



# LCA-based Assessment of the Sustainable Development Goals

Development update and preliminary findings of the project “Linking the UN Sustainable Development Goals to Life Cycle Impact Frameworks”

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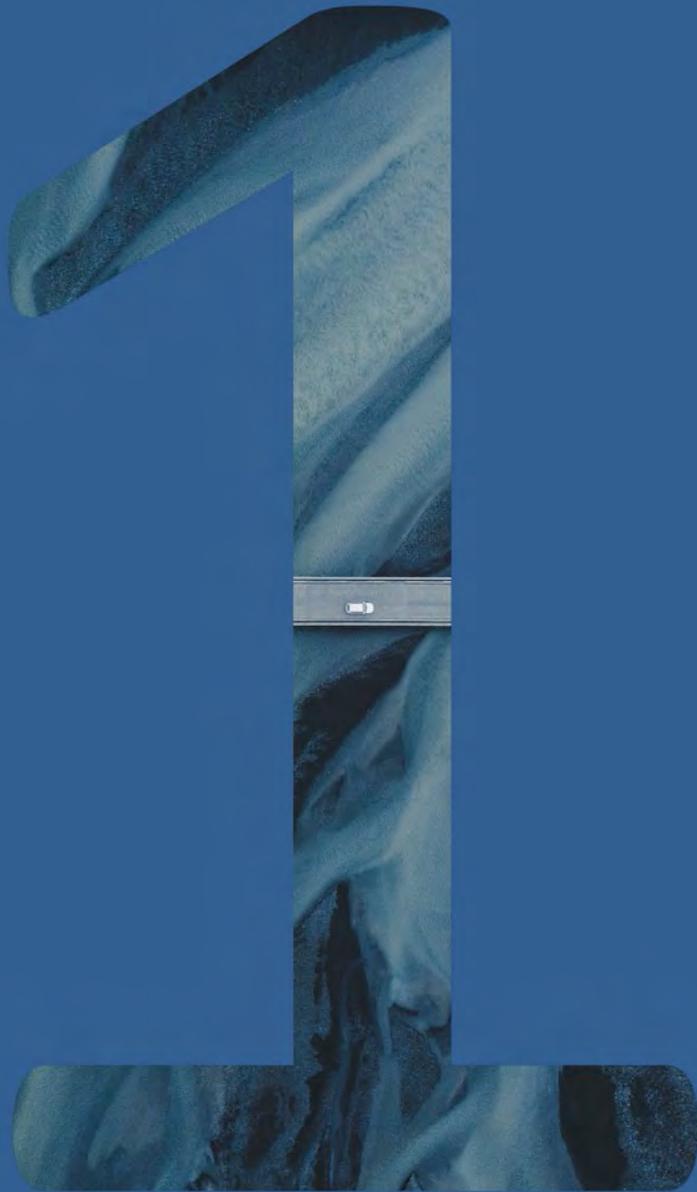
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# Introduction

# 1 Introduction

In 2015, all United Nation member states adopted the 2030 Agenda for Sustainable Development, with the 17 Sustainable Development goals (SDGs) at its heart (United Nations, 2019). The SDGs provide 17 goals, 169 targets and more than 200 indicators to guide governments toward sustainable development in 2030. The aim is to provide a roadmap and blueprint for a better and more sustainable future for all.

Although the goals are mostly defined on government and policy level, the SDGs are relevant for businesses as well. Achieving the SDGs can, for example, create business value and jobs (Business & Sustainable Development Commission, 2017). In addition, contributing to the SDGs creates opportunities to better manage risks, anticipate customer demand, secure access to resources and strengthen supply chains (World Business Council for Sustainable Development, 2017). Considering this, it is no surprise that a growing number of companies have communicated that they will align their strategy with the SDGs and have committed to support all or some of the 17 SDGs.

Often, commitment to SDGs is communicated on a company-wide level. Reaching the SDG targets, however, depends on the products and services that a company offers. Commitment to SDGs therefore also implies a change in product development and reporting: companies are expected to be able to use metrics that show if (and if so, how) existing or new products contribute to supporting the SDGs. While it is already possible to use life cycle assessment (LCA) to assess environmental and social impact at the product level, using LCA-based metrics for the SDGs is a new challenge.

An important aspect of this challenge is that the SDGs were developed for global and country-level policies, while LCA was developed for assessment on the level of individual products (Kühnen et al. 2019). Furthermore, the SDG targets and indicators, as defined by the UN, are often qualitative rather than quantitative. Finally, SDGs may overlap, interact or conflict with each other: SDG 1 (No poverty) and SDG 8 (Decent work and economic growth) overlap, while SDG 13 (Climate action) and SDG 7 (Affordable and clean energy) seem to be in conflict (Scherer et al, 2018).

## Project “Linking the UN Sustainable Development Goals to life cycle impact pathway frameworks”

The project “Linking the UN Sustainable Development Goals to life cycle impact pathway frameworks” was initiated by the UN Life Cycle Initiative to create robust links between the SDGs and LCA and to develop a methodology for measuring and reporting on companies’ contributions to the SDGs. The project is under administration of OnePlanet and is being executed by 2.-0 LCA Consultants and PRé Sustainability.

The project consists of the following aspects: methodology, consultation, and cases. At the time of writing, May 2020, the status of these aspects is as follows:

- **Methodology:** the outline of the methodology has been developed and applied to a first set of SDGs. The project team is currently working on expanding the methodology to the remaining SDGs.
- **Consultation:** A number of public and technical consultation rounds have been held, which have provided valuable input. More consultation rounds will follow in the course of the project.

- **Cases:** the methodology is now being applied and tested in a number of businesses cases. These cases are being executed by business partners that joined the project, supported by 2.-0 LCA Consultants and PRé Sustainability. The companies that are now part of the project are ArcelorMittal, Corbion, and Novozymes.

We're still in an early stage of applying and testing the methodology, so interested companies can still join the project as business partners.

This publication discusses the preliminary findings and details from our deep-dive into how LCA and the SDGs intersect. The aim is to show specific examples of how the links between LCA and SDGs can be created and how this information can be used by business. It's intended for those who want to learn more about the link between LCA and the SDGs, want to stay up to date of this project, and companies that are interested to join and want to learn more.

## Goals and application contexts

Companies may have different goals and reasons for analyzing or reporting on their contribution to the SDGs. To accommodate this, this project provides a framework for different types of assessment in different application contexts. This ensures that the proposed method is flexible enough to support different goals while providing enough structure and guidance to achieve those goals.

There are two main contexts in which companies want to link the SDGs to environmental and social LCA (Weidema et al. 2018):

1. When companies want to reuse their existing LCA procedures and results but also want to understand which products and impact categories generally contribute to which SDGs, a **life cycle SDG screening (LCSS)** can link their LCA results to the SDG targets in a qualitative way.
2. Companies that desire to go beyond existing LCA indicators and toward a more comprehensive integration of SDG indicators can do a **life cycle SDG assessment (LCSA)** instead. Such an assessment quantifies the impact pathways and makes the contributions to the SDGs comparable by tracing all impacts to the ultimate endpoint of sustainable wellbeing. This allows organizations to calculate *how much* their product contributes to each SDG, target and indicator, as well as to overall sustainable wellbeing.

Both the screening and the assessment allow organizations to identify SDG hotspots along the life cycle of the product, and determine how these SDG hotspots can be influenced. Both also result in information that can be used to steer sustainability strategies, although on different levels.

The rest of this publication elaborates on the application and expected results of the LCSS and LCSA. Chapter 2 starts with the general steps to be taken for both approaches. Chapter 3 describes the LCSS, followed by Chapter 4 on the LCSA. Chapter 5 provides an outlook for the following steps of the project.



# Steps for life cycle SDG screening and assessment

# 2 Steps for Life Cycle SDG Screening and assessment

The steps of the SDG screening and assessment are similar to those of a regular LCA study. An LCA, as described in the ISO standards 14040 and 14044 (ISO, 2016a; ISO, 2016b), consists of the following four stages, and so do the LCSS and LCSA:

1. Goal and scope definition
2. Inventory analysis
3. Impact assessment
4. Interpretation

This chapter gives a brief overview of the different stages. They will be covered in more detail per application context, in chapters 3 and 4.

## Step 1: goal and scope definition

The goal and scope stage determines the most important elements of the SDG study, such as the reason for executing the study, a definition of the studied product and its life cycle, and a description of the system boundaries.

Possible goals for conducting an SDG study are:

- **To understand *which* SDG or SDGs your product is currently contributing to.** This can support the development of a (company-wide) strategy for SDG contribution, and the choice of which SDGs to focus on as an organization.
- **To determine if and how the contribution of your product to certain SDGs has changed over time.** This ongoing impact monitoring allows a company to check whether development efforts are indeed having a positive impact on the SDGs a company is targeting.
- **To assess *how much* your product contributes to certain SDGs.** This information is valuable for more detailed monitoring and reporting on SDG progress, as well as for comparing products or innovations.
- **To support working toward an increased positive contribution to an SDG or SDGs.** The information can show the R&D department how their work affects the company's contribution to the SDGs, allowing them to focus their efforts on those aspects that matter most for improving the contribution to the SDGs.
- **To support communication about SDG contribution.** The information can be used to back up your claims regarding SDGs, which strengthens the credibility and trustworthiness of SDG reporting.

The goal of the study determines whether you need an SDG screening or a full SDG assessment. It's also possible to follow both approaches. For example, starting with an SDG screening and then diving deeper into relevant parts of the product life cycle with the assessment.

Other aspects to determine in the goal and scope phase are the target audience and the data collection strategy.

## Step 2: inventory analysis

During the inventory analysis stage, all required information about the product system under study is collected. The exact data needs vary, depending on the goal. Similar to regular LCA, ambitions for data quality will affect the required workload and the reliability of the results (Baumann & Tillman, 2004). An SDG screening approach, which is qualitative, uses the results of both an environmental and a social LCA. This data is then converted to a 5-point scale. For an SDG assessment, which is quantitative, more elaborate data has to be collected about the life cycle of the product. This includes data beyond the scope of regular environmental and social LCAs.

A data collection guideline is under development to assist organizations with this stage of the study. The guide is intended to include detailed definitions of the required data, how it should be collected and measured, and how to translate the data to the format required for the study. This guidance will be tested in practice by the project partners when collecting the data for their SDG case study.

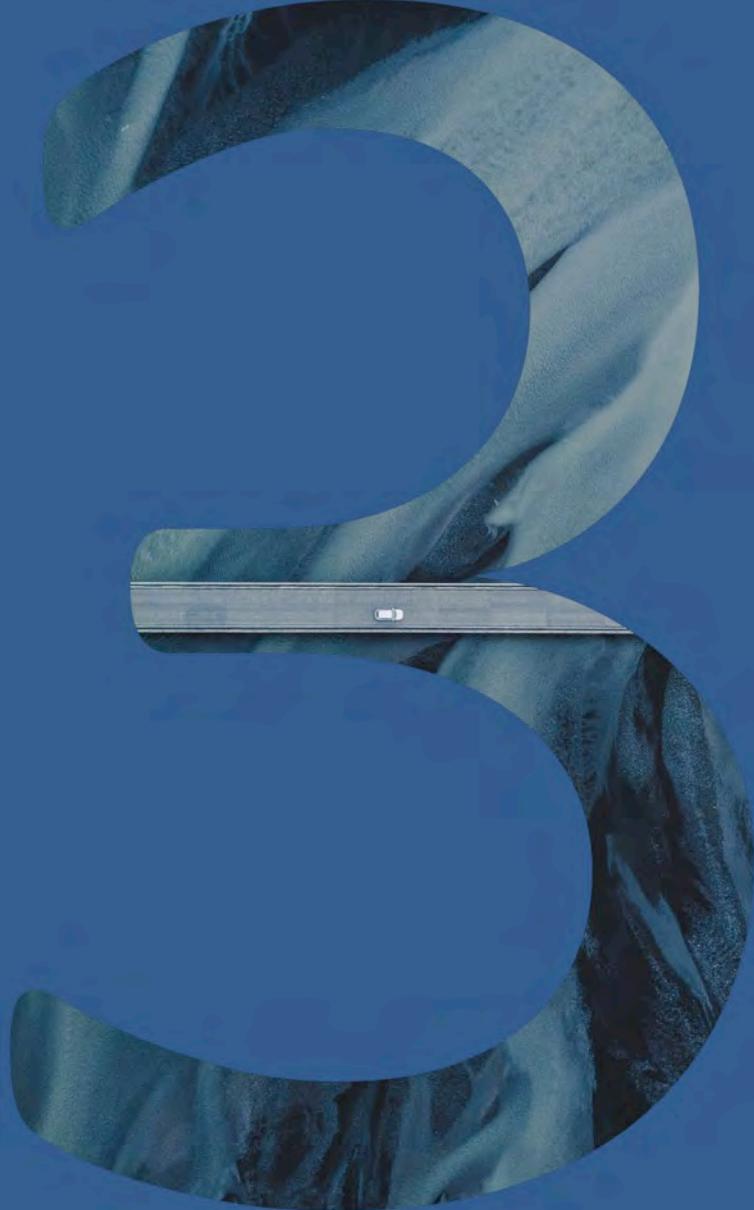
## Step 3: impact assessment

In the impact assessment stage, the data that is collected in the previous stage is translated into meaningful impact information that can support companies in their decision-making. The screening method will translate the input data into scores that show whether the product under study contributes to an SDG or not. Once the methodology is complete, it will contain all the necessary information to make this translation. The assessment method will use cause-effect relations to translate the inventory data into impact scores on midpoint and endpoint level. The impact pathways that are needed for this step are being developed within this project, as well as the characterization factors needed to calculate the results.

## Step 4: interpretation

In this final stage of the SDG analysis, the results are used to answer the stated goal. To determine the validity and robustness of the results, this stage also includes an assessment of data quality, an uncertainty determination and a reflection on the limitations of the study.

If communication of the results was part of the goal, the possibilities and limitations of communicating the results are investigated in this stage as well. More specific guidance on interpretation and communication of the results is provided in the chapters about the two different application contexts.



# Life cycle SDG screening

# 3 Life cycle SDG screening

This chapter provides more detail about SDG screening. As described in the previous chapter, the first step of any SDG study is to define the goal. The SDG screening is suitable for SDG studies where the goal is:

- To determine which SDGs your product is contributing to
- To monitor qualitative changes in the contribution of your product to the SDGs over time
- To support qualitative claims about SDG contribution
- To provide product developers with qualitative information that allows them to work toward improved SDG contribution

This list is not exhaustive, but it communicates the essence: the SDG screening approach can be used to make a qualitative analysis of a product to determine if it may potentially be a detriment or a benefit to one or more SDGs. It is important to stress the word *potentially*: since this is a screening method, there are inherent limitations to robustness and detail.

The SDG screening approach provides results on two levels:

1. For each of the Sustainable Development Goals
2. For each of the targets of each Sustainable Development Goal

These results are provided on the following spectrum:

- The contribution is potentially **beneficial**
- The contribution is neither clearly beneficial nor detrimental
- The contribution is potentially **detrimental**

If the goal requires a more elaborate and quantified understanding, an SDG assessment is better suited to achieve that understanding (see chapter 4).

## 3.1 Goal and scope definition

If the goal of your study fits the SDG screening application, the next step is to define the scope. Because SDG screening is based on the results of a social and environmental LCA, the goals of these underlying studies need to be sufficiently similar to the goal and scope of the SDG study.

The goal and scope definition of the SDG screening should contain the same elements as that of a regular LCA. This means that, for instance, the functional unit, product under study and system boundaries should be defined in this stage. In addition, a reference product should be determined (see section 3.2.2).

After these traditional LCA elements are defined, the SDGs that will be considered in the study should be determined. Which and how many SDGs you should include in the study depends on the goal. If the goal is to understand which SDGs a product contributes to, all SDGs need to be included in the scope. But perhaps only a subset of the SDGs are relevant. A materiality assessment can determine the most relevant SDGs to consider, whether for your company in general or for the specific product.

## 3.2 Inventory analysis

The SDG screening approach uses the results of an environmental and a social LCA to determine whether a product contributes to the SDGs and their targets. For the purposes of this project, the

SDG screening method is based on the ReCiPe 2016 method for environmental impact assessment (Huijbregts et al., 2016) and the Product Social Impact Assessment Handbook 2019 method for social impact assessment (Goedkoop et al, 2018). An overview of the impact categories included in these methods is presented in annex A. An interesting task for future method development team would be including additional impact assessment methods or indicators.

This inventory analysis step consists of collecting results from or executing new environmental and social LCA studies of the product, plus an environmental LCA study of a benchmark product (see section 3.2.2). If pre-existing studies are used, it is critical to pay attention the goal and scope of these studies – they should be compatible with each other and with the goal and scope of the SDG screening.

Once compatible environmental and social LCA studies have been identified or performed, the results for each impact category in scope need to be listed on a 5-point scale, as illustrated in Table 3-1. The details of the scale are further defined per type of impact (social or environmental).

*Table 3-1: Structure of the 5-point scale*

+2	Performance is a lot better than the benchmark
+1	Performance is better than the benchmark
0	Performance is equal to the benchmark
-1	Performance is worse than the benchmark
-2	Performance is a lot worse than the benchmark

### 3.2.1 Inventory analysis for social impact categories

The impact assessment method used for social LCA in this project, product social impact assessment, already presents the results on a compatible 5-point scale, as illustrated in Table 3-2. The scale is benchmarked against compliance with local laws or alignment with international standards, where a scale of 0 means the product or company is in compliance. A more specific scale exists for each social impact category. An example is shown in Table 3-3, which shows the scale for health and safety of workers plus the relevant performance indicators (see also table 3-4).

*Table 3-2: Generic structure of the 5-point scale in the Product Social Impact Assessment Handbook (Goedkoop et al, 2018)*

+2	Ideal performance; beneficial output achieved and reported
+1	Progress beyond compliance is made and monitored
0	In compliance with local laws or aligned with international standards
-1	Non-compliant situation, but actions to improve have been taken
-2	No data or non-compliant situation; no action taken

Table 3-3: 5-point scale for health and safety of workers, from the Product Social Impact Assessment Handbook (Goedkoop et al, 2018)

	Performance reference scales	Related performance indicators
+2	The company has a PDCA process in place to pro-actively protect workers' health and safety. (Beyond compliance with local laws.) Company commitments and progress on occupational health and safety are disclosed publicly. The top management of the company has publicly declared/recognized health and safety of workers as key priority and the company aims to be the best in class.	1 or 2-3 and 5-7
+1	The company has a PDCA model in place to pro-actively protect workers' health and safety. (Beyond compliance with local laws.)	1 or 2-3 and 5
0	Sufficient evidence indicates compliance with health and safety standards or local laws OR The occupational health and safety of workers is monitored, and workers have access to all the required personal protective equipment.	1 or 2-3
-1	Evidence indicates that the company does not comply with health and safety standards, and a corrective action plan with a clear timeline for completion has been developed.	4
-2	Evidence indicate that the company or facility does not comply with health and safety standards or local laws but a corrective action plan with a clear timeline for completion has not been developed OR No data is available.	-

The score on this scale is determined by looking at performance indicators, which are specific to each impact category. Table 3-4 shows the performance indicators used to determine the score of the product with regards to health and safety of workers. A full list of the performance reference scales and performance indicators for all impact categories can be found in the Product Social Impact Assessment Handbook (Goedkoop et al, 2018). An SDG study requires the performance level results, on the 5-point scale, for all impact categories and life cycle stages that are in scope.

Table 3-4: Performance indicators for health and safety of workers from the Product Social Impact Assessment Handbook (Goedkoop et al, 2018)

#	Performance indicators
1	The company or facility complies with health and safety standards or local laws. Type of evidence required: <ul style="list-style-type: none"> <li>• License to operate, certification schemes/standards on health and safety, audits, etc.</li> <li>• The company or facility has conducted a health and safety risk assessment.</li> </ul>
2	Workers have access to all the required personal protective equipment.
3	The occupational health and safety of workers is monitored.

4	In a case of non-compliance with health and safety standards or local laws, the company or facility has developed a corrective action plan with clear timeline for completion.								
5	<p>The company has a PDCA model in place to pro-actively protect workers' health and safety, beyond compliance with local laws.</p> <p>*Please note that the table below displays only examples of supporting evidence that can be provided to this question.</p> <table border="1"> <thead> <tr> <th></th> <th>Supporting evidence</th> </tr> </thead> <tbody> <tr> <td>Education &amp; training on health and safety</td> <td> <p>Examples:</p> <ul style="list-style-type: none"> <li>• Average hours of training per year per employee per category.</li> </ul> </td> </tr> <tr> <td>Appointed personnel</td> <td> <p>Examples:</p> <ul style="list-style-type: none"> <li>• In each department, an employee is appointed as health and safety officer.</li> <li>• Personnel assigned to monitor/train/etc. workers on health and safety issues.</li> </ul> </td> </tr> <tr> <td>Records of safety incidents</td> <td> <p>Examples:</p> <ul style="list-style-type: none"> <li>• Rate of total recordable injuries and illnesses per million working hours.</li> <li>• Frequency index of recordable injuries per 100 employees.</li> <li>• Total number of fatalities.</li> <li>• Rate of lost-time injuries and illnesses.</li> </ul> </td> </tr> </tbody> </table>		Supporting evidence	Education & training on health and safety	<p>Examples:</p> <ul style="list-style-type: none"> <li>• Average hours of training per year per employee per category.</li> </ul>	Appointed personnel	<p>Examples:</p> <ul style="list-style-type: none"> <li>• In each department, an employee is appointed as health and safety officer.</li> <li>• Personnel assigned to monitor/train/etc. workers on health and safety issues.</li> </ul>	Records of safety incidents	<p>Examples:</p> <ul style="list-style-type: none"> <li>• Rate of total recordable injuries and illnesses per million working hours.</li> <li>• Frequency index of recordable injuries per 100 employees.</li> <li>• Total number of fatalities.</li> <li>• Rate of lost-time injuries and illnesses.</li> </ul>
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6	Company's commitments and progress on occupational health and safety are disclosed publicly (to external stakeholders).								
7	The top management of the company has publicly declared/recognized health and safety of workers as key priority and the company aims to be the best in class.								

To apply the results of the social LCA in the SDG screening, it is necessary to aggregate the score per social impact category over the different life cycle stages. This aggregation is not part of the methodology described in the Product Social Impact Assessment Handbook, because aggregation is still a point of discussion in the field of social LCA. To make the results usable for the SDG screening, the project team is exploring several options, such as aggregation based on the added value or working hours of each supply chain step. For now, this aspect is still a point of further development.

### 3.2.2 Inventory analysis for environmental impact categories

The impact assessment method used for environmental LCA in this project, ReCiPe 2016, presents quantitative results with a different unit for each impact category. Unlike with the social LCA results, it is not possible to benchmark the studied product against compliance with the laws or regulations. A different benchmarking approach is needed.

Different ways of benchmarking are described in the literature, each with their own implementation challenges. In environmental LCA, it is common to compare multiple products that fulfill the same function, so the different products serve as a reference or benchmark for each other. Another option is to use a representative product or a sector average as a reference. Both of these methods are used

in the European product environmental footprint guidelines (European Commission, 2017). A more holistic approach is to use an absolute sustainability target as a reference, for example the planetary boundaries framework (Rockström et al, 2009). All benchmark options come with their own limitations and implementation challenges. For example, defining a representative product or developing a sector average require time and the cooperation of sector stakeholders. Absolute sustainability targets only exist for a limited number of impact categories and often come with large uncertainties. The fluctuation in these targets, depending on the chosen method and inherent value-based choices, can be in orders of magnitude (Sandin et al, 2015).

In this phase of the project, the method requires a benchmark that can be applied directly to all ReCiPe impact categories and that works for all types of products. For this reason, SDG screening studies require a reference product to determine the performance on the 5-point scale. Defining this reference product is part of the goal and scope definition of the SDG screening. A good candidate for a reference product is the previous version of the product under study: an internal benchmark. If the product is completely new and no internal predecessor exists, a readily available generic product with the same function can be considered as external benchmark.

Table 3-5 shows the generic structure of the 5-point reference scale for the environmental analysis. The given percentages are a first iteration; the applicability will be tested with the business cases.

*Table 3-5: The 5-point scale for environmental impact categories*

+2	The environmental impact is a lot lower than the reference product (>10%)
+1	The environmental impact is significantly lower than the reference product (5 to 10%)
0	There is no significant difference in environmental impact
-1	The environmental impact is significantly higher than the reference product (5 to 10%)
-2	The environmental impact is a lot higher than the reference product (> 10%)

As a consequence of using a reference product as a benchmark, any identified contribution to the SDGs is always in relation to this reference product, and should be communicated as such. A positive score on the 5-point scale indicates a step in the right direction, but does not necessarily mean that the product is sustainable on an absolute basis, or that there are no better alternatives available. For example, an improved coal energy plant could, according to this method, deliver a beneficial contribution to the SDGs compared to its less sustainable predecessor. But compared to renewable energy sources, coal may still be a very unfavorable energy source. Therefore, both the reason for using the chosen reference product and the resulting limitations need to be clearly described in the SDG screening results. Development of a more absolute benchmark will be considered in future phases of the project.

The inventory assessment for the environmental impact categories results in a score on the 5-point reference scale for each of the impact categories included in the analysis. These scores, together with the social scores, form the input for the impact assessment step that is elaborated in the next section.

### 3.3 Impact assessment

In the impact assessment step of the SDG screening, it is evaluated if and how the social and environmental LCA impact categories contribute to the individual targets of each SDG. This linking of the impact categories to the SDG targets through classification and characterization is the main focus

point of this project, as this is where the connection between LCA results and a possible contribution to the SDGs is made.

*Text box 1: Classification and characterization step of the SDG screening.*

To develop the LCA screening methodology, the project team looked at each SDG target and followed two steps: classification and characterization.

1. **Classification:** is there a relation between the LCA impact category and the SDG target?  
This is answered after careful analysis of the SDGs, their targets and indicators, and the environmental and social impact categories. Only strong links are included. Where necessary, the analysis is complemented with expert judgment.
2. **Characterization:** what is the nature of the relation between the LCA impact category and the SDG target? This step determines the score needed to qualify as a contribution to a target, per target and impact category. For example, in some cases only scores of +2 will be considered a contribution, while in other cases a score of +1 will already qualify as a contribution. Similarly, in some cases a score of -1 or -2 may be considered detrimental for that target, while in other cases these scores would be considered as neutral. As in the classification step, these links are based on detailed analysis and expert judgment.

The outcomes of these two steps were used to create the tools for impact assessment.

The following tools are needed to complete the impact assessment:

1. **An overview for every SDG**, illustrating the links between the social and environmental LCA impact categories and the SDG targets. Figure 3-1 is an example of such an overview, showing the links between a number of LCA impact categories and SDG6 (Clean water and sanitation).
2. **A scoring matrix for every SDG target**, illustrating the nature of the identified relationships. For each LCA impact category, a table captures which scores on the 5-point scale are considered a contribution, neutral or detrimental. For some of the impact categories a -2 score of your product means a detrimental contribution to the SDG, while a +1 or +2 for the impact category results in a positive contribution. An example is shown in Table 3-6.

At the moment of writing, the assessment tools have been developed for SDGs 2, 3, 5, 6, 10 and 11. The classification and characterization for the remaining SDGs is ongoing. The figure and table below show the preliminary results for SDG 6, which will be finalized at a later stage.

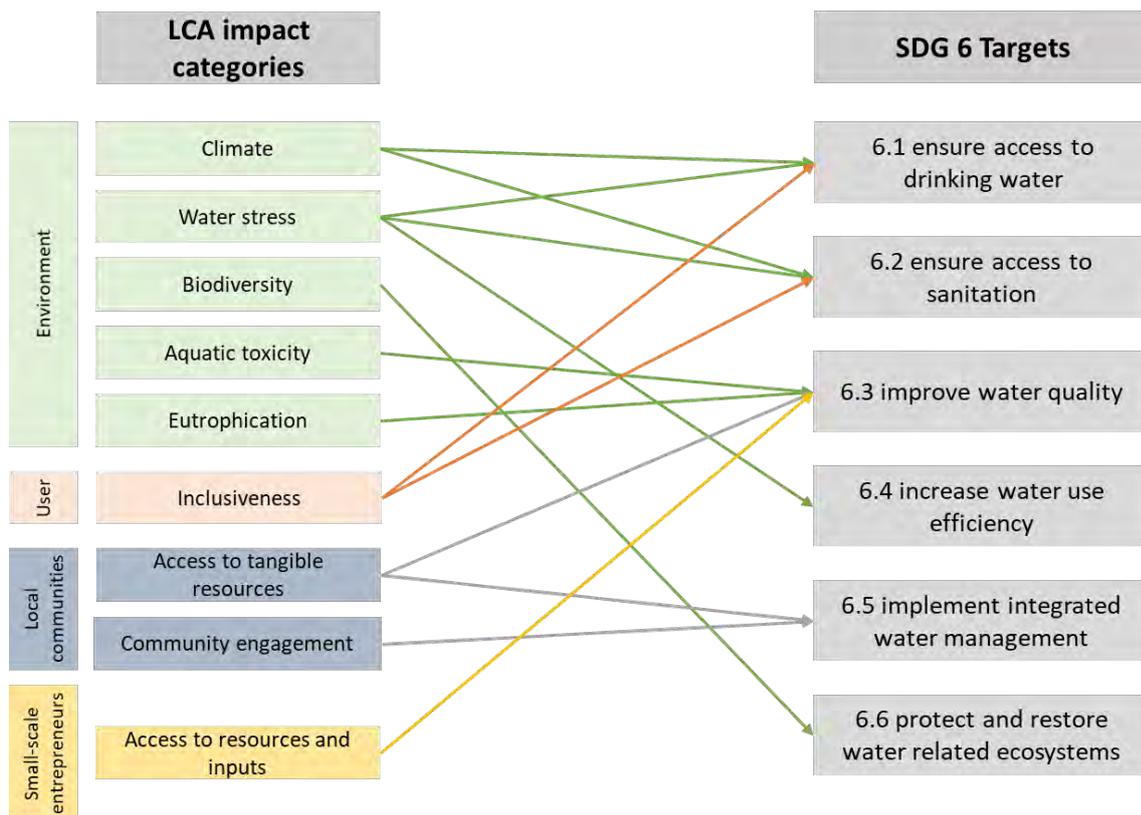


Figure 3-1: Links between LCA impact categories and targets of SDG 6: Clean water and sanitation

Table 3-6: Scoring matrix for determining whether the LCA results can support SDG 6: Clean water and sanitation

Impact category	Stop-blocks, detrimental contribution			Positive contribution		
	-2	-1	0	0	+1	+2
Climate change	-2					+2
Water stress	-2					+2
Biodiversity	-2					+2
Aquatic toxicity	-2					+2
Eutrophication, expressed as BOD or COD	-2					+2
Inclusiveness (user)					+1	+2
Community engagement					+1	+2
Access to tangible resources (local communities)	-2				+1	+2
Access to tangible resources (small-scale entrepreneurs)	-2				+1	+2

When multiple LCA impact categories are linked to a single SDG target, they are combined into an overall result for that target. Similarly, the scores of each of an SDG's targets are combined into an overall score for that SDG. This process follows the following rules:

- If any of the linked impact categories (or targets) score as detrimental to that target (or SDG), the overall score for that target (or SDG) is considered detrimental
- In none of the linked impact categories (or targets) score as detrimental to that target (or SDG), and at least one linked impact category (or target) scores as a contribution, the overall score for that target (or SDG) is considered a contribution
- In none of the linked impact categories (or targets) score as detrimental or as a contribution to that target (or SDG), the overall score for that target (or SDG) is considered neutral

Note that in this step, the underlying assumption is that all linked impact categories contribute equally to the target, and that all targets contribute equally to the SDG. In other words: each of the impact categories and targets has a weight of 1. This generalization is not likely to capture the full detail of reality. A possible future development step is to investigate the relative importance of the impact categories and targets. Another thing to note is that some targets may overlap, causing double counting of certain impact categories in the overall SDG.

### 3.4 Most important learnings

While the development of the SDG screening method is still ongoing, several interesting insights have already resulted from the project:

- Existing social and environmental LCI methods provide useful starting points for linking product-level information to the SDGs. For companies that already have existing social or environmental LCA results, only a few steps need to be added to do an SDG screening:
  - o Review whether the goal and scope of the existing LCAs is compatible with the goal and scope of the SDG analysis
  - o Identify and assess a benchmark product
  - o Relate the environmental LCA results to a 5-point reference scale
  - o Perform the SDG impact assessment step with the resources that will be provided in this project
  - o Interpret and evaluate the results
- To determine whether a contribution to an SDG is beneficial, neutral or detrimental, it is important to determine the reference. In social LCA, the law is the reference. For environmental LCA, we currently suggest a reference product as a benchmark. The applicability of these choices will be tested by the project team.
- In some cases, an SDG target could not be linked with any of the social or environmental impact categories. This suggests that the target is either not of social or environmental nature (but e.g. economic), or that the impact categories do not capture the target. It's also possible that the target is not relevant on the level of the product, because the SDG framework was developed for governments. Once all SDGs are linked, the project team will reflect on the method that is developed in this project and investigate which targets have not been captured, and why.

We expect to gain more insights as we develop the method further, which we will test with the partner companies on their business cases.



# Life cycle SDG assessment

# 4 Life cycle SDG assessment

While the life cycle SDG screening can help with identifying potential beneficial and detrimental contributions to the SDGs, the life cycle SDG assessment aims to integrate the SDGs in a more complete and quantitative life cycle sustainability assessment (LCSA). The intention is to capture both beneficial and detrimental impacts on all 17 SDGs in a comprehensive and consistent way, avoiding overlaps and gaps as much as possible, and obtaining impact assessment results in comparable units of sustainable wellbeing that can potentially be expressed in monetary values and integrated with internal and supply-chain costing data. This chapter provides more detail on the SDG assessment approach.

A life cycle SDG assessment can provide quantitative scores for:

1. The overall impact on sustainable wellbeing
2. The impact on each of the 17 SDGs, and/or their targets and indicators
3. The contribution from each impact category to the above impacts

These results can be obtained in parallel.

## 4.1 Goal and scope definition

The goal and scope definition for the SDG assessment can be executed in a similar way as for a traditional LCA. This means that this stage should include the definition of the functional unit, product under study and system boundaries.

## 4.2 Inventory analysis

The impacts on sustainable development are caused by human pressures (in LCA, typically called elementary flows or elementary exchanges), i.e., an input or output of a human activity from or to its natural, social or economic environment<sup>1</sup>. Examples of human pressures are the unprocessed inputs from nature, inputs of working hours under specified conditions, emissions to air, water and soil, direct physical impacts, monetary flows in and out of the activity, or flows of unpaid or underpaid goods and services. During the inventory analysis stage, such pressures are quantified, using inventory indicators.

This section provides a preliminary view of some of the inventory indicators used in the life cycle SDG assessment, in addition to those used for the life cycle SDG screening. Since the work of detailing the impact pathways is still in progress, this is only a partial view to illustrate the level of detail that will be provided.

### 4.2.1 List of business-relevant inventory indicator categories across the sustainable development topics

Inventory indicators are indicators that can be measured at the level of an individual activity or organization. Inventory indicator categories can be divided into two groups: those that are relevant to all organizations and those that are only relevant to specific types of organizations. Preliminary,

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<sup>1</sup> In this chapter, the term "environment" is used in a wider sense than in the previous chapters.

incomplete lists for both groups are provided below, covering a major part of the primary inventory indicators for the sustainable development topics related to SDG 1 to 6 and 10. Examples of detailed descriptions and definitions of the indicators can be found in section 4.2.2.

## Inventory indicator categories of general relevance (examples)

### Economic indicator categories

- Wages and social costs by wage level
- Net tax payments by product, including resource tax payments
- Rent payments
- Voluntary financial transfers
- Resource ownership
- Unfair commercial practices

### Emission indicator categories

- Harmful substance emissions
- Emission of ozone-depleting substances
- Emission of ionizing radiation
- Noise

### Occupational indicator categories

- Premature return to work after giving birth
- Paid breaks for breastfeeding
- Regulation of radiation exposure
- Net occupational skill development
- Education in infective disease prevention

## Additional inventory indicators for specific types of organizations (examples)

For organizations supplying basic services:

- Location-independent access costs

For activities located in urban core areas:

- Heat regulation

For organizations handling foods or beverages:

- Dietary risk factors in products

For activities handling biological materials:

- Deviations from hygienization procedures at critical control points

## 4.2.2 Examples of detailed descriptions and definitions of inventory indicators

Our inventory indicators are defined to form the starting point for impact assessment. This implies that, wherever possible, the indicators are measured on a relevant ratio scale and therefore additive.

For example, the inventory indicator for wages measures the depth of poverty (the distance between the income and the relevant poverty line). This depth-of-poverty measurement considers that not all

persons living below the poverty line are equally poor, and the measure is additive across persons, and can be used in relation to different poverty lines. In contrast, the official SDG indicator 1.1.1 measures the proportion of the population below the international poverty line. This is a unitless population-level indicator that uses a fixed poverty line and does not consider the depth of poverty. Nevertheless, the data used to calculate our person-specific depth-of-poverty indicator can also be used to calculate the contribution to the SDG indicator 1.1.1.

The following subsections provide detailed descriptions and definitions of the inventory indicators for unfair commercial practices, premature return to work after giving birth, and heat regulation. Annex B provides more examples. Eventually, detailed descriptions and definitions will be created for all inventory indicators.

## Unfair commercial practices

### **Description:**

Commercial practices include promotion, marketing, sale, procurement, purchase, delivery, and after-sales services of a product, as well as subsequent collection of debts and any connected actions, representations, or omissions by a trader. A commercial practice is unfair if it is likely to impair the ability of a trade partner (supplier or customer) to make an informed decision regarding the offer, thereby causing the trade partner to make a transactional decision that he or she would not otherwise have made. Notable examples of unfair practices are: using false or misleading information, withholding relevant information, or exploiting a position of power. Commercial practices are also unfair if they discriminate potential or actual trade partners based on irrelevant characteristics.

The extent and severity of unfair commercial practices may be quantified as the value of transactional decisions made or foregone due to unfair commercial practices, with a particular concern for discrimination against vulnerable trade partners. Numbers of complaints, numbers of complaints settled to the satisfaction of the complainant, and more general surveys on market fairness and satisfaction with trading partners may provide information that can be used to estimate this value. One of the more thorough studies on quantitative measurement of consumer detriment is the report by Civic Consulting (2017) for the EU Consumer Programme.

### **Indicator definition and unit:**

The inventory category indicator is defined as: Estimated value of transactional decisions made or foregone due to unfair commercial practices; when possible, specified per income group. The unit of measurement is nominal currency units (with indication of base year), e.g. USD<sub>2011</sub>.

## Premature return to work after giving birth

### **Description:**

In a US cohort study of singletons whose biological mothers worked in the 12 months before delivery, Ogbuanu et al. (2011) found that cessation of breastfeeding was not correlated with length of maternity leave (which does not need to be taken consecutively), but rather with first return to work. The indicator should therefore reflect requirements for early return to work, rather than the length of the maternity leave.

### **Indicator definitions and units:**

The inventory category indicator is defined as: number of annual female full-time employee equivalents multiplied by the differential between 26 weeks and the number of weeks of continuous maternity leave ensured by legal or contractual guarantee. The unit of measurement is person-weeks.

## Heat regulation (for activities located in urban core areas)

### Description:

Natural background temperatures can locally be altered by surface changes influencing the reflection or transport of ambient heat or the cooling effects of evapo(transpi)ration, as well as by direct emission of heat. The main environmental concern is the increase in afternoon temperatures in densely populated urban core areas (defined following Dijkstra & Poelman (2014) as contiguous 1 km<sup>2</sup> grid cells with a density of at least 1500 persons per km<sup>2</sup> and a minimum population of 50000) with limited vegetation and a large building volume. The most relevant indicators are changes relative to a reference situation of surface reflection (albedo), evaporated water volume, and – to a lesser extent – direct heat emission. Direct emission of waste heat can be calculated from the higher heating value of fuels combusted plus electricity consumed plus purchased heat minus any heat sold as product. Heat release or capture by chemical and biological processes is usually insignificant in comparison and may therefore be ignored.

### Indicator definitions and units:

The inventory category indicators are defined as:

- Surface area-time weighted by its solar reflectance measured according to ISO 9845-1:1992 with measurement in area-time units, such as m<sup>2</sup>-years
- Evaporated water volume with measurement in volume units, such as m<sup>3</sup>
- Waste heat emission with measurement in energy units, such as J

## 4.3 Impact assessment

In the impact assessment stage, the inventory indicators are the starting points for impact pathways that represent the causal relations between pressures and one or more affected midpoint impacts (specific changes in the natural, social or economic environment). In the life cycle SDG assessment, all impact pathways continue through the midpoint impacts and terminate with a change in the endpoint impact of sustainable wellbeing.

The impact pathways can be illustrated with a diagram, such as Figure 4-, where inventory and impact categories (boxes) are linked by their relationships (arrows). Each numbered box represents an inventory or impact category, each of which can have one or more quantitative indicators. The arrows with letters represent characterization factors: quantified relationships between the indicators of the boxes that the arrows connect.

Figure 4- shows the impact pathway diagram for undernutrition and Figure 4-2 for clean water and sanitation, the sustainable development topics related to SDG 2 and 6, respectively. Note that the numbers and letters are unique to each impact pathway diagram. In the project report (Weidema 2020), a separate chapter is dedicated to each impact pathway diagram, defining, quantifying and describing each inventory and impact category indicator and characterization factor.

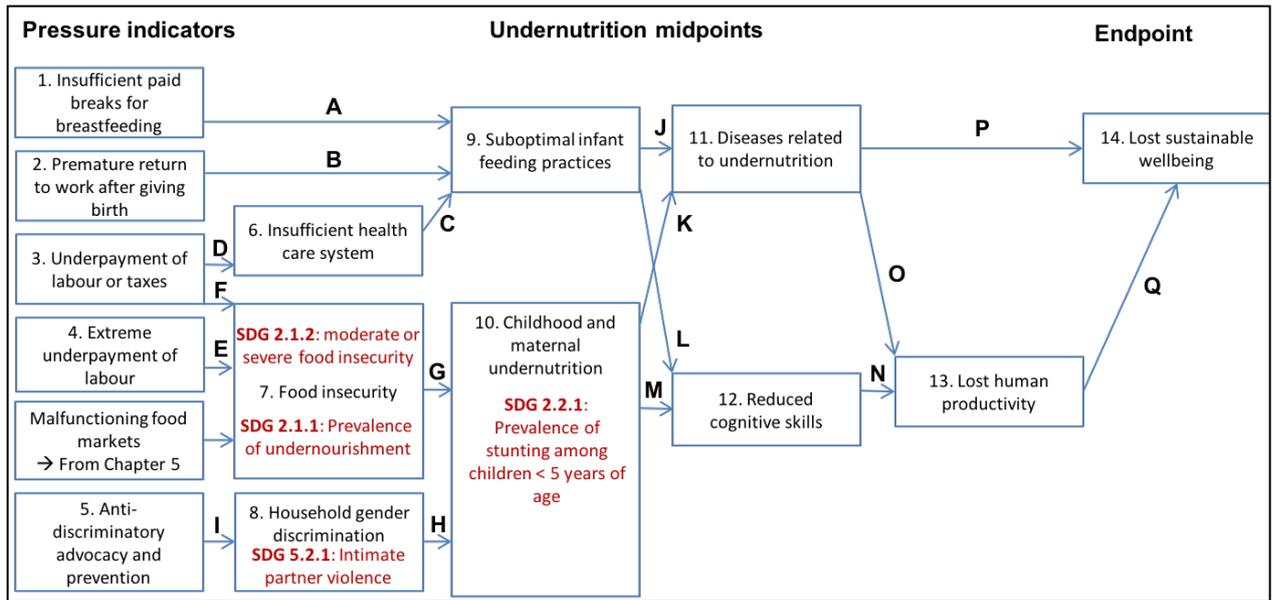


Figure 4-1: Impact pathways for undernutrition. The four SDG indicators related to undernutrition are indicated in bold red text.

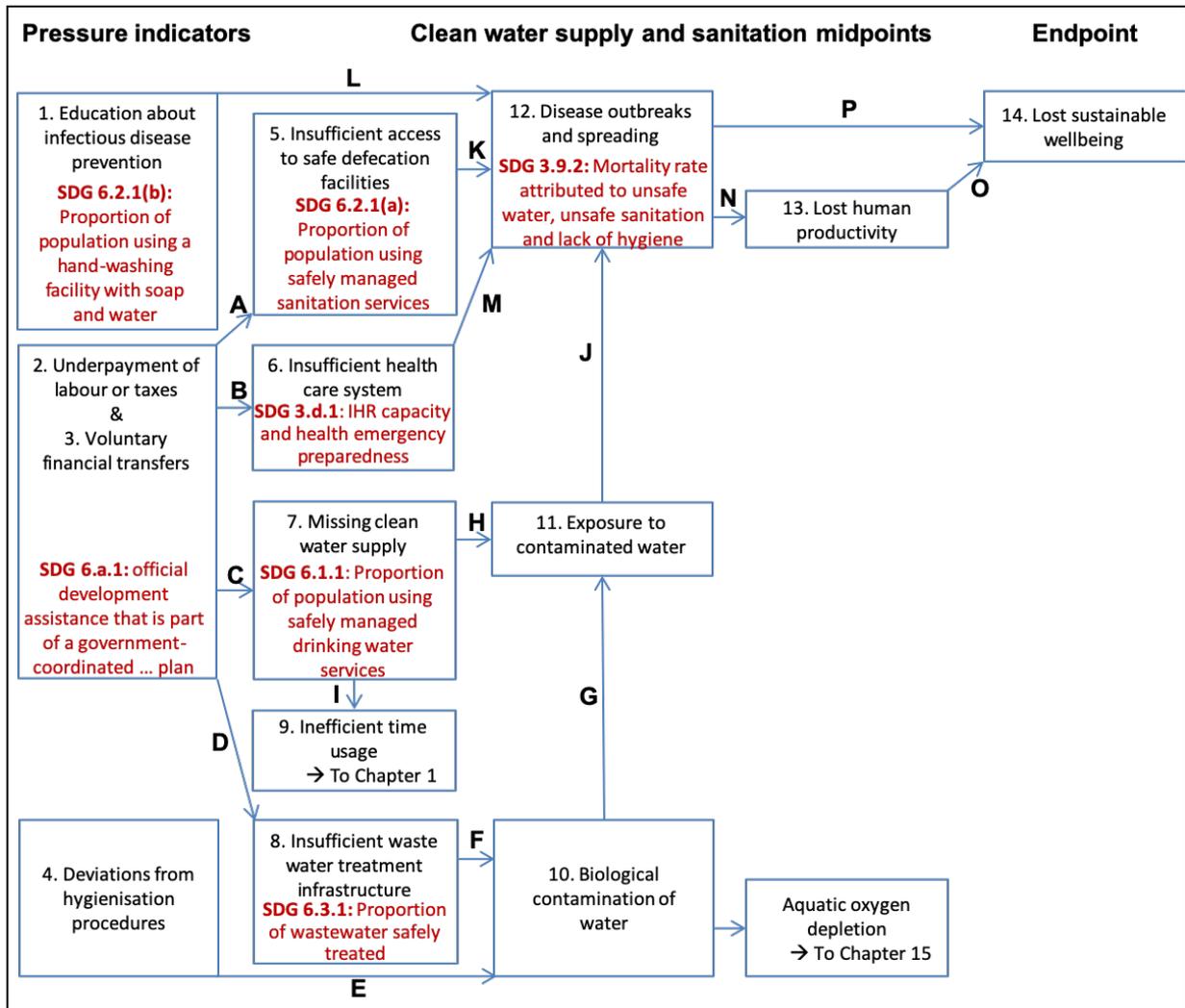


Figure 4-2: Impact pathways for clean water and sanitation. The six SDG indicators related to clean water and sanitation are indicated in bold red text.

The links between the different sustainable development topics are made explicit in the impact pathway diagrams. An example of this can be seen in Figure 4-, where an unnumbered box between box 4 and 5 points to a link between the topic of undernutrition and the impact category of malfunctioning food markets. This link comes from another impact pathway diagram, namely that of Chapter 5 of Weidema (2020) entitled “Unequal opportunities”, the sustainable development topic related to SDG 5 (figure A-3 in the annex, box 15).

Figure 4--1 and Figure 4-2-2 show that indicators from different SDGs can appear in the same impact pathway diagram. For example, SDG indicator 5.2.1 appears in relation to box 8 in Figure 4--1, although this is an impact pathway diagram related to the topic of SDG 2. Likewise, although one might have expected to find SDG indicator 2.2.2 (prevalence of child overweight) in Figure 4-1, it appears instead in the impact pathway for healthy lives (figure A-2 in annex C), since it is more related to this SDG 3-related sustainability topic than to undernutrition as such.

It is important to note that this approach does not re-define the official SDG indicators, but places them in the context of their relevant impact pathways. Since one SDG can cover several topics, its indicators can be found in several impact pathways diagrams. Also, since the SDGs are interdependent, the same SDG indicator can occur in more than one impact pathway diagram. This is illustrated in table 4-1, where three of the SDG indicators for SDG 2 (SDG 2.3.1, 2.3.2, and 2.4.1), appear under more than one topic. Each of the SDG targets and indicators are treated under the topic they logically belong to, which may be different from the SDG they originally belong to. Table 4-2 also shows that to find *all* the occurrences of the indicators for SDG 2, one would have to consult the impact pathway diagrams for sustainable development topic 2, 3, 4, 5, 8, 10, 12, 14, and 15.

*Table 4-1: The relation of the indicators for SDG 2 to the different sustainable development topics and the related impact pathway diagrams.*

2030 Agenda indicator	Sustainable development topic and related impact pathway
2.1.1 Prevalence of undernourishment	2
2.1.2 Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)	2
2.2.1 Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age	2
2.2.2 Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age, by type (wasting and overweight)	2, 3
2.3.1 Volume of production per labor unit by classes of farming/pastoral/forestry enterprise size	4, 5, 8, 12
2.3.2 Average income of small-scale food producers, by sex and indigenous status	5, 8, 10
2.4.1 Proportion of agricultural area under productive and sustainable agriculture	10, 12, 14, 15
2.5.1 Number of plant and animal genetic resources for food and agriculture secured in either medium- or long-term conservation facilities	12
2.5.2 Proportion of local breeds classified as being at risk, not at risk or at unknown level of risk of extinction	12
2.a.1 The agriculture orientation index for government expenditures	10
2.a.2 Total official flows (official development assistance plus other official flows) to the agriculture sector	10
2.b.1 Agricultural export subsidies	5
2.c.1 Indicator of food price anomalies	5

The introductory chapter of Weidema (2020), the project report that is available for the project partners, provides a full correspondence table between the SDG indicators and the impact pathway diagrams in which they occur.

The impact pathway diagrams are easier to understand when each sustainable development topic is described separately, as done in the figures here. However, like the SDGs, the impact pathways are not independent. The 17 impact pathway diagrams can be brought together into one complete and exhaustive picture or matrix, and the contributions of a human activity to a specific SDG can be calculated as the sum of its contributions to each of the indicators of that SDG, even when these indicators belong to different impact pathways.

Further examples of impact pathways can be found in annex C (for poverty, related to SDG 1; healthy lives, related to SDG 3; unequal opportunities, related to SDG 5 and income and asset inequality, related to SDG 10).

Each of the 17 impact pathway descriptions was developed with a starting point in a safeguard subject, i.e. a midpoint impact for which a measurable indicator exists for the annual human-induced damage. For example, the impact pathway descriptions for undernutrition and for clean water and sanitation (Figure 4-1 and Figure 4-2) have their starting points in the known cases of diseases related to these two environmental topics, as quantified by the Global Burden of Disease (GBD) Collaborative Network. We then identified the causes of these human-induced changes, based on the available scientific literature from the specific scientific topic areas and from the ongoing work with SDG indicators. Next, we identified characterization factors from the best available and authoritative data sources, relating each midpoint impact category back to inventory indicators (the leftmost column of boxes in the impact pathway diagrams). These inventory indicators, measurable at the level of specific human production or consumption activities, can thus be seen as the ultimate causes of the identified impacts. Likewise, we used characterization factors to link the midpoint impact categories forward to the single endpoint measure of sustainable wellbeing. These endpoint characterization factors unavoidably have the character of weighting factors, so we based them on well-established principles from welfare economics, following ISO 14008, namely that weights shall be statistically representative of the affected population, shall weight the wellbeing of each individual equally, and shall be corrected for any systematic irrational bias caused by the contextual and informational setting.

For each impact category, we characterized one of the identified causes as the default impact pathway for any residual impact that cannot be explained by more specific impact pathways. In most cases, this pathway leads back to the inventory category "Underpayment of labor and taxes". Including such default impact pathways for any residual unspecified causes is indispensable to ensure the completeness of the model, i.e., allowing us to trace all known impacts back to a human activity. However, this completeness is bought at the cost of accepting that some impact pathways have a less solid empirical basis than others, implicitly providing a call for more research.

### 4.3.1 Quantification of the impact pathways

To show the full potential of the impact pathway approach, the example illustrated in Figure 4-3 provides a full chain of characterization factors, represented by the bold letters in Figure 4-3, corresponding to the letters in figure 4-1. These characterization factors provide the quantitative links between the inventory indicators and the impact indicators, to the final single endpoint measure of sustainable wellbeing. In annex D, each characterization factor is described with definitions and units. That annex also shows the full example calculation that is summarized in Figure 4-3-3.

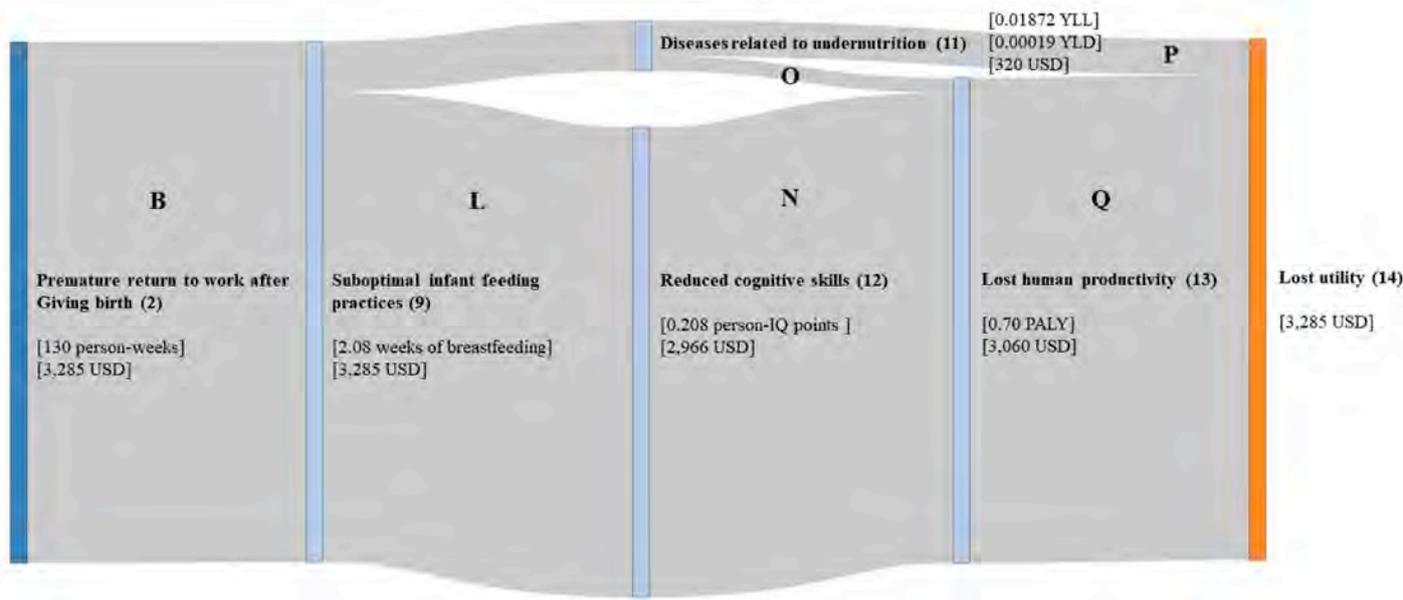


Figure 4-3: Impact pathway from premature return to work after giving birth to lost sustainable wellbeing (lost utility). Indicators along the pathway are expressed in both physical units (calculated left to right with the characterization factors provided in annex D) and in units of damage (equity-weighted monetary value, calculated from right to left, and represented in the thickness of the flows). Letters correspond to the characterization factors in figure 4-1. See annex D for the full calculation of the example.

#### 4.4 Most important learnings

Human activities contribute to the SDGs (and to sustainable development in general) through their pressures, which are represented as the leftmost column of boxes in the impact pathway diagrams (section 4.2). In general, the impact pathways have been described from the perspective of a generic organization, which can exert a pressure with its activities that can lead to beneficial or detrimental impacts at the midpoint and endpoint level. However, the division of indicators in inventory (pressure) indicators and midpoint impact indicators is not sharp, since many of the midpoints in the impact pathways are also directly related to human activities. This implies that organizations may have activities that can affect a midpoint impact indicator directly, rather than via the inventory indicators that contribute to this midpoint impact indicator. For example, a hospital may, through changes in its efficiency, directly affect the “Insufficient health care system” midpoint indicator, while a generic organization can only indirectly affect this midpoint indicator through inventory indicators such as “Underpayment of labor and taxes” and “Voluntary financial transfers”.

We have identified three groups of inventory indicators that represent three types of actions that determines an organization’s contribution to the SDGs. We have labeled these types as “How much do you pay”, “Whom do you pay” and “How much shared value do your indirect expenditures and behavior create”. We will describe these three types of actions in the next subsections, and illustrate them with examples of inventory indicators from different sustainable development topics and how they influence the SDGs through the different impact pathways.

### 4.4.1 How much do you pay

Practically all 17 sustainable development topics address specific shortcomings of community functions that depend on the availability of sufficient funds. Such funds are obtained in the form of direct payments from community members or indirect ones via tax payments. Ultimately, these funds come from the productive activities in the form of financial payments to their labor force and entrepreneurs, or via taxes, rent payments, or as voluntary transfers. Therefore, “Underpayment of labor or taxes” and “Voluntary financial transfers” appear as inventory indicator categories in nearly all impact pathway diagrams. “Underpayment of labor or taxes” is a very generic category that acts as a default starting point for all detrimental impacts that cannot, currently or by their nature, be related to more specific inventory indicators. In contrast, the category “Voluntary financial transfers” covers beneficial contributions that are directed toward specific activities or groups.

Examples of community functions that depend on the availability of sufficient funds, and their relation to the SDG framework, are:

- SDG 1: Poverty prevention and reduction activities
- SDG 2, 3 and 6: Health care system
- SDG 4: Education services
- SDG 5: Regulatory and institutional framework; anti-discriminatory advocacy and preventive or compensatory activities
- SDG 6: Water supply, sanitation, wastewater treatment infrastructure

### 4.4.2 Whom do you pay

The financial payments from productive activities have different impacts depending on the asset status of the recipient. The resulting inequality of impact is the core topic of SDG 10, and also the main impact pathway for the sustainable development topic of poverty, related to SDG 1; see Figure 4-4 and A-1, respectively. Payments done by organizations may to some extent be re-distributed via tax and insurance systems, rent payments, and voluntary transfers, as well as redistribution within households. The wellbeing (utility) impact of the resulting wealth distribution is measured by applying appropriate equity weights (also known as utility weights, welfare weights, or distributional weights) to the utility change of each population segment. Equity weights take into account that the same cost or impact is more burdensome – and that a similar benefit or improvement is more valuable – for individuals with lower initial wealth or income. This equity-weighting also allows to apply different weights for direct impacts on wellbeing and indirect impacts on wellbeing via changes in productivity (Weidema 2018).

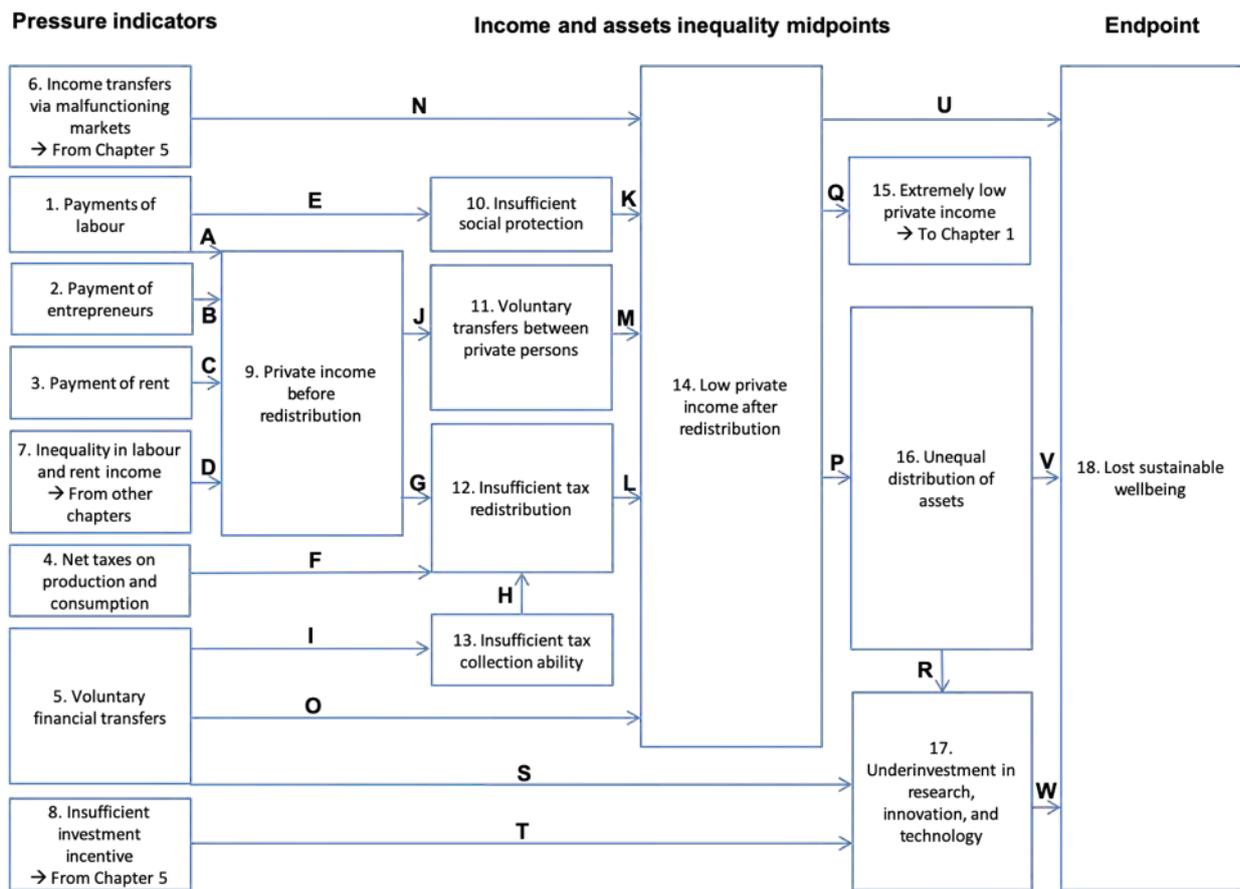


Figure 4-4: Impact pathways for income and assets inequality. Box 6 and 8, which refer to chapter 5 in Weidema (2020), can also be found in figure A-3 in the Annex. Box 15 that refers to chapter 1 of Weidema (2020) can also be found in figure A-1 in the annex.

For the measurement of payments to the labor force and entrepreneurs, as well as rent payments and voluntary transfers, it is therefore important to specify the payments by asset (or income) status of the recipient. It may be relevant to seek further resolution of recipient groups in terms of age, disease or disability, ethnic status, family relation, gender, and migratory status.

#### 4.4.3 How much shared value do your indirect expenditures and behavior create

Organizations can contribute to sustainable development not only with their direct financial payments to their labor force and entrepreneurs, or via taxes, rent payments, or voluntary transfers, but also through their indirect expenditures and behavior. Examples can be found among the inventory categories for nearly all of the impact pathways:

- Poverty (sustainable development topic related to SDG 1): For organizations that are involved in the supply of basic services (clean water supply, sanitation, solid waste disposal, electricity, housing, internet, banking), charging separate access costs can create unnecessary access barriers for poor households compared to a uniform distribution of the infrastructure costs over the unit costs of all consumers of the service. Reducing access costs for basic services can therefore contribute to reducing absolute poverty.

- Undernutrition (sustainable development topic related to SDG 2): Adequate maternity support in the form of a continuous period of maternity leave and subsequent paid breaks for breastfeeding can reduce the premature cessation of exclusive breastfeeding. Providing contractual guarantees, in excess of the legal requirements for this, can therefore be a way for an organization to contribute to reducing suboptimal infant feeding practices.
- Healthy lives (sustainable development topic related to SDG 3): Reducing emissions and occupational hazards can reduce related diseases and disabilities.
- Unequal opportunities (sustainable development topic related to SDG 5): Fair commercial practices and reduced rent seeking can lead to increased productivity and thus increased sustainable wellbeing (see figure 4.3 for the direct and indirect pathways).
- Clean water supply and sanitation (sustainable development topic related to SDG 6): The spread of infectious diseases can be prevented by appropriate behavior during both production and consumption activities. An organization can promote such behavior through motivation and education, as well as by systematic monitoring of the hygienization practices at critical control points.



Next steps

# 5 Next steps

The methodologies presented in this publication are still under development and will be tested in case studies with our business partners during 2020 and 2021. The next step to enable these case studies is to develop guidance for data collection and default data sources for both methodologies.

For the SDG screening approach, the next step is to complete the links between LCA indicators and the remaining SDGs. For the SDG assessment, the next step is to combine the impact pathway diagrams for all 17 SDGs into an integrated view that makes linkages between the different topics and pathways explicit. Because the uniform endpoint is a single unit for equity-weighted sustainable wellbeing, it is possible to express all steps of the impact pathways in the same unit. Because of this, we can represent all the pathways as Sankey diagrams, like in Figure 4-3. This will allow us to highlight the most important pathways.

As the project nears finalization, consultations will be held with experts to ensure that the best available knowledge is applied. At that stage, we will also provide a summary of the most important uncertainties.

## You can still participate

Have you also been wondering how to contribute to the SDGs, and how to report on your SDG progress? You can still join the other frontrunner companies in this project. As a business partner, you will have the opportunity to contribute to the development of the methodology. You will also be among the first to apply the method to your business case, assisted by the project team.

Multinational companies and companies in OECD countries are expected to contribute EUR 12,000, while non-OECD companies may join for EUR 6,000. We would be honored if you joined this project as a business partner.

If you are interested in participating, please [contact us](#) for additional information.



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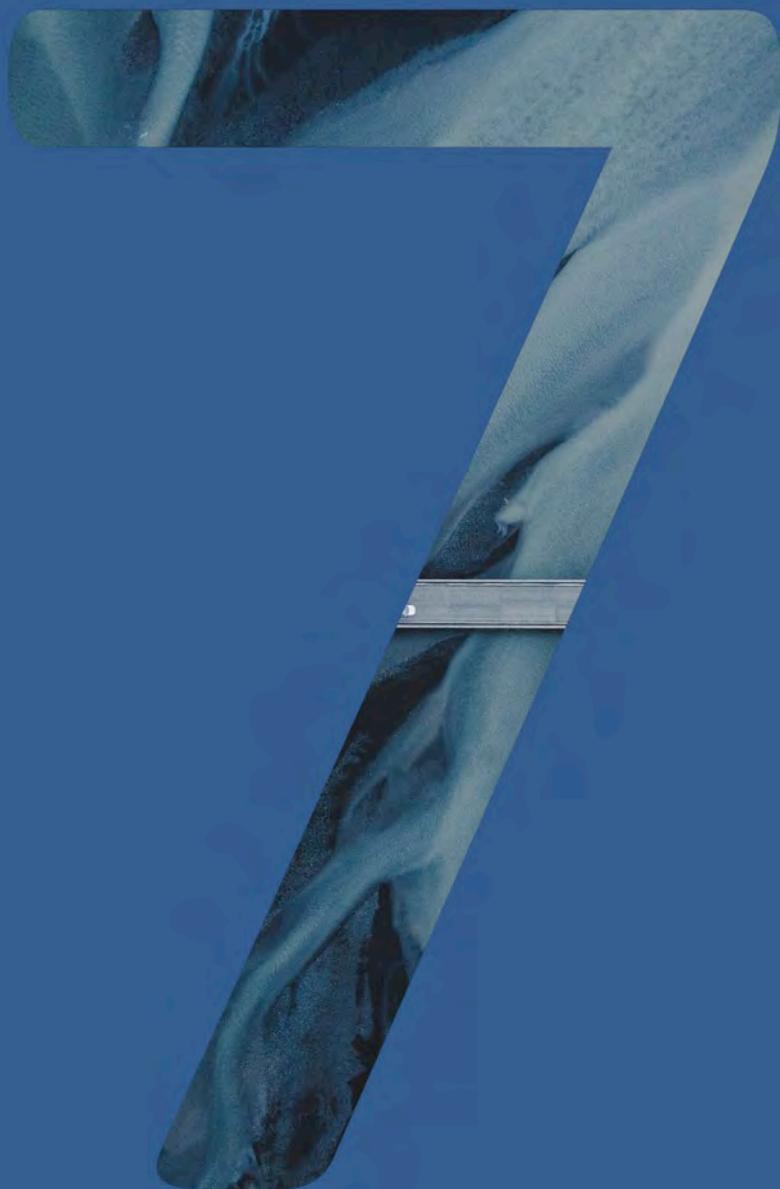
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# Annexes

# 7 Annexes

## List of annexes

- A. List of impact categories for ReCiPe and PSM Handbook
- B. Additional descriptions and definitions of pressure indicators
- C. Additional examples of impact pathway diagrams
- D. Example of a full quantified impact pathway calculation

## Annex A: Impact categories included in life cycle SDG screening

*Table A-1 Environmental impact categories from ReCiPe 2016 (Huijbregts et al., 2016)*

Midpoints
Climate change
Stratospheric ozone depletion
Ionizing radiation
Fine particulate matter formation
Photochemical ozone formation
Terrestrial acidification
Freshwater eutrophication
Marine eutrophication
Toxicity
Water use
Land use
Mineral resource scarcity
Fossil resource scarcity
Endpoints
Human health
Ecosystem quality
Resource availability

*Table A-2 Social impact categories from the Product Social Impact Assessment Handbook (Goedkoop et al, 2018)*

Workers
Health and safety
Remuneration
Child labor
Forced labor
Discrimination
Freedom of association and collective bargaining
Work-life balance
Users
Health
Product safety

Responsible communication
Privacy
Inclusiveness
Effectiveness and comfort
Local communities
Health and safety
Access to tangible resources
Community engagement
Employment
Small-scale entrepreneurs
Meeting basic needs
Access to services and inputs
Women's empowerment
Child labor
Health and safety
Land rights
Fair trading relationships

## Annex B: Additional descriptions and definitions of pressure indicators

### Noise

#### Description:

Noise, as well as sound in general, is usually measured in decibel ( $\text{dB}_{\text{SWL}}$ ), which is a logarithmic scale for the sound power level ( $L_W$ ) relative to the lowest human-audible level of 1 pico-watt ( $1\text{pW} = 10^{-12}\text{W}$ ). This is usually frequency-weighted to the A-scale, as defined in IEC (2013), giving the sound power level  $L_{WA}$  in the unit  $\text{dB(A)}$ , which accounts for the frequency-selective response of the human ear at low sound pressure levels, and/or to the C-scale ( $L_{WC}$  in the unit  $\text{dB(C)}$ ) that eliminates very low-frequency sounds and therefore is more relevant for specifically measuring the high-frequency sounds that cause hearing impairment.

The unit of  $\text{dB}$  is not additive, and the impact of noise also depends on its duration. Thus, to obtain an expression that is additive and also considers the duration of the noise, the sound power level in the logarithmic decibel ratio must be converted to the linearly additive units of frequency-weighted energy per time and multiplied by the duration ( $t$ ) in seconds, thus obtaining the frequency-weighted (typically A-weighted) sound energy  $W(A)$  in joule:

$$W(A)[J] = 1[pW] * 10^{\frac{L_{WA}[\text{dB(A)}]}{10}} * t[s]$$

Furthermore, the impact of noise depends on the time of day (typically, noise measurements are differentiated over a daytime of 12 hours, an evening of 4 hours, and an 8-hour nighttime). Damage thresholds and occupational exposure limits for high-frequency sounds are typically based on noise levels integrated over an 8-hour work-day. In addition, peak sound pressure levels above 120 and 140  $\text{dB(C)}$  should be monitored to indicate the need for protective equipment.

#### Indicator definitions and units:

The pressure category indicators are defined as:

- A-weighted sound energy, specified by time of day (daytime, evening, nighttime).
- C-weighted sound energy for sound energy levels between 80 and 140  $\text{dB}$ , specified per 8-hour work-day.
- Incidences of peak sound pressure levels above 120 and 140  $\text{dB(C)}$ .

The units of measurement are energy units, such as J (for sound energy), and unitless (for incidences).

### Regulation of radiation exposure

#### Description:

The calculation of exposure to emissions from human activities is normally performed under certain assumptions of protective equipment use and its protective effects, as well as the assumption that the exposed population reside and/or work in a specific, fixed location relative to the source of emission. This implies that the effect of specific activities that actively change the amount or efficiency of protective equipment or that actively change the location to reduce exposure can be modeled with corresponding modifications to the settings of the normal exposure factors for the emissions in question. However, separate exposure models are required for impacts that are not related to emissions from human activities, but rather to natural background pressures, or to emissions that only have human health impacts in very specific exposure conditions, such as light exposure during night work.

Work shifts during the night (starting between 8 p.m. and 3:59 a.m.) can have severe health effects, which is suspected to be caused by the exposure to artificial visible light, which disrupts the circadian rhythm and reduces melatonin secretion (Lin et al. 2015). Possible preventive measures, e.g. selectively shielding from blue light or stimulation of alternative non-harmful circadian rhythms, have not yet been sufficiently researched to provide definitive guidance.

For ultraviolet radiation, there is a disease burden associated both with excessive and with insufficient ultraviolet radiation exposure (Lucas et al. 2006). Ultraviolet radiation exposure is beneficial because it stimulates the body to generate sufficient vitamin D (> 50 nmol circulating 25-hydroxy-vitamin D per L serum corresponding to > 20 ng/mL). Webb et al. (2018b) calculate a maintenance requirement of 6.25 nmol 25-hydroxy-vitamin D per L serum per month, corresponding to an ultraviolet radiation dose of 3.25 SED on 35% of the skin (0.6 m<sup>2</sup>, corresponding to face, hands, forearms, and lower legs) of light-skinned individuals. (1 SED = 100 J/m<sup>2</sup> ultraviolet radiation dose, weighted by the ISO/CIE (1999) spectral action function that expresses the biological effectiveness of the radiation to generate erythema (sunburn) depending on its wavelengths, relative to the effectiveness of the wavelengths below 298 nm). At the equator, this amount of exposure would be obtained in less than 30 minutes per month, or 1 minute per day, and even when accounting for the typical darker pigmentation of the local population, this would not require any special attention. However, in higher latitudes, adequate exposure is hampered by the lower level of ultraviolet radiation and the temperatures during winter, which implies that more exposure is required during summer months to build up the serum vitamin D to a level that can supply the monthly requirement during the winter months. Webb et al. (2018b) suggest that at higher latitudes, the annual requirement of 39 SED can best be obtained by solar exposure of 35% of the skin during lunchtime in three summer months and 10% of the skin (face and hands) during another four months. Lunchtime exposure of less than 30 minutes per day would be sufficient for light-skinned individuals. For dark-skinned individuals, it may be insufficient to rely on solar exposure only, and they therefore may need to consider supplementing with dietary sources of vitamin D (Webb et al 2018a). Webb et al. (2018b) suggest that single exposure doses should be kept below 1 SED, since higher doses of ultraviolet radiation - whether from the sun or from phototherapy, tanning lamps, or germicidal lamps - is an important risk factor for skin cancer. While squamous cell carcinoma is found to be related to lifetime accumulated exposure, the most lethal forms of skin cancer - melanoma - are rather related to intense exposure (sunburn), i.e. single events where exposure exceeds a threshold. This threshold varies with skin sensitivity and can be as low as 1.3 SED (Webb et al. 2011). Protection against both types of skin cancer consists of avoiding outdoor occupations during the peak periods of radiation and otherwise covering the body with clothing and using UV-protecting sunglasses.

Cosmic radiation is a form of ionizing radiation to which aircrews (and aircraft passengers) are exposed at higher levels than ground-based personnel. According to Annex B of UNCEAR (2000), the effective dose at altitudes of 9-12 km is 5-8 µSv/hour at temperate latitudes and 2-4 µSv/hour at equatorial latitudes. By comparison, the cosmic radiation dose at sea level is 0.03-0.4 µSv/hour.

#### **Indicator definitions and units:**

The pressure category indicators are defined as:

- For occupational exposure to artificial visible light at night: work days with shifts starting between 8 p.m. and 3:59 a.m.
- For ultraviolet radiation: days of occupational exposures of unprotected skin above 1.3 SED. During the summer months at latitude 30 and above: days where occupation restricts access to lunch breaks with sunlight exposure.
- For ionizing radiation: change in effective dose relative to background level.

The measurement units are:

- For visible and ultraviolet light exposure: person-days

- For ionizing radiation exposure: Sievert (Sv; biological effectiveness equivalent of a joule of beta-particle radiation in a kilogram of human tissue).

## Education about infective disease prevention

### Description:

The spread of infectious diseases can be prevented by appropriate behavior during both production and consumption activities. Such behavior rests on motivation and education. Education about responsible behavior with respect to infectious diseases should include:

- Handwashing and other hygiene procedures and preventive practices recommended in the IFH guidelines (IFH 2001, 2002, 2004)
- The precaution that should be taken when encountering diseased or deceased animals to avoid spreading of zoonoses
- Self-monitoring for signs of infectious diseases
- Reducing interpersonal contact and alerting medical personnel promptly upon suspicion of infection
- Accepting screening, vaccination and quarantine when offered by medical personnel.

SDG indicator 6.2.1(b), proportion of the population using a handwashing facility with soap and water, can be seen as a population-aggregate outcome indicator for the activity measured by the pressure category indicator proposed here.

### Indicator definition and unit:

The pressure category indicator is defined as person-years of employees and their family members with skills in preventive practices with respect to infectious diseases (hygienic practices, reporting on incidences of diseased family members and animals, self-monitoring for signs of infection, reducing interpersonal contact upon suspicion of infection, and following the advice of medical personnel) and the measurement unit is person-years.

## Access costs for basic services (for organizations supplying such services)

### Description:

The cost of many basic services (clean water supply, sanitation, solid waste disposal, electricity, housing, internet, banking) may be divided into:

- access costs, typically per household or individual, to cover the infrastructure establishment and maintenance
- and unit costs for the actual amount of service supplied (cubic meters of water or solid waste, kWh of electricity, square-meter-years of housing, GB of data, time-integrated account balance in currency units).

For poor households with low consumption, the total cost will be larger if access costs are charged separately than if the access charges are distributed evenly over the unit costs of all consumers of the service. Likewise, poor households are particularly vulnerable to overdraft or late payment fees, especially when charged in excess of what is required to cover the average losses on defaults or overdue payments. For example, relative to a 2% risk-free real annual interest rate, a 20% real annual interest rate on overdrafts and late payments is sufficient to cover the income loss of a 15% average default rate of such overdraft or late payments.

While separate access charges and fees create unnecessary access barriers for poor households, they may be justified from an activity costing perspective, especially when the cost of providing access is location-dependent, e.g. when supplying remote areas that have low population density. In these

situations, it is fair to charge the location-dependent part of the access costs separately, while providing payment plans with low-cost credit for poor households.

#### **Indicator definitions and units:**

The pressure category indicators are defined as:

- Access costs for provision of basic services, charged separately from the charge per unit of service supplied, except when this can be justified by the supply location
- Differential between overdraft and/or late payment fees and the losses on defaults and overdue payments.

The measurement unit is purchasing-power-corrected currency units, e.g. USD<sub>2011,PPP</sub>.

## **Dietary risk factors (for organizations handling foods or beverages)**

### **Description:**

Dietary risk factors are components of foods and beverages that increase the risk of diseases if either added to or subtracted from an already unbalanced diet. An unbalanced diet is understood as a diet low in fruits, vegetables, legumes, whole grains, nuts and seeds, milk, dietary fiber, calcium, polyunsaturated fatty acids, and omega-3 fatty acids or precursors, or a diet high in red meat, processed meat, added sugar and ethanol, saturated and trans fatty acids, and sodium (GBD 2017 Diet Collaborators 2019). Overnutrition, or more precisely chronic surplus dietary metabolizable energy intake (Livesay 2001), is related to food items with high energy density and high glycemic index, notably processed foods with refined grains, added sugars and/or added fats (Drewnowski and Darmon 2005, Vernarelli et al. 2018, Livesay et al. 2008). Within each food group (fruits, legumes, vegetables, grains, nuts and seeds, beverages, fats and vegetable oils, and meat), it is possible to further differentiate individual food items according to their content of qualifying ingredients relative to daily recommended intake, and content of disqualifying ingredients relative to maximum reference values, as provided in Fern et al. (2015), and the glycemic index for the carbohydrate content.

### **Indicator definitions and units:**

The following pressure category indicators apply to the ingested or ingestible part of foods and beverages, and should whenever possible be specified relative to daily recommended intake and prior diet balance of the ingesting population group:

- The nutrient density of qualifying nutrients (vitamins, minerals, choline, polyunsaturated fatty acids, omega-3 fatty acids or precursors, dietary fiber according to the AOAC official method 985.29 or similar, protein, water) and disqualifying nutrients (saturated and trans fatty acids, cholesterol, sodium, and total sugars and ethanol) per unit of metabolizable energy measured according to the recommendations of FAO (2003),
- The glycemic index for the carbohydrate content.

The units of measurement are energy units, such as kJ (for metabolizable energy); mass per energy unit, e.g. gram/kJ (for nutrient density); and unitless (for glycemic index).

## **Deviations from hygienization procedures (for activities handling biological materials)**

### **Description:**

Sufficient hygienization is particularly important when moving persons, goods or wastes between locations. The definitions of critical control points and monitoring are specific to different processes

and are described in specific industry guidelines and requirements. When no industry standard exists, the IFH guidelines for everyday situations (IFH 2001, 2002, 2004) may be applied.

**Indicator definition and unit:**

The pressure category indicator is defined as incidences of deviations from hygienization procedures at critical control points, according to relevant industry standards or IFH guidelines when no industry standard exists. The measurement is unitless (incidences).

## Annex C: Additional examples of impact pathway diagrams

In this annex, you can find three more examples of impact pathway diagrams: figure A-1 for poverty, related to SDG 1; figure A-2 for healthy lives, related to SDG 3; and figure A-3 for unequal opportunities, related to SDG 5.

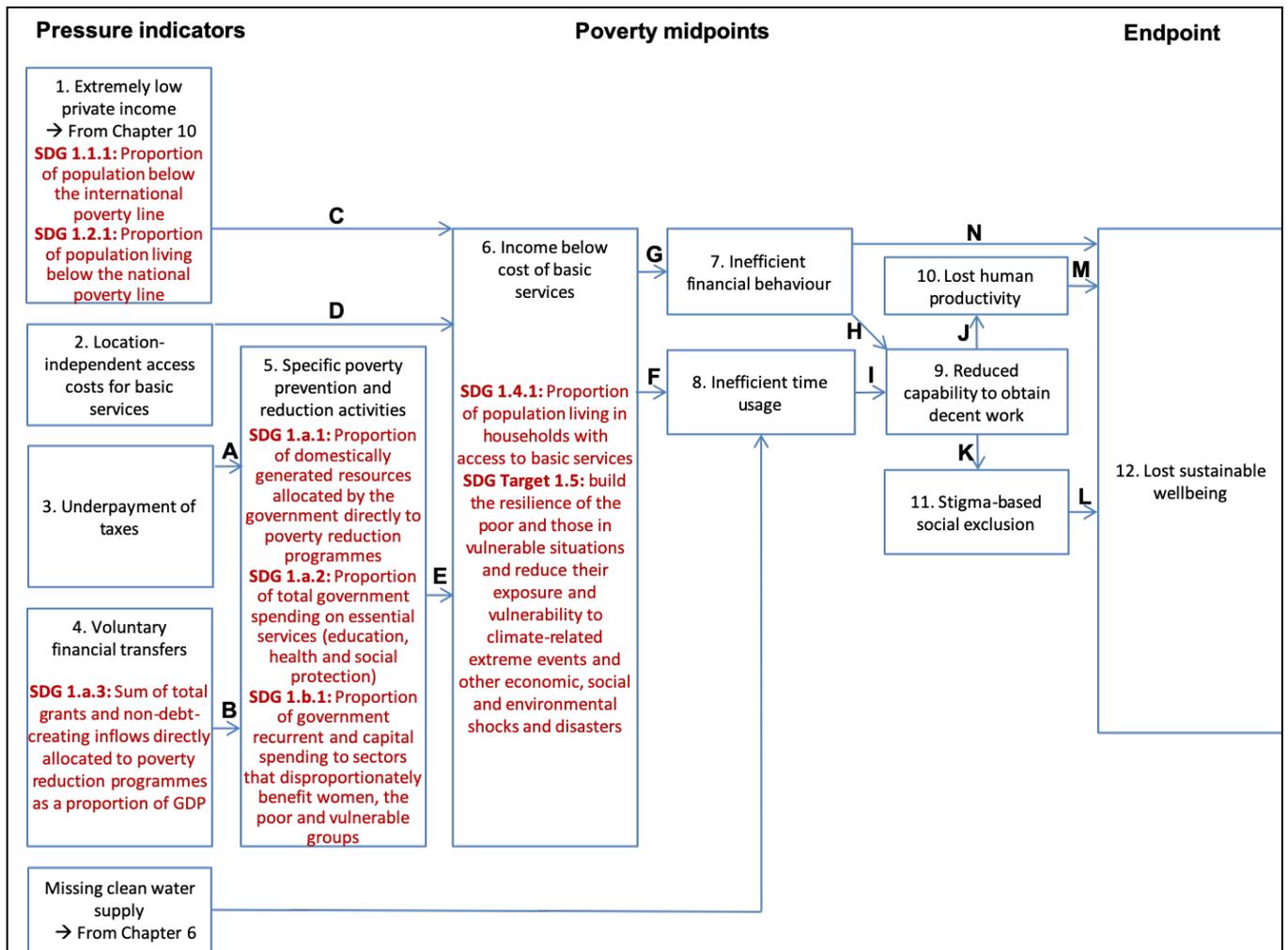


Figure A-1: Impact pathways for poverty. The SDG indicators related to poverty are included in red.

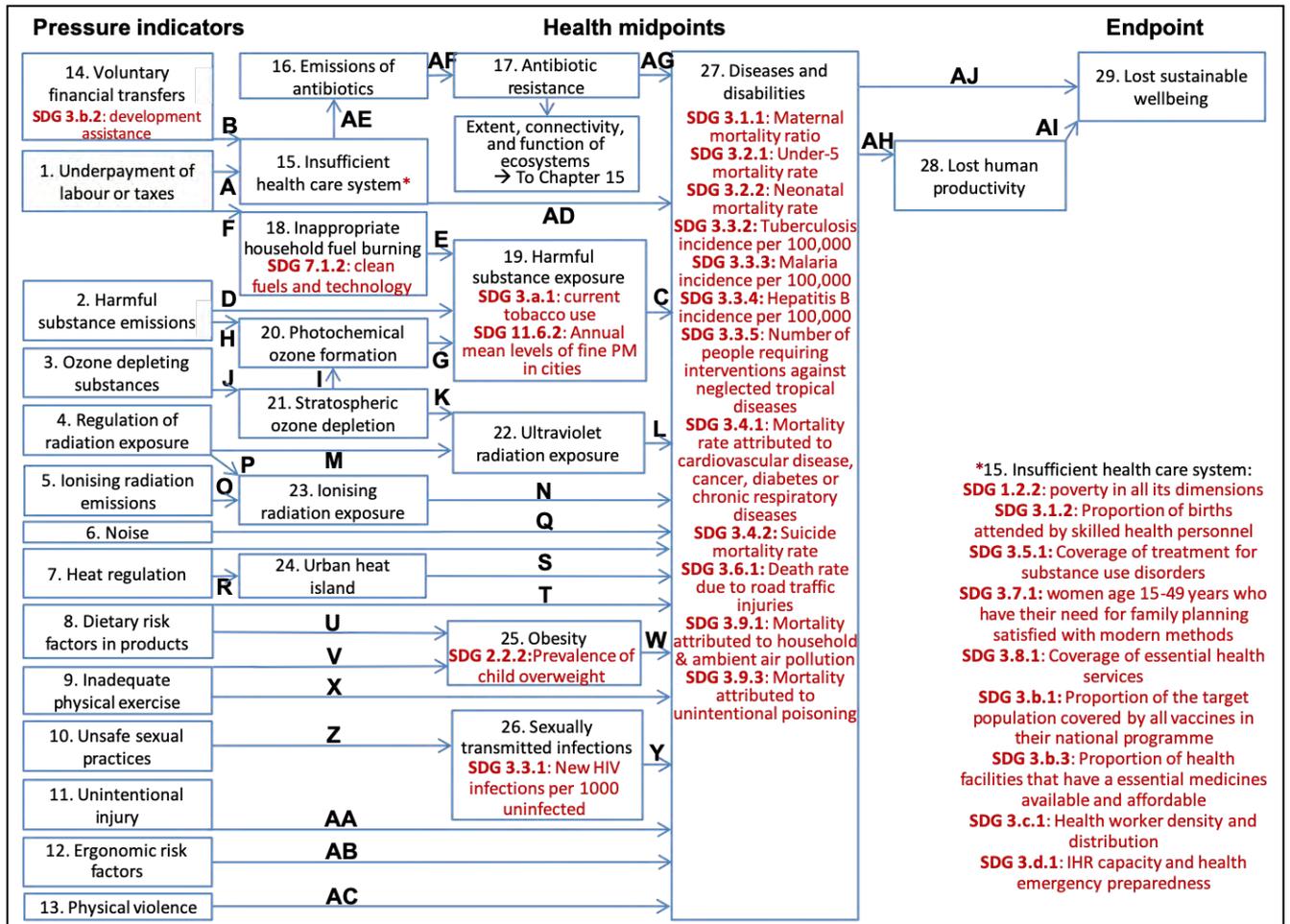


Figure A-2: Impact pathways for healthy lives. The SDG indicators related to healthy lives are indicated in red.

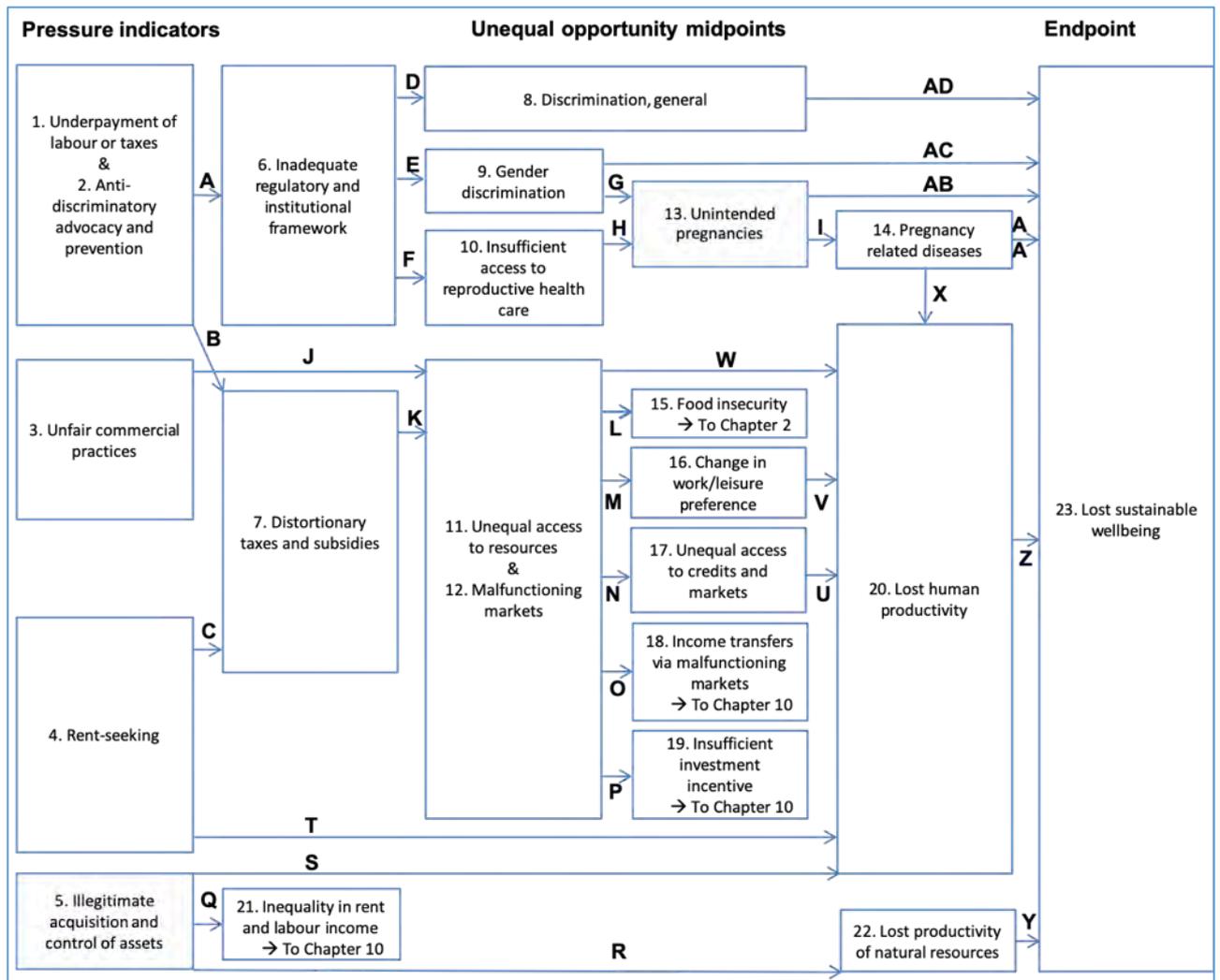


Figure A-3: Impact pathways for unequal opportunities. Due to their large number, the SDG indicators related to equal opportunities are not included in this diagram. Box 15, which refers to Chapter 2 in Weidema (2020), can also be found in figure 4-1.

## Annex D: Example of a full quantified impact pathway calculation

The following example refers to figures 4-1 and 4-3 about undernutrition in section 4.3. It provides a full chain of characterization factors from pressure indicators to the final single endpoint measure of sustainable wellbeing.

The impact pathway begins with characterization factor B from figure 4-1 (the arrow from box 2 to box 9). Characterization factor B relates suboptimal infant feeding practices (impact category 9), measured as weeks of cessation of breastfeeding before 6 months after childbirth, to the workplace pressure indicator “Premature return to work after giving birth”.

Characterization factor B is based on a US cohort study of singletons ( $N = 6150$ ) whose biological mothers were respondents at the 9-month interview who worked in the 12 months before delivery (Ogbuanu et al. 2011). The study found that among the women returning to work at  $\geq 13$  weeks, the share that continued predominant breastfeeding beyond 3 months was higher (23.8%) than among women returning within 1 to 6 weeks (11.6%), with a risk ratio of 1.99 (95% CI: 1.38–2.69). We interpret this as a probability of an increase of the duration of breastfeeding of  $1/1.99 = 0.5$  weeks for every week that the return to work can be postponed by a guaranteed continuous maternity leave.

Local (country-specific) characterization factors per female employment-year can be obtained by multiplying this duration per child with the local annual birth rate (newborns/1000 persons), the local ratio of females of working age (females aged 15-64 years/1000 persons), the inverse of the local female labor participation rate (female work-years/females aged 15-64 years). As an example, a country with 19 newborns/1000 persons, 320 females aged 15-64 years/1000 persons and a female labor participation rate of 0.53 (female work-years/females aged 15-64 years), there would be on average  $(19/320) \cdot 0.53 = 0.031$  newborns per female work-year. This would result in a characterization factor B of  $0.5 \cdot 0.031 = 0.016$  weeks of (additional) breastfeeding per week of guaranteed continuous maternity leave per female employment-year with such a guarantee. Let's say the maternity leave is guaranteed up to 6 months (26 weeks) of age for the child. For this maximum period for which an impact is calculated, this would – in the example country – correspond to  $0.016 \cdot 26 = 0.4$  weeks of additional breastfeeding per female employment-year with such a guarantee. The ILO Working Conditions Laws Database publishes data on statutory provisions on maternity leave. ILO also publishes estimates of proportion of workers covered by paid maternity leave by law and in practice. The latest ILO publication on this topic is Addati et al. (2014).

From this calculated indicator value of weeks of breastfeeding for age 0-6 months (under impact category 9, suboptimal infant feeding practices), the impact pathway continues with characterization factor J to diseases related to undernutrition (impact category 11), and characterization factor L to reduced cognitive skills (impact category 12), still referring to figure 4-1.

Characterization factor J can also be calculated at country level, by applying the annual country-specific aggregate measures of Years-of-Life-Lost (YLL) and Years-Lived-with-Disease (YLD; summed in Disability-Adjusted-Life-Years, DALY) for diarrhea and lower respiratory infections attributed to non-exclusive breastfeeding by the Global Burden of Disease (GBD) Collaborative Network.

Characterization factor J relates this DALY value to the number of exposed infants and the duration of exposure. As an example, using global data, the total number of DALY attributed to non-exclusive breastfeeding is 19 million YLL + 0.2 million YLD = 19.2 million DALY. This number is related to a total number of newborns (high income countries excluded) of 124 million in year 2010. Of these, only 34% received exclusive breastfeeding (Roberts et al. 2013), i.e. the exposed population is 124 million \* (1-34%) = 82 million. Per infant, that results in 19 million YLL/82 million infants = 0.23 YLL/exposed infant (95% confidence interval 0.18-0.28); and similarly 0.2 million YLD/82 million infants = 0.0024 YLD/exposed infant. Expressing this per week rather than per infant, which implicitly assumes that there is a linear relation between duration and impact, gives an average global characterization

factor J of  $0.23/26 = 0.009$  YLL (95% confidence interval 0.007 – 0.011) and  $0.0024/26 = 0.00009$  YLD week of exclusive breastfeeding for the period 0-6 months of age.

Characterization factor L relates reduced cognitive skills, measured in IQ points, to suboptimal infant feeding practices. Several reviews and studies have shown an effect of breastfeeding on cognitive skills (Anderson et al. 1999, Horta et al. 2007, PROBIT 2008, Lee et al. 2016, Jedrychowski et al. 2012), although these findings have also been challenged (e.g., by Der et al. 2006). If we accept a mean effect of 5.2 (CI: 3-7) person-IQ points and the implication that this is also related to duration up to 12 months of age, we obtain a global value for characterization factor L of  $5.2/52 = 0.10$  person-IQ points/week of breastfeeding (exclusive until 6 months after childbirth and continued until 12 months).

Still referring to figure 4-1, the impact pathways continue from reduced cognitive skills (impact category 12), measured as change in person-IQ-points, and diseases related to undernutrition (impact category 11) to lost productivity (impact category 13), measured in Productivity-Adjusted person-Life-Years (PALY), i.e. the affected share of the full productive capacity of a person in a year.

Characterization factor N, relating lost productivity to reduced cognitive skills, can be derived from the calculation of Jones & Schneider (2010) on the cross-country dataset of Lynn & Vanhanen (2006), later validated by Lynn & Meisenberg (2010), showing a 6.5% higher wage (CI: 6-7%) per IQ point between countries, as opposed to the much smaller effect (1% higher wage per IQ point) within a country, suggesting a spill-over effect where cognitive skills matter more for groups than for individuals. Jones (2013) explains this with the effect of cooperative productivity of same-level high-skilled workers: wages within a country are kept within a narrower range than wages between countries, because national wage levels are governed by the cooperative productivity of same-level high-skilled workers, and high-skilled workers in surplus supply will drive up wages in low-skill industries where they are close substitutes to low-skill workers. Expressing the 6.5% higher wage in PALY, we obtain 0.065 PALY/person-IQ point. Note that this applies to each productive year of the affected person, and thus accumulates over time until the expected age of death or pension of the affected person. For a typical productive life of 50 years, we obtain a value for the characterization factor N of  $50 * 0.065 = 3.25$  PALY/person-IQ point.

Characterization factor O relates the loss of productivity to diseases, as a combination of work hours lost directly (by the diseased or deceased) and hours redirected to health care from other productive work (by lay caretakers and professional health care workers). When no specific data are available, it can be assumed that a PALY is lost for every DALY, thus giving a default characterization factor O of 1 PALY/DALY. For fatal diseases, this is intuitive, since 1 DALY = 1 YLL (Year of Life Lost), while for non-fatal diseases 1 DALY = 1 YLD (Year Lived with Disease), the severity weights applied for loss of wellbeing are not necessarily proportional to the direct or indirect work hours lost. For specific diseases, more detailed data are often available. For example, for an incidence of child diarrhea, we can use data from Tucker et al. (1998) to estimate 25 work hours for the caretaker and 3 hours of health care service redirected from work-years of 1800 hours, i.e.  $(25+3)/1800 = 0.016$  PALY per incidence, of which one out of four requires medical care. Relating this to the 0.0032 YLD/incidence from the GBD 2016 Diarrhoeal Disease Collaborators (2018) gives a characterization factor O for the YLD part of the DALY from diarrhea of  $0.016/0.0032 = 5$  PALY/YLD.

The last step in the impact pathway consists of characterization factors P and Q that relate the endpoint of lost sustainable wellbeing (impact category 14) to diseases related to undernutrition (impact category 11) and lost productivity (impact category 13); see figure 4-1.

Lost sustainable wellbeing represents the equity-weighted utility (wellbeing), integrated over time, as a single-score endpoint indicator. To aggregate wellbeing across different persons and at different points in time, it is necessary to ensure that equal weight is given to the utility of each individual, considering that an impact is more burdensome (and that an improvement is more valuable) for individuals with lower initial level of wealth. For this purpose, equity-weighting of utility (also known

as utility-weighting, welfare-weighting, or distributional weighting) is applied, giving more weight to impacts (both detrimental and beneficial) on individuals who have an initial low level of wealth, and less weight to impacts on persons who have an initial high level of wealth. Since wealth data are less easy to obtain than income data, it is usual to apply income as a proxy for wealth. Thus, equity weights ( $W$ ) are calculated as the proportion between the global average income and the income of the affected subgroup raised to the power of the elasticity of marginal utility of income ( $\delta$ ):

$$W = \left( \frac{\text{AverageIncome}}{\text{SubgroupIncome}} \right)^{\delta} \quad (\text{Formula 1})$$

where both incomes are first corrected for purchasing power. The value of  $\delta$  can be empirically determined from surveys of wellbeing and income. From six such surveys, Layard et al. (2008) calculated a value for  $\delta$  of 1.24 (CI: 1.16-1.37).

Characterization factor P expresses the utility value of a DALY, expressed in purchasing-power-corrected and equity-weighted currency units, determined as the equity-weighted willingness-to-pay, i.e. the maximum amount of money an individual is prepared to give up to secure an extra life year. On average, this maximum amount is determined by the budget constraint, i.e. the amount of money that an average person in the population can earn in an extra life year. For a population with an annual income of 10000 USD<sub>2016,PPP</sub>, characterization factor P can be calculated as:

$$10000 * \left( \frac{12400}{\frac{10000}{2}} \right)^{1.24} = 30840 \left[ \frac{\text{USD}_{2016,PPP,EW}}{\text{DALY}} \right]$$

where the equity weight from Formula 1 applies as average income the global average income per person-year of 12400 USD<sub>2016,PPP</sub> and divides the subgroup income by 2, reflecting that the life years are additional and therefore should be equity-weighted by the *average* between zero and the current income level of the affected population.

Characterization factor Q expresses the utility value of a PALY, determined as the purchasing-power-corrected income per person-year, equity-weighted by Formula 1 using the current income level of the affected population. For example, with the global average income per person-year being 12400 USD<sub>2016,PPP</sub>, the characterization factor for a population with an income of 10000 USD<sub>2016,PPP</sub> can be calculated as:

$$10000 * \left( \frac{12400}{10000} \right)^{1.24} = 13057 \left[ \frac{\text{USD}_{2016,PPP,EW}}{\text{PALY}} \right]$$

The equity weight of a given population group can change over time as the wealth of the group changes. Typically, real incomes increase over time, which means that future population groups are wealthier, and their equity weights thus decrease over time. This is the societal rationale for discounting impacts that occur at future points in time. An annual discount rate consistent with the principle of equity-weighting is obtained by multiplying the elasticity of marginal utility of income ( $\delta$ ) by the expected annual increase in real income. Due to the uncertainty of the growth rate of future income, the resulting certainty-equivalent discount rate will be decreasing over time. This is well-explained by Gollier et al. (2008), who also provide a theory-consistent calculation of the annual social discount rates from an empirically based range annual increases in real income between 1.2% and 5.7%. The discount factor applicable to a specific impact will depend on its temporal location. There are two impact pathways that involve significant delays:

- Fatal diseases, where the lost years of life of each affected individual occur over their remaining expected lifetime (which can be obtained from life tables; GBD 2017 Mortality Collaborators 2018). The impacts therefore only slowly disappear as the impacted cohorts die from other causes. With an expected lifetime of 82 years and an expected working life from 16 to 64 years of age, the above discounting procedure yields net present values of 38% and 33.6% of the undiscounted impact for YLL and the related PALY, respectively.
- Reduction in cognitive skills, which will affect the productivity of the affected children and their societies over their remaining expected working life, i.e. until their expected pension age or pre-pension death, as identified from life tables (GBD 2017 Mortality Collaborators 2018). With an expected working life from 16 to 64 years of age, the above discounting procedure yields a net present value of 33.6% of the undiscounted impact.

Now that we have examples of all the characterization factors from premature return to work after giving birth (box 2 in figure 4-1) to lost sustainable wellbeing (box 14 in figure 4-1), we can calculate a full example of this impact pathway, using the above example values for the characterization factors.

Let us take as example a business located in a population with an average income of 10000 USD<sub>2016,PPP</sub> that decides to improve the contractual guarantee for continuous maternity leave for its female workers from 13 to 26 weeks. If the business has ten female full-time workers, we can calculate the annual impact of this decision as follows:

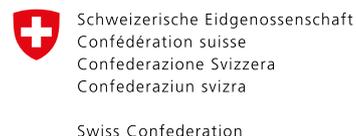
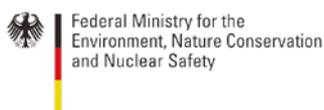
- 1) Pressure indicator: 10 annual female full-time employee equivalents multiplied by the differential between 26 weeks and 13 weeks of continuous maternity leave ensured by legal or contractual guarantee = 130 person-weeks.
- 2) Multiply this by characterization factor B of 0.016 weeks of additional breastfeeding per additional week of guaranteed continuous maternity leave per female employment-year with such a guarantee, obtaining: 130 person-weeks \* 0.016 weeks of breastfeeding/person-week = 2.08 weeks of breastfeeding (outcome of box 9 in figure 4-1).
- 3) Multiply this by characterization factors J of 0.009 YLL/week and 0.00009 YLD/week of exclusive breastfeeding to obtain: 2.08 weeks of breastfeeding \* 0.009 YLL/week of breastfeeding = 0.01872 YLL and 2.08 weeks of breastfeeding \* 0.00009 YLD/week of breastfeeding = 0.00019 YLD (outcome of box 11 in figure 4-1).
- 4) Multiply output from bullet 2 by characterization factor L of 0.10 person-IQ points/week of breastfeeding to obtain: 2.08 weeks of breastfeeding \* 0.10 person-IQ points/week of breastfeeding = 0.208 person-IQ points (outcome of box 12 in figure 4-1).
- 5) Multiply this by characterization factor N of 3.25 PALY/person-IQ point to obtain: 0.208 person-IQ points \* 3.25 PALY/person-IQ point = 0.676 PALY.
- 6) Multiply output from bullet 3 by characterization factors O of 1 PALY/YLL and 5 PALY/YLD to obtain: 0.01872 YLL \* 1 PALY/YLL = 0.01872 PALY and 0.00019 YLD \* 5 PALY/YLD = 0.00093 PALY.
- 7) Multiply output from bullet 3 by characterization factor P of 30840 USD<sub>2016,PPP,EW</sub>/DALY, separately for YLD and YLL, to obtain: 0.01872 YLL \* 30840 USD<sub>2016,PPP,EW</sub>/YLL = 577 USD<sub>2016,PPP,EW</sub> and 0.00019 YLD \* 30840 USD<sub>2016,PPP,EW</sub>/YLD = 6 USD<sub>2016,PPP,EW</sub>
- 8) Multiply the PALY outputs from bullets 5 and 6 by characterization factor Q of 13057 USD<sub>2016,PPP,EW</sub>/PALY to obtain: 0.676 PALY \* 13057 USD<sub>2016,PPP,EW</sub>/PALY = 8826 USD<sub>2016,PPP,EW</sub> related to reduced cognitive skills, 0.01872 PALY \* 13057 USD<sub>2016,PPP,EW</sub>/PALY = 244 USD<sub>2016,PPP,EW</sub> related to YLL, and 0.00095 PALY \* 13057 USD<sub>2016,PPP,EW</sub>/PALY = 12 USD<sub>2016,PPP,EW</sub> related to YLD.
- 9) Apply discounting to the USD<sub>2016,PPP,EW</sub> outputs from bullets 7 and 8 related to reduced cognitive skills and YLL, using the factors 38% for YLL and 33.6% for the cognitive skills, obtaining: 577 USD<sub>2016,PPP,EW</sub> \* 38% = 219 USD<sub>2016,PPP,EW</sub>, 8826 USD<sub>2016,PPP,EW</sub> \* 33.6% = 2966 USD<sub>2016,PPP,EW</sub>, and 244 USD<sub>2016,PPP,EW</sub> \* 33.6% = 82 USD<sub>2016,PPP,EW</sub>

10) Sum the USD<sub>2016,PPP,EW</sub> values from bullet 9 and the undiscounted YLD-related values from bullet 7 and 8, obtaining:  $219 + 2966 + 82 + 6 + 12 = 3285$  USD<sub>2016,PPP,EW</sub> (outcome of box 14 in figure 4-1, and the number at the left and right side of Figure 4-3)

Summarizing, the pressure indicator of 130 additional person-weeks of guarantee of continuous maternity leave has an impact that can be expressed in monetary terms as 3285 USD<sub>2016,PPP,EW</sub>, or 25 USD<sub>2016,PPP,EW</sub> per person-week. This can then be compared to the cost for the business (or society) of providing such a guarantee, thus allowing comparisons to other possible actions with the same cost.

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