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"Simplified and User-Friendly S-LCA: A Methodological Framework for Assessing Social Impacts of PEDs "

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Abstract

As global efforts to achieve sustainable urban transformation intensify, Social Life Cycle Assessment (S-LCA) emerges as a vital tool for evaluating the social impacts and risks of products, services, and systems, particularly in complex initiatives such as energy transitions. However, existing S-LCA methodologies, including the widely recognized *UNEP (2020)* guidelines and *ISO 14075:2024* standard, often remain inaccessible to early-stage practitioners, students, and small organizations due to their methodological complexity, resource demands, and steep learning curve. Addressing these limitations, this thesis proposes and partially validates a simplified and user-friendly S-LCA implementation methodology designed for broader usability without compromising analytical value.

The methodology was developed through a rigorous comparative analysis of the *UNEP* and *ISO* guidelines, structured across the four standardized phases of S-LCA: Goal and Scope Definition, Inventory Analysis, Impact Assessment, and Interpretation. Each phase was broken down into clear implementation steps, with each step further defined by specific, actionable tasks. These were presented in an intuitive format supported by guidance columns, "What to Do" and "How to Do It / Practical Guide", to improve clarity, reduce implementation barriers, and support both academic and applied settings.

The methodology was validated through a real-world case study: the ProLight Positive Energy District project in Milan. Phase 1 of the methodology was applied using project documents, stakeholder mappings, and digital engagement platforms. The validation confirmed the method's adaptability and usefulness in evaluating key social topics such as digital participation, inclusivity, equity in service access, and community empowerment. Despite common data constraints, the simplified approach provided a structured path to meaningful insight, confirming its operational feasibility.

This thesis contributes to the evolution of S-LCA by offering a methodology that supports not only structured assessments but also broader participation from actors traditionally excluded due to resource or knowledge limitations. It is particularly relevant in the context of growing EU-funded energy transition initiatives, where social performance is a critical yet underdeveloped area. The proposed framework also sets a precedent for future simplification of other life cycle sustainability assessments, including E-LCA and LCC. Ultimately, this work supports the democratization of social sustainability tools and provides a foundation for more inclusive, transparent, and practical assessment practices.

Keywords:

Social Life Cycle Assessment (S-LCA), Positive Energy Districts (PEDs), LCA simplification, LCA challenges, Energy transition, ISO 14075; UNEP 2020 Guidelines.

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CHAPTER 1- INTRODUCTION

This chapter has four key parts: 1. Background and Problem Statement, 2. The ProLight Project (case study), 3. Research Question, 4. Research Objectives, and 5. Thesis Structure.

It introduces the research by explaining the topic's relevance, outlining the research question, introducing the case study, and setting objectives to address the identified issues. This chapter lays the foundation for the subsequent chapters and guides the overall direction of the study.

1.1. Background and Problem Statement

Human activities, primarily through greenhouse gas (GHG) emissions, have undeniably contributed to global warming, resulting in a 1.1°C rise in surface temperatures from levels observed between 1850 and 1900 to those between 2011 and 2020. Emissions persistently rise, fueled by unsustainable energy consumption, land management practices, and diverse consumption habits across different regions, countries, and individuals (IPPC, 2023). In today's interconnected world, cities are central to communication, business, and culture. They consume over two-thirds of the world's energy and produce more than 70% of global CO_2 emissions, making them major contributors to climate change (JPI Urban Europe, 2018).

As key sources of greenhouse gases, cities have the potential to shape a sustainable future through their individual and collective actions. Positioned at the forefront of global climate challenges, they are well-suited to take a leadership role in driving efforts to combat climate change (JPI Urban Europe / SET Plan Action 3.2, 2020). The Implementation Working Group on Smart Cities, part of the Strategic Energy Technology Plan for Europe (SET Plan), was launched in October 2018 with the goal of developing around 100 urban districts or neighbourhoods across Europe by 2025. These areas are expected to demonstrate a strong commitment to sustainability, livability, and surpassing carbon neutrality by achieving energy positivity. These Positive Energy Districts/Neighbourhoods (PED/PENs) may include new developments, but should also adopt bold strategies for renewing existing urban areas. Approximately 20 European countries are currently involved in this initiative, alongside problem owners and key industry stakeholders (JPI Urban Europe / SET Plan Action 3.2, 2020).

Despite the significant focus on environmental and economic aspects in PEDs research, the social impacts, risks, and benefits remain underexplored. A systematic review conducted in 2024, analyzing 135 PED-focused articles, revealed that only 13, less than 10%, addressed social dimensions, 10 directly engaged with social issues, and 3 explored adjacent topics (Sassenou et al., 2024). Another type of social discourse considers social assessments as a means to enhance the involvement of citizens and energy communities. These studies focus on measuring social engagement in PED projects and identifying social barriers to their implementation. In this context, social assessments are often limited to evaluating citizen participation in project execution rather than addressing the broader positive and negative social impacts on stakeholder groups, including local communities and consumers (van Wees et al., 2022).

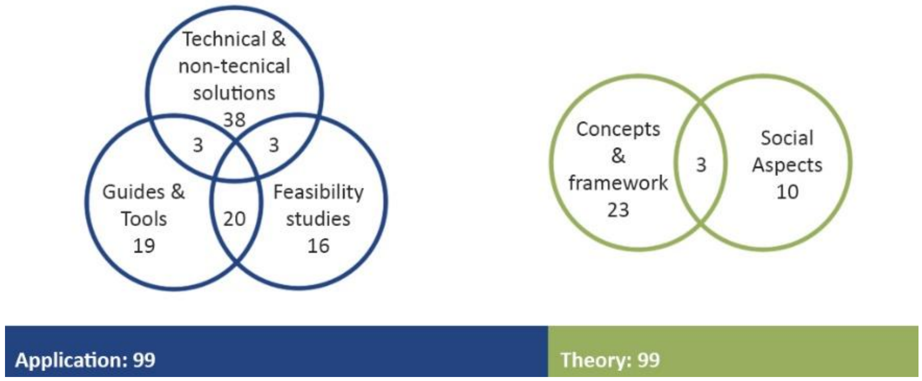


Figure 1 - Division of papers into the identified groups and categories (Sassenou et al., 2024).

On the other hand, affordable housing plays a vital role in addressing the diverse needs of urban populations, including vulnerable groups such as elderly individuals, single women, immigrants, and low-income families. The EU has committed to expanding access to affordable housing as a fundamental right, recognizing its importance in fostering social inclusion and equitable urban development (Bauer, 2018). Given that these diverse populations often reside in affordable housing, implementing PEDs in such areas offers a unique opportunity to assess the real and practical social risks and impacts of these initiatives.

In addition, Life Cycle Assessment (LCA) methodologies, including Social Life Cycle Assessment (S-LCA), face several practical barriers and enabling factors that affect their broader implementation. Common challenges include the lack of trained personnel, limited familiarity with assessment frameworks, and the perceived complexity of applying such tools in real-world contexts. At the same time, efforts to simplify LCA methods have proven to be key enablers, enhancing accessibility and encouraging wider use across various sectors and organizational scales, including but not limited to small and medium enterprises (SMEs) (Gómez-Garza et al., 2024). This study adopts a reference scale approach, also known as type I S-LCA, due to its operational maturity and established presence in practical applications. Numerous case studies support this approach, while more complex impact pathway methods remain largely in the research phase (UNEP, 2020).

This research primarily aims to provide a simplified and user-friendly S-LCA methodology suitable for educational purposes, particularly for students and beginner practitioners, addressing the need for tools that are both practical and impactful. Thanks to this simplified methodology, the study then seeks to bridge the social gaps in Positive Energy Districts (PEDs) by employing the S-LCA framework, which allows for the assessment of both positive and negative social impacts, as well as social risks. By applying this methodology to the ProLight project in Milan, with a focus on areas containing affordable and social housing, the research aims to develop structured recommendations for integrating social life cycle assessments into PED planning and implementation, thereby contributing to more inclusive and sustainable urban transformations.

1.2. The ProLight Project (Case Study)

ProLight is an EU-funded project aiming to accelerate the development of PEDs by integrating innovative technologies, policy tools, and citizen participation mechanisms. It brings together 23 partners from 9 countries to support the energy transition in six diverse urban contexts across Europe. These include urban districts in Austria, Finland, Germany, Italy, the Netherlands, and Portugal, each piloting different strategies to reduce energy consumption and increase renewable energy production (***ProLight***, n.d.).

This thesis focuses specifically on the "Planet App", a digital social innovation tool developed within the Italian pilot of the ProLight project, which is located in the *Urbana New Living* social housing neighborhood in *Milan*. The Planet App aims to promote energy awareness, citizen engagement, and behavior change by gamifying sustainable practices among residents. This makes it a fitting subject for evaluating the social impacts and risks of PEDs using a Social Life Cycle Assessment (S-LCA) approach.

1.3. Research Questions

1. How can a simplified S-LCA methodology be designed to make Life Cycle Sustainability Assessment (LCSA) more accessible for students and beginner practitioners by addressing the lack of personnel with a background in LCA and responding to the need for simplification as a key enabler?

2. How can Social Life Cycle Assessment (S-LCA) be used to evaluate social impacts, both positive and negative, and social risks on stakeholder groups within PEDs by examining its implementation in the ProLight project case study in Milan?

1.4. Research Objectives

The research objectives focus on applying and simplifying the Social Life Cycle Assessment (S-LCA) within the ProLight project to evaluate social impacts and risks in Positive Energy Districts (PEDs), with a particular emphasis on affordable and social housing, and to make the methodology usable by a broader audience.

A) To develop a simplified and user-friendly S-LCA implementation methodology suitable for educational purposes and practical application by students, beginner practitioners, addressing common barriers to implementation such as lack of training and limited resources.

B) To evaluate the social impacts and social risks within Positive Energy Districts (PEDs) by applying the developed simplified S-LCA implementation methodology to the ProLight project case study in Milan.

1.5. Thesis Structure

The research structure of this thesis is organized into five chapters, each addressing a key aspect of the study:

Chapter 1 – Introduction: Provides the background and problem statement, introduces the ProLight project as the case study, and outlines the research questions and objectives guiding the study.

Chapter 2 – Literature Review: Offers a comprehensive review of the existing literature, covering key concepts and theoretical frameworks related to S-LCA, Positive Energy Districts, and affordable housing. It also explains the rationale for adopting S-LCA as the primary assessment method.

Chapter 3 – Methodology: Describes the research design and methodology, including an overview and comparison of S-LCA approaches based on international guidelines. It also presents the ProLight case study in detail, laying the groundwork for the subsequent analysis.

Chapter 4 – Results: Presents the outcomes of the research, introducing the proposed simplified and user-friendly S-LCA implementation methodology and validating its usability through its application to the ProLight PED case study in Milan, specifically focusing on the Planet App.

Chapter 5 – Conclusion: Concludes the research by summarizing key findings, implications, and recommendations for future research and policy.

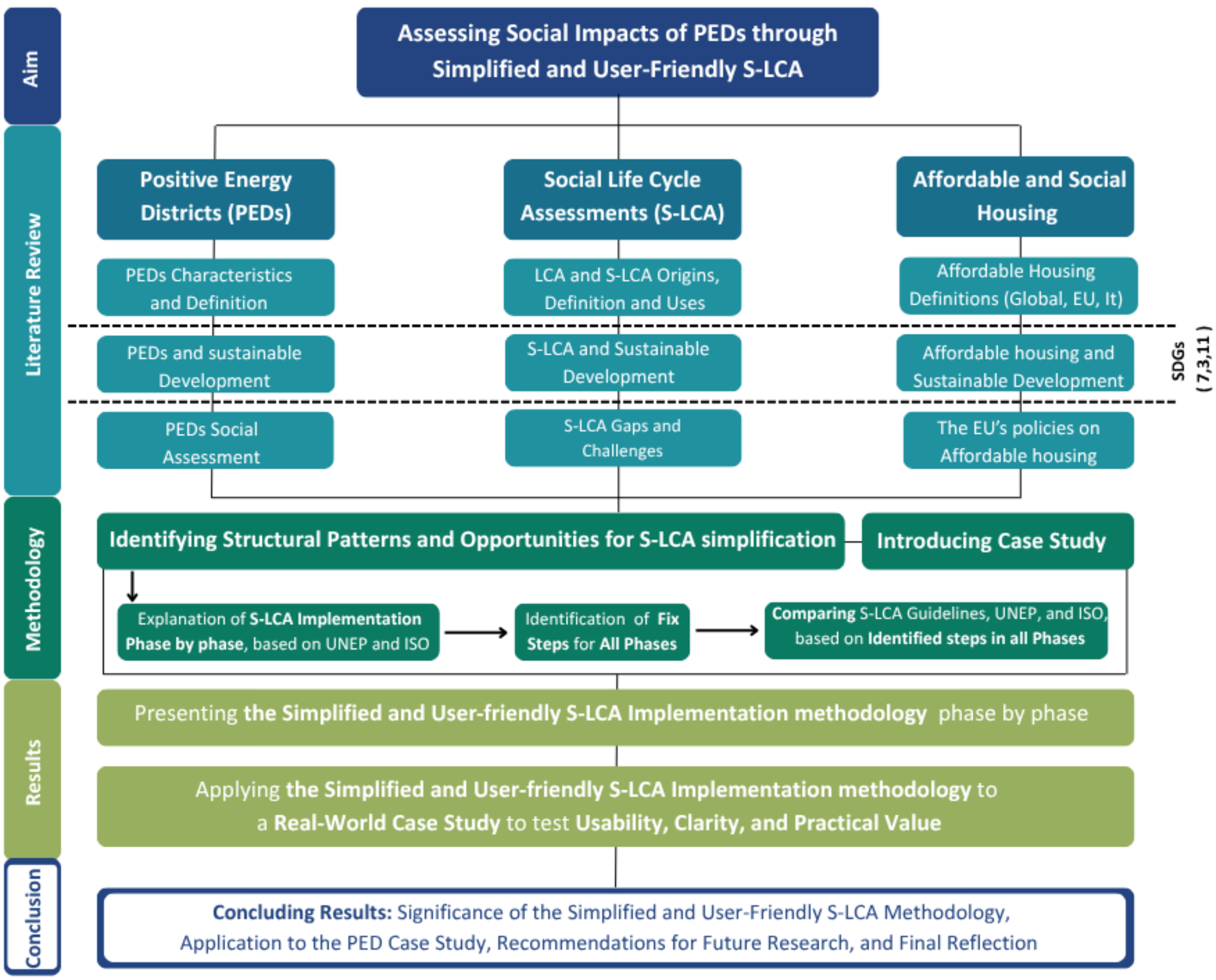


Figure 2 - Research Roadmap (Elaboration: Author, 2025).

CHAPTER 2- LITERATURE REVIEW

This chapter reviews the theoretical and contextual foundations of the study, focusing on Positive Energy Districts (PEDs), Social Life Cycle Assessment (S-LCA), and affordable and social housing. These areas are examined to understand how social impacts and risks are addressed in PEDs.

A key focus of this review is the complexity of existing S-LCA methodologies, which often limits their practical use, especially by students and early-stage practitioners. By identifying this gap, the chapter supports the thesis objective: to develop a simplified and user-friendly S-LCA method, grounded in current literature and validated through a real-world PED case study.

2.1. Concepts and Definitions of Positive Energy Districts (PEDs)

This section introduces the concept of Positive Energy Districts (PEDs) within the context of sustainable urban development and European energy policy. It outlines their key features, such as local energy generation, efficiency, and integrated social and spatial dimensions.

2.1.1. Global Warming and Renewable Energy: A Call for Energy Transition

The intensification of global warming, coupled with increasing energy consumption and the pressing need to reduce dependence on fossil fuels, has accelerated global interest in renewable energy sources (RES). The 2015 Paris Climate Agreement serves as a pivotal global framework, urging nations to limit the global temperature rise to well below 2°C, with aspirations to cap it at 1.5°C above pre-industrial levels. To achieve this, international efforts focus on transitioning to net-zero emissions by the latter half of the 21st century, setting the stage for ambitious energy reforms (Shnapp et al., 2020).

Significant progress has already been observed in the adoption of renewable energy technologies. According to the International Energy Agency (IEA), photovoltaic energy production increased from 91 GWh in 1990 to 554,382 GWh in 2018, while wind energy generation surged from 3880 GWh to 1,273,409 GWh in the same period. By 2018, approximately 26% of global energy was generated from RES (Hedman et al., 2021).

The European Union has positioned itself as a leader in renewable energy integration. Under its "Clean Energy for All Europeans" package, the EU has adopted a policy framework to deliver the energy transition and decarbonize energy systems. The binding 2030 targets set under this framework include a 40% reduction in GHG emissions compared to 1990 levels, a 32.5% share of renewable energy, and a 32.5% improvement in energy efficiency (Shnapp et al., 2020). Looking further ahead, the EU aims to achieve an 80% reduction in $CO2$ emissions by 2050 (Hedman et al., 2021).

Despite the remarkable progress, challenges remain in the variability and stability of RES generation. This variability can stress power grids, potentially compromising grid stability. Designing energy systems capable of managing these challenges is crucial to ensuring a reliable energy transition (Hedman et al., 2021).

2.1.2. Developing Positive Energy Districts (PEDs): An Innovative Strategy for Energy Transition

The imperative to transition towards sustainable and climate-neutral urban environments is a significant catalyst for the development of PEDs. These districts are characterized by achieving a net positive energy balance annually, generating an excess of renewable energy beyond the requirements of the district's energy consumption. More critically, they address a multitude of sustainability imperatives. They are conceptualized as economically viable, inclusive, and resilient urban habitats where individuals aspire to live or work, envisioning the emergence of a secure and health-conscious future. PEDs do not function as isolated energy enclaves within urban settings; rather, they are intricately integrated into their urban and regional frameworks, both from an energy-centric standpoint and from a more comprehensive perspective. They constitute a fundamental component of sustainable urban development. Frequently, PEDs manifest as urban revitalization initiatives rather than as newly constructed districts, thereby complicating and augmenting the challenges associated with their implementation (EU Smart Cities, 2020).

Presently, it is observed that only 1.3% of the EU's residential building stock is undergoing medium to deep energy retrofitting on an annual basis. Given the climate objectives set forth by the European Union, such retrofitting efforts must significantly increase in prevalence. PEDs can play a pivotal role in this undertaking, thereby contributing to the realization of the Green Deal's Renovation Wave objectives. Simultaneously, buildings should transition from being unresponsive and energy-intensive structures to highly efficient micro-energy hubs integrated within PEDs: effectively consuming, producing, managing, storing, and supplying energy in an intelligent manner, thus enhancing system flexibility and efficiency. Additionally, PEDs will distribute their surplus energy to adjacent regions where deep retrofitting presents challenges, such as areas with historical or heritage buildings (EU Smart Cities, 2020).

2.1.3. PEDs Origins and Evolutions (moving from NZEBs to ZEDs / PEDs)

The progression from Nearly Zero Energy Buildings (NZEBs) to PEDs reflects a shift from optimizing individual building energy performance to leveraging district-scale energy solutions. While NZEBs focus on achieving high energy efficiency in single buildings, they miss opportunities for technical and financial optimization available at a district level. PEDs take the next step by integrating energy systems across neighborhoods, allowing for surplus energy generated by one building to support others, particularly those with limited retrofit potential. This interconnected system enables energy exchange, reduces grid stress, and encourages urban rejuvenation projects. PEDs combine diverse energy-use profiles and promote collective renewable energy generation and storage, making the energy system more flexible and efficient (EU Smart Cities, 2020).

2.1.4. The Role of EU Policy in Advancing from NZEBs to PEDs

The European Union’s Energy Performance of Buildings Directive (EPBD) (2010/31/EU, as amended in 2018) establishes NZEBs as the standard for new buildings from 2021. NZEBs prioritize energy efficiency through integrated renewable energy systems and balanced energy operations. However, achieving the EU’s climate-neutral goals necessitates extending this approach beyond individual buildings to districts. Moving to ZEDs and PEDs enables holistic planning, aggregating energy efficiency measures and renewable energy generation across neighborhoods. This approach allows for shared energy use, optimized demand management, and tailored energy systems for diverse building typologies, significantly increasing cost-effectiveness and reducing carbon emissions (Shnapp et al., 2020).

PEDs also address broader challenges, such as accommodating energy variability and fostering energy cooperation through "energy pooling." By integrating renewable energy sources like solar photovoltaics, wind, and geothermal systems, PEDs can deliver flexible, efficient energy solutions. The district-scale framework enhances the ability to adapt to future changes, such as evolving energy needs, demographic shifts, or technological advancements, while promoting collaboration among stakeholders to achieve climate neutrality (Shnapp et al., 2020).

2.1.5. PEDs Characteristics and Definition

PEDs require comprehensive integration of buildings, users, and regional energy, mobility, and ICT systems while addressing technological, regulatory, financial, legal, social, and economic dimensions. Ideally, PEDs are developed within an open innovation framework, led by cities in partnership with industry, investors, researchers, and citizens. These districts aim to achieve net-zero annual energy imports and CO_2 emissions while working toward surplus renewable energy production (SET-Plan ACTION n°3.2, 2018). Key characteristics of PEDs:

- **Integration with Renewable Energy Systems:** PEDs are embedded within regional energy networks, driven by renewable energy, to enhance security and supply flexibility.
- **High Energy Efficiency:** PEDs focus on maintaining local energy consumption below renewable energy production levels.
- **Optimized Energy Management:** They utilize advanced systems for consumption and storage management, enabling load balancing, peak shaving, and demand response to maximize renewable energy use.
- **Sustainable Mobility and Consumption:** PEDs integrate sustainable practices, including enhanced electric vehicle (EV) charging, while minimizing grid impacts by leveraging local generation.
- **Advanced Technology and Resources:** Use of innovative materials, smart grids, waste heat, local storage, and user-driven energy management systems.
- **Affordability:** Ensuring that PEDs remain economically viable for inhabitants.

PEDs can be implemented in new developments, retrofitted districts, or areas with a mix of both, ensuring broad applicability and adaptability (SET-Plan ACTION n°3.2, 2018).

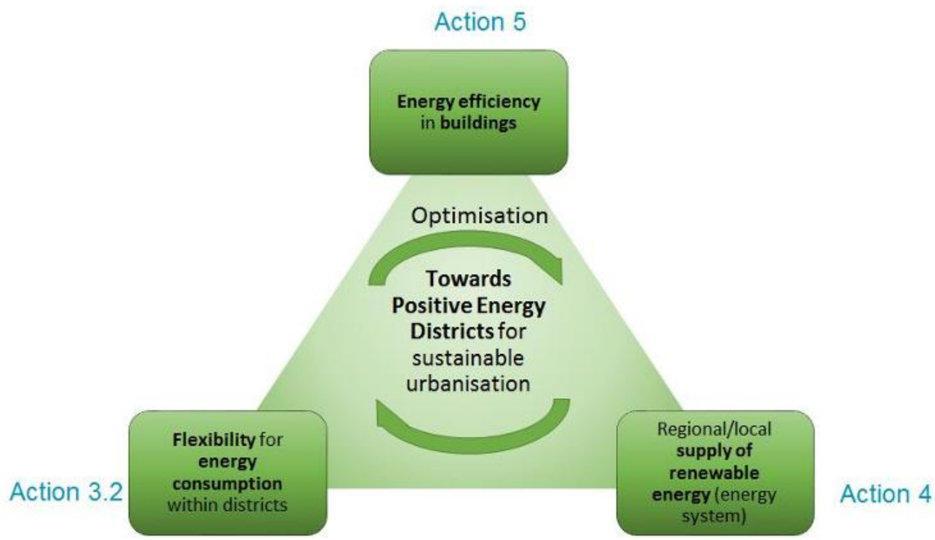


Figure 3 - Definition of Positive Energy Districts (SET-Plan ACTION n°3.2, 2018, p. 6).

Based on the mentioned explanations, the PED Reference Framework (PED Reference Framework is a strategic document aimed at guiding the planning, development, and implementation of PEDs in urban areas) proposed **definition for PED/PENs is as follows:**

"*Positive Energy Districts are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users, and the regional energy, mobility, and ICT systems while securing the energy supply and a good life for all in line with social, economic, and environmental sustainability* (EU Smart Cities, 2020, p. 7)."

2.1.6. Defining the PED Concept: Insights from EU Projects

The perspective presented by the EU project syn.ikia [1]emphasizes the relationship between Positive Energy Districts (PEDs)/Positive Energy Neighborhoods (PENs) and sustainable development, contributing to the concept of Sustainable Plus Energy Neighborhoods (SPENs). According to this vision, a PED/PEN:

- Integrates the Built Environment with Energy Systems: It links sustainable energy production, consumption, and mobility (e.g., EV charging) to create added value and incentives for consumers and society.
- **Utilizes Advanced Technologies and Resources:** PEDs/PENs optimize the use of advanced materials, local renewable energy sources (RES), low-carbon technologies (e.g., local storage and smart grids),

[1] Project aimed at creating SPENs, in 4 different climatic locations by developing a highly sustainable design approach to combat climate change and social exclusion (Marotta et al., 2021).

demand-response mechanisms, cutting-edge energy management systems, and ICT-enabled user interaction.

- **Promotes Affordability and Quality of Life:** These districts aim to provide affordable housing, improved indoor environments, and enhanced well-being for inhabitants through sustainable design (Marotta et al., 2021).

Furthermore, the MAKING-CITY [2] project provides a methodology to calculate the energy balance for districts aiming to achieve PED status. This involves defining district boundaries, determining energy demand, and calculating the primary energy balance using the formula:

$$BALANCE = PEI - PEE$$

Where:

- PEI (Primary Energy Imported) = Sum of delivered energy per carrier × non-renewable primary energy factor (PEF).
- PEE (Primary Energy Exported) = Sum of exported energy per carrier × PEF.

When PEI is greater than PEE, the district achieves PED status. However, challenges remain regarding the standardization of energy metrics, the selection of primary energy factors, and defining elements included in the calculations (Marotta et al., 2021).

2.1.7. PEDs in City Context

Positive Energy Districts (PEDs) emphasize a decentralized approach to energy production and consumption within urban contexts. They integrate renewable energy systems not only at the building level but also across districts and regions. This shift from centralized, hierarchical energy systems to connected, localized setups involves using Positive Energy Blocks (PEBs), PEDs, and even Positive Energy Cities and Regions. These systems optimize energy use through local generation and consumption, reducing reliance on external grids. Local Energy Communities (LECs) play a pivotal role in the PED framework. They empower citizens to actively participate in energy markets, whether as Renewable Energy Communities (RECs) under the Renewable Energy Directive or as Citizen Energy Communities (CECs) under the Electricity Directive. Urban planning processes must accommodate the spatial and visual impact of renewable energy infrastructure, with involvement from local authorities, grid operators, property developers, and civil organizations to ensure successful integration (EU Smart Cities, 2020).

[2] Project aimed at the clean energy transition and reduction in CO_2 emissions in 3 lighthouse cities, with an eye towards socio-economic aspects (Marotta et al., 2021).

Figure 4 - Energy from district to regional integration and beyond (EU Smart Cities, 2020, p. 9).

2.1.8. PEDs Boundaries as an Energy System

At the nucleus of a PED is the physical energy framework. The principal aims of a PED are energetic: an elevated degree of localized urban renewable energy and of energy efficacy. This segment accentuates the primary facets of the PED energy framework but does not endeavor to be exhaustive. The considerable array of energy technologies that may be employed in the PED, in conjunction with a diverse assortment of requisite energy services, results in a substantial variety of energy system configurations, which necessitate a particular evaluation (EU Smart Cities, 2020).

PED's energy system

A PED functions as a complex energy system designed to generate more renewable energy than it consumes annually. This is achieved by integrating renewable energy systems, employing energy storage solutions, and optimizing energy flows among consumers, producers, and storage units. As part of the European SET Plan, PEDs are recognized as foundational components for achieving low-carbon cities (Lindholm et al., 2021).

PED energy systems can be categorized into three distinct models, as identified during a workshop by the European Energy Research Alliance Joint Programme Smart Cities:

PED Autonomous: In this model, the district is entirely self-sufficient in energy within its defined geographical boundaries. All energy demand is met by renewable energy generated internally, and no energy is imported from external electricity grids or district heating/gas networks. However, surplus renewable energy can be exported outside the district. This model embodies total energy independence, making it ideal for isolated or highly controlled urban environments (Lindholm et al., 2021).

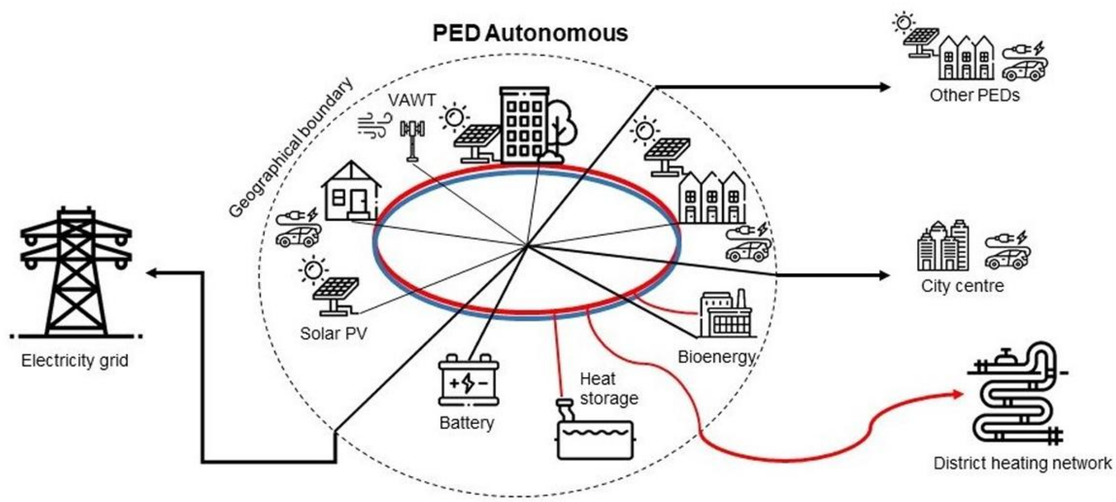


Figure 5 - Graphical explanation of a PED autonomous (Lindholm et al., 2021, p. 6).

PED Dynamic: This model allows for interactions with external energy networks. While the district generates more renewable energy annually than it consumes, it maintains connections to external grids and other PEDs. These connections enable energy exchanges, fostering flexibility and resilience within a broader energy network. The dynamic PED model exemplifies an interconnected and adaptive energy system, suitable for urban settings with diverse energy demands and resources (Lindholm et al., 2021).

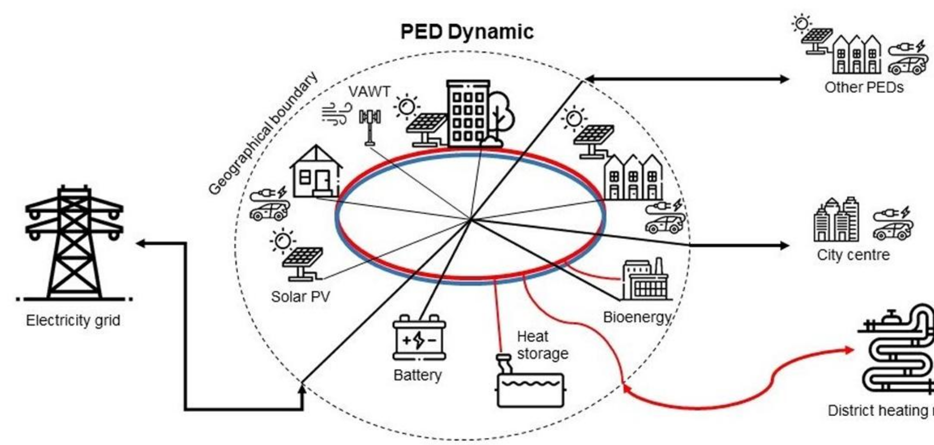


Figure 6 - Graphical explanation of a PED dynamic (Lindholm et al., 2021, p. 6).

PED Virtual: Unlike the other models, a PED Virtual extends its boundaries by incorporating virtual renewable energy systems and energy storage located outside the district. The combined energy production from these external systems and on-site resources must exceed the district's total annual energy demand. This model introduces innovative approaches to energy sharing, enabling districts to achieve positive energy status without being restricted by physical boundaries. It is particularly relevant in dense urban areas where space for on-site renewable systems is limited (Lindholm et al., 2021).

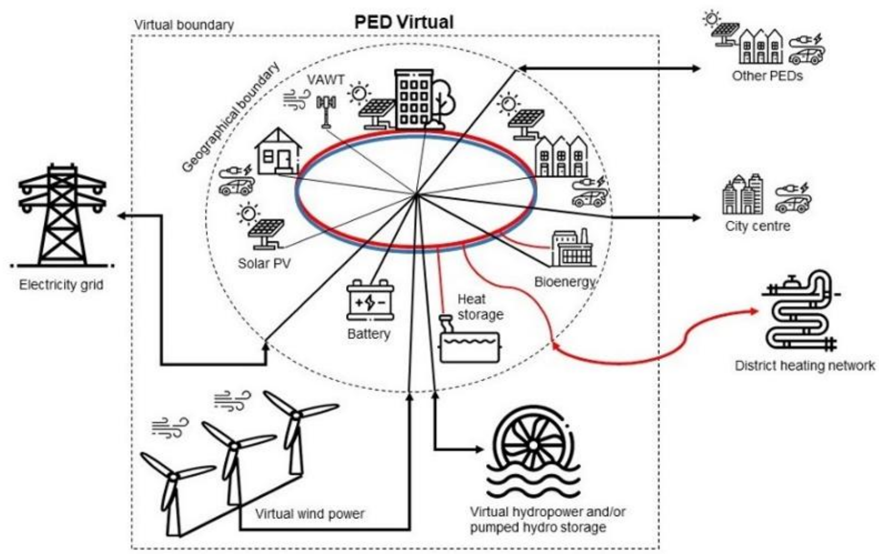


Figure 7 - Graphical explanation of a PED virtual (Lindholm et al., 2021, p. 6).

By adopting these models, PEDs can function as independent or interconnected energy systems, contributing to the decarbonization of cities while ensuring energy efficiency and flexibility. Each model caters to specific urban and regional needs, providing scalable solutions for integrating renewable energy within diverse urban contexts (Lindholm et al., 2021).

PEDs Boundaries

A Positive Energy District (PED) achieves a positive energy balance within a defined boundary, though determining this boundary can be complex. The boundaries may be geographical or virtual, and often include a virtual component due to connections with a smart grid (EU Smart Cities, 2020).

Geographical Boundaries

In a PED with geographical boundaries, the energy system operates within a physically defined area, excluding external independent energy systems. The PED ensures a net positive annual energy balance within these boundaries while dynamically exchanging energy with broader systems to address temporary surpluses or deficits. This approach emphasizes the integration and optimization of local energy generation, consumption, and storage within a contained space (EU Smart Cities, 2020).

Virtual Boundaries

Virtual boundaries expand the PED concept by connecting disaggregated energy systems via a smart grid managed by a unified energy management system. For instance, renewable energy sources dedicated to the PED may exist outside its physical limits. The PED maintains a net positive annual energy balance within these virtual boundaries, utilizing dynamic exchanges with surrounding energy systems to manage fluctuations in energy supply and demand (EU Smart Cities, 2020).

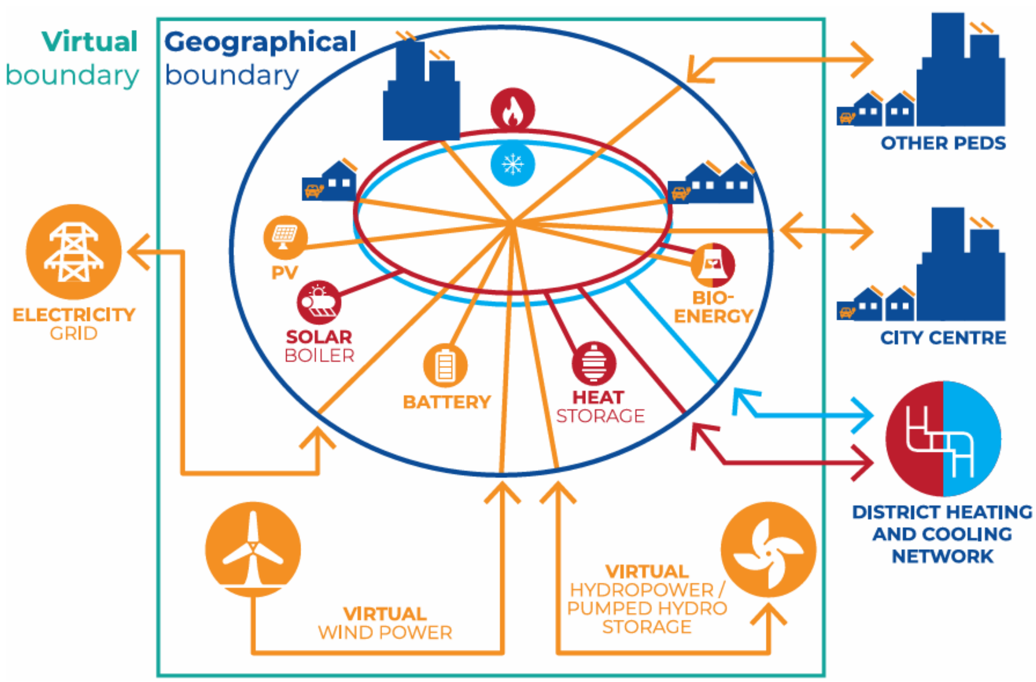


Figure 8 - PED boundaries (EU Smart Cities, 2020, p. 15).

The design of PED boundaries should align with broader energy system goals and an upscaling strategy, as these boundaries influence the design of smart grids, interconnections, and performance evaluations. However, boundaries are inherently flexible and context-dependent, often evolving as the PED integrates with wider energy networks. A rigid focus on maintaining energy positivity within a strictly defined boundary could hinder scalability and broader adoption of PED solutions. In conclusion, PED boundaries, whether geographical or virtual, play a critical role in achieving energy positivity while maintaining adaptability to meet the needs of expanding energy systems. The integration of local and external resources ensures a balance between sustainability goals and practical scalability (EU Smart Cities, 2020).

2.1.9. Feasibility and Effectiveness of Positive Energy Districts (Insights from Research and Case Studies)

According to a study in 2023 titled *"University Campus as a Positive Energy District – A Case Study,"* the feasibility of implementing PEDs was evaluated through the Sjeverni Logor University Campus in Mostar, Bosnia and Herzegovina. This study demonstrated that rooftop photovoltaic installations alone could enable the campus to achieve a net positive energy balance. The research estimated an annual energy production of approximately 750 MWh, which significantly surpassed the campus's total annual consumption of 455

MWh. This resulted in a surplus of 295 MWh, equivalent to 40% of total production, indicating that the PED concept can be realized even within existing urban infrastructures with moderate interventions.

The environmental benefits of the PED approach were also highlighted in this case study. The campus's geographic location, characterized by a Mediterranean climate and high solar irradiation, played a crucial role in achieving a positive energy balance. Data revealed that during eight months of the year, energy production exceeded consumption, while for the remaining four months, grid connection was necessary to address the energy deficit. This demonstrates the potential of PEDs to reduce reliance on non-renewable energy sources for most of the year.

Economically, the study emphasized the cost-effectiveness of PED implementation. The payback period for PV installations was estimated to be under seven years, making this investment financially attractive. Moreover, improvements in energy efficiency, such as enhanced insulation and modernized HVAC systems, were identified as key strategies for further reducing energy consumption and operational costs. Currently, 50% of the buildings on the campus lack adequate insulation, and more than 90% rely on inefficient electrical heating systems, presenting significant opportunities for improvement.

The findings suggest that while PV systems alone can establish PED status, integrating additional measures, such as optimizing building envelopes and upgrading heating and cooling systems, can enhance the environmental and economic outcomes. This case study underscores the feasibility of transitioning existing urban districts into PEDs, demonstrating their potential to achieve sustainability, energy efficiency, and economic viability simultaneously (Nezirić et al., 2023).

The second study examined is titled *"Decision Making for Sustainable Urban Energy Planning: An Integrated Evaluation Framework of Alternative Solutions for a NZED in Turin"* (2018). The research aligns with the European Union's directives to mitigate climate change and promote sustainable energy practices in urban areas. By extending energy efficiency targets from individual buildings to districts, the study introduces an evaluation framework based on Cost-Benefit Analysis (CBA) to assess the socio-economic and extra-economic benefits of Net Zero-Energy Districts (NZEDs). This framework was applied to a residential district in Turin, Italy, which consisted of 635 dwellings built between 1920 and 1980, spanning 8 hectares and housing approximately 1,950 residents. The analysis aimed to evaluate four retrofit strategies over a 30-year period, incorporating energy efficiency measures (EEMs), renewable energy systems, and district heating.

The study revealed substantial running benefits through energy demand reductions and financial savings. For instance, heating energy demand was reduced by up to 83% in some building typologies. Typology 1 reduced demand from 170 kWh/m²/year to 29.3 kWh/m²/year (a reduction of 82.8%), while Typology 4 dropped from 157 kWh/m²/year to 26.2 kWh/m²/year (a reduction of 83.3%). Additional financial savings came from revenues generated by surplus electricity sold to the grid, with PV system capacities ranging from 290 kWpeak to 348 kWpeak across the strategies.

In terms of environmental benefits, greenhouse gas emissions were reduced by 83% through the integration of biomass and PV systems. Biomass systems achieved zero CO2 emissions (0 kgCO2/kWh), while natural gas systems emitted 0.1998 kgCO2/kWh. These results highlight the district's alignment with EU decarbonization targets.

The socio-economic benefits of the retrofit strategies were equally significant. Job creation estimates indicated that for every €1 million invested, 10 new jobs were generated, leading to approximately 300 jobs during the €30 million investment in the district. Property values increased by 5–10% due to the retrofits, translating to an average increase of €1,000–€1,500 per dwelling. These economic benefits emphasize the long-term financial sustainability of the NZED model.

The retrofits also improved indoor comfort by enhancing thermal insulation and regulating indoor temperatures, particularly in winter months. While specific numeric results were not provided, the study qualitatively highlighted the positive impact on residents' quality of life. Similarly, health benefits such as reduced exposure to cold-related illnesses were discussed conceptually but not quantified. Nonetheless, the study suggested potential reductions in hospitalization rates for respiratory and cardiovascular conditions.

Energy security was another critical outcome of the NZED strategies. Local renewable energy sources met more than 90% of the district's energy needs during peak production, reducing reliance on external energy imports and mitigating vulnerability to supply disruptions. Although energy interruptions were discussed theoretically as a potential benefit, they were not explicitly analyzed in the study (Becchio et al., 2018).

Aspect	Analyzed Case Study	Numeric Results	Notes
Running Benefits	Yes	Heating energy demand reduced by up to 83%; Typology 1: 170 kWh/m²/year to 29.3 kWh/m²/year (82.8%); Typology 4: 157 kWh/m²/year to 26.2 kWh/m²/year (83.3%).	Includes heating energy demand reductions and financial benefits from energy savings.
GHG Emissions Reduction	Yes	83% reduction in CO2 emissions; Biomass: 0 kgCO2/kWh; Natural Gas: 0.1998 kgCO2/kWh.	Detailed analysis of CO2 reductions due to biomass and renewable systems.
Creation of Green Jobs	Yes	10 jobs created per €1 million investment; Total €30 million investment created ~300 jobs.	Estimated based on investments and job creation metrics.
Increase of Asset Value	Yes	Property values increased by 5–10%; Approx. €1,000–€1,500 per dwelling.	Hedonic pricing model applied to evaluate property value increases.
Improvement of Indoor Comfort	Yes	No numeric results provided.	Highlighted improvements in thermal regulation and comfort levels.
Energy Security	Yes	Over 90% of energy needs are met by local renewable sources during peak production.	Local renewable energy systems assessed for self-sufficiency.
Energy Interruptions	No	Not applicable.	Discussed as a theoretical benefit but not directly evaluated in the study.

Table 1 - Summary of Analyzed Aspects and Results in NZED Turin Case Study – Source: Author, adapted from Becchio et al., (2018)

2.1.10. Social Dimensions and Social Impact of Positive Energy Districts: Addressing the Gaps in Research and Practice

PEDs represent a significant shift in urban energy systems by emphasizing sustainability, carbon neutrality, and renewable energy. However, while the environmental and technical aspects of PEDs have been extensively researched, the social dimensions of these districts remain underexplored. This section investigates the social aspects of PEDs as proposed by the EU and examines existing research to highlight gaps in understanding the social impacts, risks, and benefits of these districts (Sassenou et al., 2024).

The European Union has emphasized the importance of societal and consumer aspects in the deployment of PEDs. According to the Solution Booklet for Positive Energy Districts (2020), PEDs must actively integrate social inclusion, stakeholder engagement, and citizen participation. The EU envisions PEDs not just as technical energy systems but as holistic urban solutions that address societal well-being. This involves setting up urban living labs that foster collaboration between municipalities, citizens, and private stakeholders to co-design PEDs (EU Smart Cities, 2020).

Moreover, PEDs are proposed to improve the quality of life, promote inclusivity, and reduce energy poverty by empowering citizens through Local Energy Communities (LECs). Citizens are envisioned as active participants in the energy system, transitioning from passive consumers to prosumers and contributors to community energy strategies. Despite these aspirations, operationalizing such social inclusivity within PEDs remains a challenge (EU Smart Cities, 2020).

2.1.11. Overview of Gaps in Social Assessments of PEDs

1. A systematic review of 135 PED-related research articles by Sassenou et al. (2024) found that only **9.6%** of the articles (13 papers) addressed social aspects. Among these, the majority discussed social innovation but focused primarily on issues of citizen engagement, such as barriers to participation, without assessing the broader positive or negative social impacts on communities and stakeholders. This highlights the lack of frameworks for evaluating social equity, well-being, and other societal outcomes of PED implementation (Sassenou et al., 2024).

2. The article *"Energy Citizenship in Positive Energy Districts"* underscores that citizen engagement in PEDs is primarily considered a tool for facilitating implementation, rather than a subject of systematic analysis. The authors observed that:

    - Research typically focuses on fostering participation through practical interventions (e.g., energy communities or behavioral nudging) rather than examining the potential risks or long-term societal impacts of PEDs on communities.

    - Few projects meaningfully involve citizens in the design of PEDs beyond consultation processes, and challenges such as the exclusion of less privileged groups are often overlooked (van Wees et al., 2022).

3. Kozlowska et al. (2024) noted that while PED frameworks aim to address energy efficiency and decarbonization, their integration with social sustainability goals is often superficial. The authors highlighted the absence of a quantitative framework to evaluate the impacts of PEDs on inclusivity,

affordability, and well-being. Without such frameworks, key issues like energy poverty, social equity, and the potential for gentrification remain underexplored (Kozlowska et al., 2024).

2.2. Concepts and Definitions of Social Life Cycle Assessments (S-LCA)

This section will present a comprehensive review of the concepts and definitions related to Social Life Cycle Assessments (S-LCA). The discussion begins with a brief overview of **sustainable development** and **life cycle thinking**, which are the backbone of all Life Cycle Assessment (LCA) methodologies. Then it explores the interconnection between sustainable development and LCA methods as tools to achieve greater sustainability in development. Finally, the focus shifts to **Social Life Cycle Assessments (S-LCA)**, providing an overview of its evolution in the literature, key definitions, and its role in addressing social dimensions within life cycle methodologies.

2.2.1. History of LCA: "Origins, Milestones, and Evolution of LCA"

1960s: The Origins of LCA

LCA emerged in the 1960s as a response to concerns about the limitations of raw materials and energy resources. One of the earliest documented studies was conducted by **Harold Smith**, who calculated cumulative energy requirements for chemical production at the **World Energy Conference in 1963**. This marked the beginning of systematic efforts to quantify resource use and environmental impacts. In the late 1960s, global modeling studies like *The Limits to Growth* and *A Blueprint for Survival* predicted the rapid depletion of fossil fuels and the environmental consequences of industrial activities. These studies spurred further interest in quantifying energy use and emissions in industrial processes.

1969–1970s: Early Applications and REPA

In 1969, **The Coca-Cola Company** commissioned a groundbreaking study to compare the environmental impacts of different beverage containers. This study laid the foundation for modern life cycle inventory (LCI) methods by quantifying raw material use, energy consumption, and environmental emissions. Similar studies were conducted in the U.S. and Europe during the early 1970s, often using publicly available data. These studies were referred to as **Resource and Environmental Profile Analysis (REPA)** in the U.S. and **Ecobalance** in Europe. By the mid-1970s, approximately 15 REPAs had been conducted, and a standardized methodology began to emerge.

1975–1980s: Decline and European Growth

Interest in LCA waned in the late 1970s as the oil crisis subsided, and environmental concerns shifted to hazardous waste management. However, LCA methodology continued to improve, with about two studies conducted annually, primarily focusing on energy requirements.
In Europe, the **European Commission's Environment Directorate (DG XI)** played a key role in advancing LCA. The 1985 **Liquid Food Container Directive** required companies to monitor energy use, raw material consumption, and waste generation, further institutionalizing LCA practices.

1988–1990s: Revival and Standardization

LCA regained prominence in 1988 as solid waste management became a global issue. During this period, LCA methodology evolved significantly, with a focus on moving beyond inventory analysis to **impact assessment**.

The **Society of Environmental Toxicology and Chemistry (SETAC)** played a pivotal role in standardizing LCA methodologies, publishing key documents in 1991, 1993, and 1997.
In the 1990s, concerns over the misuse of LCA results for marketing claims led to calls for standardization. This resulted in the development of the **ISO 14040 series** (1997–2002), which established international standards for LCA.

2002–Present: Global Collaboration and Life Cycle Initiative

In 2002, the **United Nations Environment Programme (UNEP)** partnered with **SETAC** to launch the **Life Cycle Initiative**, a global effort to promote life cycle thinking and improve LCA tools. The initiative focuses on three key areas:

- **Life Cycle Management (LCM)**: Raising awareness and building capacity for life cycle thinking.
- **Life Cycle Inventory (LCI)**: Improving access to high-quality, transparent life cycle data.
- **Life Cycle Impact Assessment (LCIA)**: Developing globally accepted indicators for impact assessment.

Today, LCA is widely used across industries, governments, and academia to support sustainable decision-making and policy development (Curran, 2006).

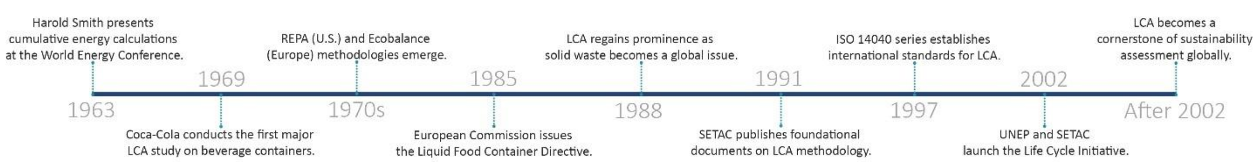


Figure 9 - History of LCA - Source: Author, adapted from Curran (2006)

2.2.2. Life Cycle Initiative

The United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) have been utilizing the life cycle approach since the 1990s, and since 2003, they have collaborated through the international 'UNEP/SETAC Life Cycle Initiative.' This partnership has played a significant role in the Marrakech Process on Sustainable Consumption and Production (SCP), a global multi-stakeholder platform established in 2003 that operated until 2011. The platform supported the implementation of SCP at regional and national levels and contributed to the development of a 10-year Framework of Programmes on SCP, as outlined in the Johannesburg Plan of Implementation from the 2002 World Summit on Sustainable Development. Additionally, the UNEP/SETAC Life Cycle Initiative supports

UNEP's Green Economy Initiative, which seeks to drive the transition to a low-carbon, high-tech, and resource-efficient global economy using 'beyond GDP' indicators (UNEP/SETAC, 2012).

The UNEP/SETAC Life Cycle Initiative has three primary goals:

1. Strengthen global consensus and the relevance of both existing and emerging life cycle approaches and methodologies.

2. Promote the worldwide adoption of these approaches by integrating life cycle thinking into decision-making processes for businesses, governments, and consumers.

3. Build global capacity by applying and refining life cycle approaches.

Initially focused on environmental Life Cycle Assessment (LCA) based on ISO 14040, the initiative has since broadened its scope to address sustainable development more comprehensively. It aims to transform the traditional environmental LCA into a triple-bottom-line approach that considers social, economic, and environmental dimensions. Following the release of the UNEP/SETAC Guidelines for a Social LCA of Products in 2009, the initiative proposed advancing towards Life Cycle Sustainability Assessment (LCSA) as a natural progression (Ciroth et al., 2011).

2.2.3. Sustainable Development

The Latin sub-tenere, assimilated sustinere (to hold up), is the root of the English word sustainability. The most frequently cited definition of sustainability and sustainable development comes from the United Nations (UN) World Commission on Environment and Development (WCED, Brundtland Commission) in 1987: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition has been used since the 1980s in reference to human sustainability on Earth (Ciroth et al., 2011).

The 2030 Agenda for Sustainable Development (United Nations General Assembly 2015) delineates a collective framework aimed at fostering peace, abundance, and prosperity for both humanity and the ecosystem. Central to this agenda is the 17 Sustainable Development Goals (SDGs), which constitute a pressing call to action for all nations, both developed and developing, within the context of a global partnership (United Nations Department of Economic and Social Affairs 2015). Establishing performance metrics is imperative to facilitate the effective implementation of sustainable development. The concept of sustainability is interpreted variably by diverse stakeholders and decision-makers. This variability complicates the coordinated assessment, mapping, and enhancement of the sustainability performance of products and organizations throughout their value chains and across different regions. The Agenda 21 (United Nations 1992), significantly contributed to the global discourse surrounding sustainable development by highlighting the challenges associated with the North-South development divide and underscoring the necessity of integrating social and economic development with environmental management of resources (UNEP/SETAC, 2007).

One of the most widely recognized interpretations of sustainability categorizes its impacts into three main pillars: economic, social, and environmental. This framework was formalized as the Triple Bottom Line (TBL) in 1999. However, it was later argued in 2018 that the full potential of TBL has neither been fully understood nor effectively implemented. There is a call for a renewed and accelerated application of TBL, emphasizing the urgency and scale required to address and prevent the overshooting of planetary boundaries. Furthermore, for any sustainability framework to be rigorously operationalized, it is essential to provide a clear and explicit definition of what sustainability truly encompasses (UNEP/SETAC, 2007).

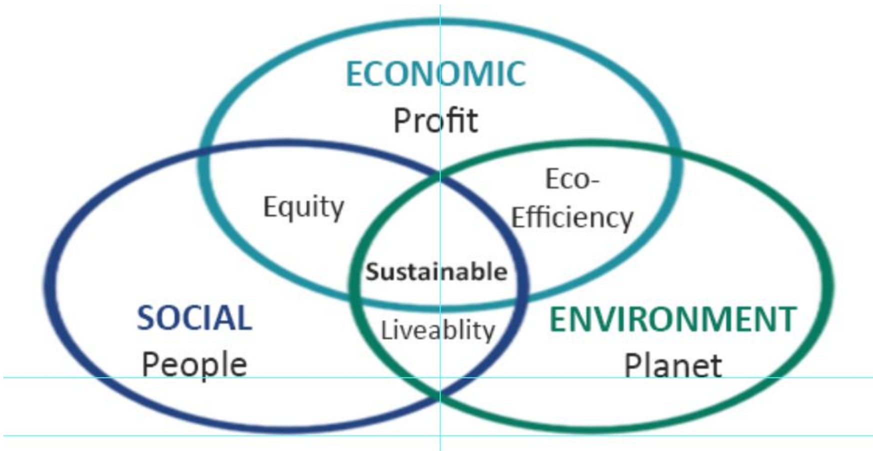


Figure 10 - Dimensions of Sustainability (UNEP/SETAC, 2007, p. 10).

2.2.4. Life Cycle Thinking

"Life Cycle Thinking (LCT) is about going beyond the traditional focus on production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle" (UNEP/SETAC, 2007, p. 12).

The primary objectives of Life Cycle Thinking (LCT) are to minimize a product's resource consumption and environmental emissions while enhancing its socio-economic performance throughout its life cycle. This approach fosters connections between the economic, social, and environmental aspects of an organization and its entire value chain. A product's life cycle typically begins with the extraction of raw materials from natural resources and energy generation. These materials and energy are then used during production, packaging, distribution, use, maintenance, and eventually in processes such as recycling, reuse, recovery, or final disposal. At every stage of the life cycle, there are opportunities to reduce resource usage and optimize product performance (UNEP/SETAC, 2007).

2.2.5. Sustainable Development and Life Cycle Thinking

Sustainable development has become a central concept in global discourse, strongly supported by initiatives such as the United Nations' Sustainable Development Goals (SDGs) (Valdivia et al., 2021).It emphasizes the need to balance environmental, social, and economic dimensions to ensure long-term prosperity and intergenerational equity. Sustainability, as defined by the Brundtland Commission, encompasses these three pillars, making it essential to develop methodologies to measure and advance sustainability across all dimensions (Schau et al., 2012). Life cycle thinking (LCT) has emerged as a key principle for achieving sustainable development, as it provides a holistic framework for identifying hotspots and addressing impacts across the entire life cycle of products and services (Valdivia et al., 2021).

To measure sustainability, several life cycle-based methodologies have been developed. The environmental dimension is the most mature, with Life Cycle Assessment (LCA) being a standardized method widely used to evaluate the potential environmental impacts of products and services from cradle to grave. LCA helps avoid burden shifting between life cycle phases, ensuring a comprehensive understanding of environmental impacts. For the economic dimension, Life Cycle Costing (LCC) is proposed as a tool to assess costs throughout a product's life cycle. While LCC has been used since the 1930s, its application in sustainability contexts is relatively new. The Society of Environmental Toxicology and Chemistry (SETAC) classifies LCC into three types: conventional, environmental, and societal LCC, with environmental LCC being the most suitable for integration with LCA. For the social dimension, Social Life Cycle Assessment (SLCA) is used to evaluate the potential social and socio-economic impacts of products and their consumption across their life cycles. However, SLCA is still in its infancy, with ongoing efforts to develop robust indicators (Schau et al., 2012).

The integration of these methodologies—LCA, environmental LCC, and SLCA—forms the basis of Life Cycle Sustainability Assessment (LCSA). LCSA provides a comprehensive framework for assessing sustainability by combining environmental, economic, and social dimensions. It can be formally expressed as: LCSA = LCA + LCC + SLCA. This approach aligns with the well-known depiction of sustainability, where the three dimensions intersect, ensuring that no single dimension is prioritized at the expense of the others (Schau et al., 2012).

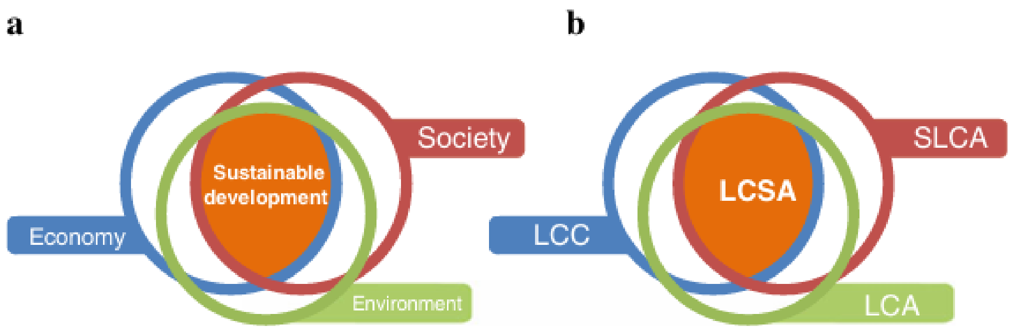


Figure 11 - Dimensions of sustainability and life cycle sustainability assessment (Schau et al., 2012, p. 13).

The application of LCT in sustainability practices is becoming increasingly important as businesses and governments face global challenges such as climate change, biodiversity loss, and environmental pollution. At the product level, LCT helps inform decisions about design, production processes, and end-of-life management, ultimately improving overall sustainability performance (Valdivia et al., 2021).By adopting LCT, stakeholders can move beyond traditional, narrow focuses on manufacturing sites and consider the broader environmental, social, and economic impacts of products across their entire life cycle and value chain. This approach is critical for achieving the SDGs and ensuring sustainable practices for future generations (Ciroth et al., 2011).

2.2.6. Life Cycle Assessments (LCA)

Life Cycle Assessment (LCA) is a technique used to evaluate the environmental impacts associated with all stages of a product's life cycle, from raw material extraction to disposal. It is a systematic process that involves four main phases: goal and scope definition, inventory analysis, impact assessment, and interpretation. LCA helps identify opportunities to improve the environmental performance of products and services, and it is widely used in policy-making, product development, and environmental management (Ciroth et al., 2011).

2.2.7. History of Social Life Cycle Assessment: "Origins, Milestones, and Evolution of S-LCA"

The origins of Social Life Cycle Assessment (S-LCA) trace back to the mid-1990s, when researchers began exploring the integration of social and socioeconomic (S&SE) criteria into life cycle thinking. Early efforts, such as the 1993 SETAC Report, proposed a social welfare impact category, laying the groundwork for S-LCA (UNEP, 2020). Significant development occurred in 2003 when the UNEP/SETAC Life Cycle Initiative established a Task Force to integrate social criteria into LCA. This led to the publication of the first *Guidelines for Social Life Cycle Assessment* in 2009, which provided a foundational framework for S-LCA (Sureau et al., 2018). Over the years, S-LCA has evolved to address the "People" pillar of sustainability, complementing Environmental LCA (E-LCA) and Life Cycle Costing (LCC) within the broader Life Cycle Sustainability Assessment (LCSA) framework (UNEP, 2020). Despite its progress, S-LCA remains a developing methodology, with ongoing research addressing challenges such as system boundaries, indicator selection, and impact assessment methods (Sureau et al., 2018).

Timeline of Key Milestones in S-LCA Development

- **1993**: The SETAC Report, *Conceptual Framework for Life Cycle Impact Assessment*, proposed a social welfare impact category, marking one of the earliest attempts to incorporate social considerations into life cycle thinking (UNEP, 2020).
- **Mid-1990s**: Research into S-LCA began, with various teams globally developing and publishing methods and case studies (Sureau et al., 2018).
- **2003**: The UNEP/SETAC Life Cycle Initiative established a Task Force to integrate social criteria into LCA, recognizing the need for a structured approach to address social impacts (UNEP, 2020).
- **2009**: The first *Guidelines for Social Life Cycle Assessment* were published under the UNEP/SETAC Life Cycle Initiative. These guidelines provided a foundational framework for conducting S-LCA, focusing on goal and scope definition and life cycle inventory (Sureau et al., 2018).
- **2013**: The *Methodological Sheets for Social Life Cycle Assessment* were published, offering practical guidance on defining impact subcategories, indicators, and data sources (UNEP, 2020).
- **2015**: The United Nations Sustainable Development Goals (SDGs) were launched, emphasizing social issues and creating a global framework that aligned closely with S-LCA objectives (UNEP, 2020).
- **2016**: The *Handbook for Product Social Impact Assessment (PSIA)* was published, building on the UNEP/SETAC Guidelines and Methodological Sheets to provide a practical method for assessing social impacts at the product level (UNEP, 2020).

- **2018**: A special issue on S-LCA in *The International Journal of Life Cycle Assessment* featured around 30 papers, reflecting the growing interest and research in the field (UNEP, 2020).
- **2020**: The updated *Guidelines for Social Life Cycle Assessment of Products and Organizations* were released, refining the methodology and addressing emerging challenges (UNEP, 2020).
- **2021**: The *Methodological Sheets* were updated, providing further clarity and practical tools for conducting S-LCA (UNEP, 2020).
- **2022**: Pilot projects based on the 2020 Guidelines were conducted, offering insights into the practical application of S-LCA and highlighting areas for further improvement (UNEP, 2020).

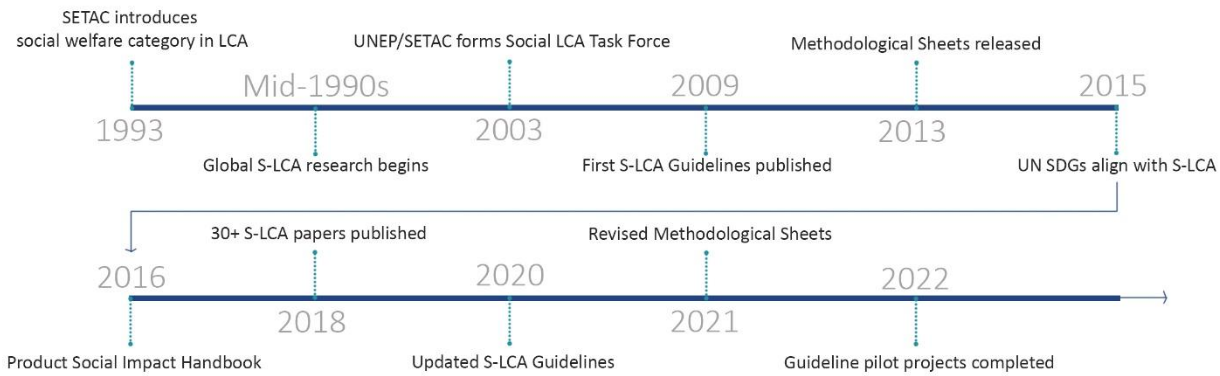


Figure 12 - History of S-LCA - Source: Author, adapted from Sureau et al., (2018) and UNEP, (2020)

2.2.8. Challenges and Gaps in the Implementation of Social Life Cycle Assessment (S-LCA)

Despite the increasing global emphasis on sustainability assessments, Social Life Cycle Assessment (S-LCA) remains the least mature and least commonly applied pillar within the broader Life Cycle Sustainability Assessment (LCSA) framework. According to Valdivia et al. (2021), the implementation of LCSA, which encompasses environmental (LCA), economic (LCC), and social (S-LCA) assessments, faces several integration and methodological challenges. Among these, S-LCA lags behind due to limited consensus on impact pathways, inconsistent system boundaries, unclear functional units, and weak stakeholder involvement. A qualitative analysis presented in the paper highlights that while environmental LCA is well-established and widely used, the tools, data, and maturity level of S-LCA remain underdeveloped, hindering its practical application and comparability across studies. Moreover, most LCSA applications either omit the social pillar or do not fully align with the ISO 14040 standard, resulting in fragmented and often incomplete sustainability assessments. The authors argue that without further methodological development and harmonization, particularly in the social domain, the LCSA framework cannot be fully operationalized to inform sustainable decision-making effectively(Valdivia et al., 2021).

Figure 13 - Maturity levels and data availability of life cycle approaches (Valdivia et al., 2021, p. 3)

In line with the thesis objective of developing a simplified and user-friendly S-LCA methodology, Gómez-Garza et al. (2024) conducted a systematic review of LCA applications in small and medium enterprises (SMEs), revealing substantial barriers and enablers for broader adoption. The study, which reviewed 61 academic papers over 20 years, identified three primary obstacles to LCA use in SMEs: (1) the lack of trained internal personnel, (2) the lack of data, and (3) the high cost of implementation. Notably, none of the reviewed SMEs conducted LCA initiatives independently; all participated through external funding or academic collaborations. To address these barriers, the authors emphasized the value of simplified LCA approaches, which can lower entry thresholds by minimizing complexity and reducing data requirements. Additionally, cluster-based LCA initiatives and narrowed scopes (such as cradle-to-gate) were highlighted as key enablers, enabling SMEs to collaboratively access shared resources and focus on manageable system boundaries. These findings underscore the necessity of tailored, accessible LCA tools for non-expert users, validating the motivation behind this thesis to propose a simplified and educationally-oriented S-LCA framework (Gómez-Garza et al., 2024).

2.2.9. The Influence of S-LCA Results on Decision-Making Processes

The findings from Social Life Cycle Assessment (S-LCA) or Social Life Cycle Inventory (S-LCI) studies play a crucial role in informing decision-making processes that involve diverse stakeholders with varying levels of expertise and backgrounds. Depending on the study's objectives and scope, S-LCA or S-LCI outcomes can guide various applications, including product development and design, strategic planning, communication and marketing, as well as the identification of both positive and negative social impacts(ISO 14075, 2024).

Additionally, S-LCA results contribute to enhancing and expanding the social responsibility of organizations within the analyzed product system. By identifying and addressing potential social risks in the product life cycle, S-LCA serves as a valuable tool for mitigating adverse social impacts and fostering more sustainable business practices (ISO 14075, 2024).

2.2.10. Uses of S-LCA

S-LCA can be used for a variety of purposes, including:

1. **Identifying Social Hotspots**: S-LCA helps identify areas in the product's life cycle where social risks are highest, such as regions with poor labor laws or industries with high rates of worker exploitation.
2. **Supporting Decision-Making**: S-LCA provides data that can inform decisions about product design, supply chain management, and corporate social responsibility strategies.

3. **Human Rights Due Diligence**: S-LCA can be used to assess and manage human rights risks in a company's operations and supply chain, in line with international frameworks such as the UN Guiding Principles on Business and Human Rights.
4. **Communicating Social Performance**: S-LCA results can be used to communicate a company's social performance to stakeholders, including consumers, investors, and regulators.
5. **Supporting Sustainable Development Goals (SDGs)**: S-LCA aligns with several SDGs, such as decent work and economic growth (Goal 8), reduced inequalities (Goal 10), and responsible consumption and production (Goal 12) (UNEP, 2020).
6.

Figure 14 - The S-LCA impact subcategories are linked to the 17 SDGs. The most prominent ones are presented (UNEP, 2020, p. 24).

2.2.11. S-LCA Implementation Guidelines, Methodology, and Tools

Several key resources have been developed to support the application of S-LCA. The Guidelines for Social Life Cycle Assessment of Products and Organizations (2020) remain a cornerstone, providing a comprehensive framework for conducting S-LCA. These guidelines are complemented by the Methodological Sheets (2021), which offer practical definitions, indicators, and data sources for each impact subcategory (Sureau et al., 2018). Additionally, pilot projects based on the 2022 Guidelines for Social Life Cycle Assessment of Products and Organizations have provided valuable insights into the practical application of S-LCA, further refining its methodologies (Traverso et al., 2022).

A major recent development is the publication of ISO 14075:2024 (Environmental management — Principles and framework for social life cycle assessment), which establishes standardized principles for S-LCA implementation. Together, UNEP 2020 and ISO 14075 serve as the most authoritative guidelines and methodologies for applying S-LCA in practice.

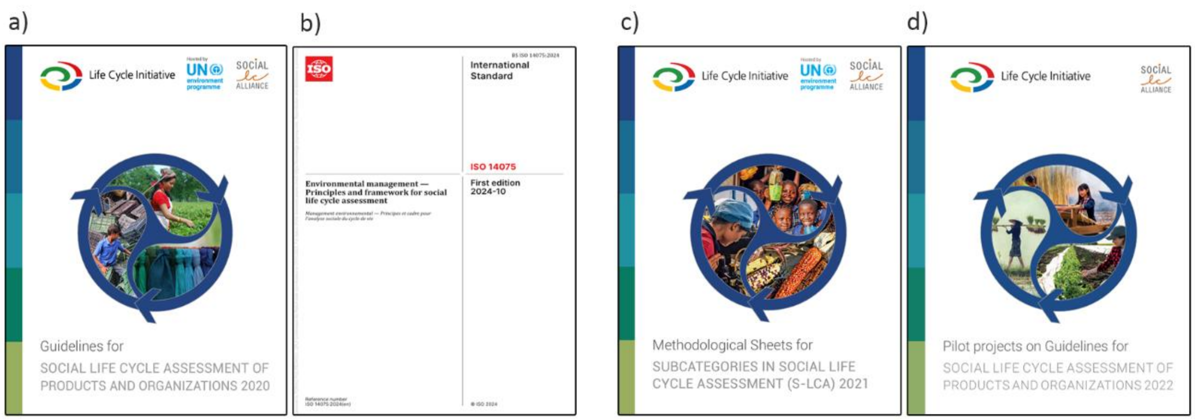


Figure 15 - Key international references supporting Social Life Cycle Assessment (S-LCA) implementation: (a) and (b): Guidelines providing standardized frameworks and principles for S-LCA. (c) and (d): Implementation supporters offering practical tools, indicators, and case-based validation (Source: Author, 2025).

2.3. Affordable and Social Housing

2.3.1. Affordable and Social Housing Definitions (Global, EU and Italy)

Global

Decent housing is a fundamental human necessity and an essential component of the right to an adequate standard of living for all. This right is acknowledged in various international frameworks, including the Universal Declaration of Human Rights and the International Covenant on Economic, Social, and Cultural Rights. Ensuring access to adequate and affordable housing plays a vital role in fostering inclusive and economically mixed communities, where residents benefit from quality services, infrastructure, and employment opportunities. Conversely, poor housing conditions can negatively impact social equity, public health, safety, and inclusion in urban areas (UN-Habitat, 2019).

One of the major obstacles associated with global urbanization is the difficulty in providing sufficient and affordable housing. Affordability, now recognized as a key indicator of housing adequacy under SDG 11.1.1, an extension of the Millennium Development Goals, remains a pressing issue. Data from the UN Global Sample of Cities highlights that a significant portion of the population struggles to afford housing. In low-income nations, families must either save nearly eight years' worth of income to purchase a typical home or allocate over a quarter of their monthly earnings toward rent (UN-Habitat, 2019).

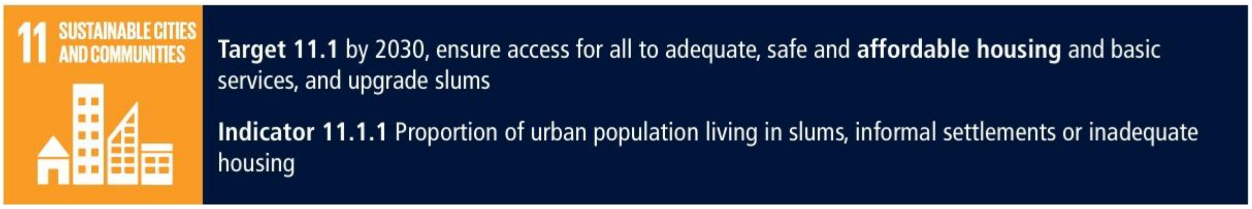


Figure 16 - SDG11, Target 11.1 and Indicator 11.1.1 (UN-Habitat, 2019, p. 2)

Affordable housing refers to well-built homes in suitable locations that are reasonably priced, allowing individuals and families to still afford other essential living expenses. Several elements influence housing affordability, including land prices, infrastructure costs, and interest rates. Affordability is typically assessed by comparing housing costs to household income. One common metric is the "house price-to-income ratio," which indicates how many years of the average income are needed to purchase an average-priced home. Another key indicator is the ratio of median annual rent to median annual income of renter households, providing insight into rental affordability (UN-Habitat, 2019).

According to the World Bank and UN-Habitat, a widely accepted guideline for affordability is that housing-related costs, including rent or mortgage payments, taxes, and insurance, should not exceed 30% of a household's income. Government action plays a crucial role in ensuring that the housing market remains accessible, equitable, and dynamic. Through effective policies and targeted support, governments can help facilitate the construction of housing that accommodates a range of income levels. In the absence of such intervention, private developers may prioritize more profitable projects, often producing homes that are too expensive for low-income families or located far from employment opportunities and essential services. This can exacerbate urban inequality. Therefore, housing affordability is central to promoting inclusive, livable, and economically resilient cities(UN-Habitat, 2019).

EU

Housing affordability is broadly understood in Europe as the share of a household's income spent on housing costs, though no universally accepted benchmark exists. One common approach suggests that households allocating more than 30% of their gross income to housing are considered burdened, while Eurostat considers housing 'overburdened' when over 40% of disposable income (after housing allowances) goes toward costs such as rent, mortgage interest, utilities, maintenance, and insurance. The concept of 'affordable housing' has Anglo-Saxon roots, generally referring to sub-market prices for low-income households, as seen in the United Kingdom's definition, encompassing both social rented and intermediate housing for those whose needs are not met by the market. Despite variations in definitions, public sentiment across Europe reflects rising concern: about one-third of households regard their housing costs as a heavy or somewhat heavy burden, and Eurobarometer surveys consistently reveal negative views on current and future affordability (Pittini, 2016).

Affordable housing can be broadly categorized into three types. First, **social housing** may be owned by municipalities, regions, or other public bodies, and often features income-based rents or cost-based rents covering maintenance and renovation. Second, **affordable rental housing** in the private sector can involve social rental agencies, charitable organizations, company-provided housing, or regulated market options supported by housing allowances or public funding. Lastly, **affordable home ownership** includes housing in formerly public buildings or private limited-profit housing, which can be subsidized through individual loans, tax measures, or other financial arrangements; in some models, subsidized rental homes eventually transfer ownership to tenants once certain conditions are met (Bauer, 2018).

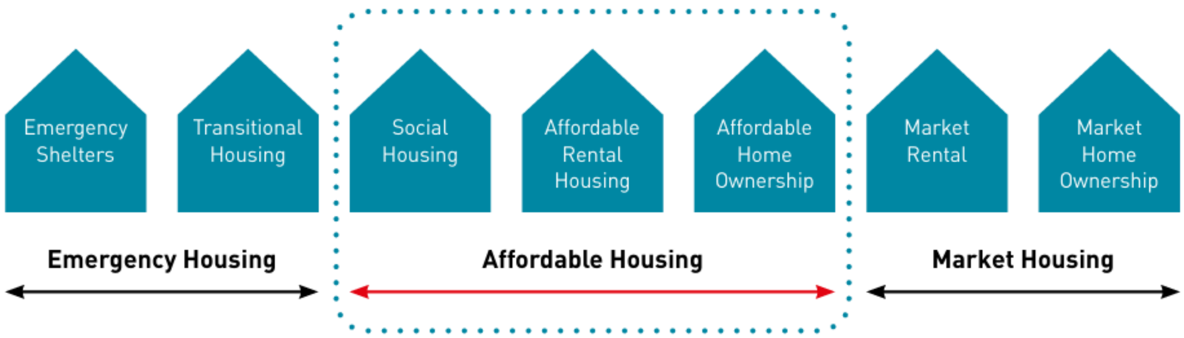


Figure 17 - EU Housing types (Bauer, 2018, p. 8).

Italy

In Italy, social and affordable housing is an evolving concept shaped by both historical housing policies and contemporary economic challenges. The Italian social housing model has traditionally relied on regional and municipal governance rather than direct state intervention. Central government retains control over policy and financial resources but delegates the implementation of social housing to local authorities.

Italy's housing affordability issue is complex, with affordability concerns not worsening as drastically as in other OECD countries. However, housing deprivation remains a significant problem, particularly among low-income homeowners, while private-sector renters face affordability challenges comparable to the OECD average. Overcrowding and urban decay persist, especially in the southern regions, while homelessness remains a pressing concern.

The country's approach to social housing differs from Northern European models that prioritize large-scale public housing stocks. Instead, Italy's model is characterized by a mix of ownership, private rental initiatives, and cooperative housing. Various housing initiatives, such as the **National Recovery and Resilience Plan (NRRP)**, aim to expand housing accessibility while integrating environmental and social sustainability efforts. The **Superbonus 110%** initiative, for instance, provides tax incentives for energy efficiency renovations, reflecting the country's strategy to integrate housing policies with broader ecological transitions.

The connection between affordable housing and energy transition is crucial in Italy's urban planning. Buildings account for nearly **40% of CO_2 emissions** in cities, making energy-efficient housing a key aspect of the country's environmental policies. The push for **green housing initiatives**, supported by cooperative housing models and energy communities, aims to reduce the environmental impact while fostering social innovation. The role of housing cooperatives is particularly notable, as they not only provide housing but also engage in community-driven sustainability projects, such as energy-efficient building renovations and renewable energy installations (OECD/Triennale de Milan, 2023).

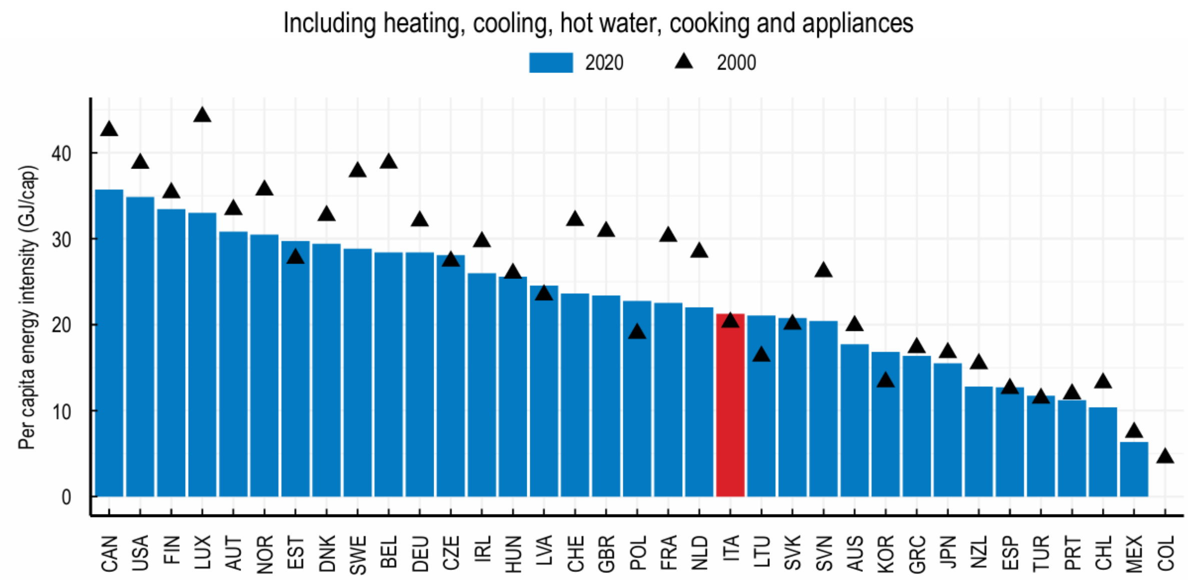


Figure 18 - Per capita energy use from residential housing (OECD/Triennale de Milan, 2023, p. 21).

Despite these efforts, the Italian housing system faces structural challenges, including **fragmented land-use policies**, limited new construction, and bureaucratic inefficiencies that hinder the expansion of social housing. Furthermore, financialization in the private rental market and the lack of a robust public housing stock continue to pose challenges to long-term housing affordability (OECD/Triennale de Milan, 2023).

2.3.2. The role of affordable housing in sustainable urban development

Affordable housing plays a crucial role in promoting sustainable urban development by ensuring that housing policies are integrated with broader economic, social, and environmental strategies. By embedding affordable housing initiatives into urban development plans, cities can create long-term socioeconomic benefits, including improved standards of living, increased employment opportunities, and strengthened economic resilience. Housing is more than just shelter; it is a fundamental part of a city's infrastructure and a determinant of economic growth, social inclusion, and environmental sustainability. Therefore, national and local governments must take an active role in formulating policies that address housing affordability, particularly for vulnerable populations, by implementing regulatory frameworks and financial mechanisms that encourage sustainable housing solutions (UN-Habitat, 2019).

Incorporating sustainability in affordable housing construction and urban planning is key to achieving long-term affordability and climate resilience. Investments in energy-efficient housing and resource-efficient building practices can reduce utility costs for households, making housing more affordable in the long run. This approach not only ensures cost-effective living solutions for low-income populations but also contributes to environmental sustainability by reducing the housing sector's carbon footprint. Moreover, sustainable housing initiatives, such as integrating renewable energy sources and green infrastructure, can help cities adapt to climate change and mitigate environmental risks. By aligning affordable housing strategies with urban sustainability goals, policymakers can foster livable, inclusive, and resilient cities that accommodate the needs of all social groups while promoting environmental responsibility and economic prosperity (UN-Habitat, 2019).

2.3.3. The European Union's policies and recommendations on access to adequate, affordable, and energy-efficient housing within the framework of sustainable development

Housing is a fundamental necessity that directly impacts social well-being, economic stability, and environmental sustainability. Recognizing this, the European Parliament resolution on "Decent and Affordable Housing for All" (C 456/145, 21 January 2021) addresses key housing challenges across the European Union (EU) and proposes comprehensive policies and recommendations aimed at ensuring adequate, affordable, and energy-efficient housing for all citizens. The resolution reflects a multifaceted approach that integrates social rights, economic development, and environmental sustainability within EU housing policies (European Parliament, 2021).

The resolution is structured into three key components:

1. References that serve as the legal and policy foundation, which outline the treaties, international commitments, and fundamental rights that justify EU intervention in housing policy.

2. Statements that provide a strong justification for the resolution, highlighting the severe housing affordability crisis, energy poverty, and increasing homelessness rates in the EU.

3. Policy proposals and recommendations, which suggest targeted actions to improve housing affordability, promote energy efficiency, and enhance urban resilience (European Parliament, 2021).

The resolution strongly justifies the need for action by addressing the intersection between the housing crisis, energy poverty, and climate change. The key challenges include:

1. High Energy Consumption and CO_2 Emissions from Buildings

- The EU's building sector accounts for nearly 40% of total CO_2 emissions.
- Many older homes are energy inefficient, leading to high carbon footprints and wasted energy resources.
- The lack of renovation in the housing sector makes achieving the EU's climate neutrality goals by 2050 more difficult.

2. Energy Poverty and Rising Utility Costs

- Millions of EU citizens live in energy poverty, where they cannot afford proper heating, cooling, or electricity.
- Winter energy disconnections leave vulnerable households without heating, increasing health risks and worsening living conditions.
- Older homes often lack proper insulation, leading to excessive energy costs for low-income households.

3. The Link Between Poor Housing and Health Risks

- Cold, damp, and energy-inefficient homes lead to respiratory diseases and other health problems.
- The EU estimates that inadequate housing costs its economies EUR 195 billion annually, largely due to health-related impacts.

4. Unequal Access to Energy Efficiency Measures

- Low-income households cannot afford energy renovations, keeping them in a cycle of high energy bills and inefficient homes.
- Rental market issues prevent energy efficiency improvements, as landlords often avoid renovation investments.

5. The Climate Crisis and the Need for Sustainable Urban Development

- Housing is directly linked to climate mitigation efforts, requiring smart urban planning and energy-efficient housing solutions.
- The Renovation Wave and Green Deal aim to reduce emissions, but more financial and regulatory support is needed (European Parliament, 2021).

CHAPTER 3- METHODOLOGY

The first objective of this thesis is to develop a simplified and User-friendly S-LCA methodology suitable for educational purposes and practical use by students and beginner practitioners.

Many individuals and organizations face significant barriers to implementing S-LCA, including limited access to training, methodological complexity, and resource constraints (Gómez-Garza et al., 2024). A simplified, user-friendly framework can help bridge this gap and support broader adoption and understanding of S-LCA.

To achieve this objective, this research draws upon the two most authoritative and internationally recognized S-LCA guidelines, which were reviewed in detail in Chapter 2 (Literature Review):

- "*Guidelines for Social Life Cycle Assessment of Products and Organizations (2020)*", published by the United Nations Environment Programme (UNEP).
- "*Environmental management — Principles and framework for social life cycle assessment (ISO 14075:2024)*", issued by the International Organization for Standardization (ISO).

The methodology chapter begins by providing a brief overview of S-LCA and its general framework as presented in both *UNEP* and *ISO 14075:24*. It then introduces the four core phases of S-LCA.

To build the simplified methodology, a structured scientific comparison of the two selected guidelines was designed and applied across each phase of S-LCA. The outcome of this methodological process is a set of comparative tables that systematically analyze the implementation steps outlined in both guidelines. These tables, presented in Chapter 4 as part of the research results, serve as the evidence base for constructing a comprehensive, step-by-step, simplified, and user-friendly S-LCA methodology.

3.1. Scientific Comparative Method

The comparative method used in this thesis is inspired by the qualitative research design applied by **Masoodi (2017)** in her work **on comparing research approaches**. Her methodology integrates principles from both **Grounded Theory and Phenomenology** and provides a structured framework for qualitative comparative analysis. Masoodi's approach involves a detailed examination of key research components, such as the research question, the role of the literature review, data collection strategy, and analysis method, under each theoretical paradigm, followed by a systematic comparison based on similarities and differences (Masoodi, 2017).

Adapting this approach, the current thesis applies a comparative qualitative method to evaluate and contrast the *UNEP* and *ISO 14075* S-LCA guidelines. As in Masoodi's framework, the comparison follows a structured sequence:

- **Explanation and summary of key concepts of S-LCA Phase by phase**, based on UNEP and ISO
- **Identification and definition of implementation steps** for each of the four S-LCA phases.
- **Development of comparative tables** that assess each step across both guidelines in terms of **availability, similarity, and difference (in Chapter 4)**.

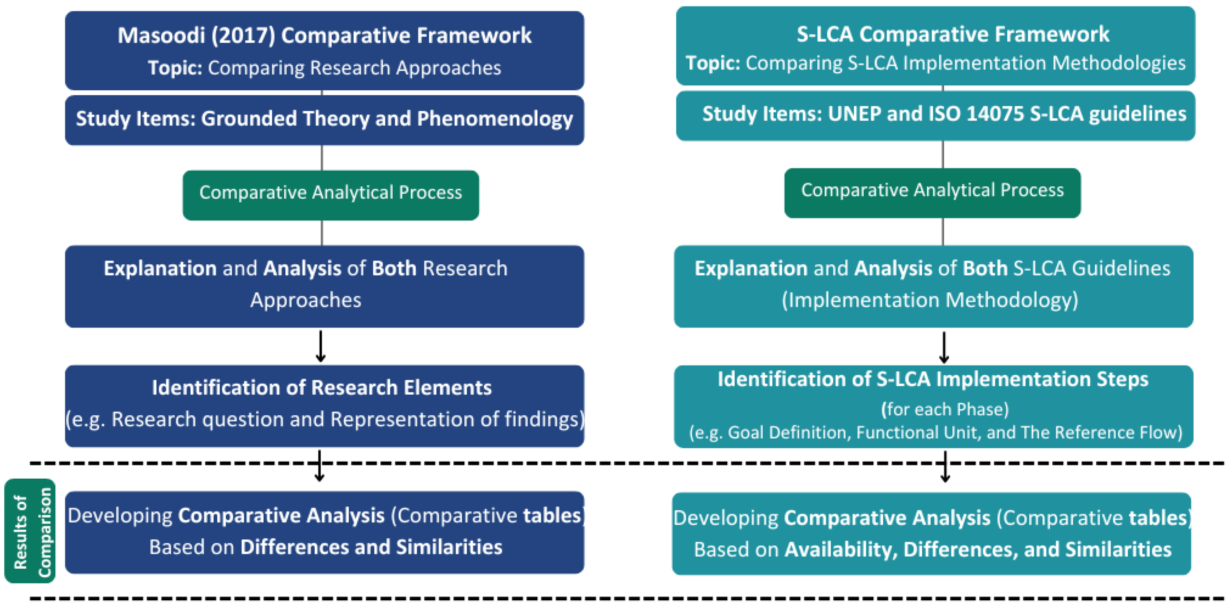


Figure 19 - Comparative Analytical Process: Adapting Masoodi (2017) Qualitative Methodology to S-LCA Guidelines Comparison (Source: Author, 2025).

These comparative tables, although developed through the methodology explained in this chapter, are not included here. Instead, they are presented in Chapter 4 as a core part of the study's findings. They serve as a transparent, evidence-based foundation for the creation of the simplified S-LCA implementation tables and offer an accessible structure, particularly suitable for academic, research, and small business environments where users may have limited prior knowledge or technical capacity.

3.2. General overview of S-LCA

3.2.1. Definition and Phases of S-LCA

"Social Life Cycle Assessment (S-LCA) is a methodology to assess the social impacts of products and services across their life cycle (e.g., from extraction of raw material to the end-of-life phase, e.g., disposal)."(UNEP, 2020, p. 20).

S-LCA studies comprise the following four phases:

— Goal and scope definition;

— Social life cycle inventory analysis;

— Social life cycle impact assessment;

— interpretation (UNEP, 2020).

3.2.2. S-LCA Principles

S-LCA is guided by several key principles that ensure a structured and transparent approach to assessing the social impacts of products throughout their life cycle. According to BS ISO 14075:2024, the fundamental principles of S-LCA are:

1. Life Cycle Perspective:

S-LCA considers the entire life cycle of a product, from raw material extraction to final disposal, ensuring that social impacts are evaluated at every stage. This prevents shifting social burdens between different life cycle phases.

2. Social Focus:

The methodology prioritizes social aspects and impacts, distinguishing it from other life cycle assessment tools, such as environmental LCA or life cycle costing. S-LCA can be combined with other tools for a comprehensive sustainability assessment.

3. Relative Approach and Functional Unit:

S-LCA uses a relative approach, structured around a functional unit, which defines the scope of analysis and provides a basis for comparisons.

4. Iterative Approach:

S-LCA follows an iterative process, meaning that each phase informs and refines subsequent phases. This ensures accuracy and comprehensiveness throughout the assessment.

5. Transparency:

Sufficient and relevant information must be disclosed to allow decision-makers to interpret results with confidence. Transparency also supports reproducibility and comparability across studies.

6. Comprehensiveness:

S-LCA aims to include all relevant aspects of human well-being, human rights, dignity, and ethical behavior. It accounts for diverse social attributes to identify potential trade-offs.

7. Scientific Approach:

S-LCA is based on scientific methods and evidence, ensuring that results are reliable and robust.

8. Recognition of International Conventions:

S-LCA aligns with key international human rights frameworks, including the Universal Declaration of Human Rights and International Labour Organization (ILO) standards (ISO 14075, 2024).

3.2.3. Key terms of S-LCA

Key terms essential for understanding the framework of S-LCA are:

1. **Stakeholder Categories, Impact Categories, and Impact Subcategories**

In S-LCA, the assessment focuses on the impacts on different stakeholder categories, which include workers, local communities, consumers, value chain actors, society, and children. These stakeholders are directly or indirectly affected by the activities of organizations involved in the product's life cycle. The impacts are further classified into impact categories and subcategories. Impact categories are broad themes such as human rights, working conditions, health and safety, and cultural heritage. Subcategories are more specific issues within these themes, such as child labor, fair wages, or access to education. Each subcategory is assessed using impact indicators, which are measurable variables that provide information on the social conditions related to the product or service (UNEP, 2020).

For example, under the impact category of Working Conditions, subcategories might include fair wages, working hours, and health and safety. The indicators for these subcategories could be the average wage paid, the number of hours worked per week, and the number of workplace accidents, respectively (UNEP, 2020).

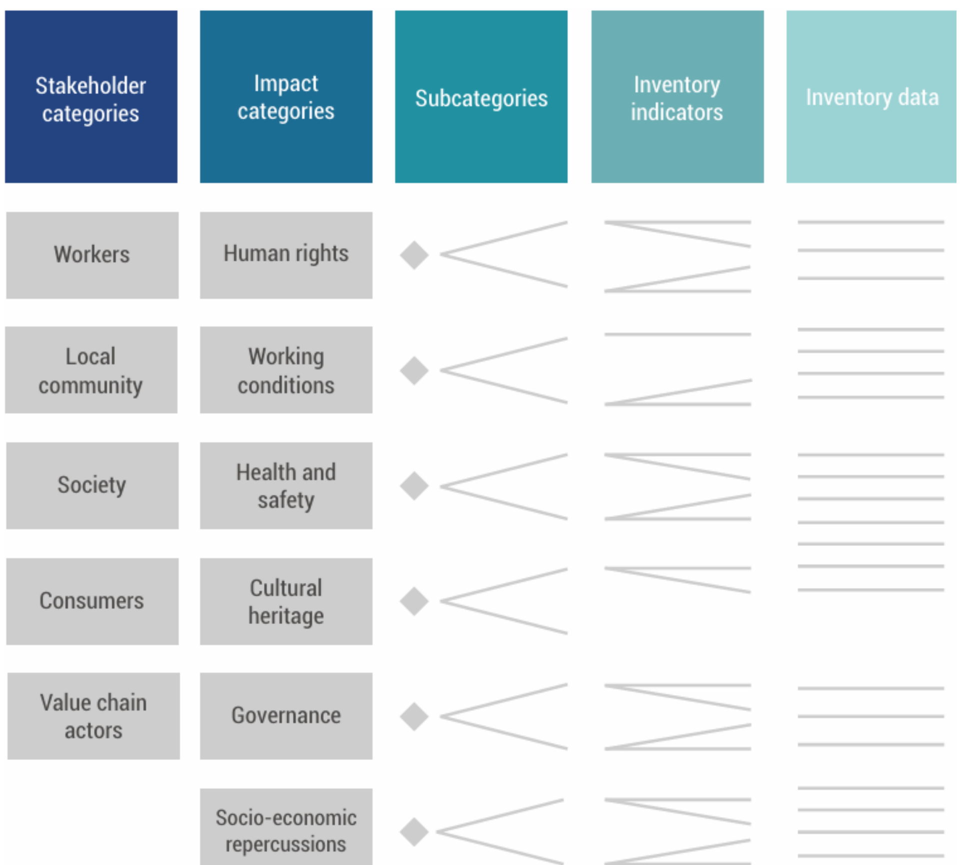


Figure 20 - Assessment system from categories to inventory data (UNEP, 2020, p. 22) .

2. Stakeholder Categories

Stakeholder categories are groups of people or entities affected by the activities of a product or organization throughout its life cycle. The S-LCA Guidelines identify six primary stakeholder categories:

1. Workers: Employees involved in the production, manufacturing, and distribution of the product.

2. Local Community: People living in areas affected by the product's life cycle activities (e.g., mining, manufacturing).

3. Consumers: End-users of the product or service.

4. Value Chain Actors: Entities involved in the supply chain, such as suppliers, distributors, and contractors.

5. Society: Broader societal groups, including governments, NGOs, and the general public.

6. Children: A specific subgroup often considered due to their vulnerability, particularly in contexts like child labor (UNEP, 2020).

Impact Categories

Impact categories are broad themes that represent the types of social impacts assessed in S-LCA. These categories are linked to the stakeholder categories and include:

1. Human Rights: Impacts related to the protection and promotion of human rights.

2. Working Conditions: Impacts related to fair wages, working hours, health, and safety.

3. Health and Safety: Impacts on the physical and mental well-being of stakeholders.

4. Cultural Heritage: Impacts on the preservation or destruction of cultural practices and heritage.

5. Governance: Impacts related to transparency, corruption, and ethical business practices.

6. Socioeconomic Repercussions: Impacts on economic development, poverty, and inequality (UNEP, 2020).

3. Subcategories

Subcategories are specific issues within each impact category. They provide a more detailed focus for the assessment. For example:

- **Human Rights:** Subcategories include forced labor, child labor, and discrimination.
- **Working Conditions:** Subcategories include fair wages, working hours, and freedom of association.
- **Health and Safety:** Subcategories include workplace accidents, exposure to hazardous materials, and access to healthcare.
- **Cultural Heritage:** Subcategories include respect for indigenous rights and protection of cultural sites.

- **Governance:** Subcategories include corruption, bribery, and transparency in decision-making.
- **Socioeconomic Repercussions:** Subcategories include job creation, poverty alleviation, and community development (UNEP, 2020).

Stakeholder categories	Worker	Local community	Value chain actors (not including consumers)	Consumer	Society	Children
Subcategories	1. Freedom of association and collective barganing 2. Child lbor 3. Fair salary 4. Working hours 5. Forced labor 6. Equal opportunities/discrimination 7. Health and safety 8. Social benefits/social security 9. Employment relationship 10. Sexual harassment 11. Smallholders including farmers	1. Access to material resources 2. Access to immaterial resources 3. Delocalization and migration 4. Cultural heritage 5. Safe and healthy living conditions 6. Respect of indigenous rights 7. Community engagement 8. Local employment 9. Secure living conditions	1. Fair competition 2. Promoting social responsibility 3. Supplier relationships 4. Respect of intellectual property rights 5. Wealth distribution	1. Health and safety 2. Feedback mechanism 3. Consumer privacy 4. Transparency 5. End-of-life responsibility	1. Public commitments to sustainability issues 2. Contribution to economic development 3. Prevention and mitigation of armed conflicts 4. Technology development 5. Corruption 6. Ethical treatment of animals 7. Poverty alleviation	1. Education provided in the local community 2. Health issues for children as consumers 3. Children concerns regarding marketing practices

Table 2 - List of stakeholder categories and impact subcategories (UNEP, 2020, p. 23).

4. Inventory Indicators

Inventory indicators are measurable variables used to assess the social conditions related to each subcategory. They provide quantitative or qualitative data that can be analyzed to determine the presence and severity of social impacts. Examples include:

- Forced Labor: Number of reported cases of forced labor in the supply chain.
- Fair Wages: Percentage of workers paid above the minimum wage.
- Workplace Accidents: Number of accidents per 1,000 workers.
- Respect for Indigenous Rights: Presence of policies protecting indigenous land rights.
- Corruption: Number of corruption cases reported in the organization.
- Job Creation: Number of jobs created in a local community (UNEP, 2020).

5. Inventory Data

Inventory data refers to the actual data collected for each inventory indicator. This data can come from various sources, such as company reports, surveys, government statistics, or third-party audits. Examples include:

- Forced Labor: Data from supply chain audits show zero cases of forced labor.
- Fair Wages: Payroll data indicates that 90% of workers earn above the minimum wage.
- Workplace Accidents: Safety records show 5 accidents per 1,000 workers in the past year.
- Respect for Indigenous Rights: Documentation of agreements with indigenous communities to protect their land.
- Corruption: Internal audit reports show no cases of bribery in the last 5 years.
- Job Creation: Employment statistics show 500 new jobs created in a rural community (UNEP, 2020).

6. Potential Social Impact:

The likely presence of a social impact resulting from the activities or behaviors of organizations linked to the product's life cycle. This is often based on indicators such as social risks or performance metrics.

7. Actual Social Impact:

The real, observed positive or negative consequences of an activity on stakeholders. This is based on verified data and observed outcomes.

8. Social Risk:

The probability of adverse social effects occurring due to an organization's activities or business relationships. For example, the risk of child labor in a supply chain.

9. Social Hotspot:

A location or activity in the product's life cycle where a social issue or risk is likely to occur. For example, a factory in a region with poor labor laws might be a hotspot for worker exploitation.

10. Social Footprint:

The overall result of an S-LCA study represents the total social impacts of a product or organization.

11. Social Handprint:

The positive social impacts resulting from changes made to improve social conditions, such as implementing fair wage policies or reducing child labor.

12. Main Approaches in S-LCA

When starting an S-LCA, the first step is to define the goal and scope of the study. This includes identifying the product or organization to be assessed, the stakeholders involved, and the specific social issues to be examined.

There are two main approaches to conducting S-LCA:

1. **Reference Scale Approach (Type I)**: This approach focuses on assessing social performance or social risk. It uses reference scales to evaluate how well an organization or product performs against certain benchmarks, such as compliance with local laws or international standards. For example, a company might be rated on a scale from-2 (non-compliant) to +2 (best in class) based on its adherence to fair wage policies.

2. **Impact Pathway Approach (Type II)**: This approach focuses on understanding the cause-and-effect relationships between activities and social impacts. It traces the pathways through which social impacts occur, from the initial activity (e.g., poor working conditions) to the final outcome (e.g., reduced well-being). This approach is more complex and often requires detailed data on social mechanisms(UNEP, 2020).

In the ISO 14075:2024, the term **'social life cycle performance assessment'** is equivalent to the 'reference scale assessment' defined in the UNEP 2020 S-LCA guideline, while **'social life cycle impact assessment'** corresponds to 'impact pathway assessment' as outlined in the UNEP 2020 S-LCA guideline **(Traverso & Mankaa, 2025)**.

13. Positive Impacts

While S-LCA traditionally focuses on negative social impacts, it is also important to consider positive impacts. Positive impacts are benefits that improve human well-being, such as job creation, fair wages, or community development. These impacts can be direct (e.g., providing jobs) or indirect (e.g., improving local infrastructure).

Positive impacts are categorized into three types:

1. Type A: Positive social performance that goes beyond business as usual, such as paying above the minimum wage.

2. Type B: Positive social impacts through the presence of a product or company, such as creating jobs in a region with high unemployment.

3. Type C: Positive social impacts through the utility of the product, such as providing clean water or healthcare services (UNEP, 2020).

3.3. Phase 1: Goal and Scope Definition

The Goal and Scope (G&S) definition is the initial and foundational phase of a Social Life Cycle Assessment (S-LCA). In this phase, the purpose, object, and methodological framework of the study are determined. The primary objective is to provide a clear statement of the study's purpose and define its breadth and depth. This phase is critical as it significantly influences how the study will be conducted and the results that will be obtained. The G&S is often developed iteratively, meaning it may be revised due to unforeseen limitations, constraints, or new information uncovered during the study. Any modifications made during this process, along with their justification, should be documented. Stakeholder participation is strongly encouraged at this stage to ensure that the study aligns with the interests and needs of those affected by its outcomes (UNEP, 2020).

3.3.1. Goal Definition

The goal definition clarifies the purpose of the study by addressing the following questions:

- Why is the study being conducted?
- What is its intended use (e.g., decision-making, communication, improvement opportunities)?
- Who is the target audience (e.g., internal stakeholders like companies, or external stakeholders like governments, NGOs, or consumers)?
- Which stakeholders are affected by the study and its results?

The goals of S-LCA studies can vary widely, including:

- Supporting sustainable product design.
- Identifying social hotspots in products or organizations.
- Quantifying and qualifying the social performance of products to promote sustainable consumption.
- Assessing potential social improvement options along the product life cycle.
- Communicating the social performance and impacts of products to the public.

The target audience may include a wide range of stakeholders, such as trade unions, workers' representatives, consumers, governments, NGOs, and product designers. If the study is intended for public disclosure or comparative assertions, a third-party review is recommended to ensure credibility (UNEP, 2020).

3.3.2. Scope Definition

The scope definition clarifies what will be studied and how the study will be conducted. It should align with the study's goal and include the following elements:

- Object of the study: Typically, a product, service, or function (functional unit).
- Reference flow: The quantity of materials needed to produce the product or fulfill the functional unit.
- Product system: The interconnected unit processes involved in the product's life cycle, from raw material extraction to disposal.
- System boundaries: The parts of the product system included in the assessment.

- Activity variables: Measures of process activity used to compare the intensity of different processes.
- Stakeholder involvement: Identification of stakeholders and their roles in the study.
- Impact assessment method: The approach used to assess social impacts (e.g., Reference Scale or Impact Pathway).
- Data collection strategies: The type of data to be collected and how it will be gathered.
- Limitations: Any constraints or assumptions that may affect the study.

The system is partially pre-defined in terms of its scope, which is determined by various factors. These scoping decisions can be influenced by practical considerations, such as the availability of data, or by theoretical reasons, such as limiting the analysis to processes up to the factory gate when comparing identical products produced through different methods (UNEP, 2020).

3.3.3. Defining the Functional Unit

The functional unit is a foundational concept in S-LCA and other life cycle-based methodologies. It serves as a quantitative representation of the primary function or service provided by a product or system under investigation. Defining a functional unit is critical because it ensures that the study is consistent with its goal and scope, provides a basis for comparison (especially in comparative studies), and allows for the normalization of social, environmental, or economic data (UNEP, 2020).

Definition and Purpose of the Functional Unit

The functional unit defines what the product or service delivers in measurable terms (UNEP, 2020). It is not merely a description of the physical product but rather a quantification of its performance characteristics (ISO 14075, 2024). For example, instead of describing a product as "one office chair," the functional unit would specify "minimum 7 years of computer workstation seating support for 8 hours/day in a European office." (ISO 14075, 2024). This shift from physical product to functional performance ensures that the study focuses on the utility of the product rather than its material form.

The primary purpose of the functional unit is to provide a consistent basis for comparison between different product systems. This is particularly important in comparative studies, where two or more products are evaluated to determine which one performs better in terms of social, environmental, or economic impacts. By defining the functional unit clearly, researchers ensure that the products being compared are evaluated on an equivalent basis (UNEP, 2020). For instance, if comparing T-shirts, the functional unit might specify "to cover the body of one person for 70 days during two years in the context of indoor sporting activities in Norway in 2019 and 2020" (UNEP, 2020). This level of detail ensures that the comparison is meaningful and relevant.

In some Social Life Cycle Assessments (S-LCA), the functional unit can be defined in monetary terms, such as dollars or euros, instead of physical or time-based measures. This approach is especially useful when working with economic models or trade data, which are common in S-LCA databases. For example, instead of saying “one T-shirt,” the functional unit could be “the economic value of one T-shirt” or “the total value of T−shirts sold in a specific region over a year” (e.g.,20) or “the total value of T−shirts sold in a specific region over a year” (e.g.,1 million). By using a currency amount, the functional unit connects the product’s function to its economic impact, making it easier to analyze social issues like labor conditions, wages, or supply chain practices. This method ensures the study aligns with economic data and provides a broader perspective on social impacts (UNEP, 2020).

Key Characteristics of a Functional Unit

A well-defined functional unit should include the following elements:

1. Functionality: The primary purpose of the product or service. For example, a T-shirt's functionality might include covering the body, being comfortable, and drying quickly (UNEP, 2020).
2. Technical Quality: The specific attributes of the product, such as material composition (e.g., cotton), design features (e.g., short sleeves), and durability (UNEP, 2020).
3. Product Utility: Beyond its basic function, the product's utility reflects the consumer's perception of its value, which may include social or cultural factors like convenience, prestige, or aesthetics (UNEP, 2020).
4. Duration of Function: The time period over which the product is expected to perform its function. For example, a T-shirt might be expected to last for 70 days of use over two years (UNEP, 2020).
5. Location and Context: The geographical and situational context in which the product is used. For instance, a T-shirt used for indoor sporting activities in Norway in 2019 and 2020 would have a different functional unit than one used in a tropical climate (UNEP, 2020).
6. Measurability: The functional unit must be quantifiable to allow for normalization of data. This is particularly important when using S-LCA databases, which often rely on economic models and trade data (UNEP, 2020).

Importance of the Functional Unit in S-LCA

In S-LCA, the functional unit plays a crucial role in normalizing social input and output data (ISO 14075, 2024). For example, if the functional unit is defined in monetary terms (e.g., the economic value of T-shirts sold or produced over a financial year), it allows for the integration of trade models and economic input-output data into the assessment (UNEP, 2020). This is particularly useful when analyzing social impacts associated with economic activities, such as labor conditions or community well-being.

Additionally, the functional unit helps identify secondary products or services required to fulfill the primary function. For example, if the functional unit of a T-shirt includes its use over 70 days, it is necessary to consider the water and detergent required for washing during this period, as their production and use may have associated social impacts (UNEP, 2020). This holistic view ensures that the assessment captures the full scope of social implications.

Examples of Functional Units

- Example 1: "Minimum 7 years of computer workstation seating support for 8 hours/day in a European office" (ISO 14075, 2024). This functional unit focuses on the performance of the chair rather than the chair itself.
- Example 2: "4 liters of semi-gloss water-based exterior paint" (ISO 14075, 2024). This example quantifies the product in terms of its functional capacity (volume of paint) rather than its physical form.

- Example 3: "To cover the body of one person for 70 days during two years in the context of indoor sporting activities in Norway in 2019 and 2020" (UNEP, 2020). This example includes functionality, duration, location, and context.

The functional unit is a critical component of S-LCA that ensures the study is aligned with its goal and scope, provides a basis for comparison, and facilitates the normalization of data. By clearly defining the functional unit, researchers can focus on the utility and performance of the product rather than its physical attributes, enabling a more comprehensive and meaningful assessment of social impacts. Whether expressed in terms of product functionality, duration, or economic value, the functional unit serves as the foundation for a robust and credible S-LCA study (UNEP, 2020).

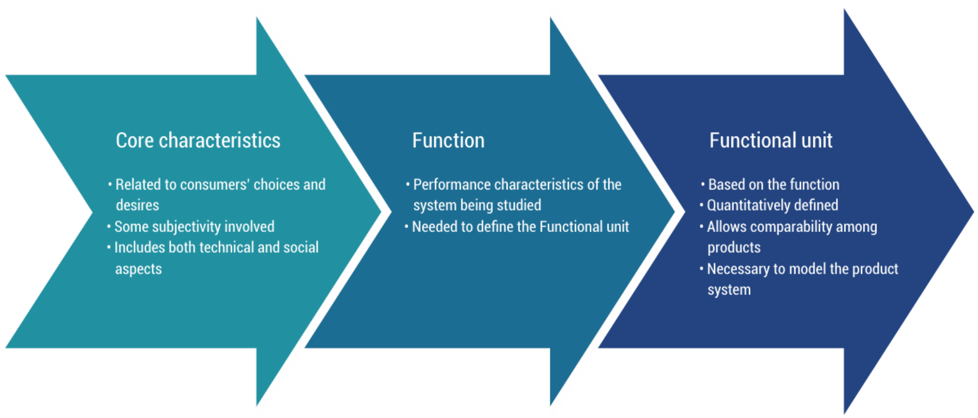


Figure 21 - Steps to identify the Functional unit (UNEP, 2020, p. 44).

3.3.4. Defining the Reference Flow

The reference flow quantifies the specific product flows required to deliver the function defined by the functional unit (UNEP, 2020). For example, if the functional unit is "to cover the body of one person for two years," the reference flow might be "2 T-shirts from Brand X" (if each T-shirt lasts one year) or "1 T-shirt from Brand Y" (if it lasts two years) (UNEP, 2020). This quantification ensures that the study accounts for the actual materials and processes needed to fulfill the function.

The reference flow is directly tied to the functional unit and helps identify the material inputs and unit processes involved in the product system. For instance, producing 2 T-shirts from Brand X would require more raw materials (e.g., cotton, water, energy) than producing 1 T-shirt from Brand Y, which could lead to different social impacts across the supply chain (UNEP, 2020).

How is the Reference Flow Used in S-LCA?

1. Linking Functional Unit to Product System:

The reference flow translates the functional unit into measurable product flows, enabling practitioners to define the product system and its boundaries. For example, in the T-shirt example, the reference flow specifies the exact number of T-shirts needed to fulfill the functional unit of covering the body for two years (UNEP, 2020).

2. Scaling Social Impacts:

In some S-LCA studies, the reference flow is used to scale social impacts to the functional unit. For example, if producing 2 T-shirts requires more labor and materials than producing 1 T-shirt, the associated social impacts (e.g., worker hours, potential labor issues) are likely to be proportionally higher (UNEP, 2020). However, not all social impacts scale linearly. For example, issues like forced labor or child labor might be flagged as present but not scaled to the reference flow due to ethical or practical reasons (UNEP, 2020).

3. Handling Aggregated Data:

When social data is only available at an aggregated level (e.g., industry averages), the reference flow helps link this data to the specific product system. For instance, if an industry reports an average rate of fatal work injuries per 100,000 workers, this data can be applied to the reference flow of a specific product if the production conditions (e.g., technology, region, legal framework) are comparable (ISO 14075, 2024).

Key Considerations for Defining the Reference Flow

1. Alignment with Functional Unit:

The reference flow must be consistent with the functional unit. For example, if the functional unit is "to cover the body for two years," the reference flow should specify the exact number of T-shirts required to achieve this (UNEP, 2020).

2. Material and Process Inputs:

The reference flow determines the material inputs (e.g., cotton, water) and process inputs (e.g., manufacturing, transportation) needed to fulfill the functional unit. These inputs are directly linked to social impacts, such as labor conditions or resource use (UNEP, 2020).

3. Handling Aggregated Data:

When using aggregated data (e.g., industry averages), the reference flow must ensure that the product system is comparable to the aggregated data in terms of technology, region, and production conditions (ISO 14075, 2024).

4. Non-Linear Social Impacts:

Some social impacts, such as forced labor or child labor, may not scale linearly with the reference flow. In such cases, practitioners may choose to flag the presence of these issues without scaling them to the reference flow (UNEP, 2020).

Examples of Reference Flows from the Sources

1. T-Shirt Example:

- Functional Unit: "To cover the body of one person for two years."

- Reference Flow: "2 T-shirts from Brand X" (if each lasts one year) or "1 T-shirt from Brand Y" (if it lasts two years) (UNEP, 2020).

2. Industry Data Example:

- Functional Unit: "Production of Product X."

Reference Flow: Industry-average fatal work injuries per 100,000 workers, if the product system is comparable to the industry in terms of technology, region, and legal framework (ISO 14075, 2024).

Why is the Reference Flow Important?

- Connects Function to Materials and Processes: The reference flow ensures that the study accounts for the actual materials and processes needed to fulfill the functional unit.
- Scales Social Impacts: It provides a basis for scaling social impacts to the functional unit, though some impacts may not scale linearly.
- Links Aggregated Data: It enables the use of industry-level data when specific data is unavailable, provided the production conditions are comparable (UNEP, 2020).

3.3.5. Defining the Product System

The product system is the collection of interconnected unit processes that make up the life cycle of a product, from raw material extraction to disposal. It is defined based on the functional unit and includes all activities, materials, and services needed to fulfill that function (UNEP, 2020).

Key Components of the Product System:

1. Unit Processes:

A unit process is the smallest element in the product system where data can be collected. It represents a specific activity or transformative step in the life cycle, such as manufacturing, transportation, or waste treatment. For example, in the T-shirt example, unit processes might include:

- Cotton farming (raw material extraction).
- Spinning and weaving (textile production).
- Sewing and finishing (garment manufacturing).
- Transportation (distribution to retailers).
- Retail (selling to consumers).
- Laundering (use phase).
- Disposal (end-of-life treatment).

Each unit process has inputs (e.g., raw materials, energy, labor) and outputs (e.g., products, emissions, waste). The geographical location and the companies or factories involved in each unit process should also be specified, as social impacts are often location-specific (UNEP, 2020).

2. Inputs and Outputs:

The product system includes all the inputs (e.g., raw materials, energy, ancillary materials, services) and outputs (e.g., products, emissions, waste) associated with each unit process. For example, the unit process of textile manufacturing might require inputs like cotton, water, electricity, and labor, and produce outputs like fabric, wastewater, and emissions (UNEP, 2020).

3. Unit Processes:

The product system is typically depicted as a process flowchart (see Figure 26), which visually represents the linkages between unit processes. The flowchart can vary in detail, depending on the complexity of the product and the goal of the study (UNEP, 2020).

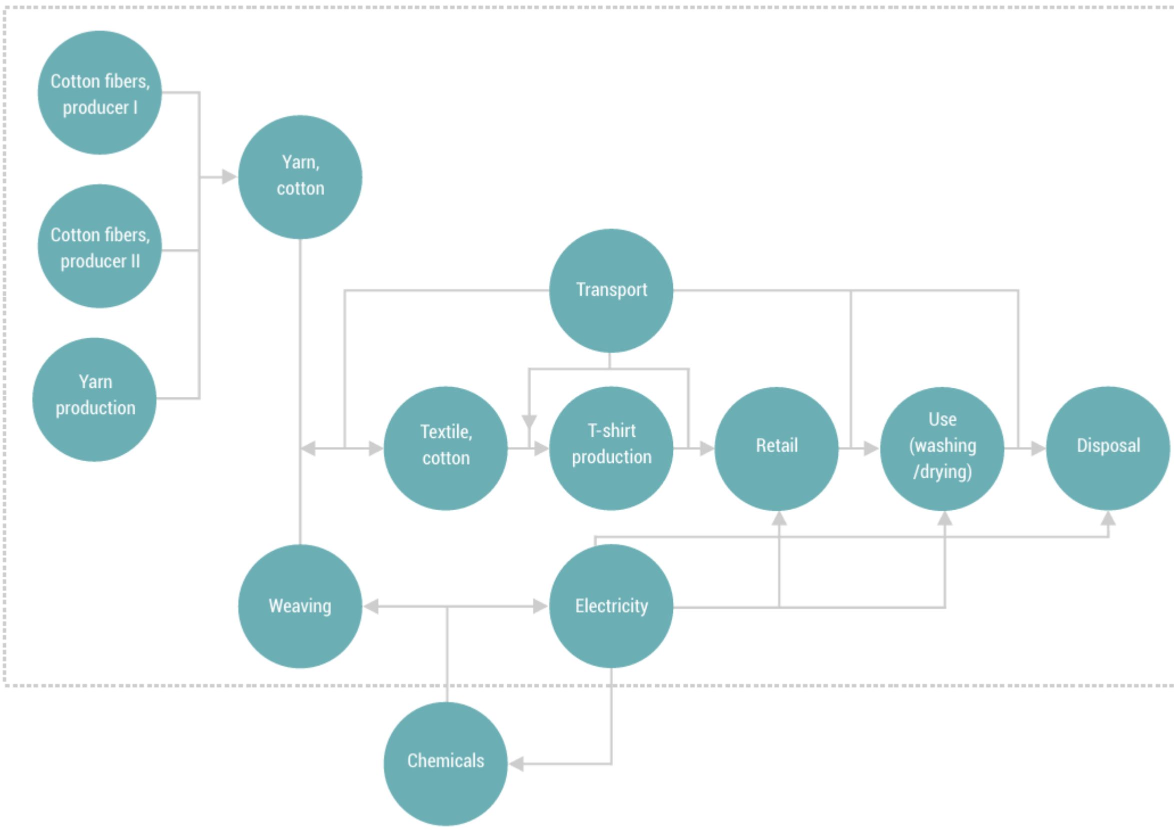


Figure 22 - A simple product system of the T-shirt (UNEP, 2020, p. 47).

Use of Input-Output Analysis in S-LCA

- Identifies social hotspots (e.g., labor-intensive processes or high-risk regions).
- Provides a framework for data collection and impact assessment.
- Ensures the study captures the full scope of social impacts across the product's life cycle.

The product system links the functional unit to the real-world processes required to fulfill it. By defining unit processes and using tools like input-output analysis, S-LCA practitioners can systematically assess social impacts throughout the product's life cycle (UNEP, 2020).

3.3.6. Identifying System Boundaries

System boundaries determine the scope of the product system being assessed, including which processes and stakeholders are included or excluded. They are defined based on the goal of the study and should follow a life cycle logic, encompassing all phases from upstream processes (e.g., raw material extraction) to downstream processes (e.g., distribution, use, and end-of-life). Ideally, the system boundaries should cover the entire life cycle (cradle to grave), but practical limitations such as data availability or resource constraints may require narrowing the scope (UNEP, 2020).

Key Components of System Boundaries

1. Foreground vs. Background Processes:

- Foreground processes: These are processes directly related to the product being studied, such as manufacturing or assembly. Specific data is often collected for these processes.
- Background processes: These are processes further upstream or downstream, such as raw material extraction or waste management. Generic data from databases is typically used for these processes (UNEP, 2020).

For example, in a T-shirt study, foreground processes might include textile manufacturing, while background processes might include cotton farming or chemical production (UNEP, 2020).

2. Physical vs. Effect Perspectives:

- Physical perspective: Focuses on the technological processes and economic flows that characterize the product's life cycle. This perspective helps define the production cycle and life cycle stages (UNEP, 2020).
- Effect perspective: Focuses on the interactions between companies, stakeholders, and their relationships. This perspective ensures that key stakeholders (e.g., workers, communities) are included in the assessment (ISO 14075, 2024; UNEP, 2020).

Both perspectives are necessary to capture the full range of social impacts, from labor conditions in factories to community well-being near raw material extraction sites.

3. Causality Perspectives:

When setting system boundaries, it is important to consider:

- The contribution of a unit process to overall social impacts, beyond just mass or energy flows.
- The representativeness of regional and sector-specific inputs.
- The social impact causality, which considers the interactions between organizations and stakeholders involved in the product life cycle (ISO 14075, 2024).

For example, a T-shirt study might exclude chemical production due to data limitations but must justify this exclusion and consider its potential social impacts (UNEP, 2020).

4. Cut-Off Criteria:

Decisions on what to include/exclude based on study goals, data availability, and social relevance. Social impacts (e.g., labor conditions) should not be excluded solely based on mass or energy flows (ISO 14075, 2024).

5. Practical Considerations:

- System boundaries are often defined iteratively.
- Exclusions must be justified (e.g., omitting chemical production due to data limitations).
- The level of detail depends on the study's goals and resources (UNEP, 2020) and (ISO 14075, 2024).

3.3.7. Activity Variable

The activity variable is a measure used in Social Life Cycle Assessment (S-LCA) to reflect the intensity of activities within each unit process of a product system. It is scaled by the output of each process and helps determine the share of a given activity associated with that process. The activity variable does not represent an impact itself but is used to compare the intensity of processes and aggregate impact assessment results (UNEP, 2020).

Key Points About the Activity Variable

1. Purpose:

- The activity variable reflects the relative significance of each unit process in the product system.
- It is used to partition impacts (e.g., working injuries) among processes based on their activity levels (e.g., worker hours per process) (UNEP, 2020).

2. Application:

- The activity variable is scaled by the output of each process. For example, if a process involves worker hours, the activity variable could represent worker hours per unit of output.
- It helps allocate social impacts proportionally across processes, ensuring that each process's contribution to the overall system is accurately represented (UNEP, 2020).

3. Use in S-LCA:

- Some studies use activity variables, while others do not. The decision to use an activity variable should be documented in the Goal and Scope of the study.
- It is particularly useful for representing the product system in a way that highlights the relative significance of each unit process (UNEP, 2020).

Why is the Activity Variable Important?

- It provides a quantitative basis for comparing the intensity of activities across processes.
- It ensures that social impacts are allocated fairly based on the share of activity each process contributes.
- It helps practitioners understand the relative importance of each process in the product system (UNEP, 2020).

3.3.8. Cut-Off Criteria

Cut-off criteria are rules used to decide which unit processes to include or exclude from the system boundaries in a Social Life Cycle Assessment (S-LCA). They help manage the scope of the study, especially when practical limitations (e.g., data availability or resource constraints) make it difficult to include all processes. The goal is to ensure that the most socially significant processes are included while maintaining transparency about what is excluded (UNEP, 2020).

Key Points About Cut-Off Criteria

1. Purpose:

- Cut-off criteria help reduce the complexity of the system by excluding less relevant processes, making the study more manageable.
- They ensure that the most socially significant processes (e.g., those with high potential for social concerns) are included, even if some less critical processes are excluded (UNEP, 2020).

2. Types of Cut-Off Criteria:

- Social Significance: Processes with high potential for social impacts (e.g., labor-intensive processes) are prioritized. This can be determined through quantitative (e.g., activity variables) or qualitative (e.g., expert judgment) approaches.
- Identical Elements: In comparative studies, processes that are identical across products can be excluded, focusing only on the differences.
- Available Resources: Processes may be excluded due to limited resources (e.g., time, budget, or data availability), but this should be avoided if possible(UNEP, 2020).

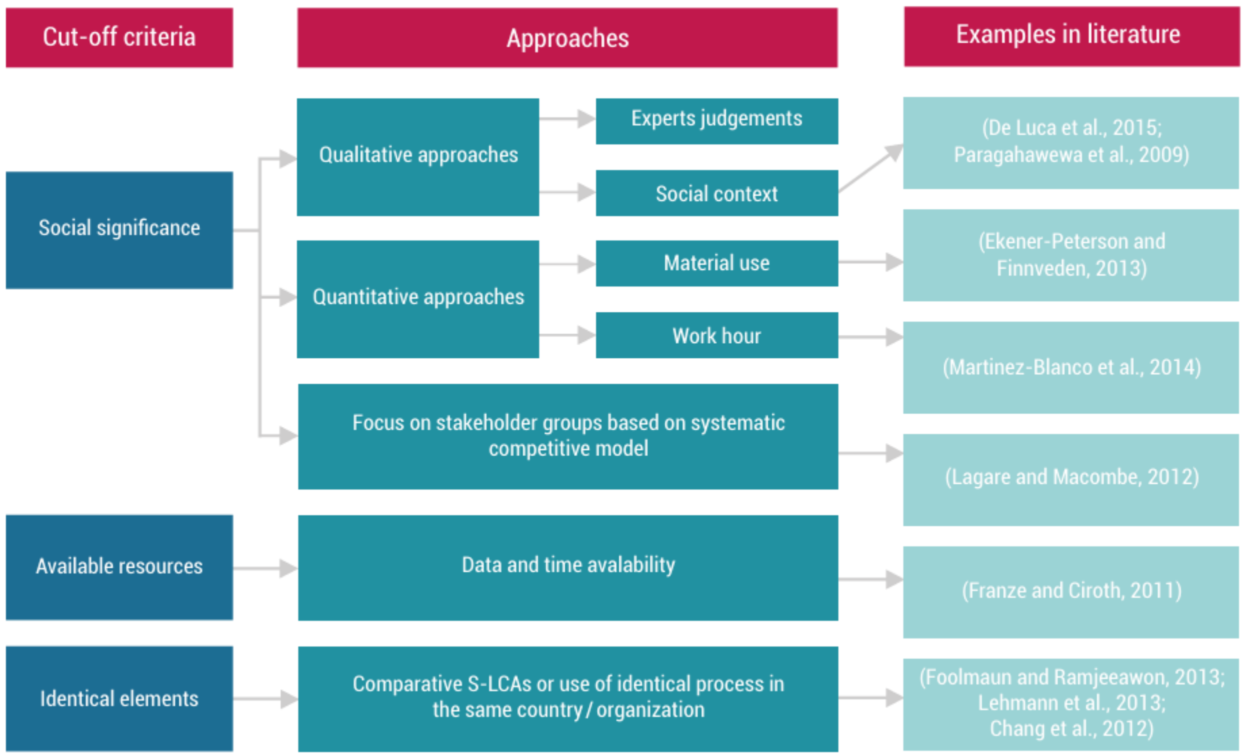


Figure 23 - Summary of types of cut-off criteria, approach used, and literature suggested (UNEP, 2020, p. 50).

3. Transparency:

- It is crucial to clearly document the cut-off criteria and justify any exclusions. This ensures the study remains transparent and credible (UNEP, 2020).

Why Are Cut-Off Criteria Important?

- They help focus the study on the most relevant and impactful processes, ensuring meaningful results.
- They make the study more feasible by reducing unnecessary complexity.
- They ensure transparency by clearly explaining what is included or excluded and why (UNEP, 2020).

3.3.9. Limitations of Data Access

Limitations of data access refer to the challenges in collecting the necessary data for conducting a Social Life Cycle Assessment (S-LCA). These limitations often arise due to the resource-intensive nature of data collection, especially for site-specific data, and the global scope of many product life cycles. As a result, practitioners often rely on a combination of generic data and site-specific data to overcome these challenges (UNEP, 2020).

Key Points About Data Access Limitations

1. **Challenges in Data Collection:**

- Site-specific data collection is often time-consuming and resource-heavy, especially when processes occur in different parts of the world.
- It is particularly difficult to obtain site-specific data for upstream processes (e.g., raw material extraction) and downstream processes (e.g., waste handling) (UNEP, 2020).

2. **Use of Generic Data:**

- To maintain a life cycle perspective, practitioners often use generic data from databases for parts of the value chain where site-specific data is unavailable.
- Generic data provides information on social aspects at the country-sector level, which can be used to complement site-specific data (UNEP, 2020).

3. **Balancing Data Sources:**

- A combination of site-specific data (for foreground processes) and generic data (for background processes) is often used to ensure a comprehensive assessment while managing resource constraints (UNEP, 2020).

3.3.10. Stakeholder categorization and Involvement

Stakeholder categorization and involvement is a critical step in Social Life Cycle Assessment (S-LCA) that ensures the study considers all relevant groups affected by the product's life cycle. Stakeholders are individuals or groups who may be positively or negatively impacted by the activities of organizations involved in the product system. Properly identifying and involving stakeholders enhances the relevance, legitimacy, and transparency of the S-LCA (UNEP, 2020).

Key Points About Stakeholder Categorization

1. **Stakeholder Categories:**

- The main stakeholder categories include: Workers, Consumers, Local Communities, Society, Children, and Other Value Chain Actors.
- These categories can be further subdivided to include more vulnerable groups, such as women workers or migrant workers, ensuring their voices are represented (UNEP, 2020).

2. **Selection of Stakeholders:**

- Stakeholders should be selected based on their relevance to the study's goal and scope.
- A materiality assessment can help identify the most relevant stakeholders and impact categories (ISO 14075, 2024; UNEP, 2020).

3. **Criteria for Stakeholder Selection:**

- Impact: Identify groups most affected by the product system.
- Legitimacy: Include representatives of interest groups.

- Completeness: Ensure diverse social representations and attributes are considered (ISO 14075, 2024; UNEP, 2020).

Key Points About Stakeholder Involvement

1. **Importance of Involvement:**

- Involving stakeholders ensures the study reflects their perspectives and values, making it more locally relevant and legitimate.
- It promotes democratic representation, empowerment, and learning opportunities for communities (UNEP, 2020).

2. **Participatory Approaches:**

- Methods like focus groups can be used to gather local perspectives and identify relevant stakeholders and indicators.
- Stakeholder participation can also help define the relative importance (weight) of each impact category during the assessment phase (UNEP, 2020).

3. **Transparency and Justification:**

- The process for selecting stakeholders and excluding certain groups should be clearly documented and justified (ISO 14075, 2024; UNEP, 2020).
- Exclusion of stakeholders should be based on their relevance to the study's goal and explained transparently (ISO 14075, 2024).

Practical Considerations

1. **Commonly Overlooked Stakeholders:**

- While workers and local communities are frequently included, consumers, value chain actors, and society are often overlooked (UNEP, 2020).

2. **Double Counting:**

- Care should be taken to avoid double-counting, as individuals may belong to multiple stakeholder categories (e.g., a person can be both a worker and a consumer) (UNEP, 2020).

3. **Engagement Questions:**

To identify stakeholders, consider:

- Who has legal obligations to the organization?
- Who is likely to be positively or negatively affected?
- Who is likely to express concerns about the product life cycle? (ISO 14075, 2024).

3.3.11. Impact Assessment Method and Impact Categories and Subcategories

The Impact Assessment Method and Impact Categories and Subcategories are crucial components of Social Life Cycle Assessment (S-LCA). They define how social impacts are assessed and which specific social issues are evaluated. These elements are determined during the Goal and Scope phase and guide the entire assessment process (UNEP, 2020).

1. Impact Assessment Method

The choice of the impact assessment method is a key decision in S-LCA. Two main approaches are commonly used:

1. Reference Scale (RS) S-LCIA:

    - This method evaluates social impacts using reference scales that measure the performance of organizations or processes against predefined benchmarks.
    - It focuses on stakeholder groups and impact subcategories (e.g., fair wages for workers, community engagement).
    - Example: Assessing whether a company meets international labor standards for fair wages.

2. Impact Pathway (IP) S-LCIA:

    - This method uses social impact pathways to trace the cause-effect relationships from social activities (e.g., labor practices) to social damages (e.g., health impacts).
    - It classifies impacts at midpoint (e.g., worker safety) and endpoint levels (e.g., human well-being).
    - Example: Analyzing how poor working conditions lead to long-term health issues for workers (UNEP, 2020).

Steps for Selecting an Impact Assessment Method:

1. Choose the approach: RS S-LCIA or IP S-LCIA.
2. Identify the social topics of interest (e.g., labor rights, community well-being).
3. Define prerequisites:

    - For RS S-LCIA: Specify the reference scales used.
    - For IP S-LCIA: Define the characterization model and impact pathway.

4. Determine the weighting approach (if applicable) (UNEP, 2020).

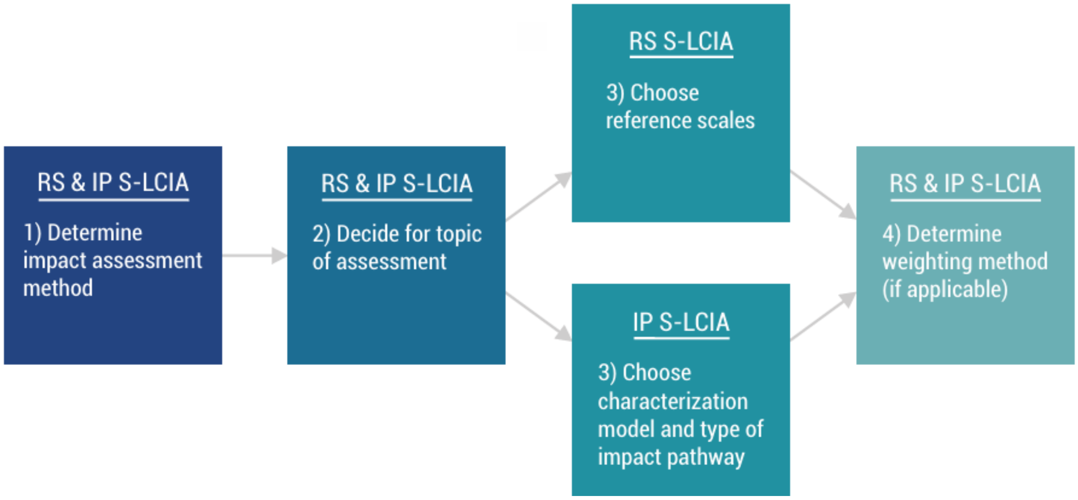


Figure 24 - Steps in the G&S about impact assessment, dividing into RS S-LCI and IP S-LCI (UNEP, 2020, p. 52).

The choice of method affects data collection and analysis, so it must align with the study's goals and scope (UNEP, 2020).

2. Impact Categories and Subcategories

Impact categories and subcategories define the specific social issues evaluated in the study. They are selected during the Goal and Scope phase and should reflect the relevant social and socio-economic impacts associated with the product life cycle and stakeholders (UNEP, 2020).

1. Impact Subcategories (RS S-LCIA):

- These are specific issues within broader impact categories, often linked to stakeholder groups.
- Example: Under the category "Workers", subcategories might include fair wages, health and safety, and freedom of association.

2. Impact Categories (IP S-LCIA):

- These are broader classifications of social impacts, often analyzed at midpoint (e.g., worker injuries) and endpoint levels (e.g., human well-being).
- Example: Midpoint category "Worker Safety" and endpoint category "Human Health" (UNEP, 2020).

Stakeholder	Impact Subcategory
Worker	Child labor
	Forced labor

Figure 25 - Example of prominent linkages between stakeholders and subcategories for RS S-LCIA, within the impact category, Labor rights (UNEP, 2020, p. 53).

Inventory indicator	Midpoint impact	Endpoint impact
Worker	Wage level	Standard of living
	Schooling	Human development

Figure 26 - Example of linkages between inventory indicators and impact categories in IP S-LCIA, within the impact category, Labor rights (UNEP, 2020, p. 53).

Key Considerations:

- Impact categories and subcategories should be iteratively refined as the study progresses.
- A materiality assessment can help identify the most relevant categories and subcategories.
- The selection should align with the chosen impact assessment method (RS or IP S-LCIA) (UNEP, 2020).

Why Are These Elements Important?

- They provide a structured framework for assessing social impacts, ensuring consistency and relevance.
- They help focus the study on the most significant social issues for the stakeholders involved.
- They ensure the assessment aligns with the study's goals and scope, making the results meaningful and actionable (UNEP, 2020).

3.3.12. Indicators, Data Type, and Data Collection Strategies

To evaluate the impact of its subcategories, data is gathered using one or more indicators that best represent the key aspects of the category.

During the Goal and Scope phase, it's essential to list the relevant indicators and metrics that will be used to assess the impact and subcategories in the study. The methods for collecting data should also be clearly defined. A simple table showing the subcategories, their indicators, and data collection methods is an effective way to present this information (UNEP, 2020).

Stakeholder	Impact Subcategory	Indicator
Worker	Child labor	Hours or percentage of child labor in the workforce

Figure 27 - Example of a linkage between stakeholders, subcategories, and indicators (UNEP, 2020, p. 53).

3.3.13. Defining the Steps of Phase 1

Following the summary and conceptual explanation of Phase 1 – Goal and Scope Definition, the framework is now broken down into a set of distinct implementation steps. These steps have been extracted and synthesized directly from the two authoritative guidelines used in this study: the UNEP Guidelines for Social Life Cycle Assessment of Products and Organizations (2020) and the ISO 14075:2024 standard.

Steps in phase 1:

1. Goal Definition

2. Functional Unit

3. The Reference Flow

4. The Product System

5. Identifying the System Boundaries

6. Activity Variable (optional)

7. Cut-off Criteria

8. Limitations of Data Access

9. Stakeholder Categorization and Involvement

10. Impact Assessment Method and Impact Subcategories

11. Indicators, Data Type, and Data Collection Strategies

3.4. Phase 2: Life cycle inventory

The Life Cycle Inventory (LCI) phase in Social Life Cycle Assessment (S-LCA) involves the collection and organization of data related to the social aspects of a product system. This phase is critical for quantifying and qualifying the inputs and outputs associated with the product's life cycle, which are then used to assess social impacts. The LCI phase is iterative, meaning that as data is collected, new insights may lead to adjustments in the data collection process or even revisions to the study's goal and scope. It involves:

1. Identifying the data to be prioritized for collection;

2. Collecting data for hotspot assessment if this is part of the Goal and Scope;

3. Collecting data for the selected/relevant stakeholders and subcategories;

4. Collecting complementary data for the impact assessment (NOTE: This part is heavily dependent upon the Type of S-LCIA chosen);

5. Collecting site specific (primary) and generic (secondary) data for unit processes and activity variables;

6. Collecting data for scoring and/or weighting(UNEP, 2020).

3.4.1. How to conduct the Life Cycle Inventory Analysis?

The Life Cycle Inventory analysis in S-LCA involves identifying, collecting, and organizing data related to the social aspects of a product system. This process is guided by the goal and scope defined in the previous phase and ensures that the data collected is sufficient to support the subsequent impact assessment and interpretation phases (UNEP, 2020).

THE BASICS OF LIFE CYCLE INVENTORY IN THE CONTEXT OF S-LCA

In the context of S-LCA, the LCI consists of collecting data on all flows within the studied system, normalized per functional unit. For example, if the functional unit is "one banana," the LCI would include data such as the amount of electricity consumed, the number of worker-hours required, and whether wages are below the living wage. The LCI also involves collecting data on activity variables, such as worker-hours, which link the socio-economic system to the product system (UNEP, 2020).

The LCI process typically involves the following steps:

Subdividing the studied system into interlinked processes that provide products or services to each other (e.g., fertilizer production and agricultural cultivation). This results in a flow chart, which is already part of the goal and scope (UNEP, 2020).

Obtaining flow amounts for each process, which are normalized to a process output (e.g., 5 kWh of electricity to produce 1 kg of fertilizer). Furthermore, information on the system can be collected (UNEP, 2020).

Quantifying total amounts of processes and their flows for the reference flow, often based on a linear relationship (e.g., if 2 worker-hours are needed for 1 kg of fertilizer, then 4 worker-hours are needed for 2 kg). This linear model is used to calculate all flows in an LCA software (UNEP, 2020).

Collecting social inventory data related to the main stakeholders defined in the goal and scope for all processes and flows (e.g., salary of workers involved in fertilizer production).

If only qualitative or semi-quantitative data is collected, only the first step (subdividing the system) needs to be applied. For quantitative approaches, steps 1 to 3 are necessary, and data can be collected from life cycle inventory databases or manually (UNEP, 2020).

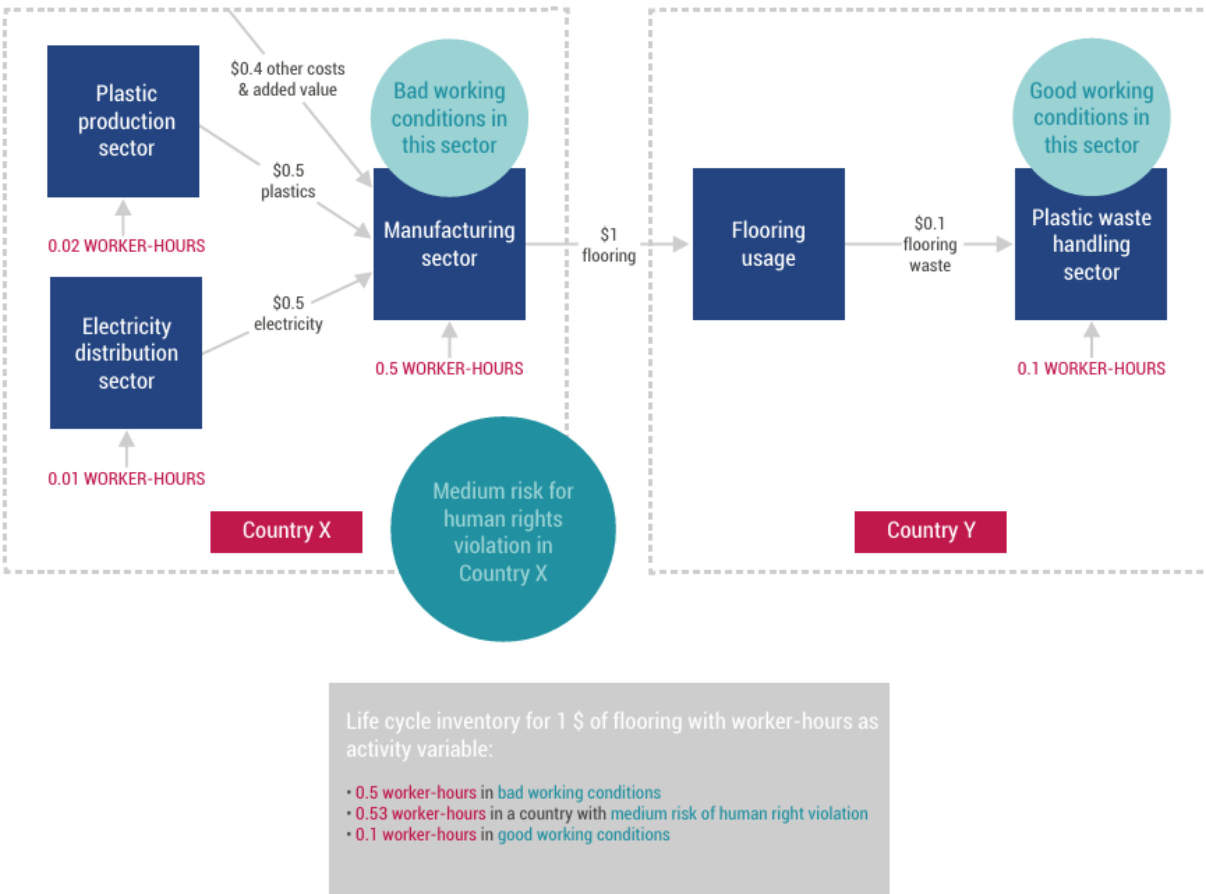


Figure 28 - Life cycle inventory based on sectors, fictional example for a part of the system of flooring products (Flows are valid for a certain time period, e.g., the year 2019) (UNEP, 2020, p. 58).

Foreground and Background Systems: The foreground system includes processes directly related to the product being studied, while the background system includes upstream and downstream processes. Foreground processes often require site-specific data, while background processes rely on generic data from databases (UNEP, 2020).

Process-Based vs. Sector-Based Approaches: The product system can be subdivided into processes (process-based) or sectors (sector-based). Sector-based approaches are often used in S-LCA, where sectors are related by economic flows. Hybrid approaches combining both methods are also possible (UNEP, 2020).

Use of LCA Software: Existing LCA software tools like SimaPro and OpenLCA provide access to linear models and impact assessment methods. These tools can automate the foreground system modeling steps and combine them with automatically generated background data to cover the complete product system (UNEP, 2020).

Qualitative Approach: When applying a qualitative approach, processes are identified without attempting to link them quantitatively. This means identifying whether there is a link or flow, but not quantifying the flow amount (UNEP, 2020).

According to ISO 14075:2024, the qualitative and quantitative data for inclusion in the inventory shall be collected for each unit process within the system boundary, and the collected data, whether measured, calculated, or estimated, are utilized to describe and quantify or qualify the inputs and outputs of a unit process (ISO 14075, 2024).

3.4.2. PRIORITIZING DATA COLLECTION

Data collection in S-LCA can be resource-intensive and time-consuming, especially when collecting site-specific data for stakeholders and impact subcategories. Prioritization is essential to focus efforts on the most significant processes and social issues, ensuring that the study remains feasible and efficient (UNEP, 2020). Three approaches can guide prioritization:

Literature Review: Identify key social issues documented in previous studies. For example, if child labor is a known issue in cotton production, data collection should prioritize this process.

Activity Variable: Determine the most active or intensive processes based on an activity variable, such as worker-hours. Processes with higher worker-hours are often prioritized for data collection.

Social Hotspots: Use databases and software to identify social hotspots—unit processes in regions with high social risks or opportunities. These hotspots should be prioritized for on-site data collection. Social hotspots are unit processes located in regions (e.g., countries) where a situation occurs that may be considered a problem, risk, or opportunity in relation to a social issue. These issues are often linked to the impact subcategories defined in the goal and scope.

If the goal of the S-LCA is to identify actual impacts, on-site visits must be organized to collect site-specific data. This is particularly relevant for prioritized processes identified through social hotspots.

The activity variable, such as worker-hours, helps identify the most labor-intensive processes in the product system. These processes are often prioritized for data collection due to their higher potential for social impacts (UNEP, 2020).

Definition of Key Databases:

- SHDB (Social Hotspots Database): SHDB is a database specifically designed for S-LCA. It contains data for 26 subcategories using over 160 qualitative, quantitative, and semi-quantitative indicators on social risks, opportunities, and positive impacts. SHDB covers approximately 13,000 country-specific industry sectors in 244 countries, based on the GTAP Input/Output database. It includes an impact assessment method and measures social risks and opportunities in worker-hours and value-added activity variables per process(UNEP, 2020).

- **PSILCA (Product Social Impact Life Cycle Assessment):** PSILCA is another database tailored for S-LCA. It contains data for 19 subcategories and 65 qualitative, quantitative, and semi-quantitative indicators on social and environmental risks, opportunities, and positive impacts. PSILCA covers approximately 15,000 country-specific industry sectors and commodities in 189 countries, based on the Eora Input/Output database. It offers two activity variables (worker-hours and value added) and provides information on data quality for every data point (UNEP, 2020).

These databases are valuable tools for identifying social hotspots and prioritizing data collection in S-LCA studies. They provide generic data that can be used to complement site-specific data, especially when resources for on-site data collection are limited(UNEP, 2020).

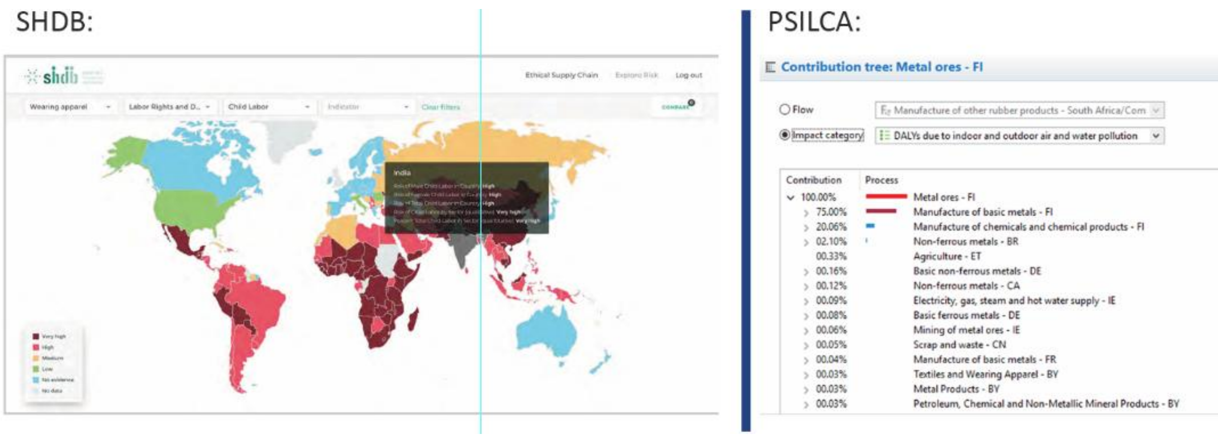


Figure 29 - Illustration of Database Results for Social Hotspots (UNEP, 2020, p. 61).

3.4.3. ACTIVITY VARIABLES

Activity variables are measures of process activity or scale, such as worker-hours or added value, used to reflect the share of a given activity associated with each unit process. They help represent the product system in a way that highlights the relative significance of each unit process (UNEP, 2020).

WHAT ARE ACTIVITY VARIABLES?

Activity Variables are measures of process activity or scale, linked to process output, used to reflect the share of an activity associated with each unit process in a product system. They help quantify the relative significance of each process in terms of social impacts or attributes (e.g., fair trade certification) (UNEP, 2020). Key points:

1. Purpose:

- Represent the product system by showing the relative importance of each unit process.
- Communicate the percentage of a supply chain with specific attributes (e.g., 90% of worker-hours are fair trade certified).

2. Common Activity Variables:

- Worker-hours: Measures the number of hours worked to complete a process (e.g., harvesting grapes).
- Added value: Reflects the economic value created in each process(UNEP, 2020).

3. Challenges and Considerations:

- Data collection: Worker-hours can be difficult to collect and may involve estimates, leading to uncertainty.
- Relevance: Worker-hours and added value may not always reflect the true social impact of a process (e.g., a process with low worker-hours but high social risk, like community displacement).
- Qualitative data: Transforming qualitative data into semi-quantitative values for activity variables can introduce uncertainty.
- Added value limitations: High added value may result from advanced technology or efficiency, not necessarily high labor input, which can skew social impact assessments (UNEP, 2020).

4. Alternatives:

- Some practitioners avoid activity variables and instead use cost, economic value, or weight to assign importance to unit processes.
- Others assume all unit processes have equal importance, though this approach has limitations, especially for complex products (UNEP, 2020).

ILLUSTRATION OF DATABASE RESULTS FOR SOCIAL HOTSPOTS

This section demonstrates how activity variables, like worker-hours, are used to quantify social risks and impacts in a product's life cycle (UNEP, 2020). Key points:

Example:

- Functional Unit (FU): "Use of a T-shirt for 70 days."
- Worker-hours are used to quantify social risks (e.g., 0.15 hours of high risk of female discrimination per T-shirt).
- Risks can also be expressed as a percentage of the life cycle (e.g., 30% of the product system involves female discrimination) (UNEP, 2020).

Scaling to Functional Unit:

- Activity variables are scaled to the FU, making social issues in processes with higher worker-hours or added value more prominent.
- This helps identify where detailed data collection is needed and where generic data suffices (UNEP, 2020).

Inventory Indicators:

- Activity variables act as inventory indicators, linking the life cycle inventory (process chain) to the life cycle impact assessment (social impacts).
- For example, child labor hours are an estimate of social impact, similar to "elementary flows" in environmental LCA (UNEP, 2020).

External Risks/Opportunities:

- Activity variables can highlight external social impacts (e.g., 75% of the product system benefits local communities through improved access to clean water) (UNEP, 2020).

Relationship Between Activity Variables and Social Hotspots

Activity variables, such as worker-hours and added value, are crucial for quantifying and scaling social risks and impacts across a product's life cycle. They help identify social hotspot processes with significant social risks or opportunities by linking process activity to social outcomes. For example:

- Worker-hours highlight where stakeholders (e.g., workers) are most exposed to potential social impacts.
- Scaling to the FU ensures that processes with higher activity levels (e.g., more worker-hours) receive greater attention in the assessment.

This approach enables practitioners to prioritize data collection, compare product options, and communicate social impacts effectively. However, care must be taken to ensure the chosen activity variable aligns with the study's goals and scope, as it may not always capture the full complexity of social issues (UNEP, 2020).

HOW TO COLLECT ACTIVITY VARIABLES DATA

Activity variable data can be collected through three approaches:

1. **Site-Specific Data Collection:** Directly collect data from specific production sites.

2. **S-LCA Databases:** Use databases like SHDB or PSILCA, which integrate activity variable calculations.

3. **Input-Output Databases:** Use generic data from input-output databases, such as GTAP or EORA, to estimate activity variables (UNEP, 2020).

Data for selected activity variables can often be obtained using generic information based on location (e.g., country or region) and sector or activity type. Useful sources include Input-Output databases such as GTAP, EORA, EXIOBASE, and WIOD, as well as national statistical agencies, intergovernmental organizations like the ILO or the World Bank, and sector-specific organizations at national or international levels.

If databases are not used, the following guidelines should be followed when defining activity variables:

- Wage rates or unit labor costs used to estimate worker-hours must be specific to both the industry and country.
- If unpaid, informal, or undocumented labor is relevant to the product system, it should be explicitly documented, as it will not be captured through worker-hour calculations based on economic data (UNEP, 2020).

3.4.4. COLLECTING DATA FOR IMPACT ASSESSMENT METHOD

Data collection for the impact assessment method in S-LCA depends on the chosen approach: Reference Scale (RS) S-LCIA or Impact Pathway (IP) S-LCIA. The type of data collected varies based on the method, but in all cases, the data must relate to the life cycle stages defined in the product system. Both site-specific and generic data, as well as quantitative and qualitative data, may be used depending on the requirements outlined in the goal and scope (UNEP, 2020).

Specifically, for RS S-LCIA, the data collection should include:

1. Collection of data for creating the REFERENCE SCALES (or use of an established one): Reference scales are ordinal scales with predefined performance reference points (PRPs) used to evaluate social performance. Data is collected to assign S-LCI results to these scales.

2. Collection of data for the different STAKEHOLDER GROUPS and SUBCATEGORIES: Data must be collected for the stakeholder groups (e.g., workers, local communities) and subcategories (e.g., fair wages, health and safety) identified as relevant in the goal and scope.

3. (Optional) Collection of data for applying the ACTIVITY VARIABLE or a WEIGHTING step: If an activity variable (e.g., worker-hours) or weighting is used, additional data must be collected to support these calculations (UNEP, 2020).

Specifically, **for IP S-LCIA, the data collection should include:**

1. Collection of data for all INVENTORY INDICATORS: Inventory indicators are variables that provide direct evidence of social conditions (e.g., number of workplace accidents, wages). Data must be collected for all indicators relevant to the impact categories identified in the goal and scope.

2. Collection of data for the CHARACTERIZATION FACTORS: Characterization factors are used to quantify the relationship between inventory indicators and social impacts. Data must be collected to support the underlying characterization model.

3. (Optional) Collection of data for applying the ACTIVITY VARIABLE or a WEIGHTING step: Similar to RS S-LCIA, if an activity variable or weighting is used, additional data must be collected (UNEP, 2020).

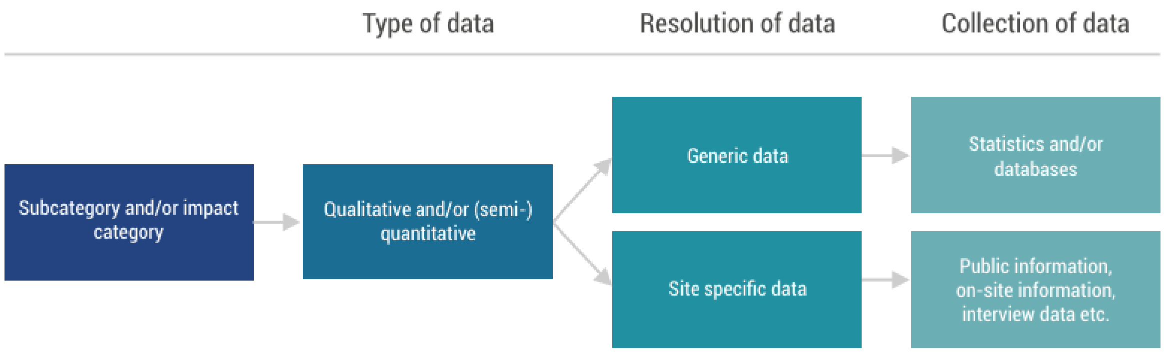


Figure 30 -Data collection and interrelations in S-LCA (UNEP, 2020).

Generic Data: Generic data refers to data that has not been collected for the specific process or product being studied. It is often obtained from databases, literature, or industry averages and provides information at a broader level (e.g., country or sector level). Generic data is useful for background processes where site-specific data is unavailable or impractical to collect (UNEP, 2020).

Site-Specific Data: Site-specific data refers to data collected directly from specific production sites or organizations involved in the product system. This data is tailored to the specific process, location, and context of the study and is often more accurate and relevant than generic data. Site-specific data is particularly important for foreground processes and for verifying risks or measuring positive impacts (UNEP, 2020).

3.4.5. DETERMINING DATA SOURCES AND SOCIAL INVENTORY INDICATORS

In S-LCA, inventory indicators are essential for assessing social impacts across different life cycle stages. These indicators, which can be qualitative, semi-quantitative, or quantitative, provide direct evidence of social conditions, such as wages or workplace accidents. The selection of indicators determines the required data collection methods, which may include interviews, surveys, audits, literature reviews, and databases.

- Indicators must align with the chosen impact assessment approach and be relevant to the study's Goal and Scope.
- Data sources should be carefully chosen based on resource availability and study objectives.
- Triangulation (using multiple data collection methods) enhances data validity.
- S-LCA databases provide readily available generic indicators, while primary data collection offers site- or company-specific insights (UNEP, 2020).

Aspect of differentiation	Subtype of data	Definition
Output type	Quantitative data	Quantitative data is data expressing a certain quantity, amount, or range (UNECE, 2000).
	Qualitative data	Qualitative data is data describing the attributes or properties that an object possesses. The properties are categorized into classes that may be assigned numeric values. However, there is no significance to the data values themselves, they simply represent attributes of the object concerned (UNECE, 2000).
	Semi-quantitative data	Semi-quantitative data is data coming from an index or similar tools, which were given a certain value/ranking based on defined characteristics/ criteria.
Level of resolution	Company data	Derived from a company but not allocated to a specific production site.
	Site-specific data	Refers to data collected for a specific production activity/ process, occurring in a specific organization and facility, at a specific location. It might be collected by the company, customer, or a third party. It might be collected from stakeholders or from managers of the company – as part of a social audit, questionnaire or similar/other process. Its origin should be made clear.
	Generic data	Refers to data that has not been collected for the specific process concerned. It can be data collected from other manufacturers of the same kind of product or in the same country. In other words, it is data with a lower resolution than site-specific data.
Source of collection	Primary data	Refers to data that has been directly collected by the practitioner through, for example, interview, survey, or participant observation. (Data on aspects that are not compliant with regulations may not be voluntarily and honestly provided!)
	Secondary data	Refers to data that has been initially collected and manipulated by another person/institution than the practitioner or collected for another purpose than the one being currently considered or, often a mix of the two. For example, a publication, third party audit, or a database.

Table 3 - Types of data in S-LCA (UNEP, 2020, p. 67).

The **Methodological Sheets** serve as a critical reference, offering a structured framework for selecting appropriate social inventory indicators. They provide:

- A comprehensive overview of existing indicators, ensuring consistency in impact assessment.

- Guidance on data collection strategies, improving the reliability and comparability of S-LCA studies.
- Support for integrating relevant impact categories from Environmental LCA (E-LCA), such as DALY (Disability-Adjusted Life Years) for health-related assessments (UNEP, 2020).

3.4.6. COLLECTING GENERIC AND SECONDARY DATA

Generic and secondary data can be collected from databases, literature reviews, or web searches. Databases like SHDB, PSILCA, and RepRisk provide data on social risks and impacts. These databases are often used to complement site-specific data and fill data gaps (UNEP, 2020).

Database	Content	Bound to software / specific online platform	Licensed or subscription-based	URL
GaBi Life Cycle Working Environ-ment (LCWE)	• Database providing social inventory data (accidents, employee qualifications, and a few others…) for the 15,000 distinct processes and products of the GaBi database, i.e. all resource extraction, production, manufacturing, and end of life processes. • The data combines US-based sec-tor-specific data, on working-time per value-added of individual unit processes with data from the Bureau of Labor statistics, ILO, and other sources on qualification profiles of the workforce in that sector, lethal and non-lethal accident rates, and some other indicators. • This unit-process level social inventory data is aggregated in parallel to envi-ronmental LCI data along the life cycle to cradle-to-gate inventories, making it methodologically the most differentiated, specific LCWE data source for quanti-tative data, one level more specific than sector-level S-LCA databases. - Own data (e.g. foreground system, other background processes), also other indi-cators can be added by the user and be combined. • Measured in seconds of labor per value added.	Yes (used in E-LCA software).	Yes	http://www.gabi-software.com/index/ http://www.gabi-software.com/internatio-nal/software/gabi-software/gabi/functio-nalities/life-cy-cle-working-en-vironment/

Table 4 - An example of a List of licensed and free databases which can be used to establish the S-LCI and S-LCIA by extension (UNEP, 2020, p. 70).

3.4.7. COLLECTING SITE-SPECIFIC AND PRIMARY DATA

The collection of site-specific and primary data is a critical step in S-LCA, as it provides accurate and context-specific information about the social conditions of the product system. Site-specific data is collected directly from specific production sites or organizations, while primary data is gathered through direct contact with organizations, companies, or stakeholders (UNEP, 2020).

Key Points:

1. Collection of Primary Data: Primary data is collected by visiting specific or relevant production sites or by collaborating with organizations and companies. This data can be gathered through direct contact, such as interviews, surveys, or on-site observations. It provides detailed and specific information about the social conditions of the processes being studied.

2. Determining the Need for Primary Data: The need for primary data can be identified through an initial hotspots assessment using generic data. This assessment helps identify data gaps and prioritize processes where primary data is most relevant. Primary data is especially important for prioritized (foreground) processes and when the specific process or product performs significantly better or worse compared to the average identified in the hotspot assessment. Additionally, primary data is crucial for measuring positive impacts, such as contributions to local communities, and comparing these impacts to local conditions.

3. Site-Specific Data vs. Primary Data: It is important to note that site-specific data is not always primary data. For example, site-specific data could come from a social audit conducted by a third party at the site under investigation. In this case, the data is considered secondary data because it was not collected directly by the practitioner. However, it is still site-specific and provides valuable information about the social conditions at the site (UNEP, 2020).

3.4.8. REFINING THE DATA COLLECTION STRATEGY

The data collection strategy may be refined based on new knowledge, such as the identification of significant processes through activity variables or social hotspots. Unavailability of data may lead to the exclusion of certain processes or the use of proxy data[3]. Sensitivity analyses conducted during the interpretation phase may also lead to refinements in the system boundary (UNEP, 2020). According to ISO 14075:2024, the treatment of missing data should be documented, and data gaps should be addressed by using justified non-zero values, zero values, or calculated values based on similar technologies (ISO 14075, 2024).

3.4.9. HANDLING CO-PRODUCTS

In systems that generate multiple co-products (e.g., a cow producing milk, meat, and leather), social impacts may need to be allocated among the co-products. Allocation can be avoided by subdividing activities or expanding the system to include additional products. If allocation is necessary, it can be based on causal relationships (e.g., worker-hours) or revenue shares (UNEP, 2020). ISO 14075:2024 states that social aspects should be attributed to each co-product on the same level in multi-output processes, and if subdivision or system expansion is not possible, no allocation scheme should be applied (ISO 14075, 2024).

[3] **Proxy data** in S-LCA refers to substitute data from secondary sources (e.g., national statistics, industry reports, databases) used when direct or primary data is unavailable.

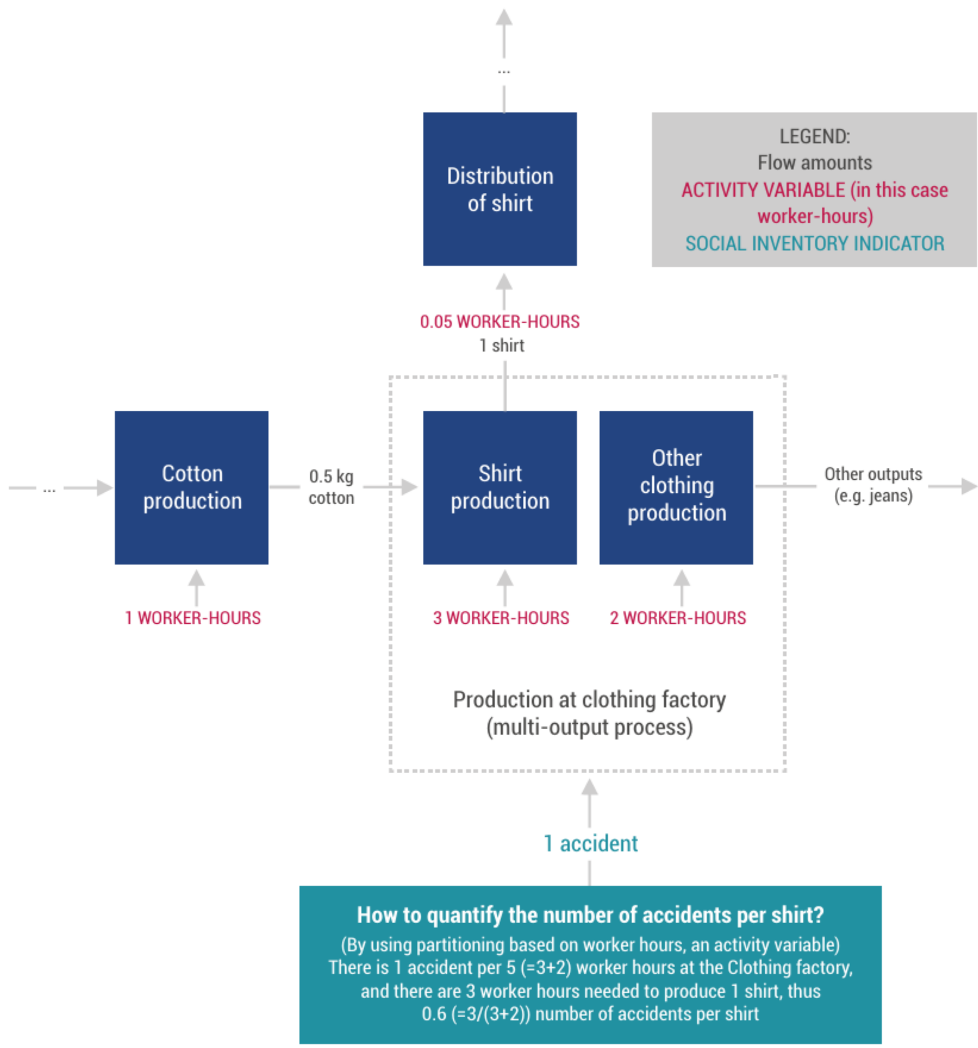


Figure 31 - Example of activity variable (worker-hours) and its use as allocation key for number of accidents (at factory level) related to the process of shirt production at the factory, as part of the life cycle of a shirt's social impacts (UNEP, 2020).

3.4.10. HANDLING CO-PRODUCTS

Data quality is critical for ensuring the reliability and validity of S-LCA results. Data quality management involves selecting appropriate instruments, sources, and collection methods, as well as documenting data quality throughout the study. Currently, no comprehensive guidance document exists that outlines general data quality requirements and management for social and socio-economic data in S-LCA (UNEP, 2020).

3.4.11. APPROPRIATE INSTRUMENTS, SOURCES, AND COLLECTION METHODS

Selecting appropriate instruments, sources, and collection methods is critical for ensuring the reliability, validity, and objectivity of the data collected in S-LCA. The choice of methods and instruments depends on the type of indicator and data needed (quantitative or qualitative, generic or specific). Both the measurement methods and the indicators themselves should meet minimum criteria, including reliability, validity, and objectivity (UNEP, 2020).

1. Reliability: The extent to which an instrument produces reliable and consistent results;

2. Validity: The extent to which an indicator and instrument are measuring an intended concept (e.g., a social issue or sub-category), based on soundness and empirical analysis (if possible);

3. Objectivity: The extent to which an investigator/data source is separated from the object of investigation and without bias (UNEP, 2020).

For example, to assess discrimination, an indicator such as the share of foreign workers at a factory might be used. However, this indicator alone is not sufficient to evaluate the full extent of discrimination. Additional indicators, such as wage disparities, access to training, or promotion rates, should be included to provide a more accurate and meaningful assessment of the situation. This ensures that the data collected is valid and aligns with the subcategory being assessed (UNEP, 2020).

Data quality should be characterized by both quantitative and qualitative aspects, and the methods used to collect and integrate data should be clearly documented. This ensures that the data collected is reliable, valid, and objective (ISO 14075, 2024).

3.4.12. DATA QUALITY MANAGEMENT

Data quality can be assessed using a pedigree matrix, which evaluates aspects such as reliability, completeness, temporal and geographical conformance, and technical conformance. This matrix converts qualitative assessments into quantitative scores, providing a transparent picture of data quality (UNEP, 2020). According to ISO 14075:2024, the treatment of missing data should be documented, and data gaps should be addressed by using justified non-zero values, zero values, or calculated values based on similar technologies (ISO 14075, 2024).

CHALLENGES FOR GENERIC AND SECONDARY DATA

Generic and secondary data may present challenges, such as a lack of validity, reliability, or objectivity. Triangulation, using multiple data sources or methods, is recommended to address these challenges and ensure data credibility (UNEP, 2020). ISO 14075:2024 highlights that when data is collected from public sources, the source shall be referenced, and details about the data collection process and data quality indicators should be stated (ISO 14075, 2024).

3.4.13. DOCUMENTATION OF DATA QUALITY

Documentation of data quality is essential for transparency. This includes describing the data collection process, the reliability and validity of instruments, and any deviations from stated procedures. External review of data collection schemes can improve the credibility of results (UNEP, 2020). According to ISO 14075:2024, the treatment of missing data and data gaps should be documented, and the assumptions made should be clearly stated and explained (ISO 14075, 2024). The following list outlines important aspects of data collection that should be documented throughout the study:

1. Overview of the data collection process, including objectives, time frame, design, sample, sources, and tools used.

2. Details on the reliability and validity of measurement instruments or methods.

3. Findings from data quality management, such as assessments using the pedigree matrix.

4. Identification of personnel responsible for data collection, along with their qualifications.

5. Templates of data collection tools or measurement methods, if available (ISO 14075, 2024).

3.4.14. Defining the Steps of Phase 2

Following the summary and conceptual explanation of Phase 2 – Life cycle inventory, the framework is now broken down into a set of distinct implementation steps. These steps have been extracted and synthesized directly from the two authoritative guidelines used in this study: the UNEP Guidelines for Social Life Cycle Assessment of Products and Organizations (2020) and the ISO 14075:2024 standard.

Steps in phase 2:

1. Plan Inventory

2. Collect Primary & Secondary Data

3. Handle Qualitative & Semi-Quantitative Data

4. Structure Product System

5. Apply Allocation

6. Ensure Data Quality & Address Gaps

3.5. Step 3: Impact Assessment

Social Life Cycle Impact Assessment (S-LCIA) is the phase in S-LCA aimed at calculating, understanding, and evaluating the magnitude and significance of potential social impacts of a product system throughout its life cycle. This phase can be applied to analyze current or past potential social impacts associated with a system or to forecast future potential social impacts of an evolving or non-existent system (UNEP, 2020).

It is important to note that S-LCIA primarily focuses on evaluating potential social impacts, not actual social impacts. A potential social impact refers to the likely presence of a social impact resulting from the activities or behaviors of organizations linked to the product's life cycle, as well as from the use of the product itself. The term "potential" is crucial because it conveys relativism, acknowledging that the assessment is based on hypotheses and indicators that carry a certain level of uncertainty. For example, forecasted potential impacts may not materialize due to unforeseen interferences (UNEP, 2020).

S-LCIA often evaluates social risks, which serve as general indicators for potential social impacts. These risks are assessed using impact indicators and impact categories or subcategories:

- Impact Indicators: These reflect the extent of a social impact and belong to a specific impact (sub)category. For example, "hours of missed education" is an impact indicator for the impact category "child labor."
- Impact Categories/Subcategories: These represent types of social impacts. For instance, "child labor" is an impact category that may have multiple indicators, such as "hours of missed education" or "number of child workers." (UNEP, 2020).

In Social Life Cycle Impact Assessment (S-LCIA), there are two main families of approaches: Reference Scale Assessment (RS S-LCIA) and Impact Pathway Assessment (IP S-LCIA) (UNEP, 2020). These approaches serve different purposes and are used based on the objectives of the study:

1. Reference Scale Assessment (RS S-LCIA):

    - **Purpose:** This approach is used to assess social performance or social risk. It evaluates the performance of organizations or processes against predefined benchmarks or reference scales.
    - **Application:** RS S-LCIA is operational and has been widely implemented in numerous case studies. It is particularly useful for identifying social hotspots and evaluating how well a product system meets social standards or norms.

2. Impact Pathway Assessment (IP S-LCIA):

    - **Purpose:** This approach focuses on assessing consequential social impacts by characterizing the cause-effect chain. It traces the pathways from social activities (e.g., labor practices) to social damages (e.g., health impacts).
    - **Application:** IP S-LCIA is primarily used in research settings, as it requires detailed modeling of cause-effect relationships. While several documented pathways are available, this approach is less commonly applied in practical case studies compared to RS S-LCIA.

Relevance to Thesis Objectives: Given the objectives outlined in Chapter 1 of this thesis, the Reference Scale Assessment is the most relevant approach. It aligns with the goal of assessing social performance and risks within the context of a Positive Energy District (PED) project in Milan, as it provides a structured framework for evaluating social impacts against established benchmarks. For this reason, the implementation of the Reference Scale approach will be discussed in detail, as it directly addresses the thesis objectives (UNEP, 2020).

3.5.1. STEPS IMPLEMENTATION OF REFERENCE APPROACHES

The Reference Scale Assessment (RS S-LCIA) is implemented through a series of structured steps, as illustrated in Figure 19 of the Guidelines. While some steps belong to the Impact Assessment phase, others are part of earlier phases in the S-LCA process.

Steps for Implementing Reference Scale Assessment:

1. Establishing Reference Scales for Impact Assessment:

Reference scales are predefined ordinal scales with performance reference points (PRPs) for each impact subcategory. S-LCA databases such as SHDB and PSILCA come with a set of pre-determined reference scales for their frameworks, which are used to evaluate social performance or risks (UNEP, 2020).

2. Data Collection:

The associated software collects data for the specific case study, drawing on generic data from pre-selected databases or other sources. This step is largely automated in S-LCA databases, which use existing data to populate the inventory (UNEP, 2020).

3. Assessing Data Against the Reference Scale:

The databases assess the collected data against the pre-determined reference scales. This step involves comparing the data to the benchmarks defined in the reference scales to evaluate social performance or risks (UNEP, 2020).

4. Applying an Impact Assessment Method:

The results are grouped by impact subcategory or impact category and aggregated over the value chain using an activity variable (e.g., worker-hours). This step allows for the quantification of social impacts across the product system (UNEP, 2020).

5. Final Weighting of Results:

The databases either apply weighting to the results or provide users with the option to apply their own weighting. Weighting reflects the relative importance of different impact categories or subcategories based on the study's goals and stakeholder priorities (UNEP, 2020).

6. Presenting the Results:

The databases provide infographics to present the results, such as charts or graphs. However, some users may prefer to use the raw data to develop their own visualizations for the Interpretation phase (UNEP, 2020).

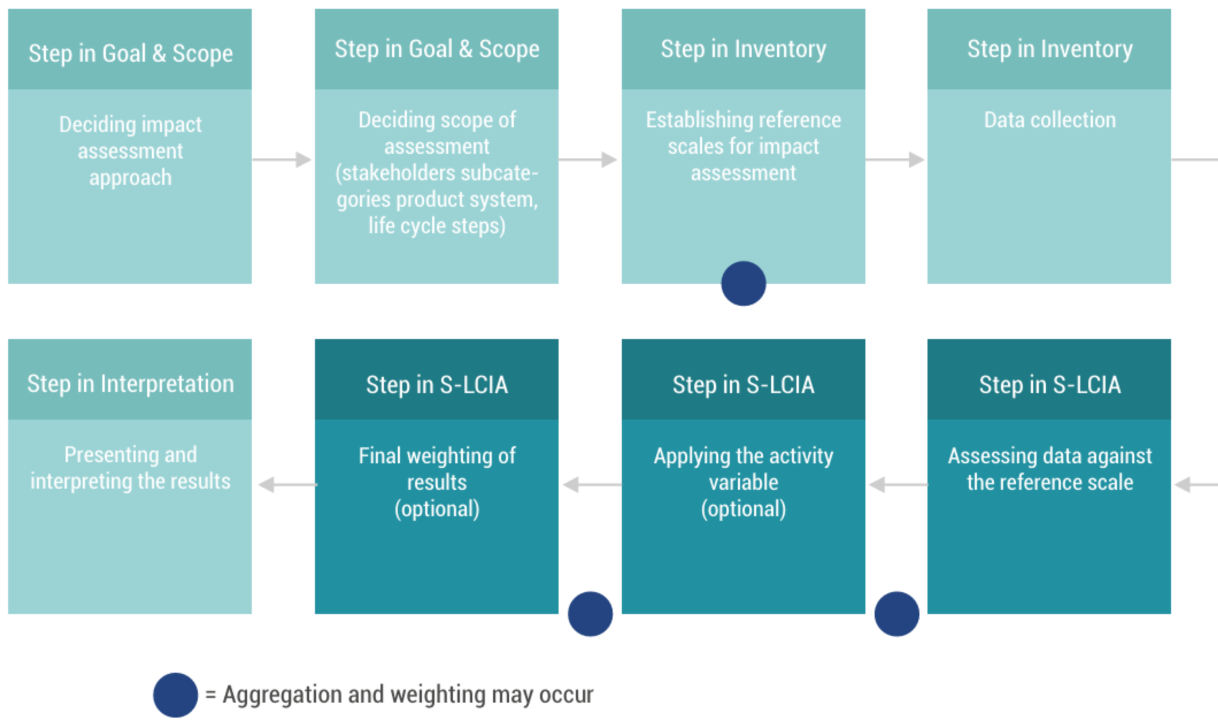


Figure 32 - Steps related to the impact assessment process for the Reference scale (Type I) approach (UNEP, 2020, p. 81).

Role of S-LCA Databases:

S-LCA databases like SHDB and PSILCA automate many of these steps, making the Reference Scale Assessment more efficient and accessible. They use generic data from reliable sources to establish reference scales, collect data, and assess results, reducing the need for extensive manual data collection and analysis. However, users can still customize the process, such as applying their own weighting or developing unique infographics for presenting results (UNEP, 2020).

3.5.2. ESTABLISHING REFERENCE SCALES

Establishing reference scales is a critical step in the Reference Scale Assessment (RS S-LCIA) approach. These scales are developed during the Inventory phase and serve as a foundation for organizing data collection and implementing the impact assessment. Reference scales are ordinal scales, typically consisting of 1 to 5 levels, each corresponding to a Performance Reference Point (PRP). PRPs are thresholds, targets, or objectives that define different levels of social performance or social risk, allowing for the estimation of the magnitude and significance of potential social impacts associated with organizations in the product system (UNEP, 2020).

Key Points:

1. Development of Reference Scales:

Reference scales should be developed for each indicator used in the assessment. Each level of the scale must be clearly defined, drawing on in-depth knowledge of the industry, geography, and local laws. Past studies and existing guidance can also inform the development of these scales (UNEP, 2020).

2. Performance Reference Points (PRPs):

PRPs are context-dependent and are often based on international standards, local legislation, or industry best practices (normative reference points). However, they can also be based on other points of reference, such as company-specific targets or stakeholder expectations (UNEP, 2020).

3. Structure of Reference Scales:

- Reference scales can be ascending (e.g., ranging from negative to positive performance) or descending (e.g., ranging from very low risk to very high risk). They may cover both negative and positive impacts or focus on one of the two (UNEP, 2020).
- Scales may use numbers (e.g., 1 to 5) or colors (e.g., red to green) to represent different levels of performance or risk. Scales with only two levels are used to identify the presence or absence of an impact, while scales with a single PRP are used in ratio-based assessments (UNEP, 2020).

4. Purpose of Reference Scales:

Reference scales allow for the comparison of inventory indicator data with predefined levels, enabling the qualification of whether the data suggests negative, positive, or intermediate performance. This step is crucial for assessing the potential social impacts of the product system (UNEP, 2020).

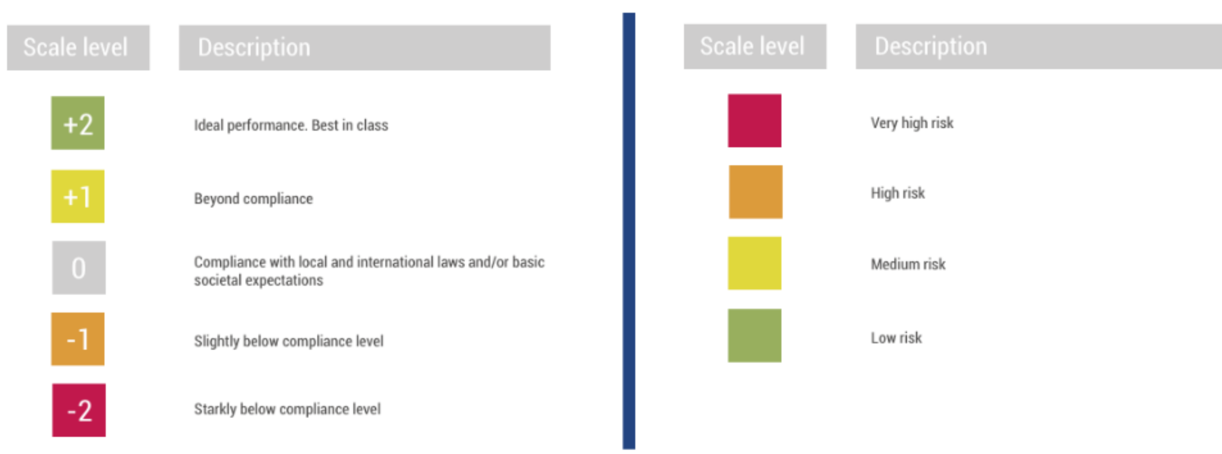


Figure 33 - The Left: Generic ascending reference scale, for social performance evaluation. The Right: Generic descending reference scale, for social risk evaluation (UNEP, 2020, p. 140).

3.5.3. ASSESSING SOCIAL PERFORMANCE AND SOCIAL RISK

In S-LCA, social performance and social risk represent two distinct but complementary aspects of social impacts, each assessed using different types of data:

1. **Social Performance:**

   - Measures the principles, practices, and outcomes of a business's relationships with stakeholders, evaluated against known standards. It includes both deliberate actions and unintended externalities of business activities.
   - Data: Typically assessed using company-specific data or close proxies, providing detailed and context-specific insights.

2. **Social Risk:**

   - Refers to the probability of adverse social effects on stakeholders due to a company's activities or business relationships, along with the potential consequences.
   - Data: Often measured using generic, sector/country-level data, which indicates general risk levels rather than specific performance outcomes.

Combining both social performance and social risk in an S-LCA study provides valuable context. For example, achieving "child labor-free" production is more significant in high-risk regions or sectors compared to low-risk ones (UNEP, 2020).

3.5.4. SETTING REFERENCE SCALES FOR POSITIVE IMPACTS ASSESSMENT

When assessing both positive and negative impacts in S-LCA, careful consideration is needed to structure and aggregate reference scales effectively. Key points include:

1. **Relationship Between Scales:**

For ascending reference scales, decide whether the top levels for positive and negative impacts should share the same numerical value in a scoring system. This choice impacts how results are aggregated.

2. **Mirroring Impacts:**

Positive and negative impacts can be mirrored around zero (neutral) or represented as positive integers. Mirroring risks misleading results, as a net-zero impact could mask significant positive and negative effects.

3. **Consistency in Assessment:**

Aligning positive impacts by inverting issues expressed as negatives. This ensures consistent treatment of positive impacts, as seen in S-LCA databases.

Setting reference scales for positive impacts requires careful planning to ensure meaningful aggregation and consistent assessment of both positive and negative impacts (UNEP, 2020).

3.5.5. TYPES OF PERFORMANCE REFERENCE POINTS

Performance Reference Points (PRPs) are used in reference scales to define levels of social performance or risk (UNEP, 2020). There are six main types of PRPs, each with distinct characteristics:

1. **Based on Norms, Practices, and Best Practices:**

PRPs are derived from specific norms, practices, or best practices. The reference scales translate these into corresponding levels, which can be qualitative or quantitative.

2. **Based on Norms and Socio-Economic Context:**

Similar to the first type, but the lower level of the scale is divided into two: one for favorable socio-economic contexts and one for unfavorable contexts.

3. **Generic Form (Expert-Based):**

The scale is not detailed and relies on expert knowledge to assess inventory data. This approach is less transparent but flexible.

4. **Based on Sector/Country Averages:**

PRPs are based on comparisons with sector, country, or global averages or medians. The scale levels can be divided into quartiles, allowing for a relative assessment of performance or risk compared to peers.

5. **Combination of Norms and Distribution:**

Combines specific norms with positioning on a distribution. For example, compliance levels (e.g., World Bank norms) are aligned with an even distribution to assess performance or risk.

6. **Combination of Expert Knowledge and Distribution:**

Uses expert knowledge to align compliance levels (e.g., low vs. medium risk) with an even distribution of data.

PRPs can be qualitative or quantitative and may aggregate multiple reference values or information sources (UNEP, 2020).

Reference scales		Relevant PIs
+2	The company or facility engages in a dialogue with the collective representation of workers and incorporates their views into management decisions.	2-3 and 5-6
+1	The company or facility recognises the collective representation of organized workers in negotiations.	2-3 and 5
0	The company or facility has a system in place to enforce the policy that allows freedom of association and collective bargaining AND no incidents have been discovered that the company or facility prevents workers' freedom of association and collective bargaining.	2-3
-1	Incidents have been discovered that show that the company or facility prevents workers' rights to freedom of association and collective bargaining, but a corrective action plan with a clear timeline for completion has been developped OR the company or facility has a policy that allows freedom of association and collective bargaining but does not have a system in place to enforce the policy.	4 or 1
-2	Incidents have been discovered that show that the company or facility prevents workers' rights to freedom of association and collective bargaining but a corrective action plan with a clear timeline for completion has not been developed.	–

Figure 34 - Example of Reference scale with aggregated reference values/information (UNEP, 2020, p. 86).

3.5.6. REPRESENTING SCALE LEVELS THROUGH SCORING OR NON-SCORING APPROACHES

When establishing reference scales, a key decision is whether to assign numerical values to scale levels. Numerical values facilitate easier aggregation of results but come with limitations (UNEP, 2020). Reference scales can be represented in three main ways:

1. Non-Numerical Representation:

Scales are represented using colors, letters, or checkmarks. Results can be visualized through dashboards, heat maps, or narrative descriptions. This approach avoids numerical aggregation but may limit the ability to combine results.

2. Linear Scoring:

Each scale level is assigned a fixed numerical value, with each level increasing by one unit. This approach allows for straightforward aggregation and predictable results, but may oversimplify the differences between levels.

3. Non-Linear Scoring:

Scale levels are assigned customized numerical values based on their perceived importance or distance from other levels. For example, higher risk levels may be assigned greater numerical values to reflect their significance. This approach is used in tools like the SHDB risk mapping tool, where higher risk levels are magnified numerically (UNEP, 2020).

Key Considerations:

- Non-Linear Scoring: Proponents argue that linear scoring is arbitrary and does not reflect the true value of social performance or risk levels. Non-linear scoring allows for more nuanced representation but requires expert judgment to define values.
- Non-Numerical Representation: Some practitioners prefer non-numerical scales to avoid oversimplifying qualitative data. However, this approach prevents aggregation, making it less suitable for complex studies (UNEP, 2020).

Practical Implications:

- The choice of representation depends on the study's goals. For example, non-linear scoring may be ideal for social hotspot assessments, while linear scoring offers predictability and ease of aggregation.
- Practitioners must transparently communicate their chosen approach and acknowledge its limitations in the study.

The representation of scale levels, whether through non-numerical, linear, or non-linear scoring, requires careful consideration to balance accuracy, aggregation, and transparency in S-LCA studies (UNEP, 2020).

3.5.7. S-LCA EXPERTS' VALUE BASED NON-LINEAR SCORING

To improve scoring in S-LCA, Do Carmo et al. (2017) proposed a value-based non-linear approach. Instead of assuming equal distances between levels (linear scoring), this method uses expert judgment to assign numerical values to qualitative levels (e.g., A, B, C, D)(do Carmo et al., 2017). Experts rate each level on a scale (e.g., 0-10), and the scores are averaged to create three possible value function shapes:

1. Linear: Equal distances between levels (default in S-LCA).
2. Concave: Higher scores for compliance levels.
3. Convex: Lower scores for compliance levels.

This approach can also involve stakeholders or decision-makers to ensure diverse perspectives. However, the scoring must be adapted for each study and cannot be generalized.

This method provides a more accurate and flexible way to score performance levels, moving beyond the simplicity of linear scoring (UNEP, 2020).

3.5.8. ESTABLISHING PERFORMANCE INDICATORS TO PREPARE FOR DATA COLLECTION

After developing reference scales, the next step is to establish a list of performance indicators (PIs) associated with each scale level. Performance indicators are quantitative or qualitative markers that define the performance reference points (PRPs) within the reference scales. Each scale level may be based on multiple performance indicators, not just one (UNEP, 2020).

Key Steps:

1. **List Performance Indicators:**

Clearly define the PIs for each level of the reference scale. This helps improve the precision of the scale and clarifies the type of data needed for the inventory.

2. **Prepare for Data Collection:**

The list of PIs guides the data collection process, ensuring that the inventory data can be compared against the reference scales during the assessment phase.

3. **Assess Inventory Data:**

During the assessment, inventory data is assigned to the corresponding reference scale level. For example, the social risk associated with forced labor might be assigned a level of +1 (one level above compliance) (UNEP, 2020).

Performance indicators

1 The company or facility has a policy that allows freedom of association and collective bargaining.

2 The company or facility has a system in place to enforce the policy that allows freedom of association and collective bargaining.

3 No evidence indicates that he company or facility/management has taken disciplinary actions against workers organising themselves collectively.

Type of data sources	Example
News	The management of the facility has taken disciplinary actions against workers organising themselves collectively.
NGO reports	
Social media	

4 Incidents have been discovered that show that the company or facility prevents workers' rights to freedom of association and collective bargaining, and a corrective action plan with a clear timeline for completion has been developped.

5 The company or facility recognises the collective representation of organized workers in negotiations.

6 The company or facility engages in a dialogue with the collective representation of workers and incorporates their views into management decisions.

Figure 35 - Performance indicators associated with the reference scale in Figure 18, assessing data against the reference scale (UNEP, 2020, p. 88).

Benefits:

- **Improved Precision:** Iteratively refining the reference scales with clear PIs enhances their accuracy.

- **Clarity in Data Collection:** Knowing the required PIs ensures that the inventory data collected is relevant and sufficient for comparison with the reference scales.

Establishing **performance indicators** is a crucial step in preparing for data collection. It ensures that the reference scales are precise and that the inventory data can be effectively assessed against them (UNEP, 2020).

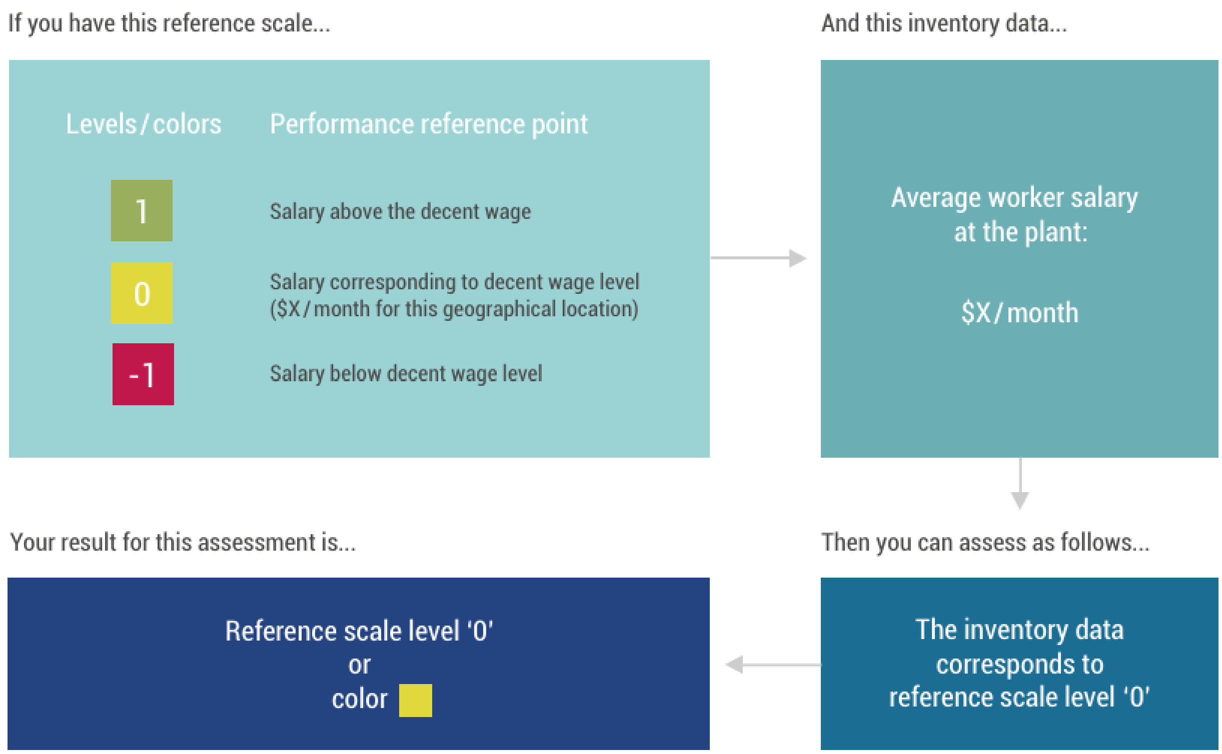


Figure 36 - Simplified illustration of assessment using this approach (UNEP, 2020, p. 89).

3.5.9. AGGREGATION AND WEIGHTING

Aggregation and weighting are essential steps in the Social Life Cycle Impact Assessment (S-LCIA) phase. They help combine and summarize complex data into meaningful results, such as single scores or stakeholder-level performances. However, these steps must be applied carefully to avoid misinterpretation and loss of context (UNEP, 2020).

Key Points:

1. Purpose of Aggregation:

- Aggregation combines multiple elements (e.g., indicators, subcategories) into a single score or result. This simplifies complex data for better understanding and communication.
- It is recommended to avoid aggregating positive and negative impacts, as positive impacts do not cancel out negative ones. Instead, present them side by side to maintain transparency.

2. **Challenges of Aggregation:**

- Aggregating results from different regions or stakeholder groups can lose important context, especially in global supply chains. For example, combining results from workers in different countries may overlook local conditions.
- Aggregation assumes that scores (e.g., -2 is twice as bad as -1) are comparable, which may not always reflect reality (UNEP, 2020).

3. **Weighting:**

- Weights are used to reflect the relative importance of indicators, subcategories, or stakeholder groups. For example, more critical subcategories are assigned higher weights to influence the final results more significantly.
- If weights are not defined, all indicators are assumed to have equal importance, which may not accurately reflect their relevance (UNEP, 2020).

4. **Transparency in Weighting:**

The weighting process must be transparent. Key questions to address include:

- Are weights based on a specific framework?
- Were weights determined by stakeholders or experts?
- What method was used to establish weights?

Different weight sets or aggregation techniques can lead to different conclusions, so the process should be clearly documented.

5. **Avoiding Bias:**

Weighting systems can introduce biases, such as overemphasizing losses (endowment effect) or catastrophes. These biases should be identified and adjusted for to ensure accurate results (UNEP, 2020).

Practical Considerations:

- Before aggregation, ensure all results are expressed in the same unit (e.g., points) to avoid combining incompatible data.
- Keep the original data available to maintain transparency and allow for alternative interpretations.
- When relevant, use parallel weightings based on different stakeholder values to contrast perspectives.

Aggregation and weighting are powerful tools for simplifying and interpreting S-LCA results, but they require careful application to ensure accuracy, transparency, and context preservation (UNEP, 2020).

Weighting approach and description	Pros, Cons, 'When to apply', and 'How to apply'
Equal weighting Attributing equal weighting to all indicator results.	**Pros:** Simple, easy to communicate. **Cons:** Provides a false sense of neutrality. **When to apply:** When indicators are deemed as robust and as relevant as one another. **How to apply:** If numerical results: do nothing. If non-numerical results: determine the average result based on observation of results.
Most robust indicators prioritized Most robust and relevant indicators are granted a higher weight than the others in the aggregation (criteria may include: timeliness, robustness of data source, level of resolution (Beaulieu et al., 2014)).	**Pros:** Results are based on the most robust and relevant indicators while including a certain level of triangulation. **Cons:** Some subjectivity may be involved in defining what comprises robustness and relevance, thus adding a certain bias. **When to apply:** When indicators are not deemed equally robust and relevant. It is important to document clearly how robustness and relevance is determined. **How to apply:** If numerical results: i) multiply each numerical result by the weight allocated to it (based on robustness or relevance); (do not forget that not applying any weight is equivalent to applying a weight of 1).
Expert or stakeholder values Weights are defined based on existing frameworks (e.g. ILO decent work agenda, corporate code of conduct) or on preferences expressed by stakeholders, product users, or pre-defined stakeholder profile values, through a stakeholder involvement process. *Rarely applied on this type of aggregation.	**Pros:** Provides opportunity to integrate stakeholder opinions to determine the relative importance of indicators within subcategories. Can boost richness and relevance of results. **Cons:** Structure and quality of stakeholder involvement process may affect results in a significant way. May be time consuming if using survey, focus group, or delphi panels. **When to apply:** When it is relevant to present weighted results for the context. **How to apply:** If numerical results: i) multiply each numerical result by the weight allocated to it through the stakeholder involvement process (do not forget that not applying any weight is equivalent to applying a weight of 1).
Worse performance prioritized A weight of '1' is granted to the worse performing indicator and a weight of '0' is granted to all other indicators. This means that the results for the impact subcategory amount to the worse performance recorded.	**Pros:** The impact subcategory results do not dilute any documented negative performances/risks among indicators. **Cons:** May provide a less balanced view on impact subcategory results, given that less triangulation is involved. **When to apply:** When indicators are deemed as robust and relevant as one another. Relevant when objective of the assessment is to ensure that no negative performance is missed. **How to apply:** If numerical results: i) a weight of '1' is granted to the worse performing indicator and a weight of '0' is granted to all other indicators; ii) multiply each numerical result by the weight allocated to it through the stakeholder involvement process; iii) apply weighted arithmetic or geometric mean (do not forget that not applying any weight is equivalent to applying a weight of 1).

Table 5 - Weighting approaches (UNEP, 2020, p. 91).

3.5.10. Defining the Steps of Phase 3

Following the summary and conceptual explanation of Phase 3 – Impact assessment, the framework is now broken down into a set of distinct implementation steps. These steps have been extracted and synthesized directly from the two authoritative guidelines used in this study: the UNEP Guidelines for Social Life Cycle Assessment of Products and Organizations (2020) and the ISO 14075:2024 standard.

Steps in phase 3:

1. Choose Assessment Approach

2. Select Impact Categories/Subcategories

3. Define Reference Scales

4. Assign Inventory Data (Classification)

5. Apply Scores

6. Aggregate (optional)

7. Weight (optional)

8. Normalize (optional)

3.6. Step 4: Interpretation

The interpretation phase is the final but critical stage of the S-LCA process. It brings together the results of all preceding phases and translates them into meaningful findings and actionable insights. The aim is to ensure that the outcomes of the assessment are not only accurate and robust but also aligned with the intended purpose of the study (UNEP, 2020).

Interpretation in S-LCA is not a one-time task; rather, it is iterative. Throughout this phase, the practitioner may need to return to earlier phases to adjust boundaries, refine indicators, or correct inconsistencies. Interpretation involves identifying significant issues, evaluating completeness and consistency, analyzing sensitivity and uncertainty, applying materiality, and, optionally, aggregating results and visualizing findings before drawing conclusions and communicating them effectively (UNEP, 2020). ISO 14075 (2024) complements this structure by emphasizing transparency, robustness, and clarity in reporting (ISO 14075, 2024).

3.6.1. Identifying Significant Issues

The first step in interpretation involves recognizing which social issues stand out based on the impact assessment results. These may be negative impacts (e.g., scores of −2 or −1) or positive contributions (e.g., scores of +2). UNEP (2020) recommends reviewing the results in relation to stakeholder salience and identifying "hotspots", issues that are both socially significant and relevant to the study's objective. The guideline suggests using a matrix format to connect impact subcategories with stakeholder categories, which can help in organizing and prioritizing the findings for the next steps. This visual could be usefully included in your thesis here to support your explanation (UNEP, 2020).

Assessment phase	Guiding questions	
GOAL AND SCOPE	• Are the Goal and Scope clearly defined? • Have all the relevant stakeholders been considered? If some stakeholders have been excluded, which criteria were used to justify it? • Have all the relevant life cycle phases and processes been taken into account? If cut-offs and omission have been applied, are they duly justified according to e.g. social significance, empirical motivations, identical elements, and decision relevancy?	ITERATIVE PROCESS
INVENTORY	• Are the data collected sufficient for evaluating the identified relevant social aspects?	
IMPACT ASSESSMENT	• Are the selected impact categories, subcategories, and indicators sufficient for addressing the performances/impacts of the study? • Are the social impact pathways sufficient for addressing the identified impacts (if applicable)?	
INTERPRETATION	• Are the results answering the research/evaluation questions? Are there unsolved questions or information gaps? • Are value choices properly detailed when drawing conclusions?	

Table 6 - Example of guiding questions to conduct the completeness check (UNEP, 2020, p. 110).

3.6.2. Completeness and Consistency Evaluation

A key part of interpretation is verifying whether the study has adequately addressed all phases and key stakeholder categories. According to UNEP (2020), completeness means that all relevant processes, data types, and social issues defined in the goal and scope phase have been carried through to the results. If not, the guideline allows for iteration: practitioners can revise their scope or expand data collection as needed (UNEP, 2020). ISO 14075 also stresses that any omitted elements must be clearly documented and justified (ISO 14075, 2024).

Consistency checks, meanwhile, ensure that methodological choices are logically aligned throughout the assessment. UNEP (2020) provides a checklist of narrative questions to assess whether impact subcategories were scored using coherent criteria and whether assumptions in data treatment remained valid across phases (UNEP, 2020). ISO 14075 requires that internal alignment between phases and methods is demonstrated, particularly when drawing conclusions or making comparisons (ISO 14075, 2024).

3.6.3. Sensitivity and Uncertainty

Since many S-LCA studies involve qualitative or incomplete data, uncertainty analysis becomes crucial. UNEP encourages simple sensitivity checks, such as modifying input data or assumptions by ±20%—to see if key results remain stable. For example, if the data on working hours is estimated, testing different values may reveal whether final stakeholder scores are robust. ISO 14075 also references the need to acknowledge uncertainty and include it in the interpretation process, particularly in cases where conclusions could influence decisions (ISO 14075, 2024; UNEP, 2020).

3.6.4. Materiality and Prioritization

Not all identified issues carry the same weight. Materiality helps determine which issues are most relevant for reporting and action. UNEP (2020) defines materiality based on two criteria: the issue's potential to contribute to the assessment goal, and the degree of influence it may have on stakeholders(UNEP, 2020). Material issues, such as human rights risks or lack of worker representation, should be prioritized in the final interpretation and recommendations. While ISO 14075 does not explicitly name "materiality" as a standalone step, the principle of prioritizing socially relevant impacts is consistent throughout its guidance (ISO 14075, 2024).

3.6.5. Aggregation and Visualization

To aid interpretation and communication, impact scores may be aggregated or visualized using tools like radar charts, bar graphs, or stakeholder dashboards. Aggregation can be done across subcategories or stakeholder groups, although it is important to preserve disaggregated data to maintain transparency. Visualization enhances stakeholder engagement by simplifying complex findings without oversimplifying them. These techniques are particularly helpful when the results are to be used in public communication or internal decision-making processes (ISO 14075, 2024; UNEP, 2020).

3.6.6. Conclusions and Making Recommendations

Concluding involves summarizing the most significant findings, contextualizing them within the assessment goal, and identifying the implications for the organization or system being studied. Recommendations may include improvement measures, policy actions, or further assessments. These conclusions must be supported by the underlying data and reflect any limitations or uncertainties discovered during earlier phases. The reporting format should be clear, concise, and structured according to stakeholder categories or thematic areas (ISO 14075, 2024; UNEP, 2020).

3.6.7. Critical Review

When the results are intended for public disclosure or comparative purposes, a critical review by independent experts is conducted to validate the methodological integrity and transparency of the assessment. This includes reviewing assumptions, data sources, scoring logic, and conclusions. A well-documented review adds credibility and is often necessary when the results may influence public policy or market decisions (ISO 14075, 2024; UNEP, 2020).

3.6.8. Defining the Steps of Phase 4

Following the summary and conceptual explanation of Phase 4 – Interpretation, the framework is now broken down into a set of distinct implementation steps. These steps have been extracted and synthesized directly from the two authoritative guidelines used in this study: the UNEP Guidelines for Social Life Cycle Assessment of Products and Organizations (2020) and the ISO 14075:2024 standard.

Steps in phase 4:

1. Identify Significant Issues

2. Completeness Check

3. Consistency Check

4. Check Sensitivity & Uncertainty

5. Apply Materiality

6. Aggregate/Visualize (optional)

7. Conclusions & Recommendations

8. Critical Review (optional)

3.7. Case study: Milan Demo Site – Urbana New Living District

The ProLight project, funded by the European Union's Horizon 2020 programme, includes demonstration sites across Europe aimed at testing energy transition strategies in urban districts. The Italian pilot is located in Urbana New Living, a newly developed neighborhood in Milan, which focuses on sustainable urban living. It is especially significant because it integrates affordable housing with renewable energy technologies and community engagement through digital tools like the Planet App and EnergyVista (*ProLight*, n.d.).

This demo case is a suitable and representative urban testbed for assessing and improving energy behaviors and social performance across diverse user groups in social and rental housing contexts (ProLight Report D2.4, 2024).

3.7.1. General Characteristics of the Milan Site

- **Location:** Urbana district, Milan, Italy
- **Housing Composition:**
  87 rental units
  50 owner-occupied units
- **Construction Year:** 2019
- **Total Living Area:** 10,039.66 m²
- **Project Type:** Deeply renovated social housing, within the Positive Energy District (PED) framework
- **Technological Innovations:** Integration of renewable energy sources and digital solutions, including:

1. **Ground-source heating/cooling systems**

These systems use the earth as a thermal reservoir to supply renewable heating and cooling to residential units. Heat pumps circulate fluid through underground pipes to absorb warmth during winter and dissipate heat during summer. This technology significantly reduces the need for fossil-fuel-based heating, cutting carbon emissions and long-term energy costs.

Function and Role:

- Provides constant and efficient thermal energy throughout the year.
- Enables energy independence from traditional grid-based heating.
- Ensures resident comfort while minimizing environmental impact (ProLight Report D2.4, 2024).

2. **Solar roof/thermal systems**

The buildings in the Urbana district are equipped with solar photovoltaic panels and solar thermal collectors. These installations are intended to generate clean electricity and heat water using solar radiation.

Function and Role:

- Solar PV panels contribute to on-site electricity generation for shared services and household consumption.
- Solar thermal systems pre-heat domestic hot water, reducing demand on electric water heating.
- Combined, these systems increase the site's energy self-sufficiency and reduce energy bills (ProLight Report D2.4, 2024).

3. **NILM (Non-Intrusive Load Monitoring) sensors**

The NILM technology allows detailed, appliance-level disaggregation of energy use without installing individual meters for each device. Instead, sensors installed on the main electricity line infer which appliances are in use based on unique power signatures.

Function and Role:

- Breaks down overall energy consumption into individual uses (e.g., heating, lighting, laundry).
- Helps residents understand their energy behavior in a clear, quantified way.
- Supplies the backend data to EnergyVista and the Planet App, supporting feedback and engagement.

Aims:

- Enables personalized and actionable energy-saving advice.
- Promotes behavioral changes by showing real-time and historical usage patterns (ProLight Report D2.4, 2024; ProLight Report D4.3, 2025).

4. **Planet App for resident energy feedback**

The Planet App is the main resident-facing digital platform. It uses gamification and social feedback mechanisms to drive participation and foster behavioral change.

Function and Role:

- Delivers daily/weekly challenges (e.g., reduce laundry frequency or turn off unused lights).
- Offers education through articles, quizzes, and real-time notifications.
- Provides performance tracking (e.g., weekly energy score) and comparisons with neighbors.
- Includes a rewards system linked to local businesses (e.g., Ciclocaffè, Farmacia del Parco).

Aims:

- Encourages active learning and engagement.
- Makes energy conservation tangible, social, and rewarding.
- Creates a bridge between digital infrastructure and everyday resident behavior (ProLight Report D2.4, 2024; ProLight Report D4.3, 2025).

5. **EnergyVista for disaggregated energy monitoring.D2.4**

EnergyVista complements the Planet App by offering deeper, disaggregated insights into energy usage. It translates raw data from NILM sensors into intuitive dashboards.

Function and Role:

- Displays time-of-use patterns and appliance-specific breakdowns.
- Helps users identify "energy hotspots" in the home.

- Supports reflective learning and personal progress tracking.

Used in:

- Citizen Lab workshops to teach residents how to understand and act on their energy profiles.
- Feedback loops that inform the app's scoring and reward mechanisms.

Aims:

- Increases energy literacy.
- Supports the interpretation of behavior-linked energy outcomes.
- Enhances transparency and resident trust in the system (ProLight Report D2.4, 2024; ProLight Report D4.3, 2025).

3.7.2. Stakeholders Involved

- **Planet Smart City:** Overall coordinator of the ProLight project.
- **REDO SGR:** Real estate developer and owner of part of the housing stock.
- **Ecopolis Servizi (LUM):** Technical and administrative property management.
- **Midori:** SME specializing in energy efficiency and NILM technology.
- **Residents:** End-users and main beneficiaries of engagement activities.
- **Cascina Biblioteca:** Community-based organization co-facilitating engagement workshops.
- **Local Businesses:** Participated in reward mechanisms (e.g., Ciclocaffè, Farmacia del Parco) (ProLight Report D4.3, 2025).

3.7.3 Community Engagement Approach

The core of the Milan demo site is its Citizen Lab methodology. These are recurring workshops and interactive sessions with the local community. Their goals include:

- Increasing awareness of energy consumption.
- Promoting sustainable behavior.
- Testing and improving digital engagement platforms (ProLight Report D2.4, 2024).

3.7.4. Technical Features and Interventions

The Urbana district was selected for its modern infrastructure, which allows testing multiple innovations. According to the benchmarking report:

- Heating & Cooling Systems: Ground-source thermal generation + radiant floor diffusion.
- Ventilation: Systems upgraded or newly installed.
- Lighting: Smart LED-based systems installed (ProLight Report D2.4, 2024).

Renewables:

- Solar roof
- Solar thermal
- Building Management Systems by Delta Controls

- Integration with Planet App and NILM for real-time data feedback (ProLight Report D2.4, 2024).

3.7.5. Social and Educational Goals

Beyond technology, the site aims to transform community behavior through:

- **Digital Empowerment:** Training users to interpret energy data.
- **Energy Equity:** Bridging knowledge gaps for low-income residents.
- **Behavioral Change:** Promoting routines that lower emissions and save costs.
- **Community Connection:** Encouraging shared learning and active participation.
- **Hands-on Learning:** Special focus on youth engagement via thematic labs (ProLight Report D4.3, 2025).

3.7.6. Challenges Identified

- Low initial participation due to limited community cohesion post-COVID.
- Digital illiteracy among some residents.
- Difficulty in scaling workshops across the full housing population.
- Communication constraints when relying only on flyers or digital posts.

Efforts were made to improve workshop interactivity, offer technical support during sessions, and build trust through in-person promotion (ProLight Report D4.3, 2025).

3.7.7. Lessons Learned & Opportunities

- Multi-stakeholder models are key to inclusive energy transitions.
- Practical, engaging formats (like children's workshops) create stronger emotional connection to energy issues.
- The Planet App combined with NILM and EnergyVista represents a novel digital-social toolchain for PED engagement.
- The replication of this model is feasible in similar affordable housing contexts across Europe (ProLight Report D4.3, 2025).

CHAPTER 4- Results

This chapter presents the main results of the research. It begins with a structured set of comparative tables that synthesize the key differences and similarities between the two most authoritative international S-LCA implementation guidelines: *UNEP (2020)* and *ISO 14075:2024*. These tables are organized according to the four standard phases of S-LCA and evaluate each step based on three key criteria: availability, similarity, and difference. This comparative analysis, developed through the methodological approach described in Chapter 3, serves as the analytical foundation for the development of a new, simplified S-LCA implementation framework.

Building upon these comparative findings, the second part of the chapter presents the simplified and user-friendly Social Life Cycle Assessment methodology developed in this study. The structure is organized phase by phase, mirroring the standard four-phase model of S-LCA.

Each phase is broken down into clearly defined implementation steps, derived from the comparative framework. For every step, one or more practical tasks are presented. These tasks are supported by two functional columns:

- **What to Do** – a concise explanation of the action or decision required.
- **How to Do It / Practical Guide** – detailed instructions, examples, and suggested tools to support implementation.

This format is designed to improve accessibility, clarity, and applicability, especially for students, educators, and early-stage S-LCA practitioners who may face limitations in training or resources.

In the final section of this chapter, the proposed simplified methodology is validated through its application to a real-world case study. This practical implementation demonstrates how each task and step can be executed and adapted in an actual Positive Energy District (PED) context.

4.1. Developing Comparative Analysis (Comparative tables)

Building upon the explanation of the four S-LCA phases in Chapter 3 and the identification of their key implementation steps based on the two selected international guidelines, *UNEP (2020)* and *ISO 14075:2024*, this section presents the comparative analysis of these references. The comparison is organized into four tables, corresponding to the four phases of S-LCA, and is structured around three analytical criteria:

Availability of the Step

Similarities

Differences

This comparative framework provides a transparent evaluation of how each guideline addresses essential elements of S-LCA implementation. It also forms the analytical foundation for the development of the simplified and user-friendly S-LCA methodology presented in the following section.

4.1.1. Comparative Analysis (Comparative tables) – Phase 1: Goal and Scope Definition

Comparative Table (Phase 1)					
Phases	Steps	Criteria	UNEP S-LCA Guideline	ISO 14075:2024	Notes
Phase 1- Goal and scope definition	1. Goal Definition	Availability	Fully available. Extensive, structured guidance on goal setting, including questions to ask, audience, use cases, and optional considerations like modeling type.	Fully available. Clearly structured, with mandatory items for the goal statement.	Available in both
		Similarity	Both include: – Intended application – Reasons for the study – Target audience – Disclosure to the public or internal use – Relevance to system boundaries	Same key components required: – Application – Reason – Audience – Use in comparative assertion/public disclosure	Core structure and intent are aligned.
		Differences	– More exploratory and flexible (open questions, broad range of goal types) – Recommends stakeholder alignment and discusses attributional vs. consequential modeling – Includes wider list of goals (e.g., human rights, social development, hotspot analysis)	– More formal and prescriptive – Less detail on types of goals – No mention of modeling perspective – Emphasizes “unambiguous” goal declaration requirements	UNEP: broader, flexible, value-driven ISO: narrower, formal, procedural focus
	2. Functional Unit	Availability	Functional unit is comprehensively discussed, with emphasis on product utility, consumer perception, and integration with trade model-based databases.	Functional unit is explicitly defined and required; it focuses more on measurability, normalization, and comparability between systems.	Both provide the steps in detail. UNEP offers more conceptual background, while ISO is stricter in methodological clarity.
		Similarity	Both emphasize the importance of consistency with the goal and scope, and the necessity of quantifying the function (not the product itself).	Both align on using the function to define the unit, stressing quantification and comparability.	Clear alignment in the core intent and purpose of the functional unit across both guidelines.

		Differences	UNEP includes broader social and cultural aspects (e.g., product utility, consumer perception, aesthetics), and links the functional unit to potential positive social impacts. It allows the use of monetary-based units when databases are used.	ISO is more prescriptive and avoids referencing qualitative aspects. It strongly promotes using function-based definitions (e.g., performance over time) for comparability and normalization.	UNEP offers a more holistic view, including qualitative social value, whereas ISO focuses more on standardization and practical, numeric comparability.
	3. The Reference Flow	Availability	Fully defined.	Fully defined.	Both guidelines provide clear guidance on defining the reference flow.
		Similarity	Both define reference flow as translating the functional unit into measurable product flows. Both link it to fulfilling the function defined in the functional unit. Both emphasize consistency with the product system and life cycle inventory.	Agrees with UNEP on the purpose of reference flow. Also uses reference flow to determine the material inputs necessary to fulfill the functional unit.	Strong conceptual alignment exists in the purpose and structure of the reference flow.
		Differences	Discusses the implications of scaling or not scaling social impacts based on reference flow. Provides examples (e.g., forced labor) where proportional scaling may not apply. Encourages contextual reflection.	Focuses more on technical guidance (e.g., comparability at high aggregation levels). Emphasizes that industry-level social data requires high product comparability.	UNEP takes a more conceptual and ethical view, whereas ISO provides more operational and data-quality-focused guidance.
	4. The Product System	Availability	Fully defined: the product system is established based on the functional unit and consists of interconnected unit processes.	Fully defined: product system scope includes a clear specification of obligatory product properties and relevant product market context.	Both guidelines require defining the product system.
		Similarity	Both emphasize defining the product system to fulfill the functional unit, and both stress geographical and market context.	Both approaches focus on identifying and specifying key product characteristics and conditions tied to space and time.	Shared emphasis on context sensitivity and functional adequacy.

		Differences	Defines unit processes, inputs/outputs, energy, services; recommends flowcharts and use of input-output tables (e.g., SHDB, PSILCA); detailed view of system boundaries.	Focuses on product properties and customer expectations in the relevant market; places less emphasis on visualizing the full system or specifying processes like UNEP does.	UNEP focuses on system mapping and data flows; ISO focuses on market properties and functional consistency.
	5. Identifying the System Boundaries	Availability	Fully defined: UNEP outlines system boundary considerations, including foreground/background processes, and both physical and effect perspectives.	Fully defined: ISO specifies system boundary definition, emphasizing physical/economic causality and social impact causality; includes criteria like cut-offs.	Both define system boundary comprehensively.
		Similarity	Both guidelines acknowledge: (1) the need for alignment with the goal of the study; (2) the importance of including relevant unit processes across life cycle stages; (3) the dual perspective of physical/economic vs. stakeholder/social interactions.	Both consider causality and emphasize stakeholder relations in addition to flows.	Shared use of dual-perspective reasoning for boundary setting.
		Differences	UNEP focuses more on iterative boundary definition, use of real-world examples (e.g., T-shirt), and data limitations (e.g., excluding chemical production). Introduces the effect perspective as critical for stakeholder inclusion.	ISO introduces more formalized decision criteria: cut-off criteria, modelling assumptions, and encourages social risk assessment to determine boundary relevance. Mentions need to ensure outputs are social elementary flows at the boundary.	UNEP emphasizes narrative clarity and practical decision-making; ISO adds structure through explicit constraints, thresholds, and social relevance rules.
	6. Activity Variable (optional)	Availability	Clearly defined in UNEP; used to quantify social inventory in the S-LCI phase.	Not explicitly defined; the concept is partially implied under inventory modeling and allocation procedures.	UNEP treats it as a key link between the functional unit and social indicators.
		Similarity	Both recognize the need to scale social data across unit processes using a measurable quantity (e.g., worker hours, revenue).	Aligned conceptually through ISO 14044 terminology; not labeled as "Activity Variable."	Partial conceptual alignment.

		Differences	UNEP introduces the term explicitly and explains its use in scaling indicators across the system.	ISO omits the term; it focuses instead on allocation and inventory flow relevance.	UNEP offers stronger practical guidance.
	7. Cut-off Criteria	Availability	Fully defined: UNEP addresses cut-off criteria as a key part of boundary setting, identifying three types (social significance, identical elements, available resources).	Embedded: ISO includes cut-off criteria within the system boundary section. Requires assumptions and criteria for inclusion/exclusion to be explicitly stated and not solely based on mass, energy, or environmental relevance.	UNEP treats cut-off as a separate sub-topic; ISO embeds it in boundary modeling requirements, with social sensitivity emphasized.
		Similarity	Both frameworks stress the importance of justifying exclusions and recognizing that social aspects may outweigh traditional environmental or material considerations in inclusion decisions.	Both recommend going beyond materiality and incorporating social risk or relevance in deciding cut-offs. ISO supports conducting a preliminary social risk assessment to ensure relevant social aspects are included.	Shared commitment to social relevance over purely quantitative metrics (e.g., mass or energy).
		Differences	UNEP clearly distinguishes between three cut-off types, recommends social significance as the preferred criterion, and warns against excluding elements due to a lack of data.	ISO formalizes the requirement to state modelling assumptions, and cut-offs must ensure that social elementary flows are captured. Introduces risk screening to prevent unintended social exclusions.	UNEP emphasizes transparency and ethical exclusion; ISO institutionalizes cut-off rules and highlights traceability and completeness of social data.
	8. Limitations of Data Access	Availability	Present: Explicitly included as a standalone step ("Limitations of Data Access").	Partially covered: Not a separate step; Data quality requirements, especially in relation to data gaps, site-specific data availability, and missing data treatment.	UNEP treats it as a major methodological constraint; ISO integrates it under broader data quality and completeness discussions.
		Similarity	Both acknowledge difficulties in collecting site-specific data, especially in early and late stages (e.g., raw material extraction or waste). Both suggest using generic data when access to primary data is limited.	Similar solutions offered for missing or hard-to-access data: (a) use of justified assumptions, (b) use of calculated/estimated values, (c) documentation of data sources and uncertainties.	Shared concern with data availability and reliability; both recommend transparent documentation and use of secondary data where needed.

		Differences	Strong emphasis on practical limitations due to global supply chains, lack of access, and resource constraints. Explicit about the trade-off between life cycle completeness and feasibility.	Focuses more on technical quality attributes (e.g., precision, completeness, reproducibility), and criteria to evaluate missing data, rather than the practical constraints in accessing data (e.g., no mention of travel cost, legal access, etc.).	UNEP centers on feasibility and decision-making implications; ISO formalizes evaluation protocols and response procedures to missing data.
	9. Stakeholder Categorization and Involvement	Availability	Present: Explicitly included as a distinct step ("Stakeholder Categorization & Involvement").	Present.	Both guidelines emphasize the importance of stakeholder identification and mapping, although ISO splits the concept into two clauses.
		Similarity	Both define groups likely to be affected by life cycle activities (e.g., workers, communities). Both recommend criteria-based selection: Impact, Legitimacy, Completeness. Both endorse materiality assessment for relevance check.	Identical in terms of stakeholder relevance logic: impact, legitimacy, and completeness. Also recommends transparency in justification for inclusion/exclusion.	Methodology, logic, and vocabulary are aligned. The terms "stakeholders" (UNEP) and "interested parties" (ISO) are functionally equivalent.
		Differences	Stronger focus on participatory tools: e.g., focus groups to support selection and indicator weighting. Warns against double-counting (e.g., worker also being a consumer).	More general on methods of engagement — does not detail participatory techniques. Doesn't explicitly caution about stakeholder role overlaps (e.g., double counting).	UNEP provides richer procedural guidance; ISO is more principle-based.
	10. Impact Assessment Method and Impact Subcategories	Availability	Present: Fully covered as Phase 3: Impact Assessment, with classification of methods, data, and categories.	Partially covered: Addressed under Goal and Scope and Inventory phase, without detailed methodological elaboration. Requires justification of chosen method and identification of social categories/subcategories.	UNEP treats it as a dedicated methodological phase, while ISO embeds it within other phases, giving less procedural detail.

		Similarity	Both require a choice of assessment method (Performance-based or Impact-based). Both involve identifying social topics, impact categories, and subcategories linked to interested parties/stakeholders. Justification of method choice is necessary.	Both frameworks support materiality assessment and call for an alignment between goal/scope and impact categories. Both require transparency in method and category selection.	Conceptually aligned. Both agree on key steps: method selection, topic/categorization, stakeholder linkage, and justification.
		Differences	Distinguishes between two methods: (1) Reference Scale (RS) and (2) Impact Pathway (IP), each with distinct data requirements and structure. Links categories to stakeholders and Areas of Protection (midpoint vs. endpoint logic). Strong emphasis on iterative refinement of categories based on materiality and findings.	Doesn't define types of assessment methods explicitly (no RS/IP differentiation). Less emphasis on midpoint-endpoint modeling, no mention of pathway modeling or characterization models. Does not detail refinement mechanisms across study phases.	UNEP is methodologically richer, offering structured options and deeper guidance (especially for impact modeling). ISO provides conceptual framing but lacks guidance on how to operationalize impact modeling and subcategory refinement.
	11. Indicators, Data Type, and Data Collection Strategies	Availability	Present: Explicitly addressed in the Goal & Scope phase. UNEP defines indicators as core elements to connect impact subcategories to measurable metrics and data collection strategies.	Present but minimally elaborated: Addressed "Data collection strategies", but mostly as part of inventory preparation. Limited detail on indicators or links to impact subcategories.	UNEP provides a structured and explicit connection between subcategories, indicators, and data methods. ISO treats this as an operational setup step.
		Similarity	Both require identification of data types, collection methods, and a link to inventory indicators.	Both acknowledge that data collected should be connected to social topics and subcategories; both allow for site-specific and generic data collection.	Conceptual alignment exists, though UNEP has a more defined methodology and linking framework.
		Differences	UNEP provides a clear indicator framework tied to subcategories and stakeholders. Also promotes the use of custom indicator tables and justifies method selection.	ISO does not define indicator structures or examples in this phase; it focuses on selecting data collection methods and defining whether data is primary/secondary, qualitative/quantitative.	ISO lacks UNEP's emphasis on indicator transparency and traceability.

Table 7 - Comparative Table of Phase 1: Goal and Scope Definition – UNEP (2020) vs. ISO 14075:2024 (Source: Author, 2025)

4.1.2. Comparative Analysis (Comparative tables) – Phase 2 Life Cycle Inventory

Comparative Table (Phase 2)					
Phases	Steps	Criteria	UNEP S-LCA Guideline	ISO 14075:2024	Notes
Phase 2- Life cycle inventory	1. Plan Inventory	Availability	Defines inventory as a structured data collection aligned with the Goal & Scope.	Requires general planning based on FU and stakeholder groups.	Both emphasize pre-alignment with the system model.
		Similarity	Defines inventory as a structured data collection aligned with the Goal & Scope.	Requires general planning based on FU and stakeholder groups.	Both emphasize pre-alignment with the system model.
		Differences	Defines inventory as a structured data collection aligned with the Goal & Scope.	Requires general planning based on FU and stakeholder groups.	Both emphasize pre-alignment with the system model.
	2. Collect Primary & Secondary Data	Availability	Gives detailed typology, sources, and guidance on triangulation.	Requires structured collection by data type and priority.	Both provide typologies.
		Similarity	Shared classification of primary/secondary; qualitative, quantitative.	Same.	Methods conceptually aligned.
		Differences	UNEP emphasizes feasibility and examples (e.g., SHDB, PSILCA, interview types).	ISO prioritizes documentation and data source control.	UNEP is more field-practical.
	3. Handle Qualitative & Semi-Quantitative Data	Availability	Covers scaling, interviews, Likert scores, and participatory validation.	Includes basic scaling formats and descriptive inputs.	Both acknowledge social data challenges.
		Similarity	Allow structured interviews, ordinal data, and yes/no indicators.	Same.	Methodological harmony.
		Differences	UNEP suggests stakeholder validation and risk matrices.	ISO focuses more on ensuring the consistency of the method.	UNEP goes deeper into participatory tools.
	4. Structure Product System	Availability	Describes flowcharts, process links, and stakeholder tagging.	Asks for linking to unit processes and FU.	Both require inventory mapping.
		Similarity	Require a visual/methodical link to FU, subcategories, and indicators.	Same.	Aligned structure.
		Differences	UNEP encourages supply chain depth (tiered approach).	ISO emphasizes structural rules for comparability.	UNEP is more illustrative.
	5. Apply Allocation	Availability	Prefers system expansion; fallback on proportional allocation.	Uses hierarchy: subdivision > expansion > simple split.	Present in both.
		Similarity	Hierarchy shared: subdivision, then expansion, then allocation.	Same.	Norm-aligned.

		Differences	UNEP warns about fairness (e.g., not double-counting labor).	ISO uses a one-line fallback rule for infeasibility.	UNEP is more socially sensitive.
	6. Ensure Data Quality & Address Gaps	Availability	Time, geography, completeness, reliability.	Provide a validation framework.	Present in both.
		Similarity	Both propose DQIs and iterative gap filling.	Same.	Shared intent.
		Differences	UNEP advises practitioner flexibility and proxy use if access is blocked.	ISO demands strict traceability and formal recording.	UNEP = pragmatic, ISO = rigid.

Table 8 - Comparative Table of Phase 2: Life Cycle Inventory – UNEP (2020) vs. ISO 14075:2024 (Source: Author, 2025)

4.1.3. Comparative Analysis (Comparative tables) – Phase 3 Impact Assessment

Comparative Table (Phase 3)					
Phases	Steps	Criteria	UNEP S-LCA Guideline	ISO 14075:2024	Notes
Phase 3 - Impact Assessment	1. Choose Assessment Approach	Availability	Explains RS vs. IP clearly; uses a decision tree.	Requires justification; includes RS/IP options.	RS is more common and more widely studied.
		Similarity	Both distinguish RS (ordinal) vs. IP (cause-effect).	Same.	Core logic aligned.
		Differences	UNEP gives guidance on method suitability per use case.	ISO offers a shorter format, with no visual decision flow.	UNEP is more applied.
	2. Select Impact Categories/Subcategories	Availability	Defines links to stakeholders and AoPs.	Requires a clear AoP link and stakeholder relevance.	Full match.
		Similarity	Focus on stakeholder relevance and materiality.	Same.	Shared structure.
		Differences	UNEP offers default category lists (workers, communities).	ISO assumes AoP is already defined; less guidance.	UNEP = guided, ISO = assumed.
	3. Define Reference Scales	Availability	Gives PRP structure, 5-level scale, scorecards.	Includes ordinal performance levels and scaling systems.	Strong alignment.
		Similarity	Both require 5-point PRP-based ordinal scoring.	Same.	Consistent.
		Differences	UNEP gives wage and freedom examples, colored tables.	ISO has a Table; no scorecard graphics.	UNEP is more visual.
	4. Assign Inventory Data (Classification)	Availability	Maps inventory to impact subcategories.	ISO describes the classification step.	Method match.
		Similarity	Both define classification as the process of mapping inventory results to impact subcategories.	Same.	Fully aligned.
		Differences	UNEP includes practical examples (e.g., mapping wage levels to "fair salary").	ISO remains procedural, without examples.	UNEP is more illustrative.
	5. Apply Scores	Availability	UNEP shows scoring logic (+2 to- 2) with stakeholder thresholds.	ISO applies scale; IP only.	RS scoring is covered in both.

		Similarity	Both use a 5-point ordinal scale based on performance reference points (PRP).	Same.	PRP logic is consistent.
		Differences	UNEP provides example scoring tables with color codes.	ISO refers to ordinal scales but gives less visual guidance.	UNEP is more user-friendly.
	6. Aggregate (optional)	Availability	Optional aggregation over stakeholder groups.	ISO allows aggregation; caution advised.	Optional in both.
		Similarity	Both allow optional aggregation of subcategory scores or across stakeholders.	Same.	Conceptual alignment.
		Differences	UNEP suggests weighted and unweighted options with stakeholder examples.	ISO notes aggregation may reduce transparency.	UNEP offers examples; ISO warns users.
	7. Weight (optional)	Availability	Stakeholder-based or equal weighting.	Optional; no detailed method.	UNEP = method-rich, ISO = option only.
		Similarity	Both identify weighting as an optional decision by the practitioner.	Same.	Shared flexibility.
		Differences	UNEP includes stakeholder-weighting scenarios.	ISO simply notes it as optional without guidance.	UNEP = prescriptive; ISO = neutral.
	8. Normalize (optional)	Availability	Convert ordinal scores to a % scale.	Not explicitly mentioned.	UNEP only.
		Similarity	Not applicable.	Not applicable.	Not addressed in ISO.
		Differences	UNEP suggests 0–100% normalization for visual dashboards.	No equivalent in ISO.	UNEP exclusive step.

Table 9 - Comparative Table of Phase 3: Impact Assessment – UNEP (2020) vs. ISO 14075:2024 (Source: Author, 2025)

4.1.4. Comparative Analysis (Comparative tables) – Phase 4 Interpretation

Comparative Table (Phase 4)					
Phases	**Steps**	**Criteria**	**UNEP S-LCA Guideline**	**ISO 14075:2024**	**Notes**
Phase 4 - Interpretation	1. Identify Significant Issues	Availability	UNEP offers an issue matrix and stakeholder flags.	ISO identifies key social topics based on results.	Full alignment.
		Similarity	Highlight hotspots based on stakeholder salience.	Same.	Shared logic.
		Differences	UNEP includes a guidance matrix and visual clustering.	ISO is less illustrative.	UNEP is more visual.
	2. Completeness Check	Availability	UNEP gives checklists by phase.	ISO Aligns with ISO 14044 completeness.	Both include this.
		Similarity	Require coverage of all phases and relevant stakeholders.	Same.	Harmonized.
		Differences	UNEP allows iteration of the Goal & Scope if incomplete.	ISO is less flexible.	UNEP allows a feedback loop.
	3. Consistency Check	Availability	UNEP shows narrative check questions.	ISO includes method alignment validation.	Present in both.
		Similarity	Emphasis on method coherence and alignment with goals.	Same.	Full agreement.
		Differences	UNEP uses narrative prompts.	ISO uses formal process checks.	UNEP is more qualitative.
	4. Check Sensitivity & Uncertainty	Availability	UNEP encourages ±20% scenario testing.	ISO mentions it as an interpretation element.	Only UNEP gives a practical approach.
		Similarity	Both recommend a sensitivity review in interpretation.	Same.	Conceptual match.
		Differences	UNEP suggests specific thresholds (e.g., ±20%); ISO does not.	ISO is more general.	UNEP is more practical.
	5. Apply Materiality	Availability	UNEP contribution & influence analysis.	ISO is not a separate step.	UNEP = explicit; ISO = embedded.
		Similarity	Both aim to prioritize issues with real stakeholder impact.	Same.	Shared intent.

		Differences	UNEP has a separate section and method; ISO integrates into significance identification.	No dedicated ISO clause.	UNEP clearer structure.
	6. Aggregate/Visualize (optional)	Availability	Radar charts, grouped by stakeholder.	ISO allows for disaggregated presentation.	Optional in both.
		Similarity	Both support graphical or grouped result presentation.	Same.	Aligned flexibility.
		Differences	UNEP gives radar chart and spider diagram examples.	ISO gives no specific visual formats.	UNEP is more user-ready.
	7. Conclusions & Recommendations	Availability	Structure includes limitations & suggestions.	Requires conclusions based on results.	Same.
		Similarity	Both require synthesis of findings into actionable insight.	Same.	Harmonized structure.
		Differences	UNEP emphasizes alignment with study goals and limitations.	ISO focuses on clarity and completeness.	Slight difference in emphasis.
	8. Critical Review (optional)	Availability	If for public use or comparisons.	required for public claims.	Optional unless disclosure.
		Similarity	Both require external review if public comparative claims are made.	Same.	Conditional match.
		Differences	UNEP provides guidance.	ISO is less descriptive.	UNEP = procedural detail.

Table 10 - Comparative Table of Phase 4: Interpretation – UNEP (2020) vs. ISO 14075:2024 (Source: Author, 2025

4.2. Simplified and User-Friendly S-LCA Implementation Methodology

Each table is organized around distinct implementation steps, and for each step, several tasks are defined. Tasks are accompanied by two key components:

- What to do – a brief explanation of the action required to complete the task.
- How to do it / Practical guide – suggestions or tools for carrying out the task effectively.

In some cases, tasks or entire steps may be optional, or may appear only in one of the two reference guidelines (particularly *ISO 14075:2024*). To guide readers through these distinctions, a visual legend has been developed and is applied consistently across all implementation tables:

- **Green** highlights an **optional step** within the methodology. These steps can enhance comprehensiveness but are not essential for basic assessments.
- **Orange** marks an **optional task**. These are useful additions, but can be omitted if constrained by resources or context.
- **Blue** indicates that **the step or task is derived from *ISO 14075:2024***, and is not explicitly addressed in the UNEP 2020 guideline.

This structure ensures the methodology is both modular and adaptable. Users may choose to follow the entire sequence for a full S-LCA or apply only selected steps and tasks that match the scope and resources of their project. By combining clarity, flexibility, and traceability to recognized standards, the tables provide a practical foundation for implementing S-LCA studies in diverse contexts.

4.2.1. Simplified and User-Friendly S-LCA Implementation Methodology- Phase 1: Goal and Scope Definition

Simplified and User-Friendly S-LCA Implementation Table (Phase 1)				
Phases	Steps	Task(s)	What to Do	How to Do It – Practical Guide
Phase 1- Goal and scope definition	1. Goal Definition	1. Define the Study Purpose	Clearly state "why the S-LCA is being conducted?"	Example: "To identify social hotspots in the product life cycle" or "To support sustainable product design".
		2. Identify Intended Application	Explain "how the results will be used?"	Example: "For internal decision-making", "For public communication", or "To support Human Rights Due Diligence".
		3. Determine Target Audience	Specify "who will use or review the results?"	Example: Internal stakeholders, consumers, NGOs, policymakers, trade unions, or investors.
		4. Define Assessment Focus	Clarify "what will be assessed socially?"	Example: "Working conditions in the value chain" or "Community impacts of supplier operations".
		5. Consider Improvement Opportunities	Identify if the study seeks to propose solutions or highlight areas for enhancement.	Example: "To improve supplier practices" or "To identify opportunities for stakeholder engagement".
		6. Clarify Use Context	Indicate whether the results will be made public or compared externally.	Example: "For public reporting and benchmarking," → external review may be needed.
		7. Specify Methodological Approach (Optional)	Mention if the approach is attributional or consequential.	Consider whether the aim is to assess current practices (Attributional → Reference Scale) or future consequences (Consequential → Impact Pathway)
	2. Functional Unit	1. Define Main Function	Identify "what service the product provides?".	Ask: What is the product supposed to do? Example: A chair provides seating support; a T-shirt covers the torso.
		2. Ensure Goal Consistency	Align the functional unit with the goal and scope of the study.	Review the goal definition and ensure the function matches the purpose of the assessment (e.g., long-term use, comparison).

		3. Quantify the Function	Make the function measurable and time-bound.	Use a clear statement: "Supports one person for 8 hours/day over 5 years in a European office." Avoid vague or product-only references like "one chair."
		4. Include Contextual Factors	Consider product utility, usage location, and social perception if relevant.	Include relevant cultural or technical elements (e.g., indoor sports, premium branding, certified labels). This helps especially in UNEP-style holistic assessments.
		5. Prepare for Comparability	Ensure the unit allows for fair comparison across alternatives.	Confirm that all compared systems provide the same function (not necessarily the same product). Example: A shirt vs. a T-shirt for the same function "covering torso."
		6. Link to Reference Flow	Use the unit as the basis to determine the amount of product required.	Example: If the function is 2 years of wear, and one product lasts 1 year, then 2 units are needed. This determines material flows in later steps.
		7. Consider Monetary Basis (if it is based on economic flows)	When using database modeling approaches (e.g., I/O trade models), define the functional unit in monetary terms.	Example: €50 worth of T-shirts sold in Q1 2024. Only do this if you're using such databases – not needed for all studies.
	3. The Reference Flow	1. Translate Functional Unit	Convert the defined functional unit into tangible product quantities.	Identify specific product quantities that fulfill the function (e.g., number of T-shirts needed over the lifespan defined in the functional unit).
		2. Identify Product Variants	Compare products with similar functions but different lifespans or qualities.	For each product option, determine how many units are needed to meet the functional unit (e.g., 2 T-shirts of Brand A vs. 1 of Brand B over 2 years).
		3. Determine Material Inputs	Link reference flows to material input requirements.	Use production or product data to estimate inputs (e.g., cotton, labor hours, packaging) required per unit of product.
		4. Check Data Consistency	Ensure product data matches functional unit and reference flow logic.	Confirm that the data used for material inputs are consistent across alternatives and scenarios (e.g., quality, lifetime, regional context).

		5. Decide on Scaling Approach (Optional)	Decide whether to scale social impact results based on reference flow quantities.	If relevant, justify the decision: e.g., scale child labor exposure based on quantity, or not if using rule-based ethical judgment. Document the rationale clearly.
		6. Estimate Uncertainty (Optional)	Consider if variability in input flows affects outcomes.	Note where ranges or assumptions could affect the outcome (e.g., different lifespans in different regions or climates).
		7. Document Reference Flow	Clearly describe the chosen reference flow for each product system.	Use a simple sentence structure like: “To fulfill the functional unit, 1 Brand B T-shirt is required over 2 years,” or in monetary units for trade-based models.
	4. The Product System	1. Define product system	Identify the full set of interconnected processes needed to fulfill the functional unit.	Use a flowchart to map out all unit processes (e.g., raw material extraction, processing, use, disposal). Confirm all processes are relevant to fulfilling the defined function.
		2. Identify unit processes	Break down the system into the smallest units where data can be collected (e.g., factory production, washing activities).	Link each unit to a specific activity performed by organizations (e.g., sewing, packaging, distribution).
		3. Determine process inputs/outputs	List all inputs (raw materials, energy, services) and outputs (products, emissions, waste) for each unit process.	Collect data from company records, LCI databases, literature, or input-output models. Include ancillary materials and support services as well.
		4. Specify geographic location	Identify where each process occurs geographically.	For each process, determine the country/region, and if possible, name the company or factory involved.
		5. Use input-output analysis (Optional)	Consider using economic input-output data to model the supply chain.	Use tools like SHDB or PSILCA that rely on global IO tables to provide a complete but aggregated view of the product system.
		6. Define product functions/properties	Clarify obligatory product characteristics based on customer expectations.	Use BSI’s approach: define performance, durability, aesthetic, etc., as seen by the target market. Consider space (region) and time (e.g., current vs. future expectations).

		7. Specify product market context	Describe the relevant product market (location, time, customer profile).	Example: "Premium athletic shoes sold in Western Europe in 2024 to consumers aged 20–40". Helps define competitive alternatives and context.
		8. Review with literature (Optional)	Conduct a literature review for system completeness and alignment with similar S-LCA studies. (optional)	Identify known life cycle stages or supply chain configurations for similar products. This can improve completeness and validation.
	5. Identifying the System Boundaries	1. Define system boundaries	Determine "which unit processes to include in the product system".	Include both foreground processes (close to the product, direct data) and background processes (upstream/downstream, generic data). Ensure all stages are aligned with the functional unit and the goal of the study.
		2. Align with life cycle logic *(life cycle phase(s))*	Cover all major life cycle phases from raw material extraction to end-of-life.	Aim for cradle-to-grave, but justify if narrowed (e.g., due to data gaps or resource limits). Document what is excluded and why (e.g., chemical production due to lack of access).
		3. Apply dual perspectives	Consider both physical/economic and social impact perspectives.	Physical/economic: Identify technical and financial flows; social impact: identify stakeholder roles, power dynamics, and potential social issues.
		4. Apply cut-off criteria (ISO)	Set thresholds for including or excluding processes based on relevance.	Define and document cut-offs not only by mass or energy, but also by social relevance. Conduct an initial social risk screening to determine what cannot be cut off.
		5. Document modelling assumptions	Explain decisions and assumptions used to set the system boundary.	State assumptions such as data availability, sector representativeness, or confidentiality. Describe limitations and rationales for including/excluding each process.
		6. Consider stakeholder causality	Ensure that key stakeholders and their interactions are represented.	Map social influence and responsibilities throughout the life cycle. Include suppliers, manufacturers, distributors, end users, and waste handlers when socially relevant.

		7. Use input-output data (Optional)	Supplement boundary setting with economic I/O models if needed. (optional)	Input-output tables or S-LCA databases (e.g., PSILCA) can help fill data gaps or provide supply chain estimates, especially for background processes.
		8. Visualize the system (Optional)	Draw a system diagram showing included/excluded processes. (optional)	Use simple flowcharts or life cycle maps. Highlight processes inside and outside the boundary with visual cues (e.g., greyed out areas for excluded stages).
	6. Activity Variable (optional)	1. Select a system-wide scaling variable for social data	Choose one quantitative unit (e.g., **worker-hours**, **value-added**, **production output**) that allows the social inventory to be distributed across all processes.	Choose one quantitative unit (e.g., **worker-hours**, **value-added**, **production output**) that allows the social inventory to be distributed across all processes.
		2. Ensure compatibility with the functional unit and data availability	Confirm that the selected variable is **measurable at every inventory node** and **aligned with the functional unit**.	Confirm the selected variable is **measurable at every inventory node** and **aligned with the functional unit**.
		3. Link activity variable to indicator scaling and scoring	Apply the activity variable in the S-LCI and S-LCIA phases to convert raw values into comparable social performance scores.	Apply the activity variable in the S-LCI and S-LCIA phases to convert raw values into comparable social performance scores.
		4. Document and justify the chosen variable	Justify your selection based on relevance, consistency, and data access.	Justify your selection based on relevance, consistency, and data access.
	7. Cut-off Criteria	1. Define cut-off criteria	Identify and document which unit processes may be excluded from the system.	Use one or more UNEP criteria: (1) Social significance (recommended), (2) Identical elements, or (3) Available resources. Clearly state why any process is cut off. Avoid excluding data only due to resource or access limitations.
		2. Use social significance (preferred)	Include processes with high potential for social impact, even if their material flow is minor.	Conduct qualitative or quantitative screening to determine which processes are socially sensitive (e.g., potential for labor violations, stakeholder conflict).

		3. Avoid unjustified exclusions	Do not omit processes simply due to a lack of access or effort constraints.	Make exclusions transparent. Document constraints but justify omissions only if they do not distort findings. Be cautious not to hide ethically or politically sensitive parts of the life cycle.
		4. Identify identical elements (Optional)	In comparative studies, omit processes that are the same across both systems.	If a unit process appears identically in both products/systems being compared, it may be excluded to focus the analysis on differences. Clearly explain when this is done.
		5. Apply BSI-style social risk filter (Optional but recommended)	Include processes that score high on potential social risk.	Use social risk assessment tools to help identify high-risk sectors or geographies. This prevents accidental exclusion of socially important processes.
		6. Document assumptions and criteria	Clearly explain all assumptions used for inclusion/exclusion decisions.	For each cut-off decision, state if it was made based on data availability, impact relevance, or comparability. Clarify any sectoral or geographic assumptions used.
	8. Limitations of Data Access	1. Identify data availability limitations	Determine "where site-specific data is missing or inaccessible".	Review the life cycle stages and mark where onsite investigation is not feasible. Highlight those needing secondary or generic data.
		2. Use generic data when necessary	Apply secondary data in stages where access is constrained.	Utilize recognized S-LCA databases (e.g., PSILCA, SHDB) for country-sector level indicators or stakeholder risk profiles.
		3. Document data sources & assumptions	Be transparent about data type and origin.	Record if the data is site-specific, generic, calculated, or assumed. Provide justification and source details.
		4. Address missing data (ISO)	Respond systematically to missing information.	Use ISO guidance: (a) assign justified “non-zero” values, (b) explain true “zero” values, or (c) calculate based on similar tech or regions. Follow ISO 14044 for gap handling.
		5. Evaluate data quality (ISO)	Assess the reliability and fitness of collected data.	Apply quality indicators: completeness, representativeness, precision, context relevance (location, culture), reproducibility, uncertainty, and sources.

		6. Maintain life cycle completeness	Avoid excluding early/late phases due to poor access.	When full primary data isn't feasible (e.g., in mining or waste management), supplement with reputable secondary data to preserve the life cycle integrity.
	9. Stakeholder Categorization and Involvement	1. Identify relevant stakeholder/interested party groups	Define those affected by or affecting the product life cycle stages	Start from UNEP's main categories: Workers, Consumers, Local Communities, Society, Children, Value Chain Actors. Add context-specific subgroups (e.g., migrant workers, smallholders) if needed.
		2. Apply relevance criteria	Use a robust, justified method to filter stakeholders	Apply three standard criteria: Impact (who is affected), Legitimacy (representation), Completeness (diverse views). Document all decisions.
		3. Involve stakeholders	Actively engage key groups in the assessment process	Apply participatory methods (UNEP): e.g., focus groups, interviews, or workshops. Useful for selecting indicators, weighting impacts, and ensuring relevance.
		4. Document inclusions and exclusions	Provide transparent records of all choices	Clearly explain why each group was included/excluded. BSI requires justification; UNEP recommends documenting methods, roles, and stakeholder overlaps.
		5. Link to impact categories	Ensure stakeholder types correspond to appropriate social topics	Align each stakeholder group with relevant impact categories and subcategories (e.g., worker → fair wages, health and safety; local community → access to resources, cultural heritage).
	10. Impact Assessment Method and Impact Subcategories	1. Choose the impact assessment method	Decide between Reference Scale S-LCIA or Impact Pathway S-LCIA	RS uses performance ratings against norms (e.g., 1–5 scale). IP models cause-effect chains using midpoint and endpoint indicators. The method should align with data availability, study goals, and stakeholder engagement level.
		2. Identify relevant social topics	Determine social issues of concern linked to selected stakeholders	Use materiality assessments or stakeholder consultations to identify key issues (e.g., child labor, fair wages, discrimination) based on relevance and influence across the life cycle.

		3. Select impact categories and subcategories	Define specific categories for the assessment of social impacts	Use standardized lists (UNEP Table 8/9, ISO templates) or customize based on product context. Categories should be relevant to the goal, scope, and selected stakeholders.
		4. Define modeling/measurement approach (Optional)	Describe how the impact will be quantified or interpreted	For RS: define rating scale and performance criteria. For IP: specify characterization models, midpoint-to-endpoint logic, and type of pathways. Can be skipped for qualitative or RS-only studies.
		5. Link categories to inventory indicators	Ensure each category is matched to relevant data points	Use stakeholder–subcategory–indicator matrices to verify data availability from the inventory phase. If no data is available for a category, consider proxy indicators or justify exclusion.
		6. Justify and refine categories (Optional)	Explain choices and revise as needed during later phases	In iterative S-LCA, subcategories may be refined based on impact assessment results or updated materiality input. Document reasons for inclusion/exclusion transparently, especially if using for public disclosure or decision-making.
	11. Indicators, Data type, and Data Collection Strategies	1. Define impact subcategories	List impact subcategories relevant to selected stakeholders	Use UNEP's Table 8 or materiality analysis to identify which social topics apply (e.g., child labor, fair salary, occupational health).
		2. Select indicators for each subcategory	Choose indicators that measure the status or risk level of each subcategory	Ensure indicators are measurable, relevant, and directly linked to social impact. E.g., "% of workers under age 15" for "Child Labor" subcategory.
		3. Link indicators to stakeholders	Connect each indicator to stakeholder categories	Build a table that shows the relationships between stakeholder → subcategory → indicator, which helps ensure data relevance and completeness.
		4. Identify data type (qualitative/quantitative)	Specify whether each indicator is quantitative or qualitative	For example, "% of female workers" is quantitative, while "Perceived job satisfaction" might be qualitative. This helps guide the data collection tool.

		5. Define data source type	Specify whether the data is primary or secondary, site-specific or generic	Choose based on availability, cost, access level, and time constraints. For high-risk subcategories, prioritize primary site-specific data when feasible.
		6. Choose data collection methods	Select tools for collecting data (e.g., interviews, surveys, databases)	Match methods to the indicator type. For quantitative data: surveys, payroll records, national statistics. For qualitative: focus groups, worker interviews.
		7. Document indicator table (Optional)	Prepare a summary table of subcategories, indicators, data type, and collection methods.	This table facilitates traceability and transparency, and may later be used for verification or stakeholder review.

Table 11 - Simplified and User-Friendly S-LCA table - Phase 1 (Source: Author, 2025).

4.2.2. Simplified and User-Friendly S-LCA Implementation Methodology- Phase 2: Life Cycle Inventory

Simplified S-LCA Implementation Table (Phase 2)				
Phases	**Steps**	**Task(s)**	**What to Do**	**How to Do It – Practical Guide**
Phase 2 - Life Cycle Inventory	1 Plan Inventory	1.1 Define inventory objectives	Link inventory to goal and scope.	Review functional purpose, stakeholder categories, and intended use of results.
		1.2 Develop a data collection framework	Create a structured plan for data needs.	Build a table outlining required indicators, data types (qualitative/quantitative), data sources, and expected availability.
		1.3 Establish process timeline and responsibilities	Allocate collection roles and deadlines.	Assign roles for internal and external data actors; develop a timeline by phase.
	2 Collect Primary & Secondary Data	2.1 Identify suitable data sources	Collect primary and/or secondary data.	Use interviews, surveys, observations, and databases.
		2.2 Select appropriate collection methods	Align methods with data types.	Choose structured questionnaires for semi-quantitative data; observation logs for qualitative data.
		2.3 Apply triangulation	Cross-verify data from multiple sources.	Combine at least two sources (e.g., stakeholder interviews and administrative records) to strengthen reliability.
		2.1 Identify suitable data sources	Collect primary and/or secondary data.	Use interviews, surveys, observations, and databases.
	3 Handle Qualitative & Semi-Quantitative Data	3.1 Structure qualitative inputs	Organize unstructured responses.	Categorize data into stakeholder themes or subcategories.
		3.2 Standardize scales	Apply scoring or semi-quantitative format.	Use Likert scales or binary response tables; convert to ordinal data if needed.
		3.3 Validate via stakeholder engagement	Engage stakeholders for verification.	Share summarized data with stakeholders and confirm interpretations.
	4 Structure Product System	4.1 Identify unit processes	Break system into process blocks.	Use life cycle logic to define process units by function or stage.
		4.2 Map product system	Show relationships between processes.	Use flowcharts to represent process linkages and data dependencies.

		4.3 Link process to reference flows	Associate each process with functional output.	Define activity metrics and reference relationships.
	5 Apply Allocation	5.1 Identify need for allocation	Detect multi-output processes.	Review each unit for shared functions or joint products.
		5.2 Choose an allocation rule	Apply accepted hierarchy.	Follow UNEP's order: Subdivision > System Expansion > Attribution.
		5.3 Justify method	Provide reasoning for the approach.	Document methodological rationale and fallback logic.
	6 Ensure Data Quality & Address Gaps	6.1 Assess data quality dimensions	Rate based on standard indicators.	Evaluate time, geography, technology, and completeness.
		6.2 Identify and manage data gaps	Address missing or weak data.	Use proxy data or expert judgment and flag incomplete fields.
		6.3 Record data limitations	Document issues in the quality log.	Create notes for transparency and future improvement.

Table 12 - Simplified and User-Friendly S-LCA table - Phase 2 (Source: Author, 2025).

4.2.3. Simplified and User-Friendly S-LCA Implementation Methodology (Phase 3)

Simplified S-LCA Implementation Table (Phase 3)				
Phases	**Steps**	**Tasks/Terms and conditions**	**What to Do**	**How to Do It – Practical Guide**
Phase 3	**1 Choose Assessment Approach**	1.1 Select assessment type	Choose between the Reference Scale (RS) and the Impact Pathway (IP).	UNEP recommends RS for simplified, user-friendly, and practice-ready studies. IP is more complex and used for research.
		1.2 Justify your choice	Explain why RS is appropriate.	Consider project size, stakeholder focus, resources, and need for transparency. Use the UNEP decision tree.
	2 Select Impact Categories and Subcategories	2.1 Identify stakeholders	List those affected (e.g., workers, community, consumers).	UNEP defines 6 stakeholder categories.
		2.2 Choose impact subcategories	Pick topics that reflect social issues relevant to stakeholders.	Use UNEP's default list: e.g., fair salary, child labor, community engagement, access to services.
		2.3 Ensure relevance and alignment	Make sure subcategories match the goal of the study.	Align with Areas of Protection (AoPs).
	3 Define Reference Scales	3.1 Use a 5-level scoring scale	Create a scale from very negative (–2) to very positive (+2).	UNEP recommends: –2 = severe risk; 0 = legal minimum; +2 = best practice.
		3.2 Define performance reference points (PRPs)	Write clear descriptions for each level of performance.	For example, for "Fair Salary," define what –2, –1, 0, +1, +2 mean using ILO or national standards.
		3.3 Be consistent and transparent	Use the same logic for all indicators and document clearly.	UNEP offers examples for child labor, wages, and community participation.
	4 Assign Inventory Data (Classification)	4.1 Match data to impact categories	Link your data to the subcategories defined in Step 2.	For example, survey results about job safety go under "Occupational Health & Safety".
		4.2 Organize your data for scoring	Prepare data in a way that helps with scoring in the next step.	Create a simple table: stakeholder → subcategory → indicator → value.
	5 Apply Scores	5.1 Score each indicator	Use your reference scale to convert data into –2 to +2 scores.	Example: If working hours exceed legal limits → Score = –1 or –2. Follow scale definitions.

		5.2 Use consistent logic	Apply same scoring rules across all subcategories and stakeholders.	Use Excel formulas or lookup tables for reliability.
	6 Aggregate Scores (Optional)	6.1 Decide if you want to aggregate	Aggregation is optional; use it to simplify results.	Average or sum scores for each stakeholder or subcategory.
		6.2 Keep individual scores visible	Don't lose detail when aggregating.	Keep raw data and scores available alongside summaries.
	7 Weight Scores (Optional)	7.1 Decide if weighting is needed	You can emphasize more important topics.	Use equal weights or ask stakeholders which issues matter most (UNEP 5.2.3).
		7.2 Apply weights carefully	Multiply raw scores by weight values.	Document your method clearly and justify the choice.
	8 Normalize Scores (Optional)	8.1 Normalize scores to common scale	Convert scores to % or 0–100 for easier comparison.	UNEP suggests: –2 = 0%, 0 = 50%, +2 = 100%.
		8.2 Use visual tools	Show normalized scores in charts or graphs.	Radar charts, bar graphs, and dashboards help communicate results.

Table 13 - Simplified and User-Friendly S-LCA table - Phase 3 (Source: Author, 2025).

4.2.4. Simplified and User-Friendly S-LCA Implementation Methodology (Phase 4)

Simplified S-LCA Implementation Table (Phase 4)				
Phases	**Steps**	**Tasks/Terms and conditions**	**What to Do**	**How to Do It – Practical Guide**
Phase 4	**1 Identify Significant Issues**	1.1 Analyze scoring results	Identify subcategories with very high or very low scores.	Look for scores of –2, –1, or +2 to detect hotspots.
		1.2 Consider stakeholder relevance	Prioritize issues that affect key stakeholders.	Use stakeholder mapping and significance matrix.
		1.3 Group findings for clarity	Organize issues into thematic areas.	Cluster subcategories (e.g., equity, safety, participation) for interpretation.
	2 Completeness Check	2.1 Verify phase coverage	Ensure all four S-LCA phases were fully implemented.	Revisit the implementation plan and check that each phase is represented.
		2.2 Confirm stakeholder and data coverage	Ensure no major gaps in data for key groups.	Review completeness checklist (UNEP Table 15); identify missing indicators or data.
		2.3 Iterate if needed	Adjust earlier phases if critical gaps are found.	UNEP allows goal/scope revisions if gaps are substantial.
	3 Consistency Check	3.1 Compare the methods used to the planned approach	Ensure actual methods align with your methodology.	Match scoring, categorization, and stakeholder logic to the original plan.
		3.2 Evaluate logical coherence	Check for internal contradictions.	UNEP suggests reflection prompts in Table 16 (e.g., "Are indicators consistently applied?").
	4 Check Sensitivity & Uncertainty	4.1 Identify uncertain or estimated data	Flag data points with low quality or proxy values.	Use ratings from Phase 2 (e.g., time/geography/technology coverage).
		4.2 Conduct sensitivity checks	Test whether small changes affect results.	Change key input values by ±20% and observe if final conclusions shift.
		4.3 Note areas with high uncertainty	Highlight results that may not be robust.	Indicate low-confidence results in final tables or footnotes.
		4.1 Identify uncertain or estimated data	Flag data points with low quality or proxy values.	Use ratings from Phase 2 (e.g., time/geography/technology coverage).

	5 Apply Materiality	5.1 Focus on high-priority issues	Identify those with high impact or stakeholder concern.	Use UNEP's "contribution" and "influence" logic.
		5.2 Support decisions with material topics	Align findings with stakeholder needs and objectives.	Select findings that guide planning, communication, or policy change.
	6 Aggregate / Visualize (Optional)	6.1 Aggregate scores to simplify interpretation	Combine values across categories or stakeholders.	Use average or sum; keep disaggregated data available.
		6.2 Choose visual tools	Improve communication and clarity.	Use radar charts, bar graphs, or heat maps.
	7 Conclusions & Recommendations	7.1 Summarize findings	Write key insights from the interpretation.	Structure around stakeholder categories or major themes.
		7.2 Propose improvements	Suggest realistic actions or changes.	Base recommendations on hotspots and material issues.
		7.3 Mention study limitations	Acknowledge data gaps and assumptions.	Add a brief paragraph on limits, e.g., "Data incomplete for X stakeholder."
	8 Critical Review (Optional)	8.1 Decide if a review is needed	Required if public or comparative results will be shared.	UNEP: Public comparisons trigger review.
		8.2 Choose a qualified reviewer	Ensure the reviewer has relevant S-LCA knowledge.	Select from academic or technical backgrounds.
		8.3 Provide access to the full method	Share documentation and scoring with the reviewer.	Include methodology, inventory data, and score tables.

Table 14 - Simplified and User-Friendly S-LCA table - Phase 4 (Source: Author, 2025).

4.3. Case study application

This section presents the practical application of the simplified and user-friendly S-LCA methodology developed in this study, using the ProLight project as a real-world case study. The focus is placed on the Urbana New Living district in Milan, Italy—one of the demonstration sites within the EU-funded ProLight initiative aimed at designing and replicating socially inclusive Positive Energy Districts (PEDs). The case study is used to validate the methodology's clarity, relevance, and feasibility in evaluating social impacts during an energy transition context.

Drawing on official project documentation, *ProLight Report D2.4. (2024)* and *ProLight Report D4.3. (2025)*, and information available on the ProLight project website, the analysis centers on Phase 1: Goal and Scope Definition of the S-LCA framework. This includes defining the purpose and context of the study, identifying stakeholders, establishing system boundaries, and determining relevant social indicators. The Planet App and EnergyVista platform, key digital tools deployed in the project, serve as reference products whose social dimensions are examined through the simplified methodology. Tasks and implementation steps are populated based on real data, stakeholder roles, and participation practices documented in the project.

By grounding the method in an ongoing EU PED project, this case study not only demonstrates the usability of the proposed approach but also confirms its applicability to decentralized, community-driven energy initiatives. The insights generated reflect actual stakeholder experiences, such as those of residents, app developers, real estate managers, and third-sector organizations, and highlight how structured social assessments can support more inclusive and transparent energy planning.

4.3.1. Case Study Validation of the Simplified Methodology- Phase 1

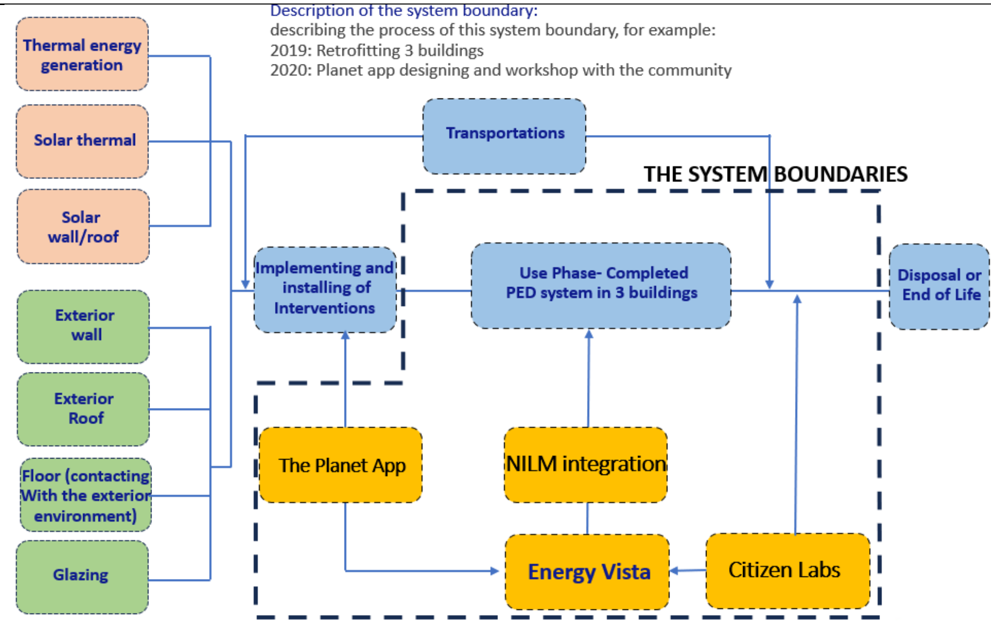
Steps	Task	Case study application
1.1. Goal Definition	1. Define **the Study Purpose**	This study aims **to assess the social impact of the Planet App**, developed by Planet Idea, **on the social housing community of Milano Urbana**.
	2. Identify **Intended Application**	The intended application of the S-LCA in this study is **to support the ProLight project's objective of developing a replicable framework for assessing the social impacts of Positive Energy Districts (PEDs) across EU member states**. By aligning with ProLight's structured stakeholder engagement strategy, outlined in ProLight Report D4.3. (2025), the assessment not only informs the project's social performance **but also contributes to the scalability and transferability of best practices in inclusive, sustainable energy transition initiatives**.
	3. Determine **Target Audience**	Based on the ProLight project's objectives and activities, the intended audience for the study's results includes: **Municipalities and Local Authorities:** Responsible for urban planning and the implementation of sustainable energy solutions. **Social Housing Providers and Property Managers:** Involved in the renovation and management of affordable housing units. **Policymakers and Urban Planners:** At both national and European levels, who can influence and adopt policies promoting Positive Energy Districts (PEDs). **Energy Service Companies and Utility Providers**: Engaged in the deployment of renewable energy technologies and services. **Academic and Research Institutions:** Focusing on sustainable urban development and energy efficiency studies. **Eurac Research**
	4. Define **Assessment Focus**	Working conditions in the value chain / Community impacts / residents' positive and negative impact
	5. Consider **Improvement Opportunities**	This knowledge can inform the development of more inclusive design, planning, and implementation strategies for PEDs, enhancing stakeholder engagement, equity, and long-term social sustainability. Additionally, the study is designed to support decision-making by providing policymakers, urban planners, and project developers with evidence-based insights that can guide the design and replication of socially responsible PED models throughout the European Union.

	6. Clarify **Use Context**	As ProLight is funded by the EU, **the results will be made publicly available after verification**. While not intended for social comparative assertions, the findings aim to **inform stakeholders and support transparency and replication**.
	7. Specify **Methodological Approach (Optional)**	The Reference Scale (RS) approach was selected for this case, as it is better suited for semi-quantitative data and stakeholder feedback from workshops and app usage patterns, consistent with UNEP and ISO for early-stage studies.
1.2. Functional Unit	1. Define Main Function 2. Ensure Goal Consistency 3. Quantify the Function 4. Include Contextual Factors 5. Prepare for Comparability 6. Link to Reference Flow 7. Consider Monetary Basis (if it is based on economic flows)	This study, aligned with approaches in both Hossain et al. (2021) and Hosseinijou et al. (2014), opts for a function-based qualitative boundary instead of a strictly defined unit. This choice is justified by the user-driven nature of the ProLight intervention and the non-material characteristics of the product system (Hossain et al., 2018; Hosseinijou et al., 2014).
1.3. The Reference Flow	1. Translate Functional Unit	Directly related to FU
	2. Identify Product Variants	Directly related to FU
	3. Determine Material Inputs	The implementation includes: ▪ The Planet App software and EnergyVista digital platform. ▪ Engagement materials (e.g., flyers, presentations) used in Citizen Labs. ▪ Smart metering infrastructure (NILM sensors, data servers). These are the primary "non-material" material inputs that support social performance tracking and user interaction.

	4. Check Data Consistency	▪ Validate household energy usage data consistency between user survey results and NILM reports (Deliverable 4.3). ▪ Cross-check system rollout parameters (app engagement, user coverage) across reports and promotional materials. Consistency was emphasized in stakeholder workshops and documented in project deliverables.
	5. Decide on Scaling Approach (Optional)	Scale the application based on: ▪ Number of users in the housing unit (e.g., 137 total units). ▪ Type of dwelling (rental/owned). ▪ Community participation level (event engagement figures). This facilitates proportional scaling of social impacts for wider district replication.
	6. Estimate Uncertainty (Optional)	▪ Uncertainty arises from voluntary participation in surveys and inconsistent user engagement with the Planet App. ▪ Estimate a ±X% error margin in user participation metrics or energy reduction reporting. ▪ Document assumptions in the interpretation section of your S-LCA.
	7. Document Reference Flow	**Directly related to FU**, to fulfill the functional unit, one Planet App system (including EnergyVista, NILM sensors, and participation in 3 Citizen Lab workshops) is implemented per social housing household for a 12-month period in the Milan Urbana district.
1.4. The Product System	1. Define product system	**The Planet App + Energy Vista + NILM integration + Citizen Labs** = the "product system" delivering social benefits such as empowerment, energy education, and improved social cohesion.
	2. Identify unit processes	▪ App Development ▪ Installation of Sensors (NILM) ▪ User Data Collection (Energy Vista) ▪ Stakeholder Engagement via Citizen Labs ▪ Feedback Collection and Reporting Each represents a step with distinct stakeholders and data flows.
	3. Determine process inputs/outputs	▪ **Inputs**: electricity, digital tools, training materials. ▪ **Outputs**: energy awareness, behavioral change, feedback.

		For example, EnergyVista outputs detailed breakdowns of energy use (e.g., by activity type like cooking, washing).
	4. Specify geographic location	▪ Citizen Labs & Stakeholder Engagement Activities: Conducted in the Urbana District, Milan, Italy, including specific locations such as the Urbana City Hall and Spazio Hub Rizzoli. ▪ Planet App Deployment and EnergyVista Use: Implemented at the household level across 137 housing units (87 rental + 50 owner-occupied), all within the Urbana New Living complex in Milan. ▪ Installation of NILM Sensors: Conducted in the same residential blocks in the Urbana district, integrated directly into the apartments where disaggregated energy consumption data is tracked. ▪ Workshops with Children and Community Members: Held at Spazio Hub Rizzoli, Milan, for thematic engagement (e.g., solar energy awareness, EnergyVista training).
	5. Use input-output analysis (Optional)	Can be considered if using regional economic data or energy service modeling to quantify indirect effects. **Not mandatory** in simplified S-LCA.
	6. Define product functions/properties	The Planet App functions as: ▪ **Educational Tool**: Enhancing user awareness. ▪ **Behavioral Change Agent**: Supporting energy savings. ▪ **Communication Platform**: Facilitating stakeholder participation.
	7. Specify product market context	The market context is social housing within a Positive Energy District pilot, with EU funding and public-private stakeholder structure. Affordability and inclusiveness are central.
	8. Review with literature (Optional)	Compare with other EU PED studies using apps or community engagement strategies. Use findings to benchmark social categories and indicators.
5. Identifying the System Boundaries	1. Define system boundaries	This study is focusing on the social impacts from the **production stage, construction stage, through the use stage** of the Planet App system in the Milan Urbana district. The boundary includes the installation and use of NILM sensors, the deployment of the Planet App and EnergyVista platform, and engagement activities such as Citizen Labs. It excludes upstream activities (e.g., raw material sourcing for hardware) and downstream phases (e.g., device disposal, long-term maintenance).
	2. Align with life cycle logic (life cycle phase(s))	**Production stage / Construction stage / Use stage** ▪ **Production/Construction Stage**: Installation of NILM infrastructure and software deployment. ▪ **Use Stage**: Daily use of the Planet App by residents, community engagement through Citizen Labs, and data collection via EnergyVista.

	3. Apply dual perspectives	Product system perspective: delivery and usage of the Planet App and its components. Organizational/social system perspective: interactions between residents, Planet Idea, REDO SGR Real estate developer (asset owner for some of the housing units in Urbana), and Citizen Lab facilitators. Both perspectives are essential to capture direct social impacts.
	4. Apply cut-off criteria (ISO)	
	5. Document modelling assumptions	▪ All 137 housing units have equal access to the Planet App system. ▪ Engagement activities (e.g., workshops) reach at least one resident per unit. ▪ NILM sensor performance and app effectiveness are consistent across households. These assumptions ensure standardization across inventory and scoring phases.
	6. Consider stakeholder causality	Resident engagement level (active, passive, or resistant) directly affects the app's social impact. The organizational actions of Planet Idea and REDO SGR —such as workshop organization and support—also contribute to causality. These actors are included as primary social drivers within the system boundary.
	7. Use input-output data (Optional)	Not applied in this case. Due to the highly localized, digital, and participatory nature of the project, conventional I/O modeling was not suitable.
	8. Visualize the system (Optional)	**Inputs** (Planet App, NILM sensors, training materials), **Processes** (installation, engagement events, app usage), **Outputs** (resident awareness, feedback, behavior change).

		
6. Activity Variable (optional)	**(optional)**	
7. Cut-off Criteria	1. Define cut-off criteria	Due to the absence of a functional unit, **cut-off criteria are based on social relevance and direct influence**. Any actor, process, or input **with no direct social interaction or measurable social effect** on Milan Urbana residents was excluded.
	2. Use social significance (preferred)	Example: **The backend development of the Planet App** (**e.g., external code libraries or AWS servers)** was excluded because residents are not exposed to these elements, and they do not contribute to social outcomes like empowerment or awareness.
	3. Avoid unjustified exclusions	No actors or activities were excluded solely due to a lack of data. For example, **Ciclocaffè** and **Farmacia del Parco** (reward partners) were included because their services affect the perceived social value of participation, even though they have limited engagement hours.

	4. Identify identical elements (Optional)	Optional: The three private "reward" service providers (Ciclocaffè, Farmacia, Officina Immagine) can be treated as a **composite service impact node**, since their social contribution (incentives for residents) is similar in nature.
	5. Apply ISO-style social risk filter (Optional but recommended)	ISO suggests identifying elevated-risk sectors (e.g., real estate, digital services) or low-income populations. In this case: ▪ **Social housing tenants = potential vulnerability** ▪ **REDO SGR = influence without daily contact** ▪ **Reward partners = low influence but public-facing** **Use this to focus data collection efforts (e.g., on tenants and app developers).**
	6. Document assumptions and criteria	Documented criteria: ▪ Only actors/processes with measurable social engagement included. ▪ Excluded elements: backend app infrastructure, upstream software licensing, and generic digital supply chain components. ▪ Justification: Lack of stakeholder contact, low social visibility, and non-material contribution to impact. ▪ Include this note in Goal & Scope: "Cut-off criteria were based on social significance in the absence of a functional unit, consistent with UNEP 2020 recommendations for use-phase-focused studies."
8. Limitations of Data Access	1. Identify data availability limitations	Some residents did not actively use the Planet App or attend Citizen Labs, leading to incomplete data on social outcomes like awareness and behavior change. Additionally, app usage metrics were not uniformly collected for all 137 housing units.
	2. Use generic data when necessary	In cases where exact participation data was not available, general statistics from the ProLight consortium (e.g., typical engagement levels, average app retention rates) were used. For example, estimated attendance at workshops was averaged across similar housing profiles.
	3. Document data sources & assumptions	All data sources (e.g., D2.4, D4.3) were noted in the inventory plan. Assumptions, such as "50% of households used the app regularly," were based on partial reporting and qualitative workshop summaries.
	4. Address missing data (ISO)	Missing data was handled by: ▪ Excluding low-impact elements (e.g., backend systems) ▪ Substituting similar stakeholder profiles (e.g., app users in rental vs. owned units) ▪ Qualitatively estimating impacts where exact numbers were unavailable

	5. Evaluate data quality (ISO)	Data quality varied across processes. For Citizen Labs and resident engagement, data was relatively complete (recorded attendance). For app use and satisfaction metrics, precision was lower due to optional use. Each dataset was rated qualitatively on a 1–5 scale (e.g., 5 = full coverage, 2 = estimated)
	6. Maintain life cycle completeness	Despite some missing details, all key stages of the system boundary—App deployment, Resident use, and Community engagement—were covered. Any remaining data gaps were documented but not considered to affect the overall integrity of the social performance assessment.
9. Stakeholder Categorization and Involvement	1. Identify relevant stakeholder/interested party groups	List all groups affected by or participating in the system under study. Stakeholders for the Milan demo include: ▪ Residents (137 units; approx. 300 people) ▪ REDO SGR (asset owner for some units) ▪ Planet Idea (App developer) ▪ LUM (Ecopolis Servizi) (housing services, technical coordination) ▪ Citizen Lab Partners (e.g., ESF, Cascina Biblioteca) ▪ Service Providers (e.g., Ciclocaffè, Farmacia del Parco) ▪ Local Authorities and Social Housing Administrators (indirect influencers)
	2. Apply relevance criteria	Using UNEP's relevance dimensions: ▪ High relevance: Residents (direct beneficiaries, vulnerable group), REDO SGR (decision-making role), Planet Idea (process owner) ▪ Medium relevance: LUM, Citizen Lab NGOs (execution partners) ▪ Low relevance: Service providers (reward contributors, limited contact)
	3. Involve stakeholders	Residents were engaged directly through Citizen Labs and app feedback loops. REDO and LUM contributed via technical and administrative implementation. NGOs like ESF helped design thematic activities (e.g., energy education). Indirect parties (e.g., reward sponsors) were informed but not involved in S-LCA decision-making.
	4. Document inclusions and exclusions	**Included:** All stakeholders with observable social contact, control, or benefit. **Excluded:** App developers' global tech partners (no presence in Milan), background supply chain actors (e.g., hardware manufacturers). Justification: Lack of local influence, no observable social link with residents.
	5. Link to impact categories	▪ Residents → Access to information, community engagement, well-being ▪ REDO SGR / LUM → Decision-making transparency, tenant communication

		▪ Planet Idea → Data privacy, service responsiveness ▪ Citizen Lab partners → Inclusivity, empowerment, and access Stakeholders will be linked to impact subcategories in Phase 3 scoring
10. Impact Assessment Method and Impact Subcategories	1. Choose the impact assessment method	The Reference Scale (RS) approach was selected for this case, as it is better suited for semi-quantitative data and stakeholder feedback from workshops and app usage patterns, consistent with UNEP and ISO for early-stage studies.
	2. Identify relevant social topics	Social topics were identified through stakeholder engagement workshops and Citizen Lab activities. These included: access to information, well-being, empowerment, and inclusivity.
	3. Select impact categories and subcategories	Impact categories were aligned with UNEP's standard subcategories for Residents, Local Community, and Workers. Examples: "Well-being" (Residents), "Community Engagement" (Local Community), "Responsiveness" (Planet Idea).
	4. Define modeling/measurement approach (Optional)	For the RS method, performance ratings were assigned using an ordinal scale from −2 to +2 based on the presence, quality, and effectiveness of activities (e.g., participation in Citizen Labs, reward utilization).
	5. Link categories to inventory indicators	Indicators such as "% of residents attending workshops," "App engagement rate," and "Perceived satisfaction" were mapped to categories like "Access to services," "Empowerment," and "Transparency."
	6. Justify and refine categories (Optional)	Categories were refined based on participation differences among rental vs. owned units. Additional indicator refinement occurred based on the diversity of data collected from EnergyVista and qualitative surveys.
11. Indicators, Data Type, and Data Collection Strategies	1. Define impact subcategories	Based on stakeholder mapping and materiality analysis, subcategories included: access to energy information, participation, equity, and data privacy.
	2. Select indicators for each subcategory	Examples include: "Resident attendance at Citizen Labs," "Number of app interactions," "Feedback received," and "Survey-based perceived inclusion."
	3. Link indicators to stakeholders	Each indicator is assigned to its relevant stakeholder: Residents → "Satisfaction", Planet Idea → "Responsiveness," REDO SGR → "Transparency of communication."
	4. Identify data type (qualitative/quantitative)	Indicators are mixed-type. Example: "% workshop attendance" (quantitative), "Resident feedback themes" (qualitative).
	5. Define data source type	Both primary (interviews, app data, workshop records) and secondary data (project reports like D2.4 and D4.3) were used.

	6. Choose data collection methods	Methods include online surveys, direct app usage statistics, and participant observation during Citizen Labs.
	7. Document indicator table (Optional)	A summary matrix linking each stakeholder to subcategory, indicator, data type, and source is included in the annex (to be completed in the final version).

Table 15 - Case Study Validation of the Simplified Methodology - Phase 1 (Source: Author, 2025).

CHAPTER 5 – CONCLUSION

5.1. Summary of Findings and Research Contributions

This thesis has addressed a significant challenge in the current practice of Social Life Cycle Assessment (S-LCA): its methodological complexity and limited accessibility to non-expert users, including students, beginner practitioners, and small organizations. Although authoritative guidelines by UNEP (2020) and ISO 14075:2024 provide comprehensive structures for implementation, these documents assume a level of technical expertise and resource availability that is often unrealistic for many early-stage users. This research directly responds to that gap by proposing and partially validating a simplified and user-friendly S-LCA implementation methodology.

To develop this methodology, the research first conducted a structured comparative analysis between the UNEP and ISO guidelines. This comparison was organized according to the four standardized S-LCA phases, Goal and Scope, Inventory, Impact Assessment, and Interpretation, and evaluated each implementation step in terms of availability, similarities, and differences. The resulting comparative tables served as an evidence-based foundation for designing a simplified implementation method.

Each phase was then broken down into implementation steps, which were further subdivided into practical tasks. These tasks were accompanied by two explanatory columns: "What to Do" and "How to Do It / Practical Guide." This format enhances clarity and supports step-by-step engagement for users who may lack formal training in life cycle assessment.

The methodology was tested through a real-world case study: the ProLight project in Milan, focusing specifically on the Urbana New Living social housing district. Phase 1 of the simplified methodology was successfully implemented using project documentation, stakeholder mappings, and technical data provided by the Planet App and EnergyVista platform. The study demonstrated that the simplified method is operational, adaptable, and robust enough to deliver meaningful insights into social impacts and risks. This confirms the utility and transferability of the proposed tool in real-world contexts and highlights its educational and operational value.

5.2. Significance and Impact of the Simplified S-LCA Methodology

The simplified methodology developed in this thesis provides value across several critical dimensions:

Educational Accessibility: The methodology's modular format, practical structure, and plain-language guidance make it particularly suited for educational use. It bridges the gap between theoretical instruction and practical application, supporting both teaching and learning.

Operational Usability: Its step-task structure allows small businesses, municipalities, and grassroots organizations to implement social assessments without needing deep prior knowledge of LCA or extensive internal resources.

Strategic Flexibility: Tasks are marked as core, optional, or guideline-specific (UNEP or ISO), allowing users to tailor the tool based on available data, context, and goals.

Relevance to Energy Transition Projects: As energy transition initiatives expand across the EU, particularly through Positive Energy Districts and other climate-neutral city programs, the need for accessible social impact assessment tools becomes more urgent. Many stakeholders in these projects are local actors or SMEs with limited LCA capacity. The simplified methodology is especially well-positioned to support these decentralized, community-focused efforts.

Perhaps most importantly, this thesis contributes directly to the **evolution of S-LCA** as a practical discipline. As shown in Figure 37, The Evolution of S-LCA, the field has undergone significant development over the past three decades, from its conceptual roots in the early 1990s, through the first UNEP guidelines in 2009, to a phase of methodological refinement and alignment with the UN Sustainable Development Goals (SDGs) after 2015. While much of the existing literature and guidance focused on establishing conceptual and structural foundations, a major bottleneck remained: the actual usability of these frameworks in low-resource or non-specialist settings.

Figure 37 - Evolution of S-LCA (Source: Author, 2025).

This thesis positions itself as part of the next phase in the S-LCA timeline. By offering a simplified, scalable, and flexible methodology, the study pushes S-LCA toward mainstream adoption. The proposed tool enables broader participation from actors traditionally excluded due to capacity gaps. It transforms S-LCA from a high-barrier technical assessment into a shared language for evaluating social sustainability, particularly in emerging contexts like Positive Energy Districts (PEDs), where community participation and equity are central concerns.

Moreover, this work sets a precedent for future simplification efforts across other forms of Life Cycle Assessment—particularly Environmental LCA (E-LCA) and Life Cycle Costing (LCC)—by offering a replicable template for methodological breakdown, task-based implementation, and user-focused guidance.

5.3. Recommendations for Future Research

This study opens several avenues for follow-up research and refinement:

Full Application Across All Phases

This thesis applied the simplified S-LCA methodology to Phase 1 only. Future studies should validate the tool across all four phases using the same or diverse case studies to test robustness, transferability, and completeness.

Quantitative Comparison with Existing Methods

Benchmarking the simplified methodology against traditional S-LCA processes in terms of time, ease of use, training requirements, and coverage would offer valuable insights and validate its benefits more rigorously.

Tool Development and Digital Integration

The current methodology could be embedded into an online platform or an Excel-based tool to guide users automatically through each task. Such software could also include indicator libraries, scoring rubrics, and data quality checklists.

Sectoral Adaptation

While this thesis focused on Positive Energy Districts, the method could be customized for other sectors such as construction, healthcare, agriculture, and mobility by adapting the stakeholder groups and subcategories.

Participatory Methods for Data Collection

Incorporating mobile tools, citizen engagement platforms, and interactive surveys into the methodology would enhance data richness and align with growing trends in participatory urban planning and energy transition.

5.4. Final Reflection

At its core, this thesis seeks to shift the perception of S-LCA from a specialized tool for experts to a practical framework that can inform real-world decisions across diverse organizational and geographical settings. In doing so, it repositions S-LCA not just as an evaluative tool but as a strategic enabler of sustainable transformation.

By validating the simplified method through a complex and socially relevant case study—the ProLight project in Milan—it becomes evident that social sustainability assessment can be both meaningful and manageable. The Planet App, EnergyVista platform, and Citizen Labs provide fertile ground for testing both technical functionality and participatory logic, highlighting how even digital tools can be assessed through a structured social lens.

In short, this research does more than simplify a method; it empowers a wider audience to engage with social sustainability using a credible, replicable, and accessible approach. In a world seeking inclusive responses to energy transition, climate change, and urban inequality, that capability is both timely and vital.

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