are available on different levels (process, life cycle stages)
- the aggregation

The situation is even more complicated given that there are different rationales for the aggregation:

- *Social impacts*: Very similar to the LCIA in environmental LCA, where characterization models lead to an aggregation of information, combining for e.g. climate change a multitude of different elementary flow emissions into one indicator score for greenhouse gas emissions. **This aggregation is impact-driven**. In addition to "mere" aggregation, purpose is here to also obtain new, impact-related information, just like the amount of carbon dioxide equivalents in greenhouse gas indicator calculation.
- *Mathematics*: the aggregation may need to follow a pure mathematical aggregation approach. An example is the LCI calculation in environmental LCA, based on the individual process balances in the life cycle;
- *Values*: the aggregation may want to reflect values inherent in the different elements that need to be aggregated. This aggregation is similar to weighting in environmental LCIA.

Before developing a specific approach for PROSUITE, let us first look at other examples from literature.

5.3.1 Some aggregation examples from social LCA literature

5.3.1.1 Social Hotspots Database study, Norris et al. (2012)

In a study based on the Social Hotspots Database (SHDB) a hotspot index is calculated based on labour intensity in the considered sector and the severity of social issues and their risk level.[25]

More in detail, the approach is as follows:

The severity / risk of an impact is scaled, e.g. on a scale from 1 until 4, and available per sector and country in the database (

1. Figure 15).

[25] Benoît Norris (2012)

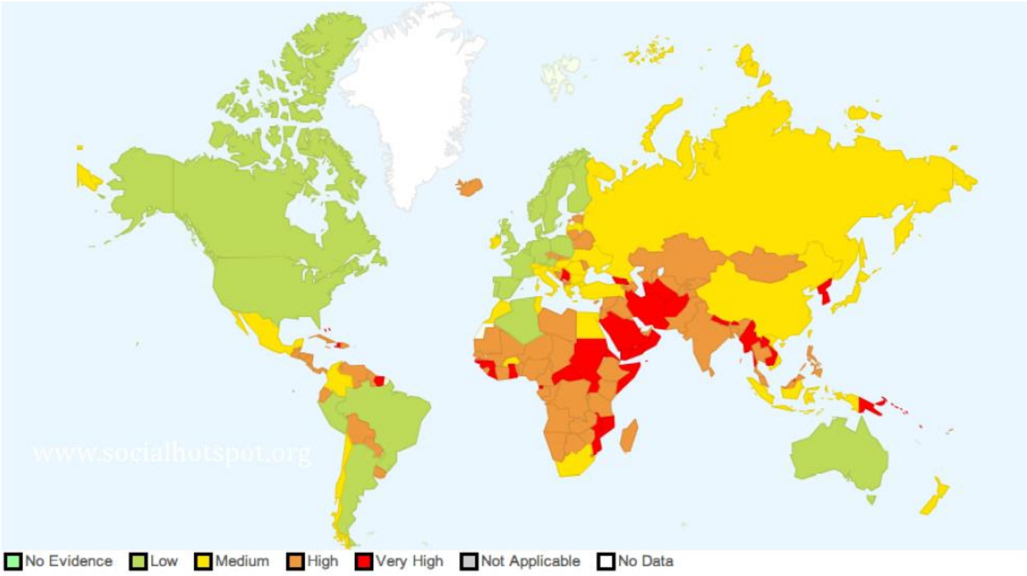

Figure 15: Impact risk level in the social hot spot database for potential countries not passing Labour Laws Source: Benoît Norris (2012)

1. Any process in the life cycle that happens in an assessed sector and country obtains the respective score, using information from the database.
2. The contribution of each process in the life cycle to the overall life cycle is assessed by the working hours spent there; these are also taken from the database.
3. Results are risks for all selected indicators over the life cycle, based on information on the process level.
4. This result is further aggregated to a hot spot index, which can be displayed in relation to percentage of worker hours for country-specific sectors in the supply chain (see Figure 16).

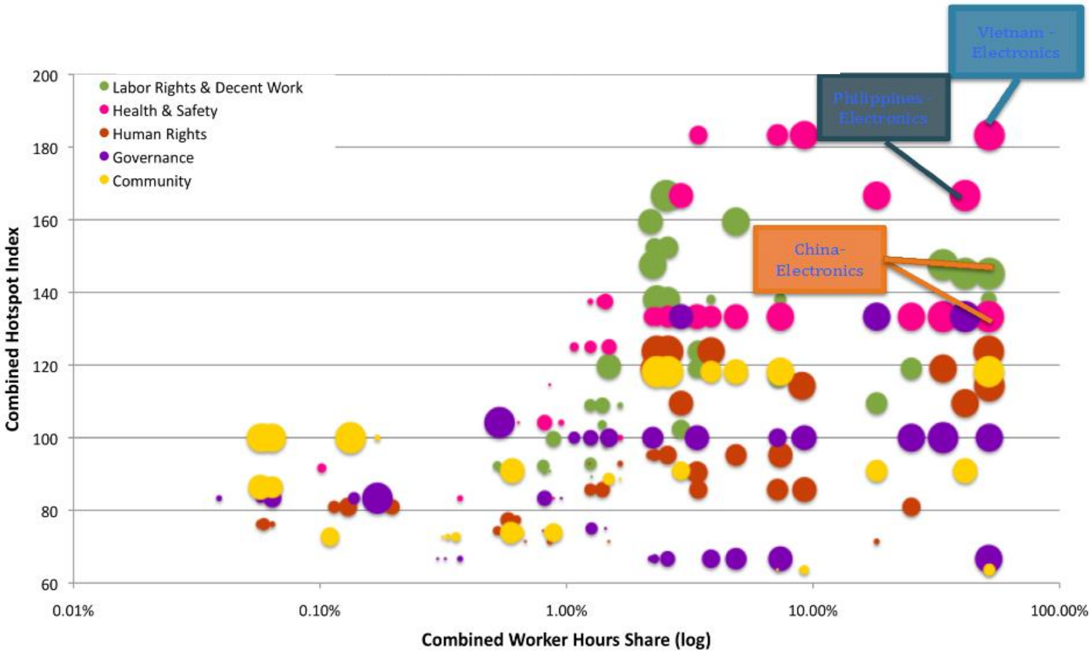

Figure 16: Hotspot indices combined with worker hours share in a laptop case study based on the SHDB Source: Benoît Norris (2012), p. 46

This approach contains both impact driven elements (assessing the contribution of each individual process to the overall life cycle) and value-laden elements (the aggregation into one single index). However, already the selection of worker hours for the aggregation over the life cycle is not a fully objective, impact-driven choice but to some extent also a value choice. Many indicators, especially those not related to the stakeholder worker, will not depend on working hours spent on a process.

5.3.1.2 AgBalance, BASF (2012)

The AgBalance method, developed by BASF in 2012[26], relies only on quantitative social indicators. The indicators values are collected per industrial sector in relation to production volumes. The social indicators are scaled to the functional unit, which is called customer benefit in the method. For example, the number of fatal working accidents per functional unit is calculated per process in the life cycle. Since all the indicators are quantitative, they can be calculated for the overall life cycle just as environmental life cycle inventory figures.

These life cycle results are then normalized and weighted, and a so called "fingerprint" is obtained, with a score from 0 to 1; in comparisons, results from one alternative are also set in relation to the best alternative, therefore results above 1 are possible. How this procedure works in detail is not published so far, some principles are described in BASF (2012). This publication also contains one example of the applied weighting schema, see Figure 17. The figure has to be read as follows (quote from BASF (2012), p. 29):

> "[the table] lists the societal weighting factors in Europe for individual environmental and social indicators and categories. The societal weighting factor for the indicator 'Erosion' contributes 62 percent to the category 'Soil', which in turn adds 11 percent to the environmental score. Likewise, the societal weighting factor of the indicator 'Access to land' is 50 percent of the category 'Local and National Community', which contributes a 25 percent weighting to the overall social score."

[26] BASF (2012)

Resources	13%				
Energy	10%				
Emissions	17%	Air Emissions	36%	Greenhouse Gases	33%
				ODP	26%
				POCP	15%
				AP	26%
		Water Emissions	39%		
		Solid Wastes	25%		
Eco-Toxicity Potential	14%				
Land Use	7%				
Water Use	13%				
Biodiversity	14%				
Soil	11%	Carbon Balance	14%		
		Nutrients Balance	14%		
		Erosion	62%		
		Compaction	10%		
Farmer	25%	Working accidents	15%		
		Fatal working accidenta	20%		
		Occupational Diseases	15%		
		Toxity Potential	25%		
		Wages	10%		
		Professional Training	10%		
		Organization	5%		
Consumer	20%	Residues in Food&Feed	60%		
		Residues of GMO	40%		
Local/Nat. Commun.	25%	Access to Land	50%		
		Employment	10%		
		Gender Equality	10%		
		Integration	10%		
International Commun.	10%	Imports from Devel. Countries	66%		
		Fair Trade	33%		
Future Generations	20%	Trainees	50%		
		Social Security	50%		

Figure 17: Example of the AgBalance weighting schema, full screenshot from BASF (2012) p 30, more explanation see text

The mathematical life cycle calculation is straightforward, the weighting combines (implicit) impact modeling and value choices. So far, only weighting sets for Europe are published.

5.3.1.3 Notebook Computer Social LCA, Ciroth Franze (2011)

A case study of Ciroth and Franze[27] on a notebook computer applies an aggregation on different levels. As result from a performance assessment, scores from 1 to 6 are available for each process in the notebook life cycle. Also for each process, an impact assessment result is available, also in six scores from 1 until 6. The impact assessment result is obtained by considering the impact of the indicator subcategory on the different impact categories (Figure 18). A stronger impact "enhances" the score obtained in the performance assessment for the impact assessment: With a strong impact, a good performance becomes a very positive impact, and a bad performance yields a very bad impact. In absence of established impact assessment models, this assessment was obtained by expert judgment.

Finally, all assessments on the process level are done for all stakeholder groups separately, leaving, for the notebook study, 5 different assessments, one for each stakeholder (workers, local community, society, value chain actors, consumers), with different indicators for each.[28]

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[27] Ciroth, Franze (2011)

[28] Ciroth, Franze (2011), p. 32

Stake-holder	Subcategory	PA	WC	HS	HR	SER	IR	G	IA
Workers	Freedom of association & collective bargaining	5	✓	✓	✓	✓	✓	✓	6
	Child labour	1	✓	✓	✓	✓	✓	✓	1
	Forced labour	1	✓	✓	✓	✓	✓	✓	1
	Fair salary	5	✓	✓	✓	✓	✓	✓	5
	Working time	6	✓	✓	✓	✓	✓	✓	6
	Discrimination	5	✓	✓	✓	✓	✓	✓	6
	Health & safety	deficient data							
	Social benefits/social sec.	5	✓	✓	✓	✓	(✓)	✓	6
	Amount	5.00							5.00
Local community	Access to material res.	3	(✓)	✓	✓	(✓)	(✓)	✓	3
	Access to immaterial res.	5	✓	✓	✓	✓	✓	✓	5
	Delocalisation & migration	2	-	(✓)	✓	(✓)	✓	(✓)	2
	Cultural heritage	deficient data							
	Respect of indigenous rights	not relevant							
	Safe & healthy living cond.	3	(✓)	(✓)	(✓)	(✓)	-	✓	4
	Secure living conditions	no data							
	Local employment	5	✓	✓	✓	✓	✓	✓	5
	Community engagement	no data							
	Amount	4.50							4.00
Society	Public commitments to sustainable issues	6	✓	✓	✓	-	(✓)	✓	5
	Contribution to economic development	4	✓	✓	✓	✓	✓	✓	2
	Prevention & mitigation of conflicts	5	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	5
	Technology development	no data							
	Corruption	no data							
	Amount	5.00							4.00
Value chain actors	Fair competition	3	(✓)	(✓)	(✓)	-	-	✓	2
	Promoting social respons.	3	✓	✓	✓	(✓)	(✓)	✓	2
	Supplier relationships	no data							
	Respect of intellectual property rights	2	-	-	(✓)	-	-	(✓)	2
	Amount	2.67							2.00
Consumers	Health & safety	2	(✓)	✓	(✓)	(✓)	-	✓	3
	Feedback mechanism	3	-	(✓)	(✓)	(✓)	-	(✓)	2
	Transparency	4	(✓)	(✓)	(✓)	(✓)	-	(✓)	2
	End of life responsibility	3	(✓)	(✓)	(✓)	-	-	✓	2
	Amount	3.00							2.25
Total amount		4.03							3.45

Figure 18: Example for performance and impact assessment scores per subcategory, and aggregation on process level Source: Ciroth, Franze (2011), p. 100

PA: Performance assessment; WC: working conditions; HS: health and safety; HR: human rights; SER: socio-economic repercussions; IR: indigenous rights; G: governance; IA: Impact Assessment;
"✓": strong impact (of subcategory indicator on impact category); ("✓"): weak impact (of subcategory indicator on impact category); "-" no impact

These results are aggregated in various ways in the study:

a) For each process and for each stakeholder, across all stakeholder indicator results
b) For each process, across all stakeholder results
c) For each stakeholders, across all processes in the life cycle (tentatively)
d) For each life cycle, across all stakeholders (tentatively)

For a) and b), the following algorithm was used for the aggregation:

The aggregate result is in principle calculated as the arithmetical mean. If however one subcategory within one stakeholder group has a score of 6, the average for this stakeholder group cannot be better than 5, if one subcategory within one stakeholder group has a 5, the average for the stakeholder group cannot be better than 4, and so on.

For c) and d), simply the arithmetical average was used. The authors of the study see this as weakness. Figure 19 shows an example of the aggregation c), for the stakeholder worker.

Figure 19: Aggregated impact assessment results for the stakeholder group worker
Source: Ciroth, Franze (2011), p. 104

5.3.1.4 Social Attribute Assessment, Norris (2006)

Norris[29] proposes a life cycle attribute assessment where, similar to labels, positive attributes of processes in a life cycle are simply counted. Attributes of a process are, e.g.: “child labour free”, “best management practices applied”, etc.. Result is a relative statement of how many percent of the processes in the life cycle fulfill the defined attributes (e.g. 75% of processes in life cycle 1 are child labour free, 53% of processes in life cycle 1 have best management practices, etc.).

5.3.1.5 QALY, Weidema (2006)

The QALY approach by Weidema[30] combines different statistical indicators to one aggregated, single score indicator. It is a purely quantitative approach that allows to sum up the results for short term damages, long term damages, and total damages (see Figure 20). Weidema’s approach combines a

[29] Norris (2006)

[30] Weidema (2006)

broad number of different sources in a direct way, implying a relation of the different indicators to the final indicator, without discussing how far this is justified.

Infringement	Capita affected annually, E+6	Short term damage, annual, QALY per capita affected	Long term damage, annual, QALY per capita affected	Average age of victim	Total short term damage, E+6 QALY	Total long term damage, E+6 QALY	Total damage, E+6 QALY
	A	B	C	D [a]	E=A*B	F [a]	E+F
Bonded labour [b]	20	0.4	0.15	30	8	7	15
Child labour [b]	180	0.4	0.15	12	72	162	234
Trafficking [c]	3.7	0.8	0.15	21	3	14	17
Incarceration [d]	9	0.8	0	n.r.	7	0	7
Excessive work [e]	1,000	0.2	0	n.r.	200	0	200
Torture [f]	0.1	1.4	0.15	21	3	14	17
Genital mutilations, female [g]	2	0.3	0.2	12	1	14	15
Genital mutilations, male [g]	13	0.3	0	n.r.	4	0	4
Interpersonal or communal violence [h]	26	0.2	0	n.r.	5	0	5
	10% of which	0.2	0.15	20	1	11	11
Crime victim compensation [h]	4	-0.1	0	n.r.	–0.4	0	–0.4
No access to contraceptives [i]	200 (women)	0.1	0	n.r.	20	0	20
Unwanted pregnancies [i]	60	0.2	0.1	24	12	90	102
Refugees or internally displaced [j]	37	0.3	0	n.r.	11	0	11
Warehoused refugees (> 5 years) [j]	8	1.5	0.2	20	12	35	47
Infringement of freedom of expression [k]	2,400	0.1	0	n.r.	240	0	240
Sum					596	334	929

[a] Average age of victim (column D) is only relevant for the calculation of long-term damage, which does not apply to all types of infringements. F is calculated as A/t*C*(47-t-D), i.e. by multiplying the prevalence (A/t), the severity (C) and the remaining lifetime (47-t-D). The duration (t) of the incidences is measured in years and generally set to 1, but for bonded labour, child labour and warehousing, a duration of 5 years per incidence is assumed, the prevalence therefore being 5 times lower than number of persons affected annually. The assumed average life expectancy of victims is 47 years, as already reduced due to the separately measured general health impacts (the health gap in Fig. 2).
[b] Source: <www.antislavery.org>. The value covers only the worst forms of child labour.
[c] 700,000 people annually are trafficked across national borders (USDJ 2004), and an additional 3 million women annually are trafficked internally (UNFPA 2000).
[d] 9 million people are in prison (Walmsley 2003). As for the other items, this is a neutral observation, and no moral judgement is implied.
[e] 1,000 million people have excessive work hours <www.ilo.org>.
[f] 100,000 people are received annually by torture rehabilitation centres <www.hiltonfoundation.org>
[g] <www.noharmm.org/HGMstats.htm>
[h] Author's estimate of violence victims, based on Krug et al. (2002). Only 4 million out of these victims of violence have access to a crime compensation programme (Calculated from combining the national assault statistics with data from the International Crime Victim Compensation Program Directory <www.ojp.usdoj.gov/ovc/intdir/>).
[i] Vlassoff et al. (2004)
[j] <www.refugees.org>
[k] The global population weighted prevalence of infringements of freedom of expression is 53% (calculated from Karlekar 2004), assumed to relate only to the adult 72% of the population.

Figure 20: A first estimate of the global burden of autonomy infringements
Source: Weidema (2006), p. 93

5.3.2 Aggregation in PROSUITE

So, how should then the aggregation for the social assessment in PROSUITE look like? We will first formulate some requirements for an aggregation, based on Ciroth (2012a), and then explain different options.

5.3.2.1 Requirements for the PROSUITE aggregation approach

The following requirements should be met by the aggregation method in PROSUITE:

a) Regarding the aggregation result

- A good overall aggregation of the social assessment result should be provided
- No introduction of biases, complete and "good" representation of the assessment results on process and LC stage level
- The aggregation result should be easy to understand
- Hot spot and contribution analyses should be possible based on the result
- Results must also be available on more detailed levels
- The result should be suitable input for the integration module in PROSUITE

b) regarding the aggregation procedure

- The aggregation needs to be applicable for all types of indicators in PROSUITE (extensive and intensive types, see section 4).
- The aggregation procedure should be practical, easy to be performed, ideally in an automated manner
- The aggregation will always, at least partially, contain value judgments; for every case study, value judgments potentially vary; the procedure should therefore be "permeable" for values as they are specified in goal and scope of a study
- The procedure should be consistent with aggregation procedures applied in the environmental and economic assessment in PROSUITE.

5.3.2.2 Aggregation options for PROSUITE

5.3.2.2.1 "School mark "

Description: The result is in principle calculated as the arithmetical mean. If however one element in the aggregation has a score of 6, the aggregation result cannot be better than 5; with a score of 5, the result cannot be better than 4. Taken from Ciroth, Franze (2011).

Expressed in a formula:

$$A = \begin{cases} \begin{cases} 5, & \frac{\sum_{i=1}^{n} xi}{n} \leq 5 \\ \frac{\sum_{i=1}^{n} xi}{n}, & otherwise \end{cases}, & \exists x \in X, x = 6 \\ \begin{cases} 4, & \frac{\sum_{i=1}^{n} xi}{n} \leq 4 \\ \frac{\sum_{i=1}^{n} xi}{n}, & otherwise \end{cases}, & \exists x \in X, x = 5 \\ \frac{\sum_{i=1}^{n} xi}{n}, & otherwise \end{cases} , X \coloneqq \{x1, \ldots, xn\}, n \coloneqq number\ of\ elements$$

Properties: The arithmetical average leads to a good, unbiased aggregation; bad performance cannot be compensated with good performance, which makes the aggregation more sensitive to bad performance than a straightforward arithmetical mean. Without activity variable, the specific importance of a process for the overall system is not considered in the aggregation, each process contributes equally to the result.

5.3.2.2.2 Pessimum

Description: This approach simply takes the worst evaluation score from each element in the aggregation.

Expressed in a formula: $\max(X), X \coloneqq \{x1, \ldots, xn\}, n \coloneqq number\ of\ elements$

Properties: The aggregation leads to a very negative result which is however useful to see the worst score in the overall system.

5.3.2.2.3 Optimum

Description: This approach simply takes the best evaluation score from each element in the aggregation.

Expressed in a formula: $\min(X), X \coloneqq \{x1, \ldots, xn\}, n \coloneqq number\ of\ elements$

Properties: The aggregation leads to a very positive result which could however be useful to see the best score in the overall system.

5.3.2.2.4 Relatively positive

Description: The share of all elements above a certain threshold is calculated, e.g. all elements that score 'good' (see the performance scales in Table 3). Adapted from Norris (2006).

Expressed in a formula: $A = \frac{\sum_{i=1}^{n}[xi \leq y]}{n}, y \coloneqq minimum\ score\ to\ count, n \coloneqq number\ of\ elements$

$$[a = b] \coloneqq \begin{cases} 1, & a = b \\ 0, & a \neq b \end{cases}$$

Properties: This aggregation obviously neglects all negative elements, and gives thereby a quite biased result. The result depends also on the sheer amount of processes in the life cycle, splitting a "good" process in two gives a better result. It is interesting as an addition to other aggregation rules, since it is often easier to detect good performance than bad performance. Without activity variable, the specific importance of a process for the overall system is not considered in the aggregation, each process contributes equally to the result.

5.3.2.2.5 Relatively negative

Description: The share of all elements below a certain threshold is calculated, e.g. all elements that score 'negative' or 'very negative' (see the performance scales in Table 3). Adapted from Norris (2006).

Expressed in a formula: $A = \frac{\sum_{i=1}^{n}[xi \geq y]}{n}, y \coloneqq maximum\ score\ to\ count, n \coloneqq number\ of\ elements$

$$[a = b] \coloneqq \begin{cases} 1, & a = b \\ 0, & a \neq b \end{cases}$$

Properties: This aggregation obviously neglects all positive elements, and gives thereby a quite biased result. The result depends also on the sheer amount of processes in the life cycle, splitting a "bad" process in two gives a worse result. It is interesting as an addition to other aggregation rules, putting a focus on hot spots. Without activity variable, the specific importance of a process for the overall system is not considered in the aggregation, each process contributes equally to the result.

5.3.2.2.6 Activity variables

Description: Activity variables have been introduced by Greg Norris into social assessment; motivation is to scale qualitative or intensive indicators to the relevance of processes in a life cycle, just as it is done in environmental LCA with the product amount of each process. Adapted from Norris (2006). An activity variable is a quantitative variable that is relevant for the social assessment. Since product amounts are rather unimportant for social impacts, worker hours are often used as activity variable.

Properties: Only with an activity variable, the specific quantitative contribution of a process to the aggregation result can be considered; the aggregation result is therefore, in this case, much more meaningful. It is however often difficult to find a suitable variable. For PROSUITE, working time is not part of the currently discussed indicators (see Table 1). Also the other indicators seem not really suitable. Therefore, for PROSUITE's current indicator set, no activity variable is proposed.

5.3.2.3 Proposal for an aggregation procedure for the social assessment in PROSUITE

All the different aggregation approaches contain value choices; for a case study, the selected approach should therefore be discussed and selected in goal and scope.

As a default, it is recommended to use all the above described approaches in parallel (!), thereby obtaining a result as follows:

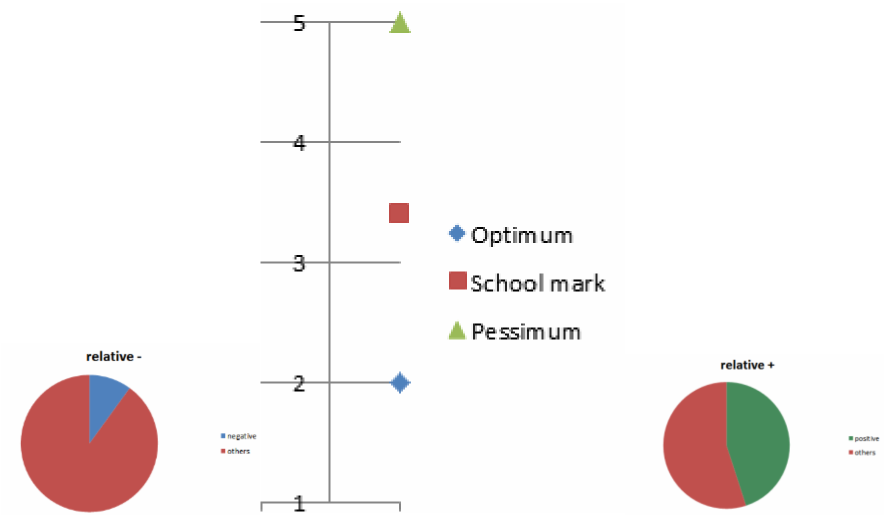

Figure 21: Proposal for a social assessment aggregation result

In any case, goal and scope needs to set the thresholds that are used in the aggregation approaches.

6 Consideration of data uncertainty

6.1 Why consider uncertainty?

The consideration of data uncertainties in S-LCA seems very important – even more important than in conventional LCAs, as social conditions can change very fast – faster than technical aspects. Thus, social data can be outdated very fast. On the other hand, conditions can be stable for years, so that data from 5 years ago can still be valid for current conditions. Further, verified data or scientific documents are only available in rare cases. Even if data in grey literature is available, their credibility is limited. Therefore, it is recommended to analyse uncertainties for each indicator in the social assessment and to consider the results of the uncertainty analysis during the interpretation phase.

6.2 Uncertainty analysis methods

Basically, the consideration of data uncertainties can be done in a quantitative way (e.g. determination of distribution, standard deviation, and other parameters depending on distribution), semi-quantitative way (grouping in uncertainty classes), or also in a fully qualitative way (description of uncertainty). Also combinations are possible. Since values for social indicators are not literally measured, as for instance the electricity consumption of a machine, pure quantitative methods do not seem suitable. It will be impossible to determine the uncertainty distribution, standard deviation, etc. for the total amount of working hours in a sector, for example. Also pure qualitative approaches seem not useful, as an aggregation is not possible. A qualitative method would provide an uncertainty description for each indicator value in the entire life cycle. Semi-quantitative approaches and the combination of qualitative and quantitative methods respectively are most appropriate, as they, first, do not need quantitative uncertainty data and second as they allow aggregation.

6.2.1 The pedigree matrix

For the consideration of uncertainties in the PROSUITE method an adaption of the pedigree matrix to social data is proposed. The pedigree matrix was brought in uncertainty analyses by Funtowicz and Ravetz, "as a means to code qualitative expert judgement for a set of problem-specific 'pedigree criteria' into a numerical scale, with criteria as columns of the table, the numerical codes as table lines, and linguistic descriptions for each value in each cell of the table."[31] The pedigree matrix transfers qualitative descriptions of relevant aspects regarding data uncertainty of an object of investigation to quantitative assessment scores. The rating scale as well as the criteria shall be selected according to the needs of the object of study; they are not predefined. The pedigree matrix was, amongst others, modified by Weidema and Wesnæs[32] for the use in LCAs and is applied in a modified form in the ecoinvent database:

Indicator score	**1**	**2**	**3**	**4**	**5** (default)
Reliability	Verified[5] data based on measurements[6]	Verified data partly based on assumptions ***or*** non-verified data based on measure-ments	Non-verified data part-ly based on qualified estimates	Qualified estimate (e.g. by industrial ex-pert)	Non-qualified estimate
Completeness	Representative data from all sites relevant for the market consid-ered, over an ade-quate period to even out normal fluctuations	Representative data from >50% of the sites relevant for the market considered, over an adequate period to even out normal fluc-tuations	Representative data from only some sites (<<50%) relevant for the market considered ***or*** >50% of sites but from shorter periods	Representative data from only one site rel-evant for the market considered ***or*** some sites but from shorter periods	Representativeness unknown or data from a small number of sites ***and*** from shorter periods
Temporal cor-relation	Less than 3 years of difference to the time period of the dataset	Less than 6 years of difference to the time period of the dataset	Less than 10 years of difference to the time period of the dataset	Less than 15 years of difference to the time period of the dataset	Age of data unknown or more than 15 years of difference to the time period of the da-taset
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar produc-tion conditions	Data from unknown ***or*** distinctly different area (North America in-stead of Middle East, OECD-Europe instead of Russia)
Further tech-nological cor-relation	Data from enterprises, processes and materi-als under study	Data from processes and materials under study (i.e. identical technology) but from different enterprises	Data from processes and materials under study but from differ-ent technology	Data on related pro-cesses or materials	Data on related pro-cesses on laboratory scale ***or*** from different technology

Figure 22: Pedigree matrix in ecoinvent
Source: Weidema et al. (2011), p. 83

[31] Funtowicz, Ravetz (1990)

[32] Weidema, Wesnæs (1996)

However, in ecoinvent, the pedigree results are not taken directly. They are used to estimate the standard deviation which is used together with an estimated basic uncertainty factor and an imputed log normal distribution to specify the overall uncertainty of a flow.

For PROSUITE a simplified method is proposed: First, the pedigree matrix used in ecoinvent should be modified taking into account the characteristics of site- and sector-specific social data. Since the requirements for site- and sector-specific data differ a lot, two different pedigree matrices are proposed. While Figure 23 shows the proposed pedigree matrix for site-specific data, Figure 24 presents the proposed pedigree matrix for social data on sector level.

Score / Indicator	1	2	3	4	5
Reliability	Verified data from primary data collection	Verified data partly based on assumptions or non-verified data based on primary data collection	Non-verified data partly based on assumptions or data based on grey, but scientific documents	Qualified estimate (e.g. by expert) or data based on non-scientific documents	Non-qualified estimate or unknown origin
Completeness	Representative data for organisation and site under study	Data from more than 75% of all individuals within the estimated sample	Data from more than 50% of all individuals within the estimated sample	Data from more than 25% of all individuals within the estimated sample	Data from less than 25% of all individuals within the estimated sample
Temporal correlation	Less than 1 year of difference to the time period of the dataset	Less than 2 years of difference to the time period of the dataset	Less than 3 years of difference to the time period of the dataset	Less than 5 years of difference to the time period of the dataset	Age of data unknown or data with more than 5 years of difference to the time period of the dataset
Geographical correlation	Data from organization and site under study	Average data from several sites of the organization in the same region in which the site under study is included	Data from other sites within the same organisation and region with similar production conditions	Data from sites from other organizations in the same region with similar production conditions or regional average sector data	Data from unknown or distinctly different organisations, sites and regions

Figure 23: Modified Pedigree matrix for site-specific social data

Score / Indicator	1	2	3	4	5
Reliability	Verified data based on primary data collection	Verified data partly based on assumptions, non-verified data based on primary data collection, data based on scientific documents, or publicly available statistics	Non-verified data partly based on assumptions or data based on grey, but scientific documents	Qualified estimate (e.g. by expert) or data based on non-scientific documents	Non-qualified estimate or unknown origin
Completeness	Representative data from all organizations relevant for the considered sector	Represenataive data from >50% of the organizations relevant for the considered sector	Represenataive data from only a few organisations relevant for the considered sector	Representative data from only one organization relevant for the considered sector	Representativeness unknown
Temporal correlation	Less than 1 year of difference to the time period of the dataset	Less than 2 years of difference to the time period of the dataset	Less than 3 years of difference to the time period of the dataset	Less than 5 years of difference to the time period of the dataset	Age of data unknown or data with more than 5 years of difference to the time period of the dataset
Geographical	Data from sector and	Average data from	Data from sector	Data from sector	Data from unknown

correlation	country under study	larger sector in the same region in which the sector under study is included	with similar production conditions in the same region or data from same sector in a similar region with similar living conditions	with slightly similar production conditions or data from same sector within slightly similar living conditions	or distinctly different sector or region

Figure 24: Modified Pedigree matrix for sector-specific social data

Further, for each indicator value the level of uncertainty should be assessed using the pedigree scores from 1 to 5. An average uncertainty score can be calculated for each indicator and also for each process. The same average calculation procedure as selected for the impact assessment should be applied. The average values based on the arithmetic average can be interpreted as follows:

Average uncertainty	Interpretation
1.0 - 1.5	Very low uncertainty
1.6 - 2.5	Low uncertainty
2.6 - 3.5	Medium uncertainty
3.6 - 4.5	High uncertainty
4.6 - 5.0	Very high uncertainty

Table 7: Interpretation of average uncertainty scores

For the interpretation, a grouping of processes and indicators with highest and lowest uncertainty can be done. Combined with the impact assessment the uncertainty estimation gives a good allusion to the validity of the results and the robustness of the study.

Example

For our example process fictitious uncertainty values are defined for each indicator. For the subcategory "Autonomy" the uncertainty factors could look like this:

Category	Indicator	Pedigree criterion	Uncertainty score
Autonomy	Number of child labour hours in site per product output	Reliability	2
		Completeness	5
		Temporal correlation	3
		Geographical correlation	1
		Arithmetic mean	**2.75**
	Number of forced labour hours in site per product output	Reliability	1
		Completeness	3
		Temporal correlation	2
		Geographical correlation	1
		Arithmetic mean	**1.75**
	Arithmetic mean		**2.25**

Table 8: Example uncertainty scores

For the entire process the following uncertainty scores are be assumed:

Category	Subcategory	Average uncertainty
Safety, security & tranquility	knowledge-intensive jobs	1.75
	total employment	2.00
	risk perception	3.50
	Misuse	3.50

Category	Subcategory	Average uncertainty
	Arithmetic mean	**2.67**
Autonomy	child labour	2.75
	forced labour	1.75
	Arithmetic mean	**2.25**
Participation & influence	trust in risk information	4.00
	involvement of stakeholders in decision making process	3.50
	trust that long-term control will is safeguarded	3.00
	Arithmetic mean	**3.5**
Equal opportunities	income inequalities	2.5
	global inequalities	2.75
	Arithmetic mean	**2.63**
Arithmetic mean		**2.76**

Table 9: Example performance assessment with scale A

In this example the entire process has a medium uncertainty. The lowest uncertainty has the subcategory “Autonomy”, while the subcategory “Participation & influence” shows the highest uncertainty. The indicator “Trust in risk information” is the most uncertain indicator in the example process.

6.2.2 Weighting of pedigree criteria

As additional step, it is possible to weight the pedigree criteria in order to highlight that the pedigree criteria influence the uncertainty of indicator values in a different way. For instance, the reliability of the data source is likely more important for the uncertainty than its completeness resulting in a higher weighting factor for the reliability criterion.

To meet the requirement of consistency regarding the overall PROSUITE method the weighting method should analogues to the applied weighting in the impact assessment. Therefore, weighting factors from A to C are proposed. Table 10 gives suggestions for weighting factors for each pedigree criterion.

Pedigree criterion	WF
Reliability	A
Completeness	B
Temporal correlation	A
Geographical correlation	B

Table 10: Proposal for weighting factors for pedigree criteria

The weighting classification can be used to group the uncertainty factors to be able to analyse the level of uncertainty more differentiated. A high uncertainty score in a more relevant pedigree criterion entails a higher uncertainty than a high uncertainty score in a less relevant pedigree criterion.

Example

Table 11 shows grouped uncertainty scores. For both considered indicators can be stated that the average uncertainty scores for the more important pedigree criteria are lower than for the less important pedigree criteria.

Category	Indicator	Pedigree criterion	Uncertainty score	Weighting
Autonomy	Number of child labour	Reliability	2	A

Category	Indicator	Pedigree criterion	Uncertainty score	Weighting
	hours in site per product output	Temporal correlation	3	A
		Arithmetic mean	**2.5**	A
		Completeness	5	B
		Geographical correlation	1	B
		Arithmetic mean	**3**	B
		Arithmetic mean	**2.75**	
	Number of forced labour hours in site per product output	Reliability	1	A
		Temporal correlation	2	A
		Arithmetic mean	1.5	A
		Completeness	3	B
		Geographical correlation	1	B
		Arithmetic mean	2	B
		Arithmetic mean	**1.75**	

Table 11: Weighted uncertainty scores

6.3 Conclusion

A combination of qualitative and quantitative methods for uncertainty estimation is recommended. The use of two modified pedigree matrices based on the pedigree matrix from the ecoinvent database are suggested: one for the site-specific social data and one for average sector-specific data.

Although the weighting of considered uncertainty criteria allows a more differentiated uncertainty estimation, the added value of the weighting in relation to its effort seems limited. Therefore, weighting of uncertainty factors is not recommended.

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