DELIVERABLE C.1.3.2

Methodology guide for environmental, social and economic impact mitigation

Delivery Date: June 2022

Partner in charge: Fundació Universitària Balmes

Content

Definitions and Abbreviations

BAT	Best Available Techniques
EC	Electrocoagulation
ED	Electrodialysis
EPA	Environmental Protection Agency
EQS	environmental quality standard
EU-28	Member States of the European Union
FL	Flocculation
LCA	Life Cycle Assessment
LCC	Life Cycle costing
LCSA	Life Cycle Sustainability Assessment
PSIA	Product Social Impact Assessment
PSILCA	Product Social Impact Life Cycle Assessment
RO	Reverse Osmosis
SETAC	Society of Environmental Toxicology and Chemistry
SHDB	Social Hot-spot Databases
S-LCA	Social - Life Cycle Assessment
UNEP	United Nations Environmental Program
WFD	Water Framework Directive

1. Methodology guide for Environmental impact mitigation

Life Cycle Assessment LCA is a methodological framework developed to estimate and evaluate the impacts attributable to a product, service, or process on the environment, from its initial phase (extraction of raw materials) to the end of the process (final disposal of the resulting waste). Environmental impacts such as climate change, ozone depletion, eutrophication, acidification, toxicological stress on human health and ecosystems, loss of natural resources, and water use, among many others, are evaluated through this tool.

LCAs are currently used as a tool for decision-making at the organizational, regional, governmental, political, administrative, etc. levels, to provide decision-makers with the necessary elements to approach response strategies based on an informed knowledge of such effects. In general, an LCA is a comparative analysis of the potential environmental impacts of alternative processes and products, i.e., assessing the outcome in terms of potential impacts on so-called impact categories (attribute or aspect of the natural environment, human health, or natural resources, identifying an environmental issue of concern), when using alternative materials or designs.

Within LCAs, both materials and energy input and output flows are measured in each system under analysis, to determine the environmental effects of these inputs and outputs, referred to as elemental flows or environmental interventions (amount of energy or matter entering the system under analysis, which has been extracted from the environment or is released into the environment as an emission without further human transformation), on category indicators (quantitative representation of an impact category).

In general, an LCA is composed of a defined structure. In the first stage, the Life Cycle Inventory (LCI) is elaborated, which corresponds to the identification and compilation of changes, environmental interventions, or elementary flows (emissions and resource consumption) in a product system under analysis. It is then necessary to calculate and interpret the indicators of the potential impacts associated with the identified changes, which corresponds to the life cycle impact assessment (LCIA) phase. The final stage that may correspond to the interpretation of the results; however, being iterative, this phase is present in all the other stages of the analysis. Figure below shows the general outline of the application of an LCA with its general structure.

Figure 1. Methodological framework of an LCA, based on ISO 14040

A life cycle analysis typically has three main stages: i) identification of the objectives and scope of the LCA, ii) elementary flow analysis (resource withdrawals and/or resulting emissions), and iii) life cycle impact assessment.

Elemental flow inventory analysis

This stage of the LCA refers to the collection of physical flows in terms of inputs of those resources, materials, and products (e.g., water captured, use of wood, construction materials, use of electrical energy, etc.), as well as outputs of emissions, waste, and products (e.g., discharges, CO2 emissions, solid waste, by-products), which represent the operation of the system analyzed in each of its processes in the supply chain. In general, this information comes from generic databases with information on a global scale.

The result of the inventory analysis of the elementary flows is the so-called Life Cycle Inventory, where the elementary flows of the system under analysis are listed quantitatively by a unit of analysis called the functional unit. The functional unit refers to the quantitative description of the function or service for which the assessment is performed and is the basis of the reference flow of the product.

Life Cycle Impact Assessment

This stage of the LCA corresponds to the interpretation of the inventory of flows in the form of impacts on the environment and is made up of five elements, as shown in the figure below.

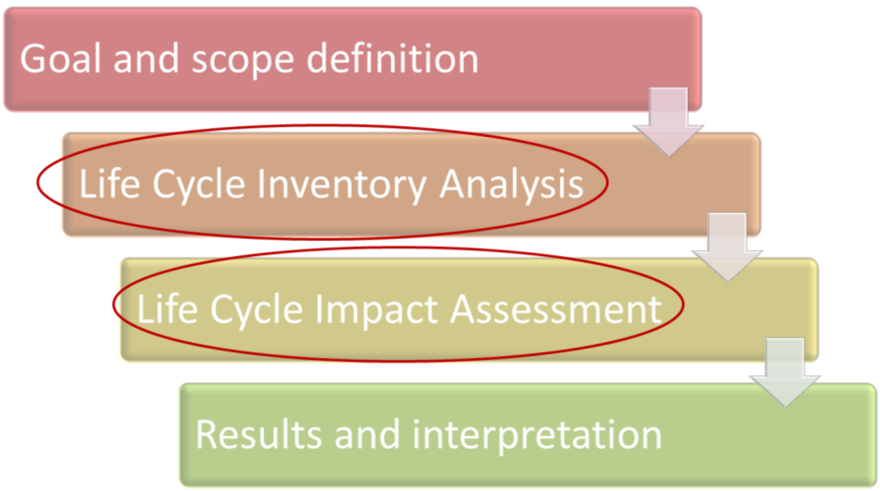

Figure 2. Elements of the Life Cycle Impact Assessment, based on ISO 14040

To fully understand the importance of the Impact Assessment phase, it is first necessary to define what an environmental impact is in the LCA framework. An environmental impact is understood as the set of negative environmental changes due to anthropogenic action. In this sense, the objective of this stage is to determine the magnitude of the contribution of each emission or resource extraction (environmental intervention or elementary flow) to the impact on the environment. The description of each element is presented below:

1. **Selection of impact categories:** this element refers to the designation of the impact category, defined as the class representing the environmental issues of interest for the analysis. Within the standardized LCA framework there are three significant groups of impact categories or areas of protection (AoP-Areas of protection) that should be considered for scoping: i) Human health, ii) Ecosystem quality, and iii) Natural resources. For each impact category, an indicator is chosen to quantify the environmental impact of the elementary flows (environmental intervention).

2. **Classification of the elementary flows of the inventory:** This element corresponds to the assignment of the elementary flows of the LCA inventory to each impact category to which they contribute; for example, water consumption as an elementary flow will correspond to the water use impact, while a CO2 emission will correspond to a climate change impact.
3. **Characterization through environmental models**: this element seeks to quantify the ability of each elemental flow to impact the category indicator, i.e., each elemental flow of the inventory is evaluated according to the degree of contribution to the classified impact.
4. **Standardization of results:** this element corresponds to the way of reporting the results obtained on the relative magnitude of each score characterized in the different impact categories.
5. **Grouping or weighting of results:** this corresponds to the grouping and weighting of the impact categories according to the perceived severity or their weighting using factors.

Within the Impact Assessment phase and based on the development of these five elements, it is possible to define two impact groups, impacts by emission or by extraction. The general characteristics of these groups are presented below.

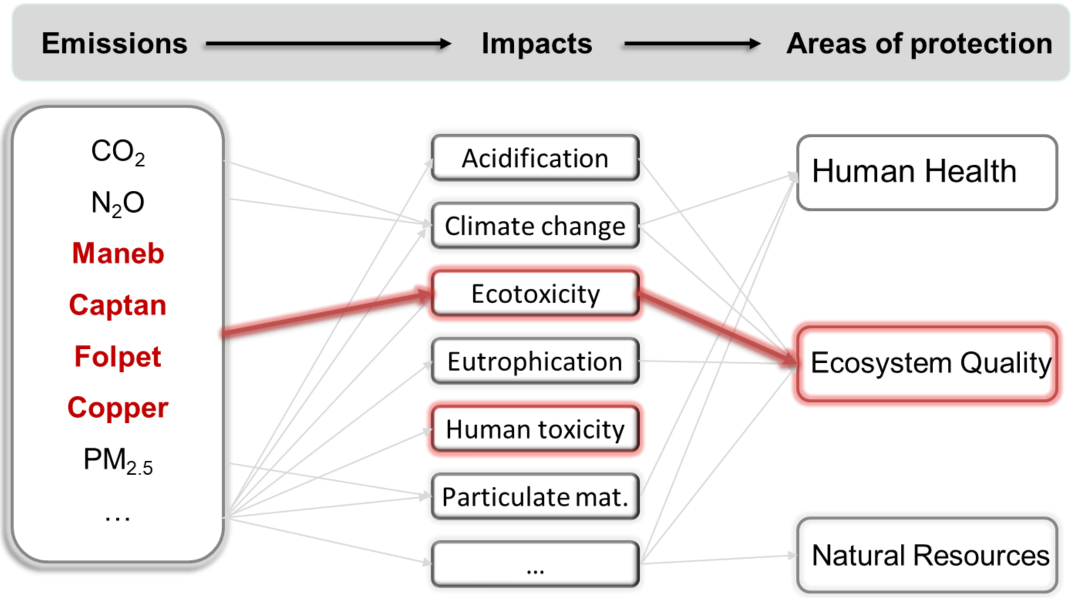

Figure 3. Environmental impacts due to emissions and extraction

The LCA methodology is based on the determination of midpoint and endpoint impact category (or environmental damage) indicators. The midpoint category is defined in ISO 14044 as the intermediate variable that quantifies the risk associated with extractions (inputs) and emissions (outputs) related in turn to an endpoint impact category, such as water scarcity, water availability, and eutrophication; while the endpoint category is defined as the attribute or aspect of the environment, human health or resources that identify an environmental problem of concern.

In this sense, the impact assessment framework of a life cycle assessment allows analyzing the ultimate effect of the environmental impact (endpoint) or considering intermediate effects (midpoints). The latter provides detailed information on how and at what point the measured impact affects the environment, while the endpoint categories are variables that directly affect society, so they are more frequently used in global-scale studies. The figure below schematizes the relationships between environmental interventions, impacts of midpoint and endpoint effects, and protected areas.

2. Methodology guide for social impact mitigation

In social impact assessment, products are assessed for their potential positive and negative impacts along their life cycle regarding their social and socio-economic aspects. The social and socio-economic Life Cycle Assessment (S-LCA) covers the extraction and processing of raw materials, manufacturing, distribution, use, reuse, maintenance, recycling, and final disposal. Through the assessment of social and socio-economic factors, S-LCA also complements E-LCA. As a stand-alone method or in combination with E-LCA, it can be applied.

A social impact can be defined as either a positive or a negative consequence of social relations (interactions) that are woven into a particular activity (production, consumption, or disposal) or by preventive or reinforcing actions taken by stakeholders (e.g., enforcing safety measures in a facility). Typically these positive or negative consequences affect social endpoints (i.e., the well-being of stakeholders).

Providing information on social and socio-economic aspects for decision-making, S-LCA instigates dialogue on factors of production and consumption, with the prospect of improving the performance of organizations and, ultimately, the well-being of stakeholders.

Assessment Framework

Subcategories are the basis of a S-LCA assessment because they are the items on which justification of inclusion or exclusion needs to be provided. The subcategories are socially significant themes or attributes and are classified according to stakeholder and impact categories. On the other hand, inventory indicators are used to assess subcategories, whereas the unit of measurement (or variable) is used to measure them. Several inventory indicators and units of measurement/reporting types may be used to assess each of the subcategories. Inventory indicators and units of measurement may vary depending on the context of the study.

Social/socio-economic subcategories may be first classified by stakeholder categories, which might assist with the operationalization. It can also ensure the comprehensiveness of the framework.

The purpose of the classification into impact categories is to support the identification of stakeholders, to classify subcategory indicators within groups that have the same impacts, and to support further impact assessment and interpretation.

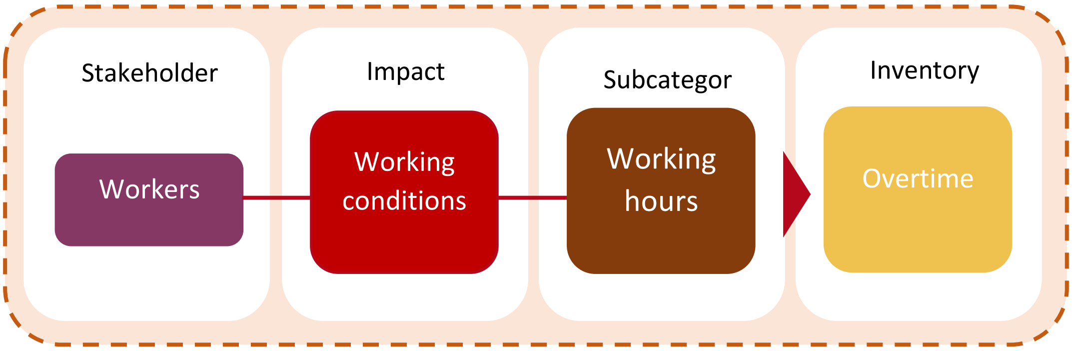

Figure 5. Key components of the methodology

Each of the life cycle stages (and their unit processes) can be associated with geographic locations, where one or more of these processes are carried out (mines, factories, roads, rails, harbours, shops, offices, recycling-firms, disposal-sites).

At each of these geographic locations, social and socio-economic impacts may be observed in five main stakeholder categories:

- Workers/employees
- Local community
- Society (national and global)
- Consumers (covering end-consumers as well as the consumers who are part of each step of the supply chain)
- Value chain actors

A stakeholder category is a cluster of stakeholders that are expected to have shared interests due to their similar relationship to the investigated product systems. The stakeholder categories provide a comprehensive basis for the articulation of the subcategories. The proposed stakeholder categories are deemed to be the main group categories potentially impacted by the life cycle of a product. Additional categories of stakeholders (e.g., NGOs, public authorities/state, future generations) or further differentiations or subgroups (e.g. management, shareholders, suppliers, business partners) can be added.

Table 1. Life Cycle stages

<table>
<tr><td></td><td colspan="5">Life-cycle stages</td></tr>
<tr><td rowspan="4">Stakeholders addressed</td><td colspan="2">Supply chain
Raw material extraction, manufacturing, retail</td><td>Use</td><td colspan="2">End of life</td></tr>
<tr><td>Value chain actors</td><td>Workers</td><td>Consumer</td><td>Value chain actors</td><td>Workers</td></tr>
<tr><td colspan="5">Local communities</td></tr>
<tr><td colspan="5">Society</td></tr>
</table>

When conducting the goal and scope phase of a study, one may refer to a stakeholder classification and, according to this, classify the subcategories. The purpose of the classification of subcategories according to stakeholder groups is to make sure that the S-LCA matches the goal and scope and assesses the bulk of the situation. It is clear that stakeholders can vary not only from one study to the other but also within each step of the supply chain. Subcategories represent the basis for a S-LCA. However, efforts will have to be made, while conducting a S-LCA, to find and (re-)define the appropriate indicators (to assess the subcategories) adapted to the particular context and understanding. It is within this context that a comprehensive set of subcategories is presented below.

Figure 6. Subcategories for each stakeholder category

The next points of this document set out the stages of the S-LCA. The four stages are:

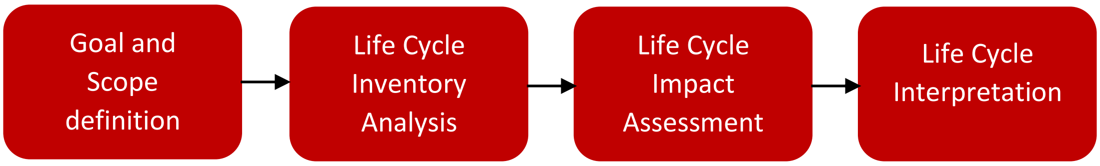

Figure 7. S-LCA steps

Definition of Goal and Scope

The first step of the S-LCA aims to describe the study. Why is a S-LCA being conducted? What is the intended use? Who will use the results? What do we want to assess? The definition of the goal has to be clearly specified to ensure the study will fulfil the intended application.

The scope is also defined in the first phase of the study. It encompasses issues of depth and breadth of the study. It defines the limits placed on the product's life cycle and on the detail of information to be collected and analyzed. It defines where the data will be coming from, how up-to-date the study will be, how the information will be handled, and where the results will be applicable.

It is necessary to specify the function and the functional unit in a S-LCA. Specifying the functional unit and the reference flows is essential to build and modeling the product system. Modeling the product system is essential to identifying locations and specific stakeholders involved.

Life Cycle Inventory Analysis

The inventory is the phase of a S-LCA where data are collected, the systems are modeled, and the LCI results are obtained. With a definition of the goal and scope of the study, an initial plan for conducting the inventory phase of the S-LCA is available. Adhering to the following operational steps when performing the life cycle inventory is suggested:

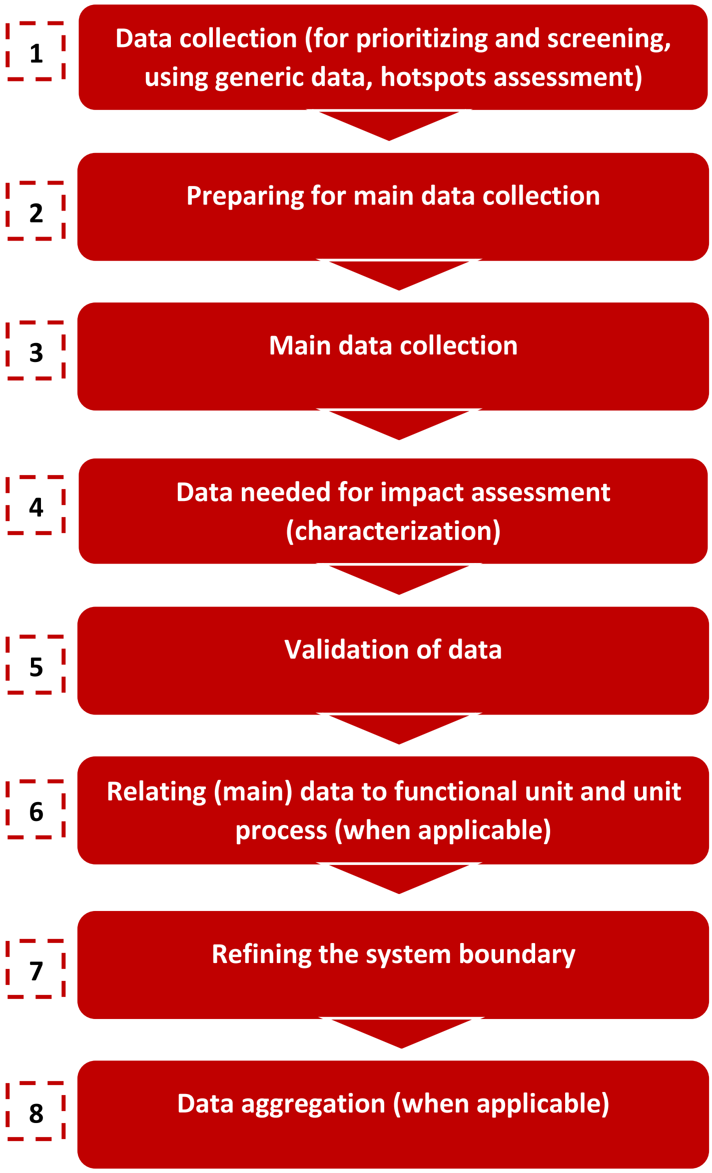

Figure 8. Overview of the Life Cycle Inventory Analysis

Life Cycle Impact Assessment

Impact Assessment (sLCIA) is the third phase of a S-LCA. The purpose of sLCIA is to provide a combination of:

(a) aggregating some inventory data within subcategories and categories; and

(b) making use of additional information, such as internationally accepted levels of minimum performance, to help understand the magnitude and significance of the data collected in the Inventory phase.

Therefore, sLCIA may provide assessment of social and socio-economic impacts that can range from specific to very general, from final to preliminary, depending on which level of precision is reached in the summarization and the interpretation, which in turn is influenced by data availability. It includes steps of primary aggregation and meaning assessment, in addition to possibly estimating social impacts.

The sLCIA phase consists of the three mandatory steps identified in ISO 14044 (2006) for LCIA, which allow for tracing the Inventory data through the relevant social and socio-economic mechanisms to define a social and socio-economic Impact. Those three steps are as follows:

- Selection of impact categories and characterization methods and models
- Linkage of inventory data to particular sLCIA subcategories and impact categories (classification)
- Determination and/or Calculation of subcategory indicator results (characterization).
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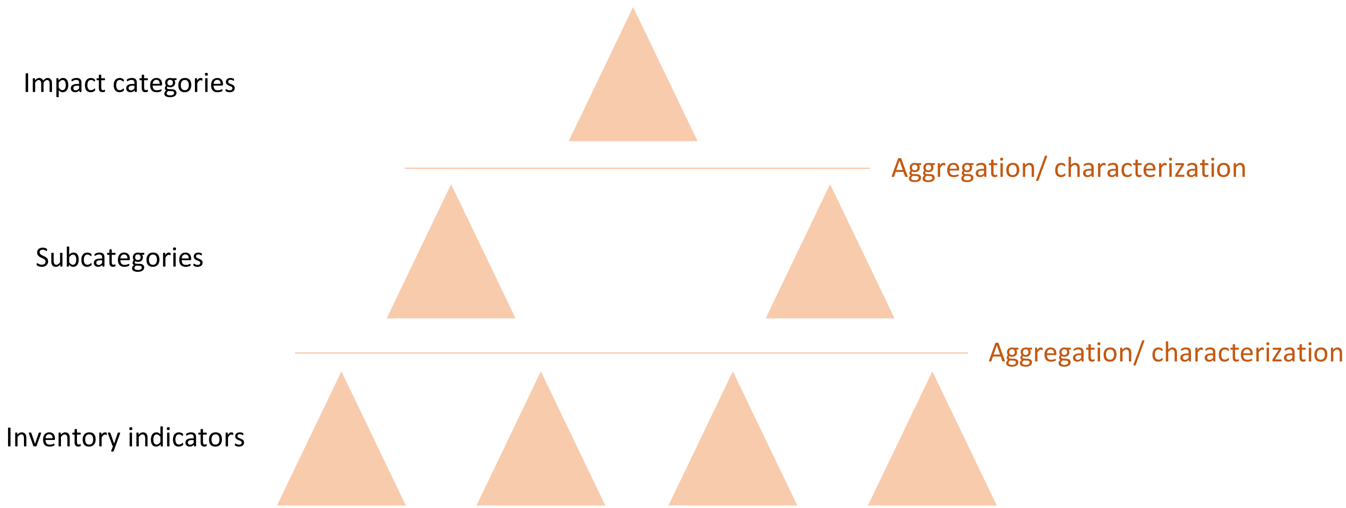

Figure 9. Concept of inventory indicators, subcategories and impact categories

Impact Categories are logical groupings of S-LCA results, related to social issues of interest to stakeholders and decision makers. For the time being, stakeholder categories and subcategories are the basis on which to build. Impact categories aggregate the results for the subcategories within a theme of interest to a stakeholder, e.g., Human Rights. Impact Categories used in S-LCA will correspond to the goal and scope of the study and represent social issues of interest that will be expressed regarding the stakeholders affected and may cover health and safety, human rights, working conditions, socio-economic repercussions, cultural heritage, and governance. The subcategory indicator results are aggregated into impact category results. All the aggregation formula (characterization) must be transparent. The information can be aggregated on one resulting end-category that may be Human Well-being or Fairness of relationships.

Subcategories (e.g. Fair Salary, Hours of work, etc.) aim to represent impacts within an Impact Category (Working Conditions of the stakeholder workers, for instance). Subcategories are used because of the tendency to split categories because they are too heterogeneous and do not allow for scientifically valid aggregation. Several subcategories may be used to cover an Impact category. Subcategories of an Impact Category seek to describe the overall meaning of the indicators used to represent this subcategory. This is done through a set of indicators used to represent this Category (e.g., Impact category: Working conditions, Subcategory: Social security and benefits, inventory indicators: percentage of employees covered by 1) health insurance, 2) retirement insurance, 3) paid maternity and paternity leaves, 4) legal contracts, etc.). Hence, there may be two weighting/aggregation steps. One that allows passing from inventory indicator results (inventory results) to a subcategory result and one that allows passing from subcategories results to an impact category result.

Social and socio-economic mechanisms can take different forms, and so can the indicators. Because some social and socio-economic impacts might be best captured through qualitative indicators, one can choose between quantitative, semi-quantitative, and qualitative indicators depending on the study's goal and the nature of the issue at stake. A quantitative indicator describes the issue assessed using numbers, for example, the number of accidents by the unit process. Qualitative indicators describe an issue using words. They are nominative, for instance, text describing the measures taken by an enterprise to manage stress. Semi-quantitative indicators are categorizations of qualitative indicators into a yes/no form or a scale (scoring system), for example, the presence of a stress management program (yes-no).

Life Cycle Interpretation

1. **Identification of the significant issues.** Significant issues are the important social findings and the critical methodological choices. They include the identification of key concerns, limitations, and assumptions made during the study and resulting from the study. The purpose here is to account for any assumptions made and for the consequences of decisions taken throughout the study.
2. **Evaluation.** The evaluation can use a range of qualitative, semi-quantitative, and fully quantitative approaches. Some essential requirements regarding the evaluation process include the performance of a critical review, the documentation of the evaluation process, the actions taken to ensure transparency, and the verifiability of results.

3. **Conclusions, recommendations and reporting**. Conclusions have to be drawn and a recommendation made, based on the goal and scope of the study. The reporting should be fully transparent, implying that all assumptions, rationales, and choices are identified. Recommendations are a means to formulate options for action.

Table2. Principle, criteria, and indicators for Social
Adapted From Worrall et al. 2009

Social

Principle	Criteria	Indicators
Socio-political	Land use planning	
		Federal government plans
		State government plans
		Local government plans
		Private planning initiatives
		Adjacent land use plans
		Planning conflicts
	Legislation	International
		Federal government
		State government
		Local government
		Legislative conflicts
	Ownership	Historic
		Current
		Current owners intentions
	Responsibility	Government level
		Private ownership
		Third party monitoring
		Voluntary agreements
	Cultural issues	Stakeholder engagement
		Public participation
		Indigenous concerns
	Health and safety	Community safety
		Complaints received
		Health issues related to area

Table3. Principle, criteria, and indicators for Economic and environmental criteria

Adapted From Worrall et al. 2009

Economic

Principle	Criteria	Indicators
Economic	Equitable wealth sharing	Local communities
		Public sector
		Employees
	Productive land use	Area
		Proportion
		Current uses
		Future plans
		Economic benefit
	Local economic contribution	Regional investment value
		Direct job creation
		Indirect job creation
		Contribution to GDP of local area
	Cost of rehabilitation	Total dollar cost
		Cost of potential offsets
		Funding sources
		Agency responsibility

Environmental with clear social link

Principle	Criteria	Indicators
	Rehabilitation	Number of sites
		Number of sites rehabilitated to 'sign off
		Number of sites closed
		Number of abandoned, derelict/orphaned sites
		Number of sites used Success Policy summary
	Land condition	Hazardous solid waste on site
		Hazardous liquid waste on site
		Tailings on site
		Coarse rejects on site
		Spontaneous combustion
	Off-site impacts	Visual
		Noise
		Dust
		Sediment yield
		Water quality
		Water discharge
		Weed invasion

3. Methodology guide for Economic impact mitigation

A techno-economic evaluation typically aims to answer a number of interrelated questions about an industrial process. Those questions address topics such as i) What is the overall economic performance of the whole project? or ii) What contributions do single cost items have on the overall costs? Or iii) What are the total costs of the main process steps?

To answer this, the process may be evaluated by modelling the capital expenditures (CAPEX) and the operational expenditures (OPEX). The process for LCC evaluation is showed in figure 10.

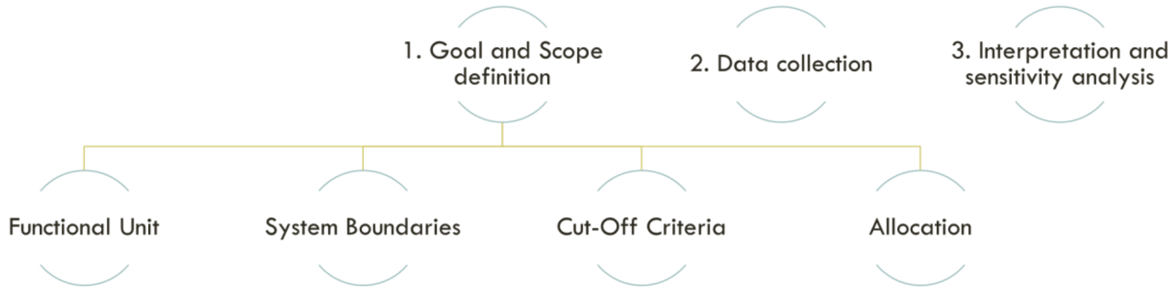

Figure 10. Outline of the CAPEX model

4.1 Outline of the CAPEX model

The total investment needed for a project, also called Capital expenditures (CAPEX), can be roughly divided into the sum of the fixed capital investment (FCI) and working capital investment (WCI). According to the BIOCORE model (2013), the FCI is the total cost of the plant ready for start-up. It is a once-only cost that is not recovered at the end of the project life, includes the complete construction cost of the plant with all its processing and handling equipment as well as its ground preparation and non-process structure and equipment. The FCI should also include the investment for purchasing land to build the plant. However, this investment is left out of the analysis of DEMINE, given the nature and structure of the METP technology.

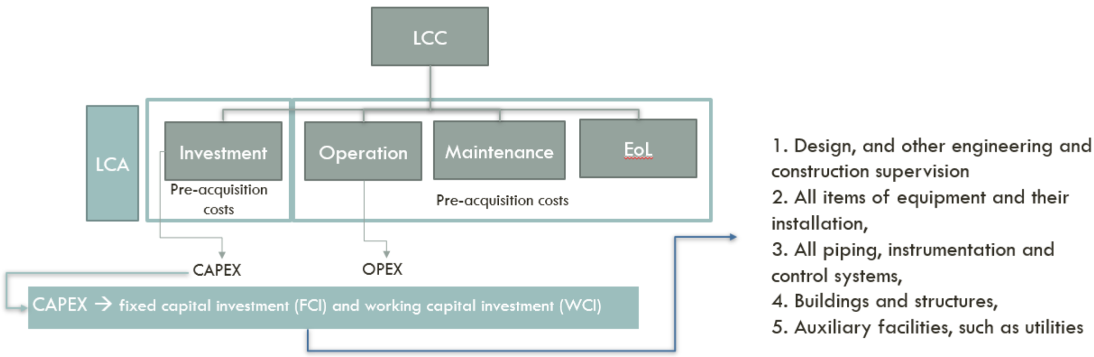

Figure 11. Outline of the CAPEX model

The WCI, on the other hand, includes the initial cost of resources, as well as money required for labour and services required to start the operation of the plant. WCI is the additional investment needed, over and above the fixed capital, to start up the plant and operate it. The WCI includes:

1. Start-up.
2. Initial catalyst charges.
3. Raw materials and intermediates in the process.
4. Finished product inventories.
5. Funds to cover outstanding accounts from customers

4.2 Outline of the OPEX model

According to Turton et al. 2012, the annual operating expenditures (OPEX) can be grouped into direct or variable manufacturing costs (DMC), fixed manufacturing costs (FMC) and general expenses (GE). This cost items can be grouped, as follows:

DMC	FMC	GE
Raw materials	Depreciation	Administration costs
Utilities	Local taxes and insurance	Distribution and selling costs
Operating labour	Plant overhead costs	Research and development
Direct supervisory & clerical labour		
Maintenance and repairs		
Operating supplies		
Laboratory charges		
Patents and royalities		

The OPEX can be also determined when the following costs are known or can be estimated: i) Fixed capital investment (FCI), ii) Cost of operating labor (COL); iii) Cost of utilities (CUT) and iv) Cost of raw materials (CRM). This result follows from the assumption, as described in Turton et al. 2012, that all other cost items are fixed factors of the above four cost components. And this cost components can be directly calculated from the DEMINE process data. The model therefore provides a robust and transparent means of estimating both CAPEX and OPEX from data availability.