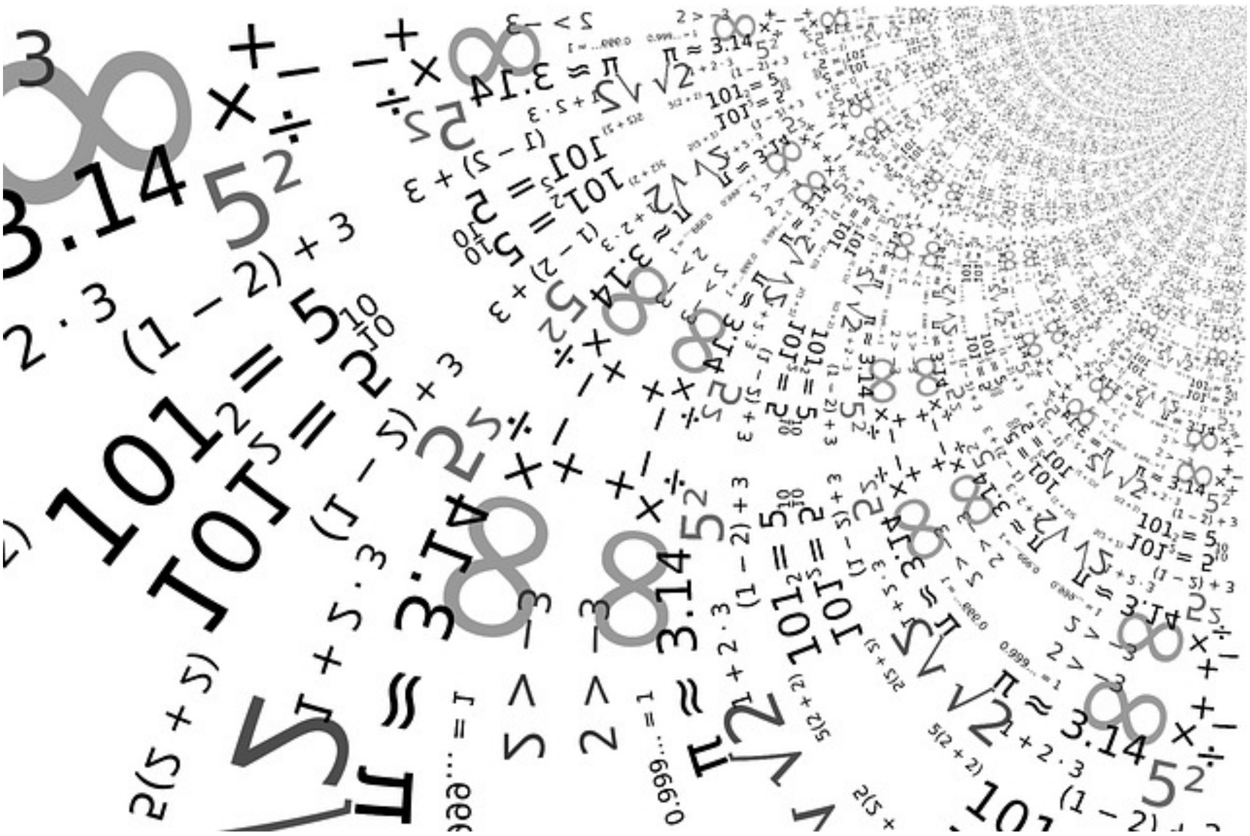

Instructions for software implementation for Life Cycle Sustainability Assessment
(Social footprint methodology 2021)

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Preface

This is an accompanying document for the data files for “Life Cycle SDG Assessment impact data for 2019 (Social footprint methodology 2021)”. The purpose of this document is to enable the application of these data in a software implementation for Life Cycle Sustainability Assessment. This report has been prepared by Bo P. Weidema of 2.-0 LCA consultants, Denmark, for the 2.-0 SDG and Social LCA Clubs and the UNEP Life Cycle Initiative as part of the project “Linking the UN Sustainable Development Goals to life cycle impact pathway frameworks”.

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Contents

1 Introduction

This document provides the necessary guidance for performing a quantitative life cycle sustainability impact assessment, applying an impact pathway framework that links pressures from human activities via cause-effect chains to their impact on sustainable wellbeing.

The unique contribution of the current method is the use of sustainable wellbeing (utility, measured in Quality-Adjusted person-Life-Years, QALY) as a comprehensive summary indicator for all social, ecosystem and economic impacts. This allows to quantify trade-offs and synergies between impact categories, to compare business decisions, performance, and improvement options across industry sectors. By applying the exhaustive 'capitals' approach to defining the Areas of Protection, the method ensures comprehensiveness in terms the set of impact categories covered (Weidema 2021b). To enable the method to be applied for Life Cycle Assessment (LCA), the applied indicators have been chosen to allow for aggregation and disaggregation at any level of geographical, organisational, and product detail.

The impact pathways descriptions have been structured in 17 chapters, largely mirroring the 17 UN Sustainable Development Goals (SDGs), however restructuring the indicators so as to avoid overlaps and gaps.

2 Accompanying data files

The file **'Life Cycle SDG Assessment_Links to SDG indicators.xlsx'** show the full links between the 17 impact pathway chapters of the method and each of the 244 SDG indicators.

The file **'Life Cycle SDG Assessment impact data for 2019 (Social footprint methodology 2021).xlsx'** includes data for a total of 76 impact categories defined at the level of Areas of Protection:

Areas of Protection	**Impact category numbers**
Natural assets	N1 to N9
Manufactured physical assets	M1 to M6
Intellectual assets	I1 and I2
Human capabilities	H1 to H35
Social networks	S1 to S24

These 76 impact categories provide an exhaustive coverage of all sustainability impacts, as defined and described in Weidema (2021b). The file includes a sheet **'Link to pressure indicators'** providing:

- Data sources for the related pressure indicators ('inventory indicators' in LCA parlance), colour-coded in four groups:
    - *Non-production-specific:* The largest group in terms of overall annual impact (3113 million QALY or 77.7% of all wellbeing impacts, varying from 87.2% of all impacts in Syria to 26.5% of all impacts in Bahrain). These impact categories are all related to missing governance at the country level, ultimately linked to economic pressure indicators, notably 'underpayment of labour and taxes' and (insufficient) 'voluntary transfers'. The insight that a large part of the overall impacts (here 77.7%) come from the same limited set of pressure indicators was used as basis for developing the 'social footprint' methodology (Weidema 2018).
    - *Greenhouse gases:* Covering the global warming impact on five Safeguard Subjects (marine, freshwater, and terrestrial biomass and biodiversity, property damage, and human health impacts), summing to overall annual impact of 28 million QALY or 0.7% of all wellbeing impacts, varying from 54.3% of all impacts in Bahrain to 0.19% of all impacts in Nigeria.

- *Data reasonably available:* This group, representing an annual impact of 490 million QALY or 12% of all impacts, cover impact categories with a very diverse set of pressure indicators, for which data availability is nevertheless reasonable. Many of these are already included in databases used for LCA, e.g., data on the mass of extracted subsoil resources, area of land occupied, incidences of injuries, and mass of emissions of harmful substances. Others are available from – or can be imputed from – public data sources, such as UNESCO for untreated wastewater, or the Walk Free Foundation for forced labour.
- *Depends on survey data:* Although clearly resulting from specific activities, responsible for an annual impact of 376 million QALY or 9% of all impacts, this group is the most difficult for which to obtain pressure indicator data. This is due to the very local nature of the impacts, such as specific detrimental working conditions, reductions in amenity value of real estate, or insufficient protection of cultural heritage. Data for such pressure indicators requires different kinds of locally representative surveys that are not regularly carried out and often not using standardised data collection instruments.

For most of the pressure indicators, more detailed description of the data sources is available in the data collection guideline (Weidema 2021a).

The sheet **'2019 QALYimpact_live formulas'** include the calculation of the above mentioned QALY data for each of the 76 impact categories for 163 countries, using a large number of different data sources. The derivation of overall global data per impact category (in the column 'World, total') is described in Weidema (2021b). The data sources for the distribution over the 163 countries (and the residual Rest-of-World that represent 0.8% of the global population, 0.6% of the global GDP, and 0.9% of the overall impacts) are described in column D, while the live formulas in rows 6 to 94 allows the user to see exactly how the data are derived from the original data sources that are reproduced in rows 97 to 184. However, when manipulating the data, e.g., for sorting, copying, or filtering, the live formulas may be corrupted, so for such purposes, it will be safer to use the data in the sheet **'2019 QALYimpact_numbers only'** that do not contain formulas. The references and more detailed documentation for the original data sources are reported in the sheet **'documentation for impact sheet'**.

The file **'Social footprint update 2022_QALY 2019 by skill level and industry using Exiobase 2011 as economy_20220127x.xlsx'** provides an example of the implementation of the procedures described below in Sections 3.2 and 3.3.

3 Procedures for implementation in Life Cycle Assessment (LCA) software

3.1 General introduction to LCA calculus

With reference to Heijungs and Suh (2002), the mathematical calculation of life cycle impacts is performed by matrix inversion of the economic activity matrix **A** of dimension n*n, which by multiplication with the final demand vector (or any other exogenous driving vector) **f** of dimension n*1, produces the vector of scaling factors (**s**), which are then applied to the matrix of elementary flows **B** of dimension b*n, thus providing the vector of life cycle totals of each of the b elementary flows per unit of output of each activity (**m**):

$$\mathbf{s} = \mathbf{A}^{-1}\mathbf{f}$$

$$\mathbf{m} = \mathbf{Bs} = \mathbf{BA}^{-1}\mathbf{f}$$

These life cycle inventory totals represented by the elements of **m** may then further be multiplied by characterisation factors and/or weighting factors to rescale them to comparable and therefore additive units and sizes.

Note that each row vector in **B** must have the dimension 1*n, i.e., the same dimension as the row vectors in **A.**

3.2 Prerequisites

The first prerequisite for an LCSA calculation is thus to have an appropriate economic activity matrix **A**. In the context of LCSA, where supply chains are global and there is a large diversity in indicator values between countries, an **A** matrix with a high level of country disaggregation is essential. Also, since a large part of the impacts are related to payments of wages and taxes, and these vary significantly between industries both between and within countries, it is preferable to have an **A** matrix with a high level of industry disaggregation and availability of matching data for payments of wages and taxes in the **B** matrix, preferably disaggregated in income classes of the recipients. These requirements limit the choice of data to global IO matrices with high country detail, such as Eora and EXIOBASE.

It is unlikely to find a global IO matrix that have exactly the 163 countries for which we have impact data in the **'2019 QALYimpact'** sheets. For example, EXIOBASE has only 43 countries and 5 RoW regions, as shown in row 4 of the **'2019 QALYimpact'** sheets. This row can be used for aggregating the detailed data for the 163 countries to the 48 countries and regions of EXIOBASE.

The global IO matrix may not be available for the year of the impact assessment data (in this case 2019). For example, year 2011 is currently the most recent year for which the hybrid version of EXIOBASE is available. Extrapolating (forecasting) the IO matrices from the available year to the year of the assessment data is a possible option. However, this is neither straightforward nor simple. The simpler option is to use the impact factors (impact per person) from 2019 and apply that directly to the available IO matrix, while considering the differences in the denominator (population) between the years. The simpler option requires accepting the assumption that the structure of the global and national economies has not changed significantly between the years.

The data in the **'2019 QALYimpact_live formulas'** sheet is provided in million QALY for the 2019 population. Applying the absolute QALY numbers directly to the 2011 version of EXIOBASE would give too high an impact per person. Instead, we apply the 2019 impact factors (QALY/person, given in the **'2019 QALYimpact_per person'** sheets) to the country populations of 2011, thus obtaining an assessment of 2019 impacts, accepting the assumption that the structure of the economy in 2011 is an acceptable proxy for the economy in 2019.

3.3 Implementing the non-production specific impact pathway in EXIOBASE

In the sheet **'2019 QALY impact_numbers only'**, the cells in row 87 (named 'Non-production-specific impacts, absolute numbers') represent the sum of non-production specific impacts for each country. According to the social footprint method (Weidema 2018), a co-responsibility for these impacts exists for local enterprises because they benefit from the current low internal costs of labour. These impacts should thus be distributed over the industries in proportion to their responsibility. A simple distribution relative to the value added of the industries, so mimicking a value added tax, would punish industries that actually do pay a fair wage. The social footprint method therefore makes the distribution in a somewhat more complex way, including the differences in wage levels between and within industries, with the intention to give more weight to those industries that have low-paid employees.

In EXIOBASE, the data on wages ('Compensation of employees incl. social contributions') is provided for each of 164 industries in three skill levels. The number of work hours for each of these skill levels is also provided, so that the wage/work-hour can be calculated. The compensation data for the three skills only make up part of value added, the rest being 'Vulnerable labour' 'Taxes less subsidies on products purchased', 'Other net taxes on production', and 'Operating surplus'. In absence of detailed data on tax re-distribution, the two rows on (net) taxes are ignored, and the (questionable) assumption is then made that 'Vulnerable labour' (including self-employed and workers' collectives) and 'Operating surplus' also will end up with the same three skill-level based population groups, proportionally to the wages (essentially equal to an assumption that vulnerable labour has the same skill distribution as 'non-vulnerable' (!) and that all industries are owned by the workers (!)), for which reason 'Vulnerable labour' and 'Operating surplus' is also distributed over the skill groups proportionally to the wages. With this assumption, we now have the direct income (i.e., value added minus net taxes on products and production) per country divided over industries and divided over three skill groups for each country. For each country, each cell in this direct income matrix of 164 industries * 3 skills groups is named $DI_{i,g}$ and each cell is then weighted with an equity-weight EW (where WH is Work Hours and subscript c is country):

$$DI_{i,g}*EW_{i,g} = DI_{i,g}*((DI_c/WH_c)/(DI_{i,g}/WH_{i,g}))^{\wedge}1.24$$

Finally, $DI_{i,g}*EW_{i,g}$ is used as distribution key for the country QALYs (from row 87 in sheet **'2019 QALY impact_numbers only'** or rather, when applying the 2011 version of EXIOBASE, from row 87 in the **'2019 QALYimpact_per person'** multiplied by the 2011 populations of each country), to the cells in the matrix, and thus to each industry. The resulting vector is a vector of 'Non-production-specific impacts' that can be added to the **B** matrix, and which does not need any further characterisation of weighting because it is already expressed in QALY. The justification for the specific equity-weighting is provided in Weidema (2018). However, in Weidema (2018) the World average wage level is used for the equity-weighting, while here, the country average wage level is used, as justified in Weidema (2022).

The quality adjustment of the person-life years in the unit QALY are done with reference to the subjective wellbeing (Cantril-ladder) scores from Helliwell et al. (2020) which originally has a score from 0 to 10, which here are divided by 10 to obtain scores relative to 1 as a representation of 1 person-year lived at maximum subjective wellbeing. It is important to note that the parallel concept of a DALY (Disability-Adjusted Life-Years), used in health economics to express health impacts on a scale from 0 to 1 per person-year) does not convert directly 1:1 to a loss of 1 QALY. Rather, 1 DALY is valued at 0.3 QALY, a conversion factor that has been derived by constraining the global amount of QALY per year that can be derived from health impacts to 15% of the total impacts on subjective wellbeing (Weidema 2021b), based on the findings of Helliwell et al. (2020), although the relative importance of health impacts varies from 4% of all impacts in Bahrain to 47.7% in Chad (see row 92 in the **'2019 QALY impact'** sheets).

An example of the above implementation of the **'2019 QALYimpact_per person'** for use with EXIOBASE 3.18 is provided in the file '**Social footprint update 2022_QALY 2019 by skill level and industry using Exiobase 2011 as economy_20220127x**'.

3.4 Implementing the QALY impacts of global warming in EXIOBASE

In EXIOBASE, data are provided for the emissions of individual greenhouse gasses. Since the impact of the emissions go via a global temperature change, the impact of the same amount of each substance will have the same global impact, irrespectively of where it is emitted. Thus, the global-warming-characterized emissions (expressed, e.g, in mass units of CO_2-equivalents) from the EXIOBASE inventory can be expressed in QALY by multiplying by the ratio of the global QALY value in cell G90 sheet **'2019 QALY impact_numbers only'** (or rather, when applying the 2011 version of EXIOBASE, from cell G90 in the **'2019 QALYimpact_per person'** multiplied by the 2011 global population) divided by the global sum of global-warming-characterized emissions from EXIOBASE. If applying a global warming metric that allows to distinguish between impacts on marine, freshwater, and terrestrial ecosystems, property damage, and human health impacts, then the global QALY value from cell G90 should be replaced by the impact-specific QALY values in cells G7, G9, G13, G17, and G82, respectively.

3.5 Implementing other impact categories with available pressure indicator data

As indicated in the sheet **'Links to pressure indicators'** of the file **'Life Cycle SDG Assessment impact data for 2019 (Social footprint methodology 2021).xlsx'** there are 23 of the 76 impact categories that have been classified as having pressure indicator 'Data reasonably available'. In some cases, data from the suggested sources have already been added to EXIOBASE, e.g., the data for sub-soil resource use, although maybe not at the most desirable level of detail. In other cases, data from the suggested sources would have to be added to the **B** matrix of EXIOBASE (or any other relevant IO database).

A few of these 23 impact categories can be handled in the same ways as for global warming, namely those for which the impacts are independent of where the pressures occur, so that the same characterisation factors are globally applicable, even though the impacts as such do not have to be geographically uniform. This is the case for 'Sub-soil resource use' and those impact categories where the pressure is measured in indiscriminate, unitless 'incidences', for which the characterisation model is limited to a linear relation to the number of DALYs, and thus QALYs, per incidence.

For the remaining of the 23 impact categories characterisation factors are geographically differentiated, i.e., they depend on where the pressures occur, although the impacts themselves may or may not be limited to the geographical area where the pressures occur. For these impact categories, the translation from pressure indicators to QALY requires the implementation of specific characterisation models, some of which may already be partly available in existing collections of life cycle impact assessment methods, while others may need to be developed based on the indications provided in Weidema (2021b) and the file **'Life Cycle SDG Assessment_Links to SDG indicators.xlsx'**.

Finally, in the sheet **'Links to pressure indicators'** of the file **'Life Cycle SDG Assessment impact data for 2019 (Social footprint methodology 2021).xlsx'** there are 17 of the 76 impact categories for which the pressure indicators have been classified as 'Depends on survey data'. These are local impacts that depend on individual local activities for which data are not likely to be available at the most desirable (enterprise- or industry-specific) level. Even statistical data may only be available for selected countries or industries, from which extrapolations will only provide a poor representation of the wide variety of local practices and conditions. The poor data availability should not be seen as justifying an exclusion of these impact categories from further assessment, but rather as an incentive for specific data collection efforts in those countries and industries that from the available, poorly disaggregated data can be identified as hotspots.

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