D4.4 FunTomP full sustainability evaluation, including LCA, LCC, and S-LCA reports

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Executive Summary

The primary goal of FunTomP project is to preserve the Mediterranean diet considering the current consumer trend of 'functional foods'. Particularly, it focuses on developing enriched tomato-based products using plant-based proteins, such as pea protein and olive powder, through a novel and eco-friendly processing technologies that will impact the nutrients minimally.

This report outlines the outputs of the triple pillar sustainability (environmental, economic and social) evaluation conducted as part of FunTomP for the products targeted under WP4, i.e., liquid-base tomato products. The standardised Life Cycle Assessment (LCA) methodology (ISO 14040 series) has been used to quantify the environmental impacts at a lab scale of FunTomP products. The scope selected for the life cycle stages are farming and production, which is defined as "farm-to-gate". In parallel, its economic performance and social impacts have been also evaluated by, respectively, Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA) methodologies. Both assessments were done following the same boundaries and scope as the LCA study. Nevertheless, for LCC & S-LCA an industrial scale was modelled.

For the environmental LCA, electricity consumption and glass bottles and jars used for packaging were identified as environmental hotspots. To mitigate these impacts, an increase in the share of renewable energy use and the replacement glass packaging with Tetra Pak containers was recommended.

Economically, FunTomP tomato sauce proved to be more profitable, demonstrating strong financial indicators at a selling price of €3.07 per kg. In contrast, tomato juice, priced at €1.37 per kg, did not yield favourable economic results, necessitating new price proposals to achieve acceptable economic and financial indicators. A price sensitivity analysis where several scenarios were assessed, revealed that tomato sauce has a more robust production scheme and is more tolerant to price variations compared to tomato juice.

The S-LCA identified social hotspots in the industrial production materials and manufacturing labour within the plant in Türkiye. These factors should be considered when selecting suppliers.

Therefore, a complete sustainability assessment has been conducted in this report, considering the three dimensions of sustainability. With this feedback recommendations and guideline could be granted towards the consortium partners.

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ABBREVIATIONS

CN: China

DCFR: Discount Cash Flow Rate

DED: Damage to ecosystem diversity

DHH: Damage to human health

DRA: Damage to resource availability

FEc: Freshwater ecotoxicity

FEu: Freshwater eutrophication

FPMF: Fine particle matter formation

FRS: Fossil resource scarcity

FU: Functional unit

GHG: Greenhouse Gas

GW: Global warming

HCT: Human carcinogenic toxicity

HNCT: Human non-carcinogenic toxicity

HPH: High Pressure Homogenisation

IR: Ionizing radiation

LCA: Life Cycle Assessment

LCC: Life Cycle Cost

LCI: Life Cycle Inventory

LCIA: Life Cycle Impact Assessment

LU: Land use

MEc: Marine ecotoxicity

MEu: Marine eutrophication

MedD: Mediterranean diet

MRS: Mineral resource scarcity

NPV: Net Present Value

OFHH: Ozone formation, Human health

OFTE: Ozone formation, Terrestrial ecosystems

PP: Payback Period

ROI: Return of Investment

S-LCA: Social Life Cycle Assessment

S-LCI: Social Life Cycle Inventory

S-LCIA: Social Life Cycle Impact Assessment

SOD: Stratospheric ozone depletion

SP: Spain

TA: Terrestrial acidification

TEc: Terrestrial ecotoxicity

TPC: Total Product Cost

TRL: Turkish Lyra

TUR: Türkiye

USD: American Dollar

WC: Water consumption

1. INTRODUCTION

Mediterranean diet (MedD) has been associated with a wide range of health benefits, including a reduction in the incidence of cardiovascular outcomes and in the risk factors for obesity and hypertension, among others. In addition, this dietary model has been reported to have low environmental impacts regarding water, nitrogen, and carbon footprint (Guasch-Ferré and Willett 2021). Despite its anticipated benefits, recent studies have shown that the MedD is now progressively disappearing in southern Europe countries, particularly among the youngest generations (Ochs 2018).

The FunTomP project aims to reformulate traditional Mediterranean tomato products using by-products of sugar beet (*Beta vulgaris L.*) and olive processing, offering extra health benefits to satisfy consumer's demand while keeping a sustainable product and process cycle with the valorisation of agricultural waste. However, the originally planned beet leaf protein was replaced by pea protein. Even though the proposed value chain is fully aligned with the EC Farm to Fork Strategy, at the heart of the European Green Deal, it is necessary to ensure an optimal environmental profile and preserve affordability for a competitive and sustainable deployment.

The objective of this deliverable is **to identify the environmental, economic, and social impacts of the liquid tomato-based products** proposed during the project from a life cycle perspective, beyond the production or consume from 'farm-to-consumer' system boundary.

The current assessment is framed in the project's fourth work package (WP4), which aims to produce liquid functional tomato products, juice and sauce, using different technologies during its manufacturing. Each formulation will be assessed in terms of nutritional characteristics, quality, shelf life, sustainability, and consumer acceptance. The most valuable proposals will be studied to finally present a guide for sustainable practices of FunTomP products before scaling up.

1.1. Deliverable structure

In the current Section 1, an introduction to FunTomP project is presented, in addition to a description of the studied products and a literature review of comparable products. Section 2 provides the methodological framework on the work done. In the following sections, the environmental (Section 3), economic (Section 4) and social assessments (Section 5) for both liquid products and the ingredients developed during FunTomP are presented. The results of the assessments findings are interpreted and discussed in Section 6. Finally, Section 7 presents the conclusions and future work proposals.

1.2. Studied products

The subject of the current report are the two liquid tomato-based products developed by the consortium along the project: a tomato juice and a tomato sauce. In the following, a brief description of the developed products is presented. Complementary, comparable studies were identified for the sauce and juice.

TOMATO JUICE

The composition of the tomato juice developed in FunTomP is presented in **Table 1**.

Table 1. Final juice formulation

Ingredients	Percentages in final product
Tomato powder	1.0 %
Pea protein	1.0 %
Olive powder	1.0 %
Mix of tomato pulp 26% (from cold break) and tomato pulp supernatant 70% (from centrifugation)	96.0 %
Salt	1.0 %

Tomato juice is produced at laboratory scale following the flowchart presented in **Figure 1**. The tomatoes undergo initial washing and peeling, followed by blending and heating in a process known as *"cold break"* to extract pulp and to separate the seeds and peels. Subsequently, one part of the pulp is centrifugated to remove the pellet containing fibre. Blending and High-Pressure-Homogenization (HPH) are utilized to ensure proper mixing of the juice (supernatant from centrifugation), bypassed pulp (from the cold break process), pea protein, tomato peel powder, olive powder, and salt. The resulting functional tomato juice is then pasteurized and bottled. As shown in Figure 1, there are two supplementary processes: the processing of tomato peel powder and olive powder. These two ingredients are included in the formulations of both the tomato juice and tomato sauce. Tomato peel powder is derived from tomato pomace (waste) generated during processing, which consists of a mixture of peels and seeds. This byproduct is dried and ground to be reintegrated into the formulation of the juice and sauce, thereby minimizing waste generation, utilizing their nutraceutical value, and promoting a circular process. Olive powder is produced by blending seedless olives with water, followed by freeze-drying, and grinding. It also contributes to the functional food as it is filled with phenolic compounds enhancing nutraceutical properties. These additional ingredients are incorporated simultaneously before high-pressure homogenization.

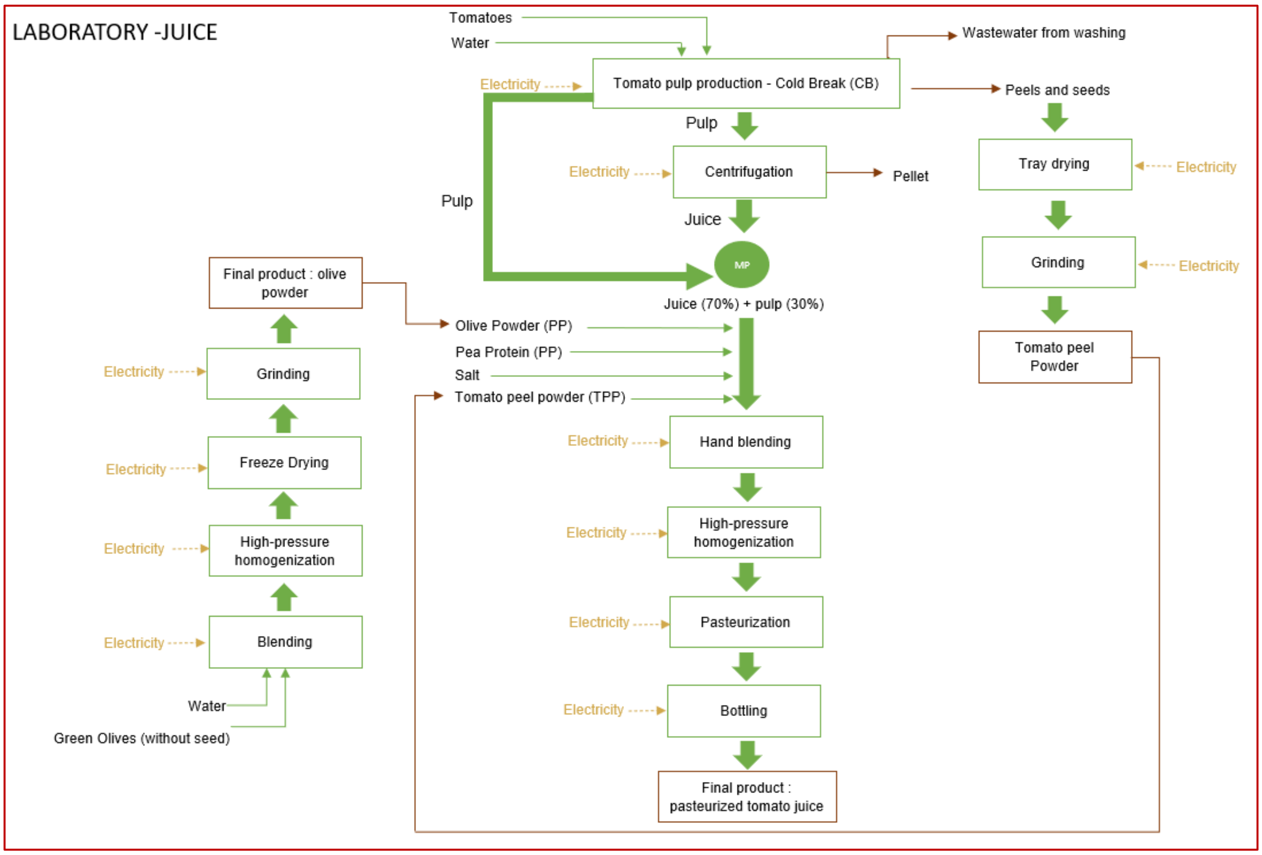


Figure 1. Flow chart of tomato juice processing at laboratory scale.

The successive steps composing the whole tomato processing chain were developed, tested and validated at laboratory or pilot scale during the project. Primary data for these foreground processes were collected from partners to develop a comprehensive life cycle inventory (LCI) of tomato juice and sauce production. It is important to point out that although an LCA can be created using mass balance and energy usage data from these smaller-scale test runs, the results are not directly comparable to those from industrial-scale processing. Besides the evident scale distinction, laboratory production is typically conducted as a batch process, requiring considerable energy for startup and shutdown, along with potential product loss during equipment cleaning. Comparative LCAs conducted on the same process at different scales revealed a substantial disparity between the industrial-scale LCA and the one derived solely from laboratory results. Indeed, previous research findings suggest that a study based solely on laboratory-scale data should never be utilized to publish a comparative LCA against an established commercial technology for an external audience (Hetherington et al. 2014). As this work will not be used to compare with other processes but to highlight environmental hotspots, it is considered acceptable to use laboratory scale data.

An industrial scenario was designed based on the laboratory scale. Nevertheless, it will not be used for LCA as the process needs further research and will change in the future. Currently, the laboratory production processes are undergoing testing across various locations (METU, UAlg, UoZ-1, UoS), as each centre has its own expertise and tasks. Further ahead with industrial scale lines, all production processes will take place in the same location. The industrial facility that will be used to produce the tomato juice and the tomato sauce is located in Türkiye, as the industrial partner - Kraft Heinz - is based in Susurluk, Balıkesir Province. To scale up the process, certain steps will be adapted to align with industrial production lines. For instance, some freezing or transportation stages will be eliminated as the entire process will be carried out within the same factory. Additionally, energy consumption of full-scale equipment cannot be straightforward extrapolated, and field measurements would be needed to avoid high uncertainty in the environmental performance indicators determined under this approach.

However, for Life Cycle Costing (LCC) study it is mandatory to consider industrial data to have significant and functional results. Even though OPEX data will suffer from the same uncertainty as for the LCA study, within the economic context is easier to identify potential disparities or wrong assumptions and act on them, facilitated through the industrial partner advice. Consequently, an estimated industrial production line will be assessed based on the flow chart of **Figure 2**. As the social life cycle assessment (S-LCA) is based on the LCC inventory, it is also based on industrial scale.

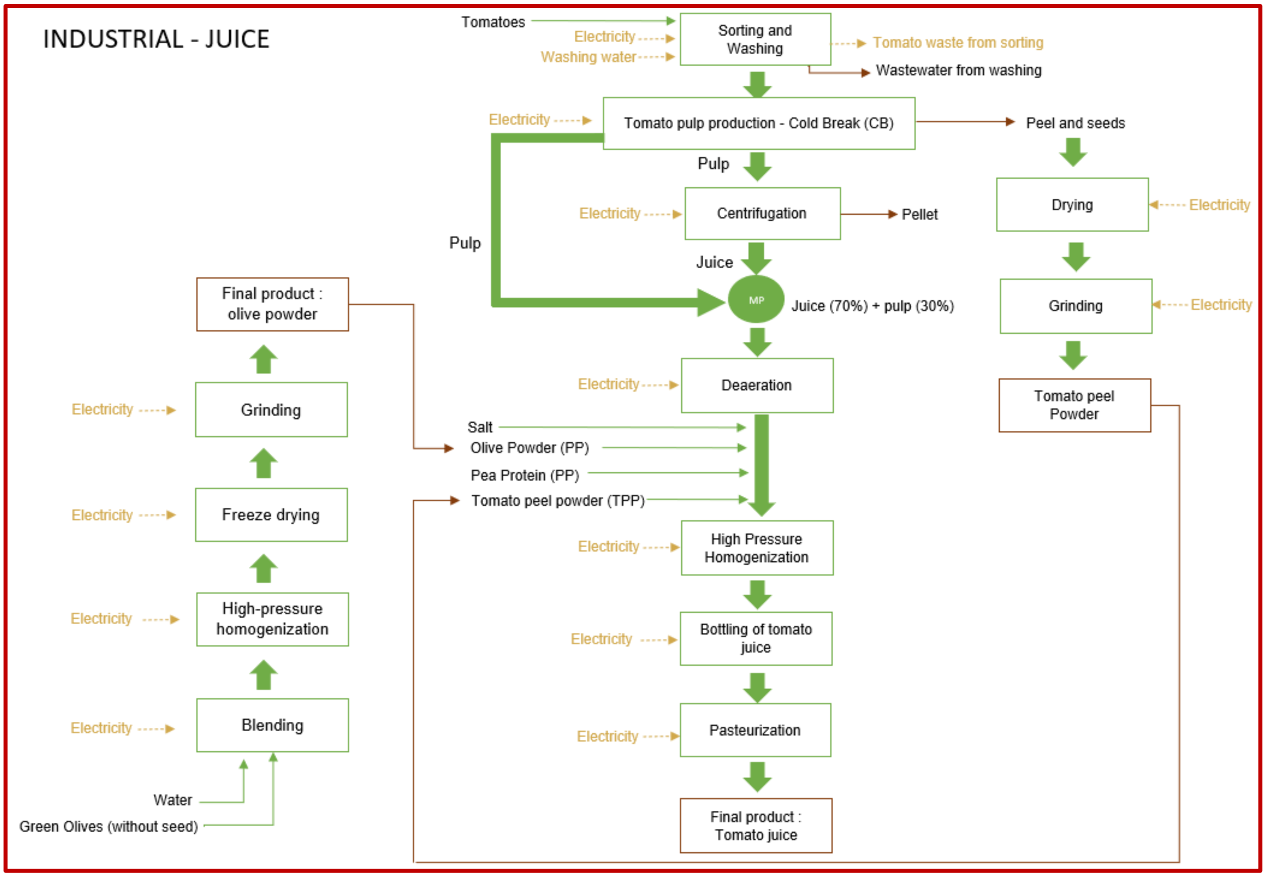


Figure 2. Flow chart of tomato juice processing at industrial scale.

TOMATO SAUCE

The second liquid product entering in the project is tomato sauce. The formulation is indicated in **Table 2**. At laboratory scale, the process is similar to the juice's one. The tomatoes are sorted, washed, and peeled manually before the pulp production step, performed by "*hot-break"* processing. Once the pulp is obtained, it is blended with the rest of the ingredients including olive powder, pea protein and tomato peel powder. The following steps of HPH, pasteurisation and packing are identical to tomato juice, with the only difference being the packaging, a 300mL glass jar instead of a bottle. Similarly to the tomato juice, the tomato peel powder and olive powder, whose production processes were described earlier, will be manufactured in the same factory. The full process is represented in **Figure 3**.

Table 2. Final sauce formulation

Ingredients	Percentages in final product
Tomato powder	3.5 %
Pea protein	1.8 %
Olive powder	1.7 %
Tomato pulp (from hot break)	93.1 %

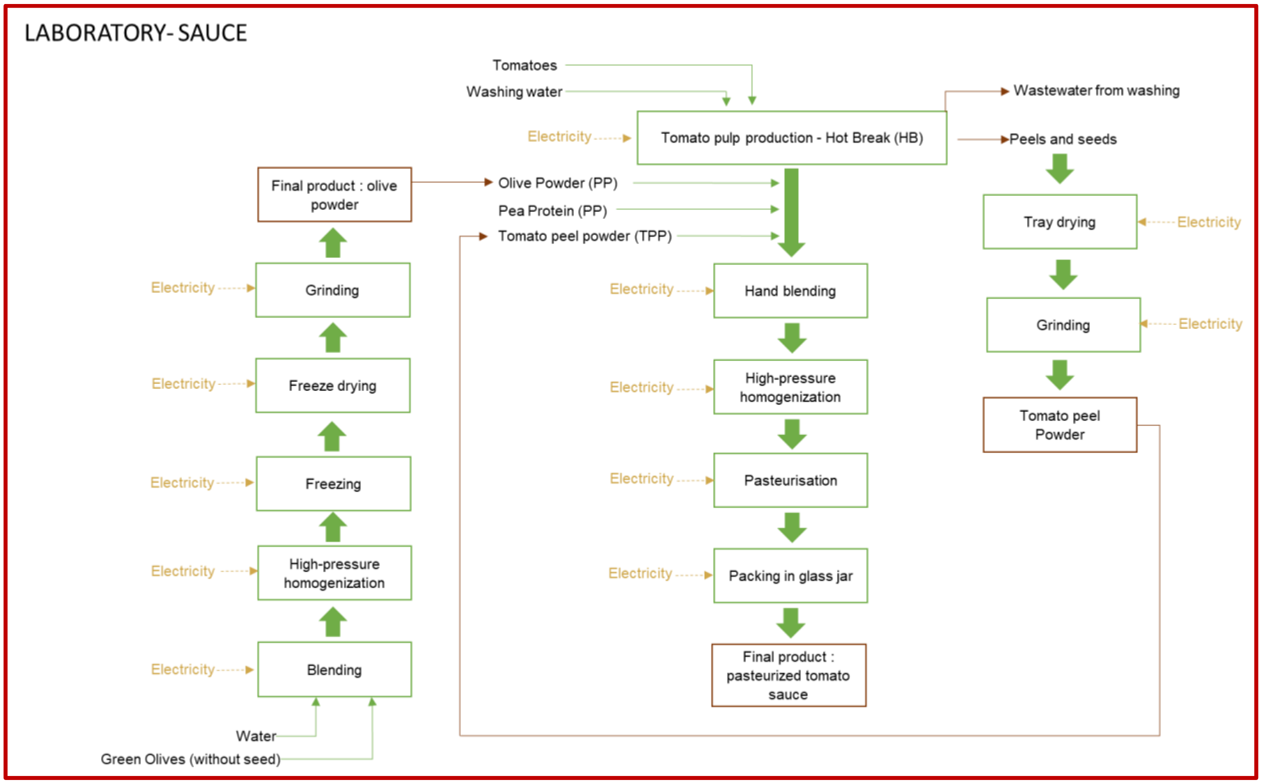


Figure 3. Flow chart of tomato sauce processing at laboratory scale.

As explained in **1.2.1**, the laboratory scale is only used for LCA while industrial scale is considered for LCC and S-LCA. The industrial scenario designed here is presented in **Figure 4**.

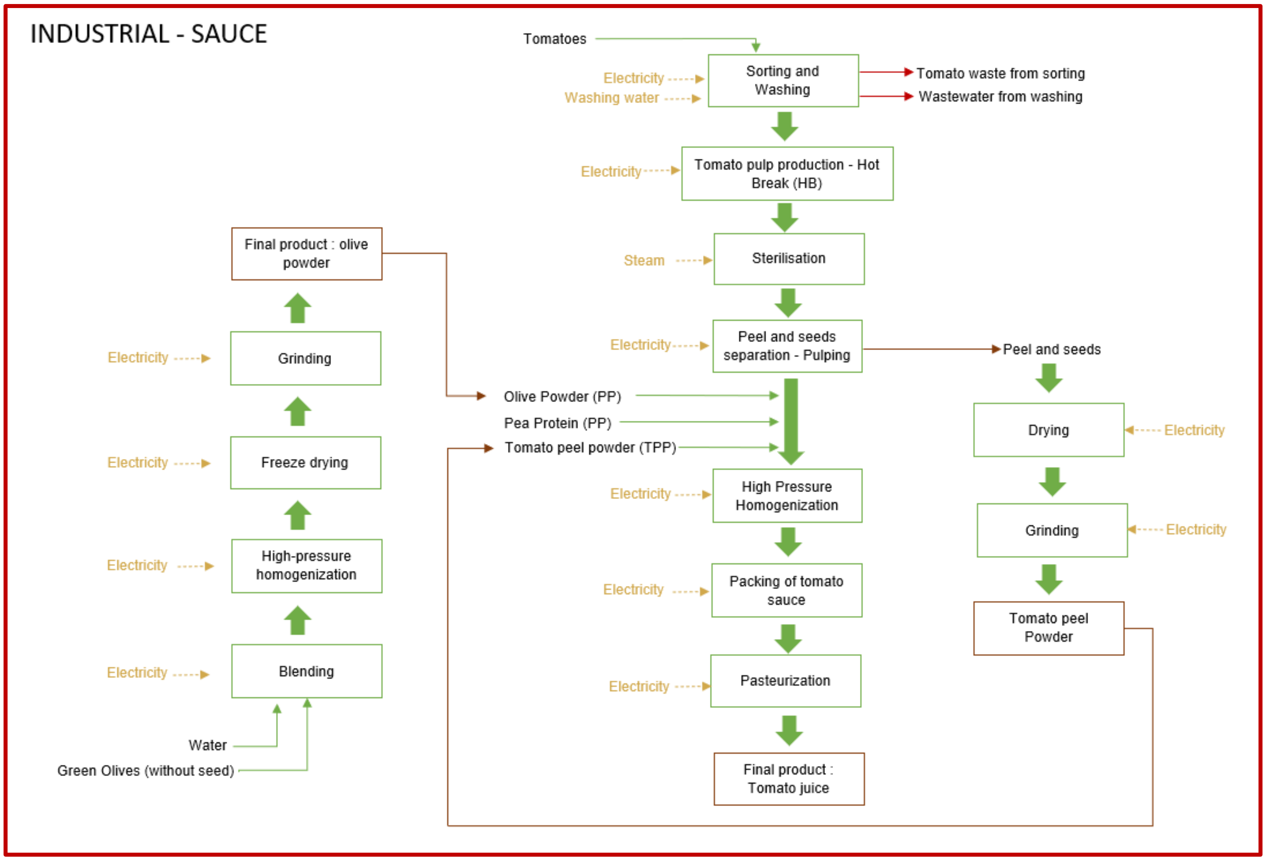


Figure 4. Flow chart of tomato sauce processing at industrial scale.

LITERATURE REVIEW

In this work, it was not possible to provide a direct comparison with baseline as the functional foods sector for similar product has not been studied in LCA. Instead, a comparison of the hotspots between other similar products and tomato juice and sauce proposed in FunTomP project is provided.

During literature analysis, sustainability features of food market products were assessed. For example, in the article of Palma et al. (2015), environmental performance of the production of French and Turkish tomato paste to produce tomato sauce through LCA methodology was compared. The researchers drew the conclusion that there is very little difference in terms of impacts between the two products. The hotspots identified were mainly at the manufacturing stage, with the choice of packaging and the consumption of electricity and steam, while agriculture and international transportation accounted for a small percentage of the environmental impacts.

In this study, the impact categories chosen were greenhouse gases (GHG) emissions, human toxicity, and eutrophication.

In the study conducted by Brodt et al. (2013), researchers highlighted the importance of the location of tomato farming, as the climate, soil type and water resources play a huge role in some environmental impact categories. While long distance transportation contributes minimally to GHG emissions for large volumes, it is crucial to compare regional advantages in crop production. The assessment of production locations is strongly affected by the choice of the environmental impact criteria to take into account. For example, one region can be more efficient in terms of GHG emissions per unit of tomato produced but not in water use, depending on the climate.

In the same context, FLONUDEP, a French national research program, aimed to generate knowledge on the impact of the fresh and processed tomato production chain from field to end-use. This program integrated three decision levels: environmental, nutritional, and socio-economic. The goal was to develop a decision-making tool for professionals seeking to optimize the balance among these three dimensions by highlighting hotspots all along the production, distribution and consumption chain until the product end of life. The experimental fields for this study were located in France, Morocco, and Türkiye with processing factories in France and Türkiye (FLONUDEP 2010; Padilla 2013). The type of production method, the organisation of logistics circuits, and the choice of packaging were underscored as critical factors in determining environmental impacts, according to the intermediate results of the project.

Moreover, Calero et al. (2022) compared different pasteurisation technologies at industrial scale for *salmorejo* (a Spanish cold tomato soup) production. The process was scaled-up to compare the pilot plant with medium and large industrial scale through prospective LCA. Using "gate-to-gate" system boundaries, industrial scales reduce the environmental impacts compared to pilot scale, as expected, thanks to energy recovery but also to a more efficient use of water, energy, and ingredients. Furthermore, the "farm-to-factory-gate" analysis emphasizes that ingredients and tomato valorisation are the stages with the most significant impact. Finally, they conclude that using tomato pomace for valorisation is less favourable compared to landfill disposal due to the high energy consumption required for the drying process. This perspective is interesting as in FunTomP, the tomato peels and seeds are also dried to make Tomato Peel Powder (TPP) and included in the formulation.

Concerning the processes used in FunTomP, some have been assessed in the *“D2.1: Sustainability assessment review of protein extraction methods”*, like freeze drying or High-Pressure Homogenisation (HPH). Even if it was decided finally not to include Sugar Beet Leave protein, these two technologies are used for other steps.

In the **D2.1**, it has been reported that freezing and drying techniques are particularly energy demanding, accounting together for more than 2/3 of the electricity consumption of the overall transformation process (Cao et al. 2018). Problems also arise from the use of ammonia as refrigerant agent as it increases the environmental footprint of the processes. Regarding freeze-drying, it is found to have a significant environmental impact and optimisation as well as the choice of primary energy sources for electricity production is crucial in reducing it (Merone et al. 2020; Rodriguez Meizoso et al. 2012).

2. METHODOLOGY

A life cycle thinking approach is employed within FunTomP project to assess the environmental, economic, and social impacts of the proposed products beyond the production, encompassing the entire 'farm-to-consumer' system boundary. In this work, we present a holistic triple assessment of the liquid products which includes environmental, social and economic aspects.

2.1. Life cycle assessment (LCA) methodology

Life Cycle Assessment (LCA) is a tool used for environmental management that aims to evaluate the environmental burdens associated with a defined system, such as a product, a process or a service. This assessment usually includes the entire life cycle of the system, starting from the extraction of resources and processing of raw materials, continuing through production, use and recycling, and concluding with the final disposal of any remaining waste (ISO 2006a). In essence, LCA involves conducting a material and energy balance for the product system, while also evaluating the environmental impacts associated with the input and outputs to and from the product system, as depicted in Figure 5.

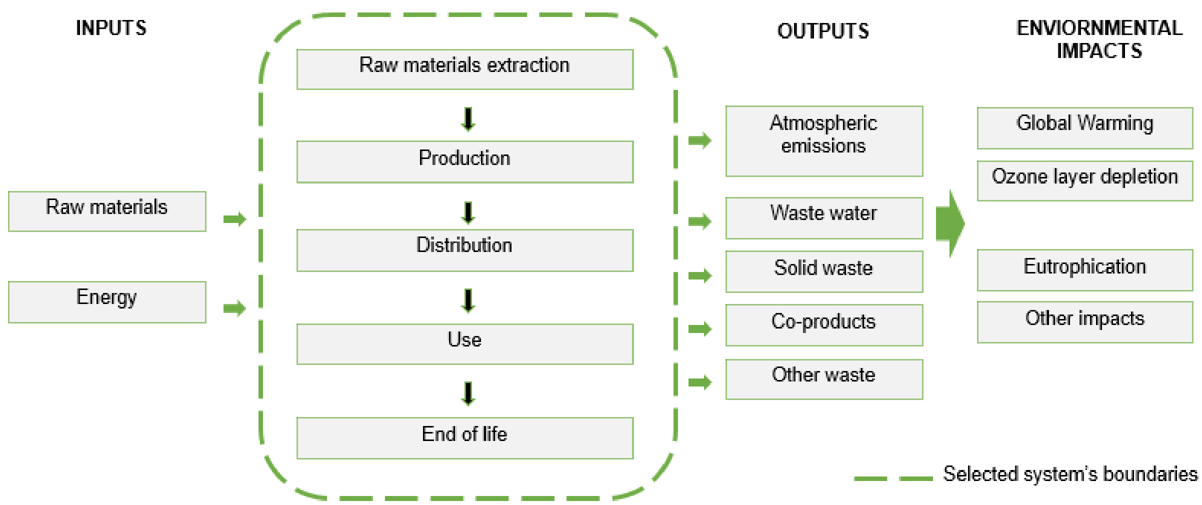


Figure 5. Schematic overview of the LCA possible boundaries and scope.

LCA proves to be an invaluable approach in facilitating well-informed decision-making by enabling a comprehensive comparison of the environmental effects associated with various products and activities. Undoubtedly, it stands as the most widely acknowledged methodology for assessing environmental impacts, having undergone standardization and harmonization processes (European Commission 2021; Hauschild, Rosenbaum, and Olsen 2018; ISO 2006a, 2006b; Klöpffer and Grahl 2014). According to ISO 14040 (ISO 2006a), LCA as a methodology for assessing the environmental aspects and potential impacts associated with a product or service, by:

- Compiling an inventory of relevant inputs and outputs of a product system.
- Analysing the potential environmental impacts related to those inputs and outputs.
- Interpreting the results of the inventory analysis and impact assessment concerning the goals of the study.

The standardised LCA framework encompasses four phases (ISO 2006a), which are presented in the Figure 6 and defined in the following points.

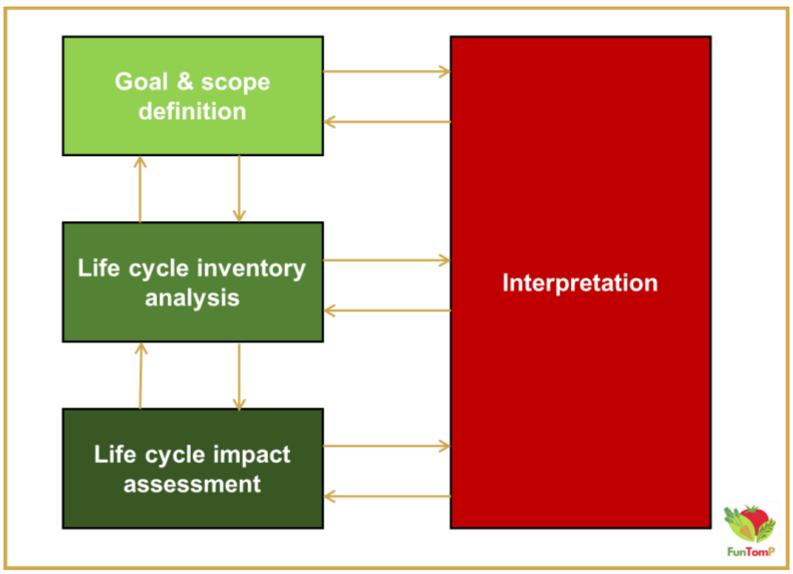


Figure 6. Four phases of the LCA. Source: ISO (2006a).

GOAL AND SCOPE DEFINITION

In the initial stage of the LCA, the guidelines for the entire study are established. This is achieved by outlining the purpose of the study, the intended utilization of the results, the target audience, the functional unit, the boundaries of the system, the data requirements and any limitations of the study. Firstly, it is essential to define the goal and determine the decisions that will be made based on the obtained results. Secondly, it is crucial to clearly identify the specific scope of the study to ensure that the breadth, depth and level of detail are compatible and appropriate for addressing the stated objective. This entails defining the system and its boundaries in terms of its conceptual, geographical, and temporal aspects.

Determining the **functional unit (FU)**, which serves as the reference for normalizing all assessment data is crucial during this phase. Stated differently, the functional unit is the specific quantitative description of the functions offered by the system that is being studied. In order to define and specify the functional unit, which should, to the greatest extent feasible, reflect the function provided by the system, questions like “what”, “how much”, “how well” and “for how long” are addressed. In comparative studies, the functional unit is especially important because it makes it possible to compare various systems that carry out the same functions on an equal footing.

The **system boundaries** define the unit processes that will be counted in the system under study. The stages, processes, and flows that will be taken into account during the assessment are determined by these boundaries. The foreground system and the background system are the two sub-systems that are included in the system boundaries. All the processes that directly interest the product or technology developers are comprised in the foreground system. The background system consists of all the operations and processes that support the foreground system. These include, for example, the extraction of raw materials, their final transformation before they enter the foreground system, and the production of electricity and materials used in the foreground system. To define the system boundaries and life cycle stages that should be part of the analysis, there are various approaches available. (**Figure 7**). The "cradle-to-cradle" approach, which addresses the entire life cycle, including the recovery and reuse of materials at the end of life (EoL), is the more holistic one. The "Gradle-to-grave" method does not cover the phase that occurs between EoL and resource extraction. "Cradle-to-gate" evaluation considers every stage of the process, from resource extraction to production, whereas "Gate-to-gate" evaluation concentrates solely on the production phase. Finally, “Cradle-to-consumer” evaluation includes the phases between resource extraction and the consumption of the product, after the distribution phase. To customize the approach to the purpose and scope of the study, LCA practitioners can add or remove some life cycle stages when defining the system boundaries (Guinée and Lindeijer 2002).

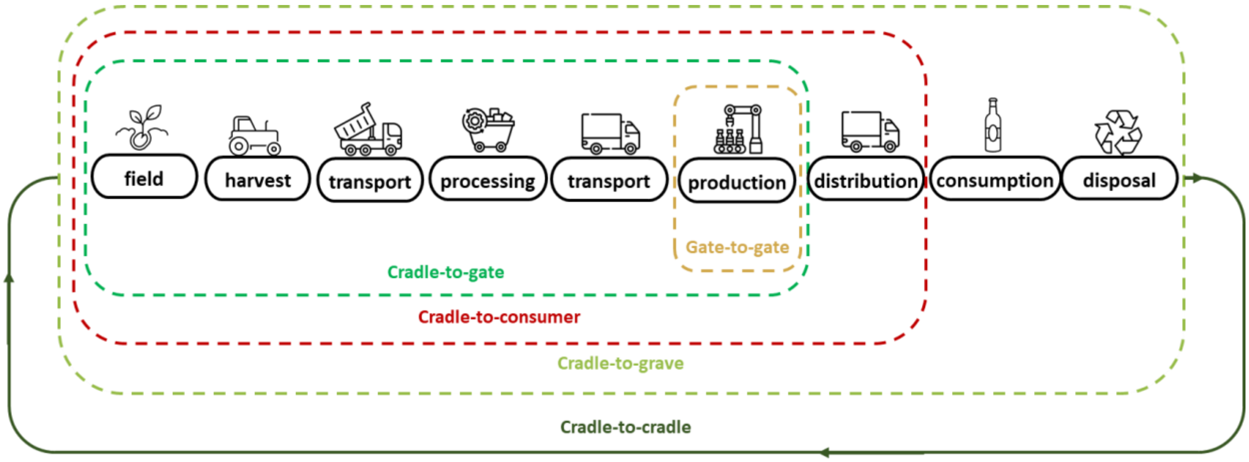


Figure 7. LCA approaches with different system boundaries.

INVENTORY ANALYSIS

During the inventory analysis, data is compiled to create a Life Cycle Inventory (LCI) of the inputs (energy and materials) and outputs (environmental releases, by-products, and wastes) of the system as defined in the scope. A data collection template was prepared and distributed to partners for them to supply data of their developed process to gather inventory data for the foreground system. A mass balance of the inputs and outputs of the foreground system is conducted to ensure the study of a consistent system. Similarly, an energy balance can also be carried out, depending on the importance of the energy inputs and outputs in the study. Using primary data detailing all inputs and outputs for each process, all the materials, water and energy carriers going in, all the products, waste streams and emissions going out of the foreground system should be inventoried. At the same time, when byproducts exist, the environmental burdens shall be allocated according to the norm. The allocation procedure can be done by mass or price, depending on the criteria adopted by the researcher.

Inventory data for the background processes are usually based on secondary data taken from LCA databases, such as Ecoinvent (Wernet et al. 2016), or from the scientific literature. A background process simulated in these databases or previous studies models the production of each input of the foreground system (e.g., electricity, waste treatment operations or specific raw materials). For example, the background process "production of electricity" should be identified in the databases if it has been specified that 1 kWh of electricity is consumed in the foreground system. The most relevant processes for the system under study should be selected based on context-specific information (e.g., the electricity mixes in the region where the foreground system takes place).

IMPACT ASSESSMENT

In this phase, an impact assessment method is used to translate LCI outcomes into potential environmental impacts. The elementary flows of natural resources consumed, and emissions released are multiplied by the so-called characterisation factors, which convert them into environmental impacts. Impact assessment methods developed by research centres and academia are used to define characterisation factors for several sustainability topics, also called impact categories (e.g., global warming, ozone depletion or eutrophication). As an illustration, in the analysis of global warming, every emission that falls into this impact category and happens along the supply chain is multiplied by a particular characterisation factor that represents its power to contribute to global warming and turns it into a common unit (kg of CO_2 equivalent in this case).

The life cycle impact assessment (LCIA) procedure is depicted in Figure 8. LCIA consists in inventorying all the emissions related to the background and foreground systems, considering the emissions contributing to global warming (in this example the greenhouse gases CH_4, CO_2 and N_2O) and multiplying by the corresponding characterisation factors (28 kg CO_2 eq/kg CH4, 1 kg CO_2 eq/kg CO_2 and 265 kg CO_2 eq/kg N_2O). All of the emissions are added up after being converted to the same unit to determine the product A's overall impact on global warming (i.e., 218.5 kg CO_2 eq).

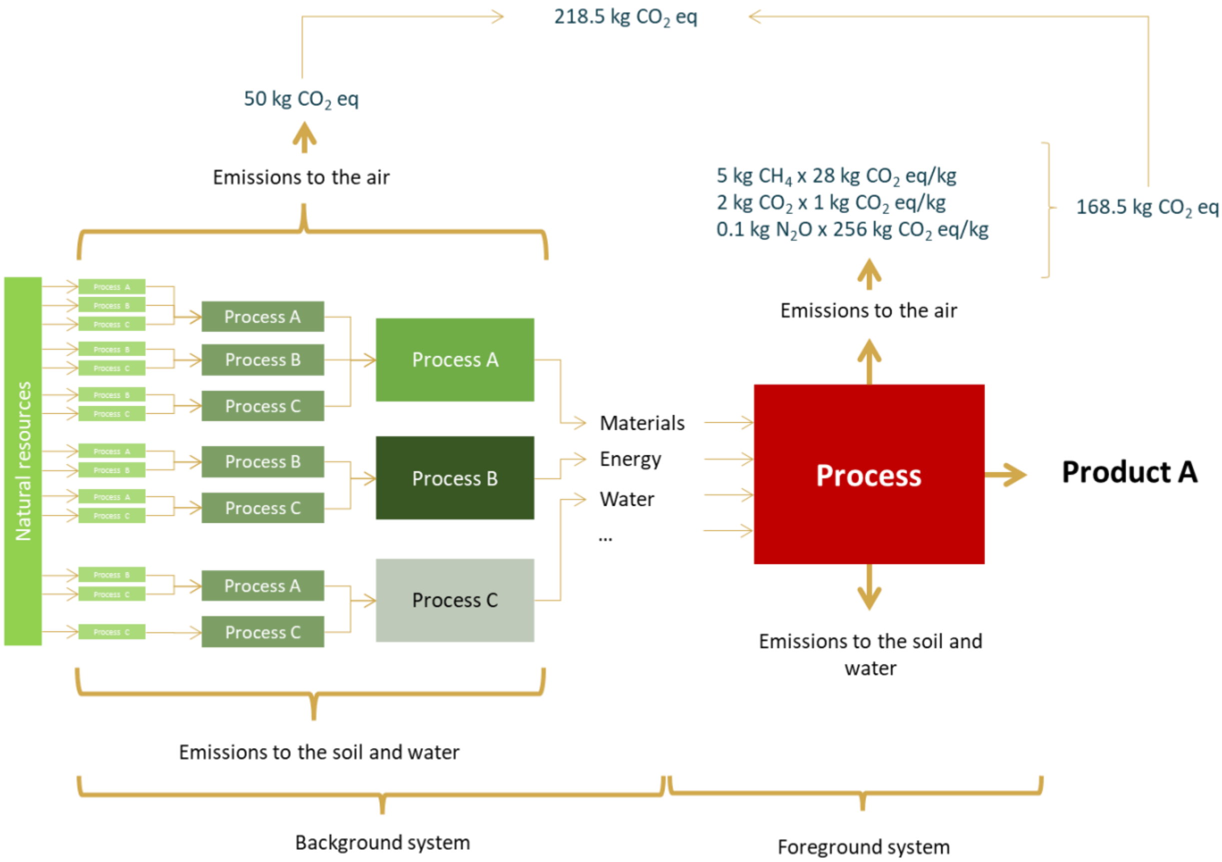


Figure 8. Illustration of the impact assessment phase (note: numbers are provided as an example).

There are numerous LCIA methods (**Figure 9**), which are conveniently integrated into LCA software such as SimaPro, openLCA or GaBi. These approaches can be grouped into two primary categories based on the assessment's objective: i) *midpoint methods*, these examine the effects earlier in the cause-effect chain before the endpoint is reached, producing impact indicators for single environmental issues such as global warming, eutrophication or ozone layer depletion among many others; ii) *endpoint methods*, these examine the environmental impacts at the end of the cause-effect chain, resulting in damage indicators for protection areas such as human health, ecosystems, and resources, which show the ultimate effects at higher aggregation levels. Since several impact pathways eventually end up as damages to human health, ecosystems or resources, these three endpoints capture the effect of many different midpoints. Midpoint methods are the preferred choice in the scientific/academic field because statistical uncertainties in the endpoints are higher due to the accumulation of assumptions and data gaps along the cause-effect chain. Midpoint results may appear more daunting and take more effort to understand, but they are more dependable and provide far more specific knowledge in return, such as the discovery of trade-offs that may be masked at the endpoint level. Consider a scenario in which one product has a significant influence on global warming but a low impact on ozone layer depletion, contributing both impact categories to the endpoints of human health and ecosystems, and thus the different impacts may cancel each other out. The interpretation of endpoint outcomes does not necessitate significant understanding of the many environmental effects, and deriving general conclusions is simplified because there are just three impact categories to examine. Endpoint methods can therefore be beneficial for sharing environmental outcomes with non-expert audiences, such as when demonstrating the environmental benefits of a new product to high-level managers, public administration, or society.

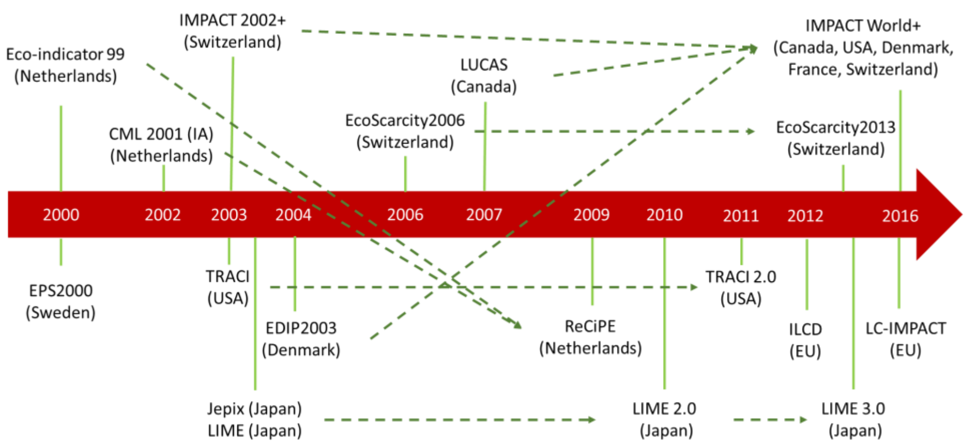


Figure 9. LCIA methods published since 2000 (Rosenbaum, 2017).

The ReCiPe 2016 method assesses the environmental impacts according to midpoint and endpoint categories (Huijbregts et al. 2017). It also allows to assess the environmental impacts in 18 midpoint categories: global warming, stratospheric ozone depletion, ionising radiation, ozone formation (distinguishing impacts on human health and on terrestrial ecosystems), fine particulate matter formation, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human toxicity (distinguishing carcinogenic and non-carcinogenic toxicity), land use, mineral resource scarcity, fossil resource scarcity, and water consumption (**Figure 10**).

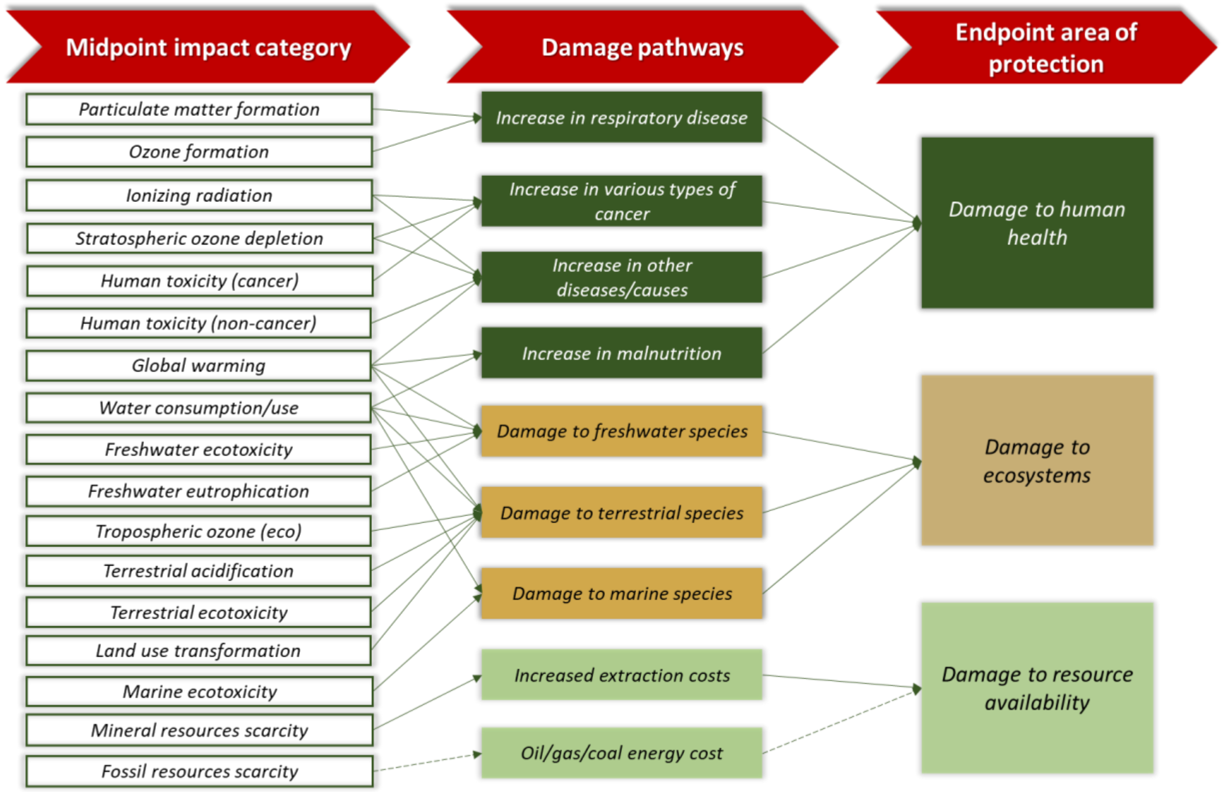


Figure 10. ReCiPe midpoint and endpoint impact categories

Endpoint impacts are derived directly from the midpoint impacts through endpoint characterization factors, which vary based on the cultural perspective employed in the assessment. Environmental impacts can be evaluated from three cultural perspectives: egalitarian, hierarchist, and individualist. In this study, both midpoint and endpoint impacts were assessed from the hierarchist perspective, grounded in scientific consensus regarding time horizon and other considerations such as adaptation capacity and technology development.

According to ISO 14044 (ISO 2006b), the selection of the impact categories should take into consideration the following aspects: i) the categories are not redundant and do not result in double counting, ii) they do not conceal significant impacts, iii) they are complete, and iv) they enable traceability. In addition, other essential considerations to be addressed during the selection of LCIA methods (Hauschild et al. 2018) include : i) what sort of environmental concerns need to be covered?, ii) in which region the study is taking place?, iii) are midpoints or endpoints needed to be assessed, or both?, iv) what elementary flows must be characterized?, v) how effectively is the approach documented?, vi) how feasible will it be to communicate the results?, vii) when was the method published and have there been significant scientific developments in the meantime?.

Within the framework of this deliverable, it was defined after a literature review which impact categories had to be considered in the analysis.

INTERPRETATION

Finally, the interpretation phase integrates and summarizes the results of inventory analysis and impact assessment (in accordance with the established goal and scope) in order to reach conclusions and suggestions. The outcomes of this phase are synthetized, highlighting the major causes of environmental impacts and potential mitigation measures. First, environmental hotspots must be identified (i.e., the life cycle steps and/or processes that have the greatest influence).

The interpretation phase also intends to validate the data and methodological choices used to carry out the study and draw conclusions about the system's sustainability. For this purpose, sensitivity analysis is carried out. It consists in altering a model parameter or assumption and analysing the impact on the LCA results. It can help identify the assumptions that need to be adjusted to obtain more accurate results.

The phases and actions outlined above are neatly organized. However, LCA studies are iterative, which means that the LCA steps are repeated to fine-tune the input data, assumptions and results with a focus on the most relevant processes, resources and emissions. The previous iterations' assessments help to identify the most significant aspects and the corrections to be made in each iteration (**Figure 11**).

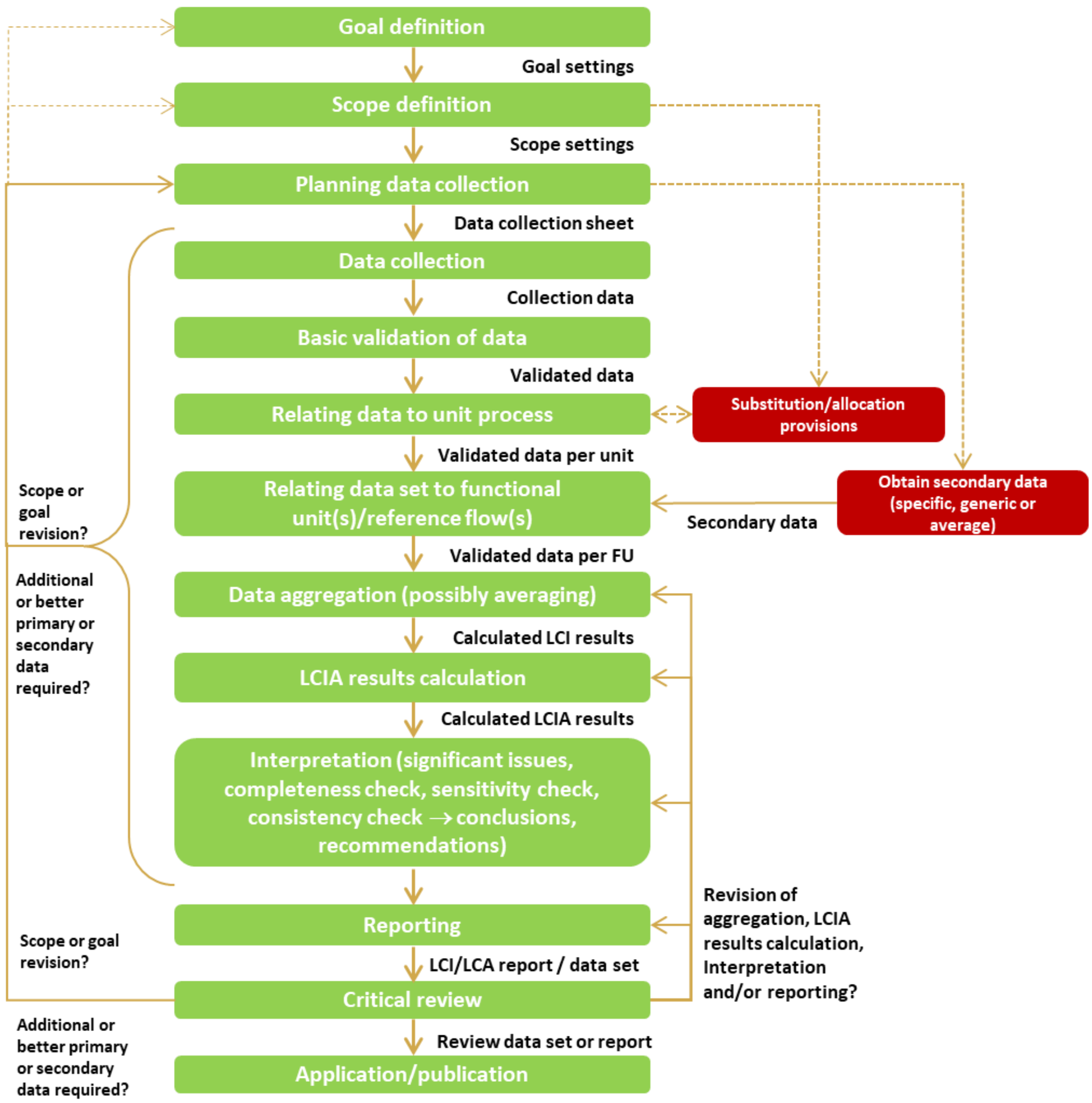


Figure 11. Details of the iterative LCA approach (JRC-IES, 2010).

2.2. Life cycle costing (LCC) methodology

Life cycle costing (LCC) is a technique used to evaluate the total costs associated with a product or system throughout its entire life cycle. It enables aggregated and comparative cost assessments over a specified time period, accounting for relevant economic factors such as initial capital costs, future operational expenses, and asset replacement costs. Together with LCA & Social Life Cycle Assessment (S-LCA), LCC is considered one of the three pillars of sustainability evaluation, with the third pillar being social assessment (Hunkeler, Lichtenvort, and Rebitzer 2008). The LCC takes into account initial costs, such as capital investment, acquisition, and installation expenses, as well as future costs. These future costs include operation and maintenance expenses, such as those for energy and water supply, materials and other consumables, taxes and insurance, labour, repairs and replacements, and disposal costs, which encompass waste transport, treatment, and final disposal (Estevan and Schaefer 2017). LCC can also account for revenues, treating them as negative costs, which may be necessary in certain contexts to effectively aid decision-making (Rödger, Kjær, and Pagoropoulos 2018).

The LCC methodology adheres to the main steps of the standardised LCA (**Figure 12**):

1. Define the goal and scope of the assessment.
2. Compile an inventory of all the relevant expenditures and revenues within the previously defined systems and scenarios.
3. Evaluate the economic impacts associated with the inventory data typically using spreadsheet computations.
4. Interpret the calculation the results and thoroughly check the data quality in relation with the study’s objectives.

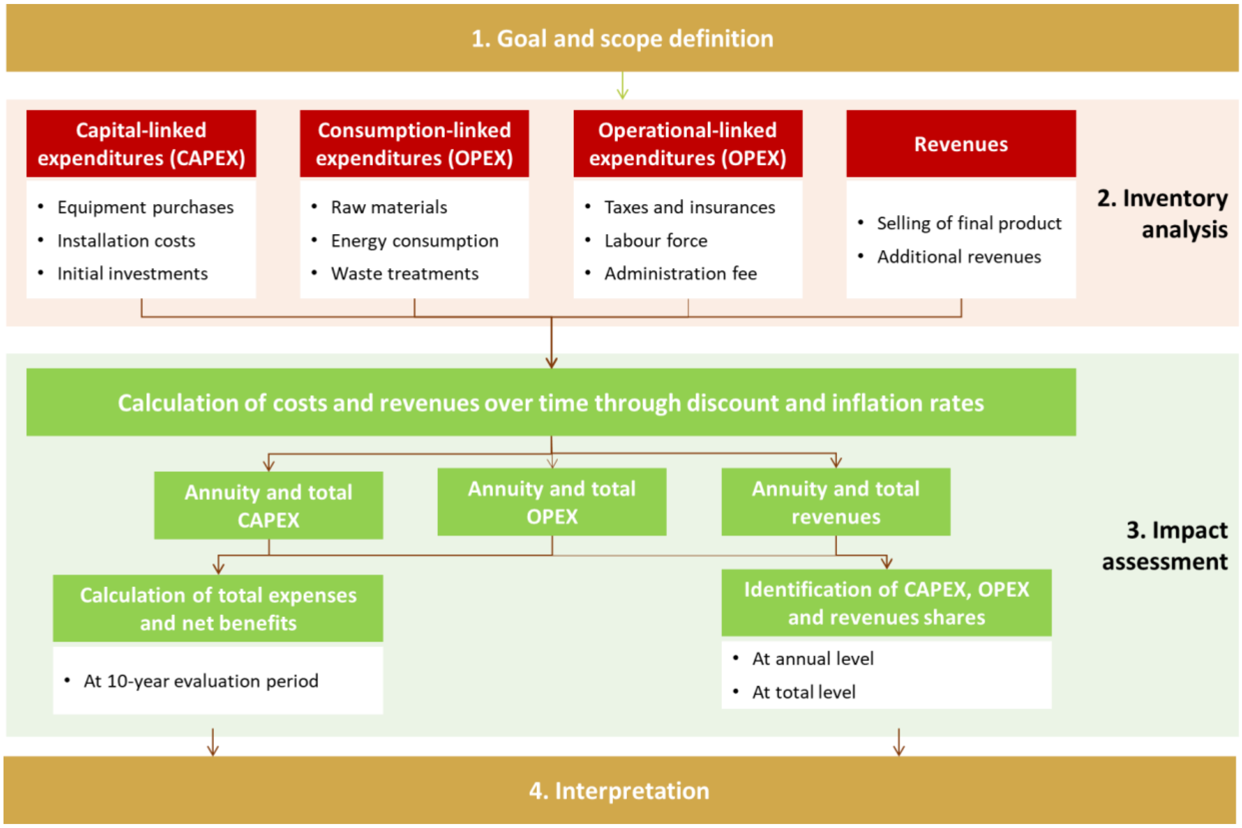


Figure 12. Schematic overview of the LCC methodology.

GOAL AND SCOPE DEFINITION

This step mirrors the environmental LCA process. It defines the study's objectives, the functional unit, and the system boundaries, which should align with those of the LCA and be based on the same product-system model.

INVENTORY ANALYSIS

In this step, all expenses within the system boundaries are inventoried and categorized as follows:

- **Capital expenditures (CAPEX)**: this includes all initial capital investments for purchasing equipment, other acquisitions, installation, commissioning and other indirect costs.
- **Operational expenditures (OPEX)**: these are further divided into:
  - **Consumption-linked expenses:** costs of raw materials, auxiliaries, energy and waste management.

- **Operation-linked expenses:** costs of labour force, maintenance and repairs, taxes and insurance, and other indirect costs like plant overhead and administrative expenses.

The selling prices of the generated outputs (including the main product and any by-products) can also be inventoried to estimate the revenues from the studied product or service and compare them with the costs. Both costs and revenues must be appropriately allocated to account for shared expenses and incomes. This allocation ensures that only the portion of costs and revenues relevant to the assessed time period is considered.

IMPACT ASSESSMENT

To measure the feasibility of the project, several indicators are used. These indicators reflects the viabbilyt of the project from several points of view and are categorized differently. One way to categorice them is according the value of money during tim.Time adjustments, are a crucial aspect of LCC.The time adjustment evaluation ensures that money spent or gained over time is compared accurately. Money's value changes over time due to its earning potential, varying risk in future revenues or savings, and the impact of inflation on purchasing power. This recognition of money's changing value is vital for a valid assessment of a project's life-cycle costs and benefits.

Present Value (PV) is crucial in assessing the capital costs and is commonly used in capital budgeting to evaluate investment profitability. The time value of money emphasizes that a euro earned in the future is worth less than one earned today. The discount rate used in the Present Value (NPV) formula addresses this by adjusting for time value. Identifying the discount rate involves various methods, often relying on the expected return of investments with similar risk levels as a common approach.

PV can be calculated as:

$$PV = \frac{V_n}{(1+r)^n} \qquad \text{[eq. 1]}$$

where: V_n = cash flow at year n; n = number of years, where 0 ≤ n ≤ np; r = nominal or real discount rate; np = total considered lifespan of the project or time horizon of the analysis.

The discount rate is a factor used to discount and transform future cash flows into present value costs. It is usually country and sector specific. Real discount rates represent the prevailing rate of interest on borrowed funds (equal to the nominal discount rate), less inflation. Real discount rates used in LCC analysis typically range from 3 to 5 percent. The rate of interest of borrowed funds reflects, in turn, the cost of capital. Because there is always an opportunity value of time, real discount rates will always exceed zero. The denominator is also known as discount factor and is always less than or equal to 1. Real discount rates can be calculated using the following formula (derived from the Fisher equation):

$$r_t^{real} = \frac{r_t^{nominal} - i}{1 + \mathrm{i}} \quad \text{[eq. 2]}$$

where: i = expected inflation rate; $r_t^{nominal}$ = nominal discount rate at time t.

The inflation indexes can be withdrawn from the Consumer Price Index. The nominal discount rates are communicated directly by the project partners according to their Weighted Average Cost of Capital (WACC) or, when unknown, taken from literature or official sources. In the second case, the input might be less precise, as the rates are sector and country specific.

Usually, the CAPEX values do not need to be actualized, as it assumed they occur during the first year of the analysis; in case they occurred in the past or they are paid in different rates an actualization is necessary, as well as an allocation if they serve also for other production processes or services.

The sum of all present values gives the LCC **Net Present Value (NPV)** or Total Present Value (TPV), which is the desired output of the analysis.

The possible life cycle times for LCC analyses usually vary from a few years to 25 years, the latter representing the general limit of the analysis also for the LCA, as it is assumed that after this period of time new materials or technologies might gain the market. Moreover, discount and inflation rates assumptions lose relevance after several years.

Few years life spans are considered as investors are often interested in shorter periods of time, while longer life spans might be chosen to evaluate the **Return on Investment (ROI)** over different scenarios. As a specific financial measure, ROI is expressed as a percentage over a specific period. ROI differs then from the NPV of a project, that is equal to the benefits minus the costs, and is expressed in monetary units, providing information about the magnitude of the project.

Two more financial indicators are commonly used to evaluate the feasibility of an investment project. **Payback Period (PP)** and **Discount Cash Flow Rate (DCFR).** Payback Period is a financial metric used to assess the amount of time it takes to recover the initial investment in a project. It represents the length of time required for the cash inflows generated by the investment to equal the initial cash outflow or the cost of the investment. Typically, shorter payback periods are considered more favourable as they indicate a quicker return on investment. It is a simple way to evaluate the risk or the time it will take to recover the funds invested. According to literature**Fuente especificada no válida.** PP can be expressed as in equation 3:

$$PP = \frac{V + A_x}{\left(\frac{1}{N}\right) * \sum_{n=1}^{N} A_n} \qquad \text{[eq. 3]}$$

where: V= Manufacturing fixed-capital investment in M€; A_x= Non-manufacturing fixed-capital investment in M€; A_i = Annual cash flow in M€.

Furthermore, **DCFR** provides interesting information regarding the future value of the money. The DCFR is the return obtained from an investment in which all investments and cash flows are discounted. It is determined by setting the NPV equal to 0 and solving iteratively equation 4.

$$\sum_{\mathrm{n}=1}^{\mathrm{n}} \frac{\mathrm{PV}_n}{(1 + \mathrm{DCFR})^n} = 0 \qquad \text{[eq. 4]}$$

where: PV =Present Value in M€; n= Year of the project; $DCFR$= Discounted Cash Flow Rate.

The DCFR is only of concern when the project rates are favourably compared to the value of a minimum acceptable rate of return (m_{ar}). Clearly, if the NPV that is calculated equals zero, then the m_{ar} used is the DCFR.As guidance, the DCFR will be greater than the m_{ar}. When the NPV is favourable, the DCFR will necessarily be favourable and will be the actual earning rate of the investment.

INTERPRETATION

Similar to LCA, the interpretation phase in LCC combines and summarises the results of inventory analysis and impact assessment to draw conclusions, identify hotspots, and offer recommendations for optimising the studied costs.

2.3. Social Life Cycle Assessment (S-LCA) methodology

S-LCA is a methodology designed to assess social aspects that can impact stakeholders across the supply chain -positively or negatively- such as workers, local communities, society, consumers, children and value chain actors or suppliers throughout the life cycle of systems. It aims to provide social and socio-economic information crucial for decision-making (UNEP 2020). The potential benefits of S-LCA are outlined in **Figure 13**.

Figure 13. Benefits of the S-LCA implementation (UNEP, 2020).

S-LCA methodology integrates certain modelling and systematic assessment processes used in LCA and LCC. It is structured within the ISO 14040 framework (ISO 2006a, 2020) and can be applied independently or in conjunction with E-LCA and/or LCC. Thus, it operates within the same methodological context, consisting of four phases: (1) Goal and scope definition, (2) Social life cycle inventory (S-LCI), (3) Social life cycle impact assessment (S-LCIA), and (4) Interpretation.

GOAL AND SCOPE DEFINITION

During this initial phase, guidelines for the remainder of the study are established. This includes specifying the purpose of the study, intended use of the results, methodological framework, core characteristics (functions and utility) of the product or service, its functional unit, and defining the system boundaries as well as outlining the limitations of the study.

Furthermore, the first phase includes defining the functional unit which serves as the quantitative reference of the product or service under study. Defining the functional unit is crucial for comparing alternatives since it establishes a consistent basis for the assessment (UNEP 2020).

S-LCI: DATA COLLECTION

Calculating social impacts begins with a data collection phase to gather information throughout the life cycle of the system being studied. This phase aims to develop a S-LCI, which defines the composition and geographic distribution of the supply chain. Project partners provided primary data on the life cycle stages, processes involved, raw materials used, energy consumption and environmental emissions from manufacturing and recycling, and associated costs. This information is then refined and supplemented with additional supply chain data, such as market prices and production locations, in order to obtain the S-LCI.

S-LCIA: CALCULATION OF THE SOCIAL IMPACTS

The data gathered in the preceding phase is normalized based on the functional unit and subsequently analysed using the SimaPro software. This process requires the use of relevant databases like the Social Hotspots Database (SHDB) and characterisation methods to convert the S-LCI into its associated social impacts. Through this approach, the overall social footprint of each product is calculated, detailing its impact across various sectors, activities and geographical locations within the supply chain.

INTERPRETATION OF RESULTS

After completing the preceding steps, an interpretation phase is necessary to thoroughly review the iterative methodology, analyse and discuss the obtained social footprint of the product or service. Delving into the main results will guide the outcomes and conclusions of the S-LCA study, with a focus on identifying improvement opportunities and providing recommendations for decision making.

Social Life Cycle Assesment Assessment utilises S-LCA databases, typically integrated into LCA software (e.g., SimaPro), which enable data processing during the S-LCIA phase by incorporating generic data from national and international organizations. The present study employs the Social Hotspot Database (SHDB), which evaluates 22 social sub-categories that can be grouped into five social categories (see Figure 15). SHDB includes a weighted aggregation model that converts the values of impacts for each social subcategory into aggregated impact values for each social category. These aggregated values can be further combined to produce a single global social impact indicator known as the Social Hotspot Index (SHI). **Figure 14** outlines the SHDB method used in this S-LCA study. Consequently, S-LCA will be applied for the farm-to-consumer stage of the FunTomP technology, as it gathers the results **Section 5**.

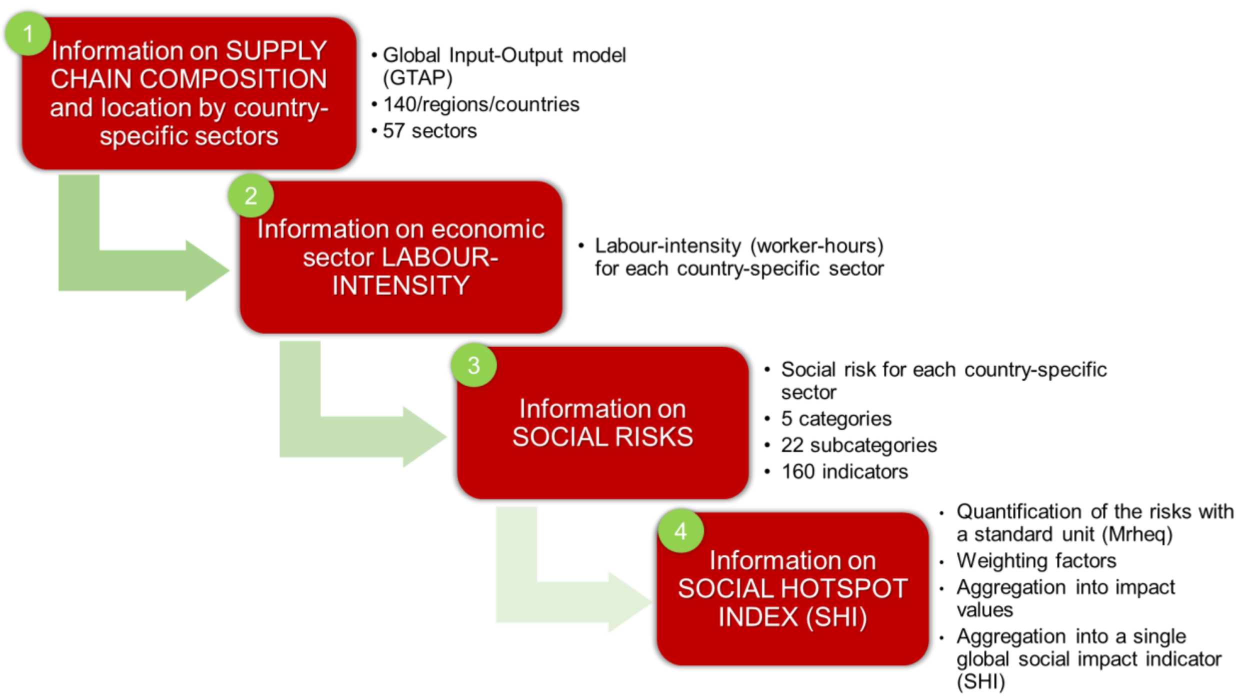


Figure 14. Main data components of the SHDB (adapted from Benoit Norris and Norris 2015).

1) Information on supply chain composition and location: Understanding the geographic locations of production activities is crucial in S-LCA due to the impact of societal, political and cultural factors on potential social impacts (Benoit Norris, Aulisio, and Norris 2012; Benoit Norris and Norris 2015; Benoit Norris, Norris, and Cavan 2014). Therefore, S-LCA requires defining the composition of the supply chain by detailing how the production costs are allocated among country-specific sectors (CSS). This involves determining how costs are distributed to each sector/country pair (for example, euros spent in the food manufacturing sector in China).

The SHDB integrates a Global Input-Output model that details trade flows between the economic sectors across various countries and regions worldwide (covering 57 sectors in 140 regions/countries). The Global Trade Analysis Project (GTAP) model was employed to finalise the definition of the supply chain composition for the target products by modelling how the monetary purchases from the CSS relating to Tier 1 suppliers are distributed across other CSS (related to lower-tier suppliers).

2) Information on the economic sector labour-intensity: Labour intensity, measured in of worker-hours, signifies the basic or first-order “intervention” by a production process that correlates with outcomes or interest impacts. More generally, worker-hours are particularly significant as they indicate the level of labour required by each CSS directly involved in production (Benoit Norris, Aulisio, et al. 2012; Benoit Norris and Norris 2015).

The SHDB utilises a worker-hours model derived from average wage payments across sectors in each GTAP country/region. Consequently, the SHDB determines the number of worker-hours associated with each CSS within the supply chain of the target products, based on the economic requirements quantified in the earlier stages.

3) Information on social risks: The SHDB also offers insights into social risks and opportunities across countries and economic sectors, encompassing 160 social impact indicators for the CSS covered by the GTAP model. Depending on the data context, impact subcategories or social themes (**Figure 15**) can be evaluated using varying numbers of indicators. Sometimes only one relevant indicator is available, while in other cases, several indicators are used for a specific social subcategory. Data interpretation and risk level determination (ranging from low risk, LR, to very high risk, VHR) are most often performed through consideration of the range and distribution of values exhibited for the indicators across the full population of sectors and countries (Benoit Norris, Aulisio, et al. 2012; Benoit Norris and Norris 2015).

The labour-intensity information for each CSS is used together with the social risk levels there to determine how many worker-hours are linked to the social risk level for a given social subcategory in each CSS.

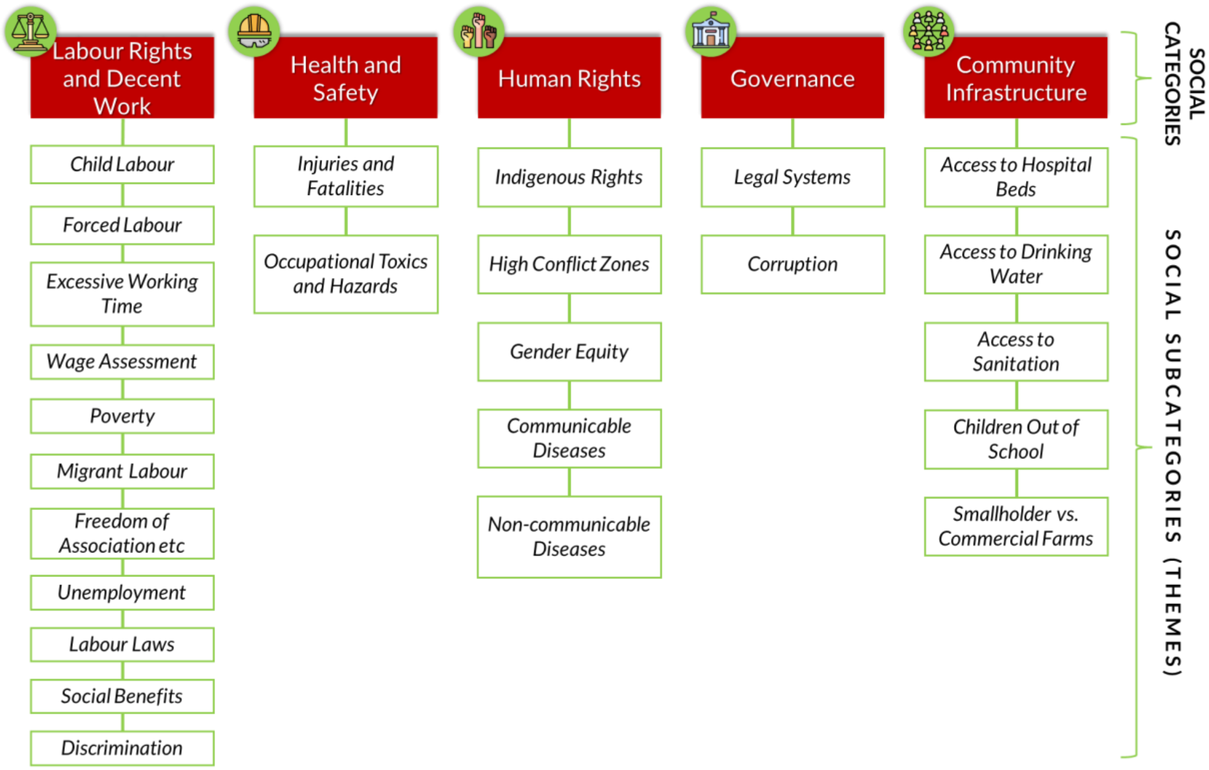


Figure 15. SHDB categories and subcategories included for the S-LCA (Benoit Norris and Norris 2015).

The 25 social impact subcategories are described in detail below:

- ***Wage assessment*.** Minimum wage is a core indicator of the wage assessment as it defines the minimum amount of remuneration perceived by a worker for his labour. Wages are compared to the reference minimum wage but also to the minimum living wage (the incomes needed to cover essential needed like housing, food, access to health services, etc.).

- ***Poverty*.** The state of poverty refers to the lack of material resources or incomes to provide essential standard of living. By extension, it is also linked to the definition of decent work that includes a fair and sufficient pay for the workers.

- ***Child Labour*.** Child labour refers to the activities that are mentally, physically or socially unsuitable or dangerous for children. Any alteration of the capacity to follow an education is also considered as child labour. The status of "child" is defined independently by each country, but the International Labour Organisation (ILO) age convention stated some age limitation according to the type of work (any work under the age of 12, and older for dark or hazardous working conditions).

- ***Forced labour*.** ILO defined forced labour as any activity that is performed without consent or under a form of menace or a threat of a penalty. Forced labour refers to works and services in all activities sectors, including the illegal one. Each worker should be informed and free to take a job but also to leave it.

- ***Excessive working time*.** Daily, weekly and annual working hours and periods should be organised to ensure the protection of physical and mental health of the workers. Most of the countries are following the ILO framework of maximum 48 working hours weekly and mandatory resting periods.

- ***Freedom of association*.** Another requirement for a decent work is the possibility for workers to express their concerns freely individually or collectively. Freedom of association is integrated in the Universal Declaration of Human Right of 1948, enabling workers to participate to the economic and social policies definition.

- ***Migrant labour*.** One of ILO main concern is the protection of workers interests when they are employed in a country different than their own. That covers the fundamental human rights of the migrants and similar conditions as local workers.

- ***Social benefits*** It defines social benefits as cash transfers paid to specific individuals and/or households to mitigate the effect of social risk. (IPSAS 2019, 2022)

- ***Labour laws.*** Labour laws or employment laws is the legal framework defining rights and duties of the workers and employers, but also unions and governments.
- ***Discrimination.*** Discrimination is an action or a decision that treats a person or a group badly for reasons such as their race, age, or disability.(Canadian Human Rights Commission 2017)
- ***Unemployment*****.** Organisation for Economic Co-operation and Development (OECD) defined unemployment as the status of people that are available and allowed to work but without professional paid activities on the current period of time.
- ***Occupational Toxics and Hazards*****.** Exposure and effects of chemical substances and other operational risks related to the working environment or activities can be considered for this impact category.
- ***Injuries and fatalities.*** This category refers to the number or rate of working accidents and their consequences on the workers' health.
- ***Indigenous rights*****.** Indigenous rights were defined by the United Nations (UN) in 2007 in the Declaration on the Right of Indigenous People. This text includes common human right guaranties and the protection of cultural traditions, customs, and way of living for indigenous populations.
- ***Gender equity and non-discrimination*****.** Gender equity and non-discrimination is a fundamental right ensuring equal opportunities and treatments, independently of gender, race, sexual orientation,religion, or any other status.
- ***High conflict zones*****.** Conflicts are referred as a tense situation between different parties because of interests, aims or value systems, which at the end may increase disturbances (so called as conflict zones). Thus, it should be considered if the organization and its activities are acting in these zones.
- ***Non-communicable diseases*****.** Noncommunicable diseases (NCDs), also known as chronic diseases, tend to be of long duration and are the result of a combination of genetic, physiological, environmental, and behavioural factors.(WHO 2023a)

- ***Communicable diseases*****.** Communicable, or infectious diseases, are caused by microorganisms such as bacteria, viruses, parasites and fungi that can be spread, directly or indirectly, from one person to another.(WHO 2023b)

- ***Legal system*****.** A legal system defines the framework of rules, procedures and institutions of a specific geographical area (country, region, etc.).

- ***Corruption*****.** Corruption is the dishonesty or offence undertaken by an organisation or a person that take advantage of its position of authority to obtain illegal benefits.

- ***Access to drinking water and sanitation*****.** These are recognized as a Human Rights by the UN since 2010. Everyone has the right to sufficient, continuous, safe, acceptable, physically accessible and affordable water for personal and domestic use (drinking, food production, hygiene, etc.).

- ***Access to sanitation.*** It is also recognized as a Human Right by the United Nations since 2010.

- ***Children out of school*****.** Out-of-school children is an indicator used by organisation like UNESCO to measure to access of local communities to education.

- ***Access to hospital beds.*** The accessibility to medical services can be evaluated with indicators related to the number of hospital beds available for a local community.

- ***Smallholder vs Commercial farms*****.** This impact category evaluates the agricultural practices and outcomes in local communities. The difference between the two types of farming system has consequences on many aspects: yield, employment density, value chain, incomes, etc.

4) Social Hotspot Index (SHI): Due to the high number of indicators and impact subcategories used and considering the specific evaluation for each country and economic sector, the S-LCA generates a large amount of data on social impacts that make it challenging to base decisions on. Therefore, to facilitate the understanding of the results and make sense of the social impact information available for each CSS, the SHI was created (Benoit Norris, Aulisio, et al. 2012; Benoit Norris, Cavan, and Norris 2012; Benoit Norris et al. 2014). The SHI is an impact assessment method that combines the labour-intensity information with the social risk levels to express social risks (and opportunities) in terms of **medium risk hours equivalent** (**Mrheq**) by sector and country for the five social impact categories and the 25 social impact subcategories. The SHI is first determined by weighing the risk level identified for each social impact subcategory, using weighting factors (as shown in **Table 3**). This weighting enlarges or reduces the number of workers-hours depending on the risk level, converting them into **points (Pts)**. Thus, the same unit is used to calculate the impact on each social subcategory, so the impacts for different subcategories can be aggregated into single impact values for the corresponding social categories, which in turn can be aggregated into a single global social impact indicator, the Social Hotspot Index or SHI. Furthermore, it is helpful to identify target areas in the supply chain to improve social conditions, i.e., social hotspots or individual production activities/countries (identified by CSS) that contribute most to the risks (overall and/or by impact category or subcategory).

Table 3. SHDB impact assessment method: weighting factors. Source: Benoit-Norris et al. (2019).

Risk level	Weighting factor
Very high risk (VH)	10
High risk (HR)	5
Medium risk (MR)	1
Low risk (LR)	0.1

It should be noted that weighting factors in **Table 3** are default values for this methodology, whilst the factors applied herein varied for each impact subcategory according to the number of social indicators used to assess such a subcategory.

3. LIFE CYCLE ASSESSMENT

3.1. LCA goal and scope definition

This study aims to evaluate the potential environmental impacts and benefits of the two new liquid functional tomato products developed in FunTomP. The products have been developed and produced during the project at laboratory or pilot scale. The LCA study will be performed with pilot scale primary data, knowing their limits and that large scale production will result in a more resource efficient value chain.

Therefore, the **goals** of the LCA study are:

- Identifying main environmental hotspots over the whole assessed value chain in order to set recommendations for improvement.

- Quantifying the environmental impacts associated to the end products before launching on the market.

The **audience** for this report and for the results of the project may be diverse, including: technical personnel, who may be interested in the sustainability performance of FunTomP technologies; business- and marketing-oriented personnel, since the obtained results can deliver valuable market information and be useful to increase the attractiveness of the developed functional foods; policy-makers and general public, who may be motivated by the environmental feasibility of the technological proposal to implement new policy measures and change consumption patterns.

The **system** being assessed consists of the lab/pilot scale production of liquid tomato products (i.e., **tomato juice and tomato sauce**), encompassing farming of tomato and olive, formulation, and their processing until they reach the form of packaged tomato juice and tomato sauce. The process flowcharts are shown in Figure 1 and Figure 2 for the tomato juice and sauce, respectively.

The **functional unit** (to which the LCA results are related) was defined in this study as 225 mL of tomato juice bottled and ready for distribution (including packaging) and 300 mL of tomato sauce produced and ready for distribution (including packaging).

The present LCA study includes the environmental aspects and impacts from the farm to the exit gate from the production factory (without distribution, **farm-to-gate** approach). **Figure 5** shows the system boundaries considered in the present study, including the life cycle stages and processes that have been included and excluded from the scope of the study. The stages of FunTomP products distribution, use and end-of-life have been excluded from the scope of the study.

In the future, all production processes for tomato juice and sauce will be centralized at the **Kraft Heinz industrial facility in Susurluk, Türkiye**.

3.2. Life cycle inventory analysis

INVENTORY ANALYSIS FOR TOMATO JUICE PRODUCTION

The inventory data collected for tomato juice production is presented in Table 4, in alignment with the flowcharts shown in **Figure 1** and **Figure 3**.

The subprocess of pulp production, known as "*cold break*", is directly included in the LCI table (**Table 4**). Centrifugation is indicated in the same box than tomato pulp since they both constitute the liquid phase. The tomato and olive powders mentioned above are incorporated in the recipe along with other ingredients: pea protein, salt, tomato pulp and centrifugation supernatant. The lab-scale values for electricity consumption are significant, especially for HPH and pasteurisation. Nevertheless, it is assumed that optimisation of the pasteurisation technologies tested in this project could reduce these values. Further ahead, scaling up the process will lower these numbers.

Tomato powder is produced using the waste from the pulping steps (hot break or cold break), which contains peels and seeds. This process involves drying the tomato residue and grinding it for reuse in both tomato juice and sauce formulations. The inventory data for the tomato powder production process is compiled in **Table 5**. However, the centrifugation pellet is not utilized in FunTomP products.

Table 4. LCI of the tomato juice process (for 225 mL of juice + packaging)

Input/Output				Amount	Unit
Materials	Washing water			800	g
	Tomato powder			2.39	g
	Pea protein			2.39	g
	Olive powder			2.39	g
	Tomatoes	Cold Break Centrifugation	Tomato pulp + supernatant	386	g
	Salt			2.39	g
	Packaging material	Glass bottle		225 [1]	g
		Tin lid		7 [2]	g
Energy	Cold break: Crushing + Heating			0.092	kWh
	Centrifugating			0.08	kWh
	Blending			0.007	kWh
	HPH			0.636	kWh
	Pasteurisation			0.159	kWh
Transport	Transportation of fresh tomato/tomato juice			0.036	tkm
Byproducts	Peels and seeds			14	g
	Pellet from centrifugation			156.88	g
Wastewater	Tomato washing wastewater			800	g
Scoped Product	**Tomato juice***			**225** **238.5**	**mL** **g**

* For conversion purposes, the tomato juice density has been assumed to be 1.06 g/mL (Razi Parjikolaei et al. 2010).

Table 5. LCI of tomato powder process

Input/Output		Amount	Unit
Materials	Tomato residue / spread	10000	g
Energy	Tray dryer	56.57	kWh
	Grinding	0.017	kWh
Scoped Product	**Tomato powder**	**10000**	**g**

[1] Weight for one unit.
[2] Weight for one unit.

Then, olive powder process is based on mixing green olives with water, homogenising under high pressure, drying and grinding. Olive powder is employed in tomato juice and sauce's recipes. In **Table 6**, the inventory is displayed.

Table 6. LCI of olive powder process

Input/Output			Amount	Unit
Materials	Green olives		250	g
	Water		5500	g
Energy	Blending		0.25	kWh
	HPH		0.4	kWh
	Freeze drying	Freezing part	0.68	kWh
		Drying part	3.83	kWh
	Grinding		0.001	kWh
Wastewater	Water		5715	g
Scoped Product	**Olive Powder**		**35**	**g**

INVENTORY ANALYSIS FOR TOMATO SAUCE PRODUCTION

Even though the process of making tomato sauce is similar to that of making tomato juice (**Table 7**), some differences can be highlighted. The formulation is slightly altered: the hot break process replaces the cold break process for pulp production, and centrifugation is omitted. Additionally, the same ingredients are mixed, except for the salt and pulp supernatant. As with the juice, the energy consumption for HPH and pasteurization processes is significant.

As for the juice, tomato powder and olive powder items correspond to the inventories of **Table 5** and **Table 6**, respectively.

Table 7. LCI of the tomato sauce process (for 300mL of sauce)

Input/Output				Amount	Unit
Materials	Washing water			634	g
	Tomato powder			11.41	g
	Pea protein			5.98	g
	Olive powder			5.46	g
	Tomatoes	Hot break	Tomato pulp	305.9	g
	Packaging material	Glass jar		250 [3]	g
		Tin lid		13 [4]	g
Energy	Hot Break: Heating + crushing			0.123	kWh
	Blending			0.009	kWh
	HPH			0.8	kWh
	Pasteurisation			0.219	kWh
Transport	Transportation of fresh tomato/tomato juice			0.048	tkm
Byproducts	Peel and seeds			11.1	g
Wastewater	Tomato washing wastewater			634	g
Scoped Product	**Tomato sauce***			**300** **328.8**	**mL** **g**

* For conversion purposes, the density of tomato sauce is considered to be 1.096 g/mL (Kumbár, Ondrušíková, and Nedomová 2019).

3.3. Life cycle impact assessment

This section presents the results of the environmental assessment. SimaPro v 9.5.1. software was used to calculate the different environmental impacts for the proposed technologies. Among the methods available in SimaPro, the ReCiPe 2016 (v1.06) method was selected to translate the data gathered in the LCI into the corresponding environmental impacts. Among the 18 categories available at the midpoint level in ReCipe 2016, the following categories were chosen in this work to assess the environmental impacts of the production of FunTomP functional liquid foods: global warming (GW), land use (LU), water consumption (WC), fine particle matter formation (FPMF)

[3] Weight for one unit.
[4] Weight for one unit.

and, finally, fossil resource scarcity (FRS). Midpoint categories can be further translated and grouped into three endpoint categories: damage to human health, damage to ecosystem and damage to resource availability, that were also included in this work (Figure 10). The selection of these categories responds mainly to their relevance in other LCA works accomplished in the agrifood sector (Arnal et al. 2018; Canaj et al. 2020; Del Borghi et al. 2014).

Table 8 presents the impacts categories and characterisation factors used.

Table 8. Overview of the midpoint and endpoint impact categories and characterisation factors used in this work.

Impact category		Characterisation factors	Unit
Midpoint	Global Warming (GW)	Global warming potential	kg CO_2 eq to air
	Land Use (LU)	Agricultural land occupation potential	m^2 x yr annual cropland eq.
	Water consumption (WC)	Water consumption potential	m^3 water eq. consumed
	Fine particle matter formation (FPMF)	Particulate matter formation potential	kg PM2.5 eq to air
	Fossil resource scarcity (FRS)	Fossil fuel potential	kg oil eq
Endpoint	Damage to human health (DHH)	Disability-adjusted life years	DALY
	Damage to ecosystem diversity (DED)	Time-integrated species loss	Species x year
	Damage to resource availability (DRA)	Surplus cost	Dollar (USD 2013)

LIFE CYCLE IMPACT ASSESSMENT FOR TOMATO JUICE PRODUCTION

Concerning juice production, **Table 9** shows data source used for the LCIA. As presented, it primarily originates from the Ecoinvent database. Allocation at the point of substitution was selected whenever available. Moreover, the electricity market was specifically calculated for Türkiye, as the manufacturing plant will be located there. The impact of the scoped product, tomato juice, encompasses the total impact generated by materials, processes, transport, and waste treatment. To distribute these impacts between the scoped product and byproducts, **allocations were made based on price**, attributing impacts to each product according to its monetary value. The value of tomato pomace, such as peels and seeds and pulp centrifugation pellet, is estimated at 0.03€/kg (Indiamart n.d.) .

Table 9. LCIA data source for tomato juice.

<table>
<tr><th colspan="4">Input/Output</th><th>Data source</th></tr>
<tr><td rowspan="14">Materials</td><td colspan="3">Washing water</td><td>Tap water {RoW}| market for | APOS, U</td></tr>
<tr><td colspan="3">Tomato powder</td><td>Peel and seeds
Electricity, medium voltage {TR}| market for | APOS, U</td></tr>
<tr><td colspan="3">Pea protein</td><td>Protein pea {GLO}| market for | APOS, U</td></tr>
<tr><td colspan="3">Olive powder</td><td>Olive {GLO}| market for olive | APOS, U
Tap water {RoW}| market for | APOS, U
Electricity, medium voltage {TR}| market for | APOS, U</td></tr>
<tr><td>Tomatoes</td><td>Cold break</td><td>Tomato pulp + supernatant</td><td>Tomato, processing grade {RoW}| tomato production, processing grade, open field | APOS, U</td></tr>
<tr><td colspan="3">Salt</td><td>Sodium chloride, powder {GLO}| market for | APOS, U</td></tr>
<tr><td colspan="2" rowspan="2">Packaging material</td><td>Glass jar</td><td>Packaging glass, white {GLO}| market for | APOS, U</td></tr>
<tr><td>Tin lid</td><td>Tin plated chromium steel {GLO}| market for tin plated chromium steel | APOS, U</td></tr>
<tr><td colspan="3">Centrifugating</td><td rowspan="4">Electricity, medium voltage {TR}| market for | APOS, U</td></tr>
<tr><td colspan="3">Blending</td></tr>
<tr><td colspan="3">HPH</td></tr>
<tr><td colspan="3">Pasteurisation</td></tr>
<tr><td>Transport</td><td colspan="3">Transportation of fresh tomato/tomato juice</td><td>1 tkm Transport, freight, lorry 7.5-16 metric ton, euro5 {RER}| market for transport, freight, lorry 7.5-16 metric ton, EURO5 | APOS, U</td></tr>
<tr><td rowspan="2">Byproducts</td><td colspan="3">Peel and seeds</td><td>Allocation made based on price</td></tr>
<tr><td colspan="3">Pellet from centrifugation</td><td>Allocation made based on price</td></tr>
<tr><td>Wastewater</td><td colspan="3">Tomatoes washing wastewater</td><td>Wastewater, average {Europe without Switzerland} | treatment of wastewater, average, capacity 1E9l/year | APOS, U</td></tr>
</table>

Using the inventories listed above and the database, the environmental impacts of each input/output were calculated for the selected impact categories. The results are displayed in **Table 10**.

Table 10. Life cycle impacts obtained for tomato juice. FU: 225 mL of juice + packaging

Input/Output	Midpoints					Endpoints		
	GW	FPMF	LU	FRS	WC	DHH	DED	DRA
	kg CO_2 eq	kg PM2.5 eq	m^2a crop eq	kg oil eq	m^3	DALY	species.yr	USD2013
Washing water	8.44E-04	1.85E-06	1.95E-05	2.18E-04	8.02E-04	3.72E-09	1.42E-11	5.12E-05
Tomato powder	8.53E-02	6.57E-04	7.67E-04	2.16E-02	6.79E-04	4.93E-07	3.66E-10	3.42E-03
Pea protein	8.35E-04	1.41E-06	3.25E-02	1.51E-04	1.23E-02	1.94E-09	6.86E-11	6.16E-05
Olive powder	3.43E-01	2.62E-03	3.20E-02	8.67E-02	2.86E-03	1.97E-06	1.76E-09	1.41E-02
Tomatoes – Cold break – Tomato pulp + supernatant	1.05E-01	5.17E-04	5.61E-02	2.47E-02	1.24E-02	4.38E-07	1.01E-09	5.49E-03
Salt	4.66E-04	9.20E-07	6.19E-06	1.13E-04	7.94E-06	1.03E-09	2.05E-12	2.80E-05
Packaging material – Glass bottle	2.70E-01	5.97E-04	3.54E-02	7.25E-02	3.00E-03	6.32E-07	1.64E-09	2.57E-02
Packaging material – Tin lid	3.90E-02	1.28E-04	9.71E-04	8.98E-03	2.98E-04	1.42E-07	1.98E-10	3.00E-03
Centrifugation	5.02E-02	3.87E-04	4.38E-04	1.27E-02	3.97E-04	2.91E-07	2.15E-10	2.02E-03
Blending	4.19E-03	3.23E-05	3.65E-05	1.06E-03	3.31E-05	2.42E-08	1.79E-11	1.68E-04
HPH	4.02E-01	3.10E-03	3.50E-03	1.02E-01	3.17E-03	2.33E-06	1.72E-09	1.61E-02
Pasteurisation	1.01E-01	7.75E-04	8.76E-04	2.54E-02	7.94E-04	5.82E-07	4.30E-10	4.03E-03
Transportation of fresh tomato/tomato juice	6.29E-03	5.11E-06	1.44E-06	2.05E-03	2.82E-07	9.41E-09	2.43E-11	9.26E-04
Peel and seeds	1.04E-05	1.60E-08	1.44E-05	2.04-06	3.08E-06	2.33E-11	1.89E-13	5.76E-06
Tomatoes washing wastewater	9.93E-05	5.13E-07	2.37E-06	2.16E-05	-7.18E-04	-2.75E-11	-5.98E-12	5.01E-06
Pellet from centrifugation	7.73E-05	5.74E-07	6.83E-06	1.94E-05	1.47E-06	4.35E-10	3.92E-13	3.21E-06

Figure 16 visually presents these results in relative terms, meaning the contribution of each step or ingredient to the total impact of tomato juice, for the selected categories.

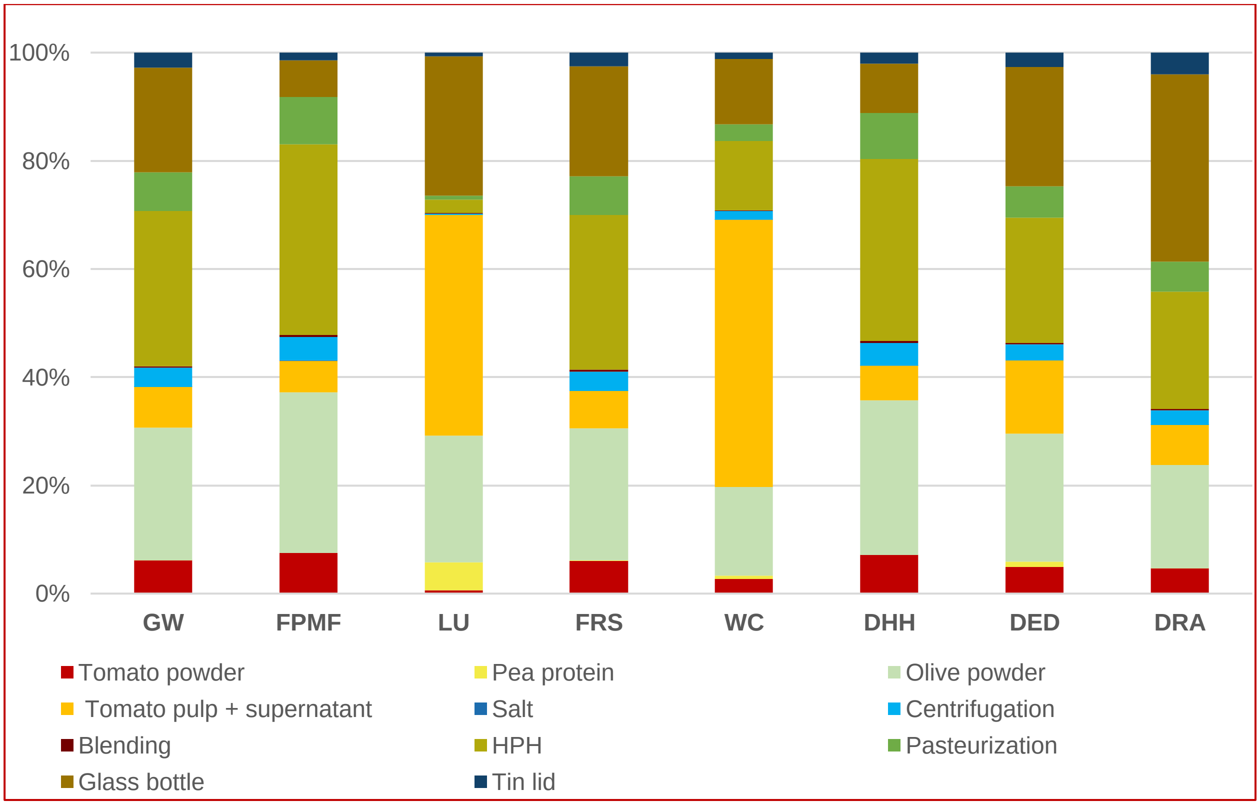


Figure 16. Contribution of each item to environmental impacts for tomato juice production (FU= 225mL).

The main environmental hotspots revealed by **Figure 16** come from the tomato pulp produced by the cold break process, the olive powder, the energy consumption at HPH stage and the glass bottle used for packaging. The impact share is not homogeneously distributed among categories. For instance, tomato pulp input dominates the land use and water consumption categories, while global warming, particulate matter formation and fossil resource scarcity are straightforward connected to the use of energy of the HPH process. In order to disentangle the environmental concerns of the cold break and olive powder production processes, they have been individually analysed. **Figure 17** exposes the impacts breakdown of the cold break process used to generate the tomato pulp. In most of the analysed categories, crushing/heating and tomato farming are the primary contributors. Other inputs and outputs as washing water and its treatment have negligible impacts. As expected, tomato farming has significant impacts in land use and water use, which are thus transferred to the endpoint category damage to ecosystems. An important fact to be highlighted is the negative impact of tomato washing wastewater in the category water consumption. A negative figure represents avoided impacts or flows towards the environment. In this case, according to the model utilised, for 1m^3 of wastewater, there is an output of 0.9 m^3 of water treated.

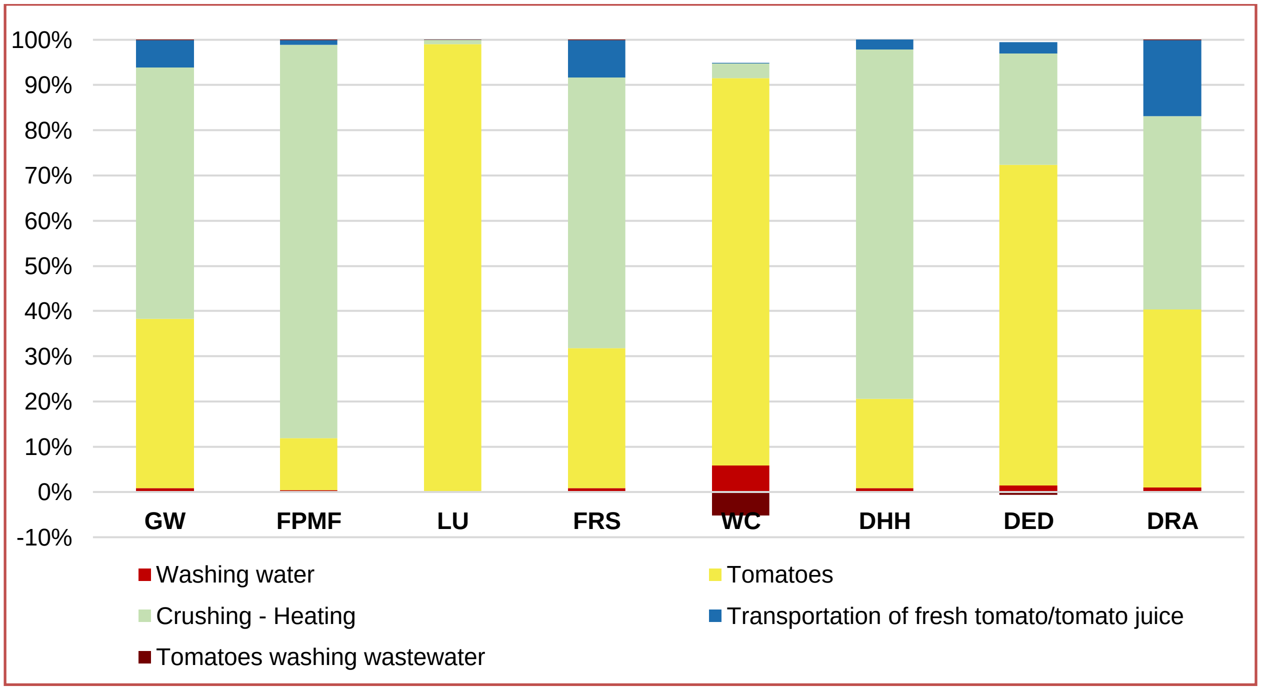
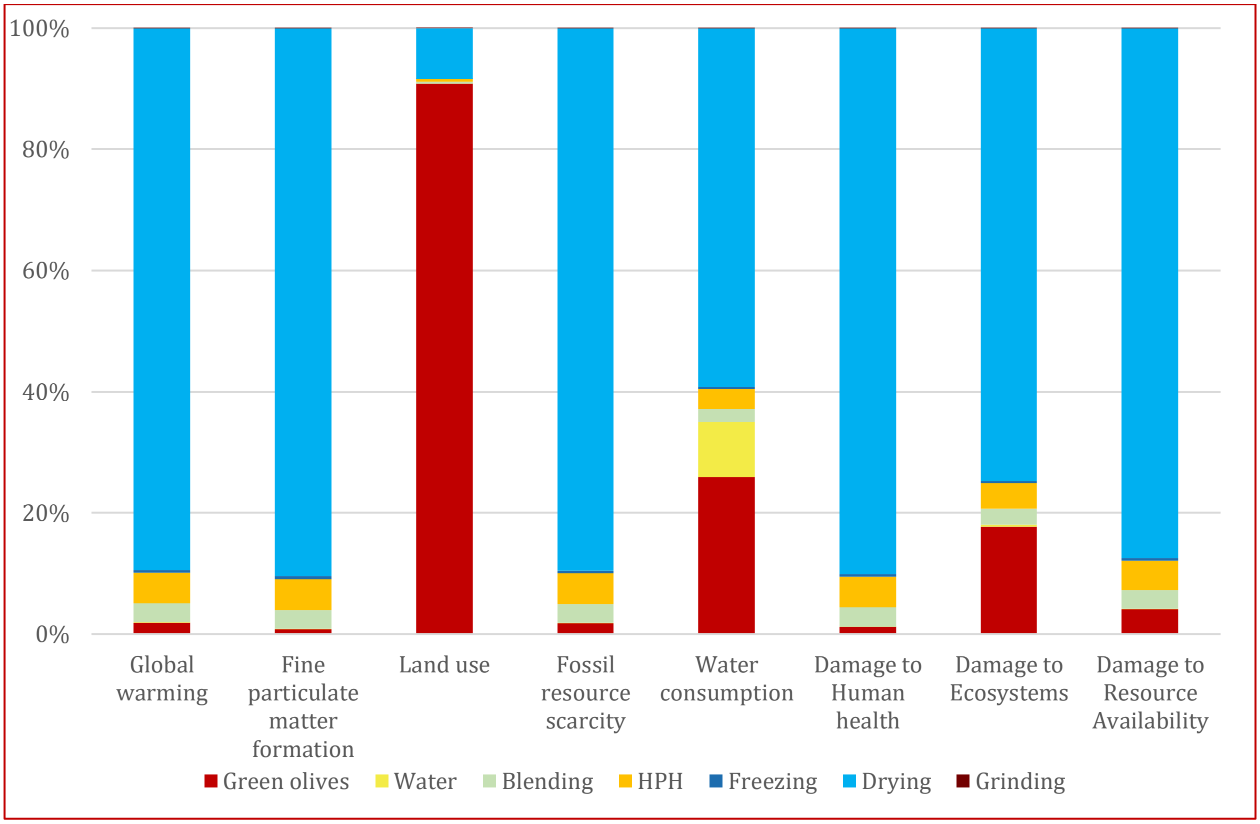


Figure 17. Contribution of each item to environmental impacts for cold break process (FU= 225mL of tomato juice).

Similarly, **Figure 18** details the environmental impacts of the olive powder production process. Freeze-drying is the main contributor to nearly all impact categories, except for land use, where olive farming is the primary factor. These results were expected, as freeze-drying consumes a substantial amount of electricity. To mitigate the impact of olive powder production, energy efficiency optimisation should be a must in the industrialisation roadmap.

Overall, for tomato juice production, the main impacts are related to energy consumption and the farming of olives and tomatoes. As previously mentioned, electricity consumption per unit of product will be significantly reduced at an industrial scale so as its contribution to the environmental impacts.

Figure 18. Contribution of each item to environmental impacts for olive powder process (FU= 35g of olive powder).



LIFE CYCLE IMPACT ASSESSMENT FOR TOMATO SAUCE PRODUCTION

For sauce production, LCIA has been carried out in a similar fashion. **Table 11** exposes the data sources used for the LCIA, primarily derived from the Ecoinvent database and selecting allocation at the point of substitution. Additionally, the electricity market was specifically calculated for Türkiye, where the manufacturing plant will be located. The impact of the scoped product, tomato sauce, includes the total impact generated by materials, processes, transport, and waste treatment. To distribute these impacts between the scoped product and byproducts, allocations were made based on price, attributing impacts to each product according to its value.

Table 11. LCIA data source for tomato sauce.

Input/Output				Data source
Materials	Washing water			Tap water {RoW}| market for | APOS, U
	Tomato powder			Peel and seeds Electricity, medium voltage {TR}| market for | APOS, U
	Pea protein			Protein pea {GLO}| market for | APOS, U
	Olive powder			Olive {GLO}| market for olive | APOS, U
	Tomatoes	Hot break	Tomato pulp	Tomato, processing grade {RoW}| tomato production, processing grade, open field | APOS, U
	Packaging material	Glass Jar		Packaging glass, white {GLO}| market for | APOS, U
		Tin lid		Tin plated chromium steel {GLO}| market for tin plated chromium steel | APOS, U
	Blending			Electricity, medium voltage {TR}| market for | APOS, U
	HPH			
	Pasteurisation			
Transport	Transportation of fresh tomato/tomato juice			1 tkm Transport, freight, lorry 7.5-16 metric ton, euro5 {RER}| market for transport, freight, lorry 7.5-16 metric ton, EURO5 | APOS, U
Byproducts	Peel and seeds			Allocation made based on price
Wastewater	Tomatoes washing wastewater			Wastewater, average {Europe without Switzerland} | treatment of wastewater, average, capacity 1E9l/year | APOS, U

With the inventories listed above, the environmental impacts of each input and output were calculated for the eight chosen impact categories. The results are shown in **Table 12**.

Table 12. Life cycle impacts obtained for tomato sauce. FU: 300 mL of sauce + packaging.

Input/Output	Midpoints					Endpoints		
	GW	FPMF	LU	FRS	WC	DHH	DED	DRA
	kg CO_2 eq	kg oil eq	kg PM2.5 eq	m^3	m2a crop eq	DALY	species.yr	USD2013
Washing water	6.67E-04	1.79E-04	1.46E-06	6.33E-04	1.54E-05	2.94E-09	1.12E-11	4.04E-05
Tomato powder	4.12E-02	1.04E-02	3.17E-04	3.58E-04	5.15E-04	2.38E-07	1.78E-10	1.66E-03
Pea protein	2.10E-03	3.79E-04	3.53E-06	3.53E-04	1.81E-02	4.86E-09	1.72E-10	1,55E-04
Olive powder	7.85E-01	5.99E-03	7.33E-02	1.98E-01	8.59E-03	4.51E-06	4.02E-09	3.23E-02
Tomatoes – Hot break – Tomato pulp	1.17E-01	4.45E-02	6.25E-04	2.85E-02	1.00E-02	5.13E-07	9.40E-10	6.09E-03
Packaging material – Glass jar	3.00E-01	6.64E-04	3.94E-02	8.05E-02	3.34E-03	7.02E-07	1.82E-09	2.86E-02
Packaging material – Tin lid	7.24E-02	2.38E-04	1.80E-03	1.67E-02	5.53E-04	2.64E-07	3.68E-10	5.56E-03
Blending	5.77E-03	4.45E-05	5.03E-05	1.46E-03	4.56E-05	3.34E-08	2.47E-11	2.32E-04
HPH	5.05E-01	3.90E-03	4.40E-03	1.28E-01	3.99E-03	2.92E-06	2.16E-09	2.03E-02
Pasteurisation	1.38E-01	1.07E-03	1.21E-03	3.50E-02	1.09E-03	8.01E-07	5.93E-10	5.56E-03
Transportation of fresh tomato/tomato juice	8.32E-03	2.27E-06	1.90E-06	2.71E-03	3.73E-07	1.28E-08	3.22E-11	1.23E-03
Peel and seeds	4.09E-04	1.02E-04	1.55E-04	9.91E-05	3.48E-05	1.85E-09	3.27E-12	2.12E-05
Tomatoes washing wastewater	8.16E-05	1.78E-05	4.22E-07	-5.90E-04	1.95E-06	-2.26E-11	-4.92E-12	4.12E-06

Figure 19 illustrates the main hotspots of tomato sauce production process, as presented in the previous table. These hotspots include olive powder production, the hot break process, HPH and the glass jar. Detailed impacts of olive powder production are presented above in **Figure 18**. For HPH and hot break processing, electricity consumption significantly contributes to their contribution to their environmental impacts. Indeed, **Figure 20** shows the predominant effect of heating, crushing and tomato farming, similar to cold break processing in tomato juice production **(Figure 17**). In this case also, tomato farming has subsequent impact in land use and water consumption categories, which has repercussions on the endpoint category damage to ecosystems.

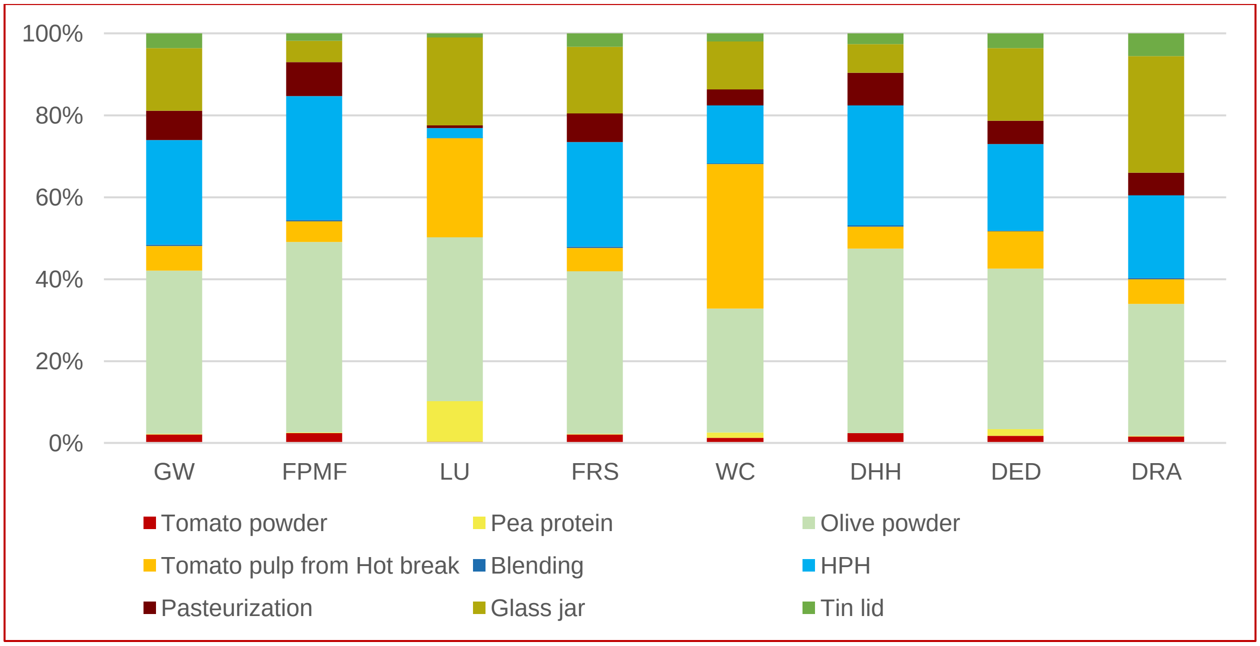


Figure 19. Contribution of each item to environmental impacts for tomato sauce production (FU= 300mL).

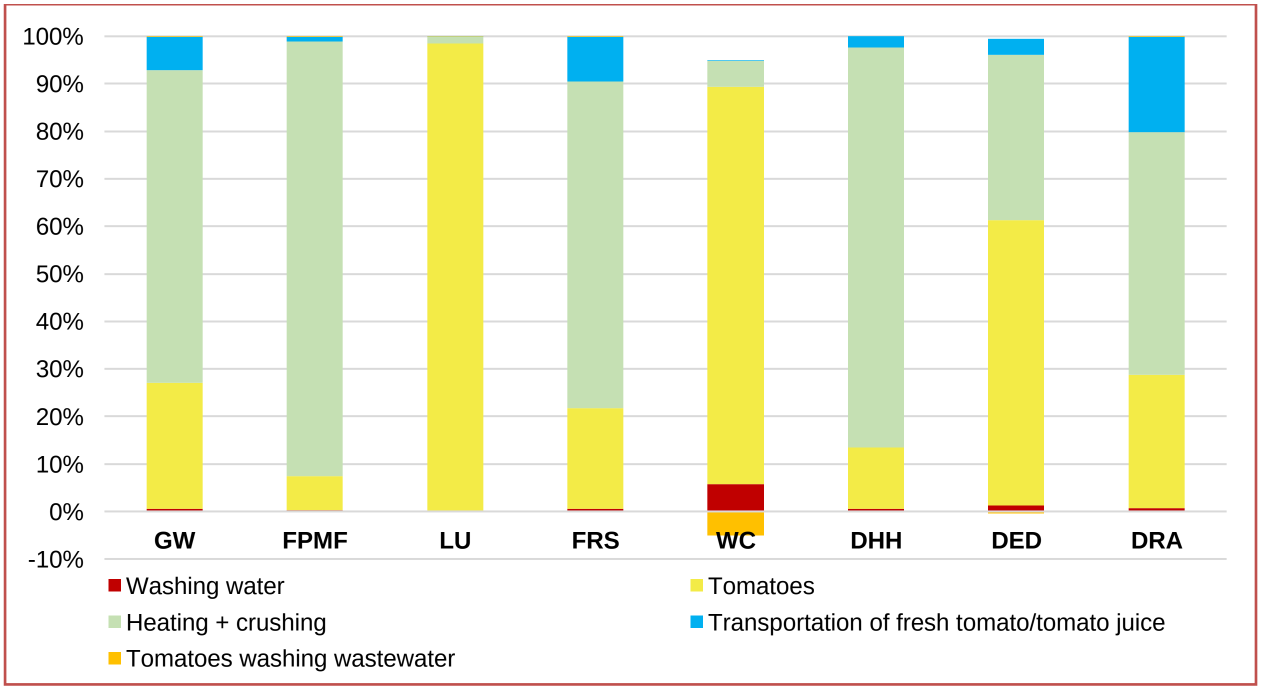


Figure 20. Contribution of each item to environmental impacts for hot break process (FU=300mL of tomato sauce).

3.4. Interpretation of LCA results for both tomato products

To summarise, the LCA of tomato juice and sauce has identified key environmental concerns to be addressed to improve the products' environmental performances. Firstly, many hotspots are related to high energy consumption (HPH, freeze drying, crushing and heating tomatoes), which is expected with laboratory data. The high impacts of electricity related steps could be explained by the fact that the mix of Türkiye is rich in fossil fuels, mainly hard coal, lignite and natural gas. Industrial manufacturing could reduce the contributions of HPH, pulp production and freeze drying (Martínez-Monteagudo, Yan, and Balasubramaniam 2017). Some technologies, mainly freeze drying and centrifugation, should be adapted in terms of machinery and optimised when scaling up the process. Heat exchangers could be used to intensify energy processes (heating, pasteurisation, cooling) and reduce overall consumptions.

It is important to note that in both pulp production processes, the water used for washing the tomato is then returned to nature after treatment, resulting in negative impact figures for tomato washing wastewater. Then, the valorisation of tomato peels and seeds into tomato powder improves the environmental footprint of FunTomP products, since they do not sum impact due to waste treatment operation, contrary to previous studies (Calero et al. 2022). Lastly, packaging, especially the glass bottle and the glass jar, significantly contribute to environmental impacts. Better results could be achieved by using recycled glass (currently, it is considered that 57% of the glass is made from recycled material) or ensuring the glass is recycled afterwards to distribute the impacts. Other environmentally friendly packaging could also be envisioned, compostable or even returnable.

SENSITIVITY ANALYSIS

The main hotspots identified for both products were electricity consumption and glass packaging. The sensitivity analysis aims to modify certain parameters and assess eventual changes on LCA results, potentially implementable in future project stages and/or upon scaling up.

Sensitivity analysis on the energy sourcing

As one of the hotspots is the electricity consumption, different scenarios were created to see how the results would change by varying the electricity mix. In Türkiye, electricity is mainly produced from coal (21%), natural gas (18%) and lignite (14%). **The processes as there are evaluated in this report are considered to be the baseline scenarios in this sensitivity analysis**. Two alternative scenarios were imagined, one with 25% of diminution of the fossil fuels part in the global mix and the second with 50% of reduction. The decrease of electricity generated from fossil fuels was compensated by increasing renewable energy, especially hydropower plant production part as it is the most common renewable energy production mode in Türkiye. Both cases (25 and 50% of reduction) were applied to tomato juice and sauce production processes.

Therefore, the following scenarios were created: <u>Scenario A</u>: reduction of the fossil fuel part of 25% compared to the baseline scenario; <u>Scenario B</u>: reduction of the fossil fuel part of 50% compared to the baseline scenario.

<u>Tomato juice</u>

The results of the assessments are presented in **Table 13** and

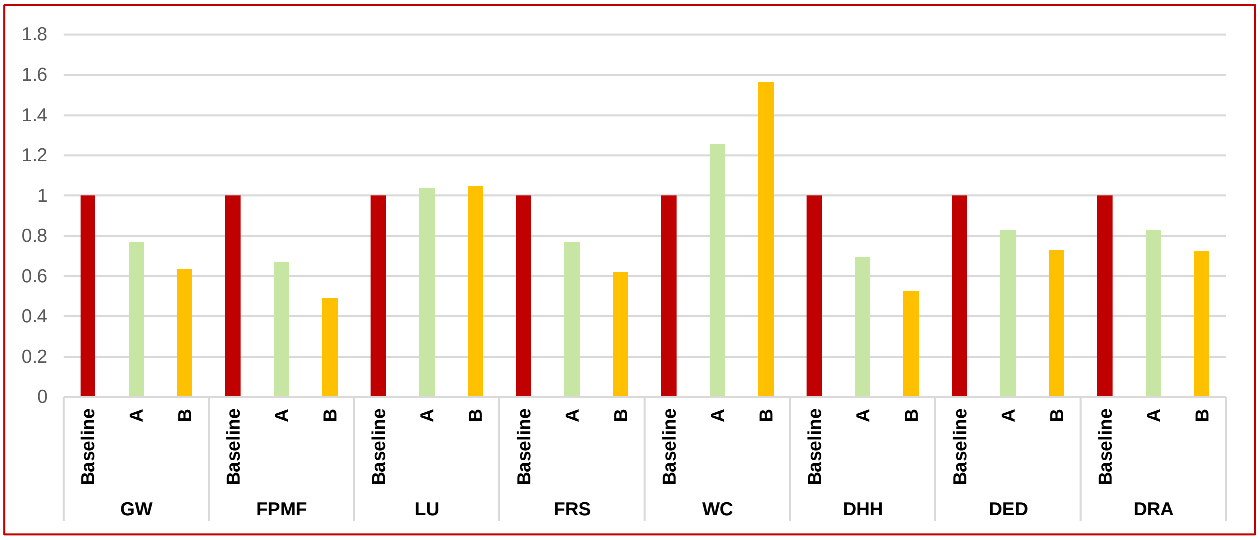


Figure 21.

Table 13. Environmental impacts of tomato juice production process for different electricity mix scenarios. The functional unit is 225mL of tomato juice produced plus its corresponding packaging.

Impact category		Scenario	Environmental impacts
Midpoint impact categories	Global warming (GW)	**Baseline**	1.40E+00
		A	1.08E+00
		B	8.87E-01
	Fine particulate matter formation (FPMF)	**Baseline**	8.82E-03
		A	5.92E-03
		B	4.34E-03

Impact category		Scenario	Environmental impacts
	Land use (LU)	**Baseline**	1.37E-01
		A	1.42E-01
		B	1.44E-01
	Fossil resource scarcity (FRS)	**Baseline**	3.55E-01
		A	2.73E-01
		B	2.21E-01
	Water consumption (WC)	**Baseline**	2.50E-02
		A	3.17E-02
		B	3.94E-02
Endpoint impact categories	Damage to Human health (DHH)	**Baseline**	6.91E-06
		A	4.81E-06
		B	3.63E-06
	Damage to Ecosystems Diversity (DED)	**Baseline**	7.42E-09
		A	6.16E-09
		B	5.43E-09
	Damage to Resources Availability (DRA)	**Baseline**	7.42E-02
		A	6.14E-02
		B	5.39E-02

For most of the impact categories, the reported impacts drop considerably, about 20 to 50% of reduction for the scenario B compared to the baseline process. However, water consumption impact outputs increase substantially when more renewable energy is used, while land use category also observes a slight rise for scenarios A and B. Both issues can be explained by the hydropower electricity production which requires water and to a lesser extent, land. This information is clearly shown in

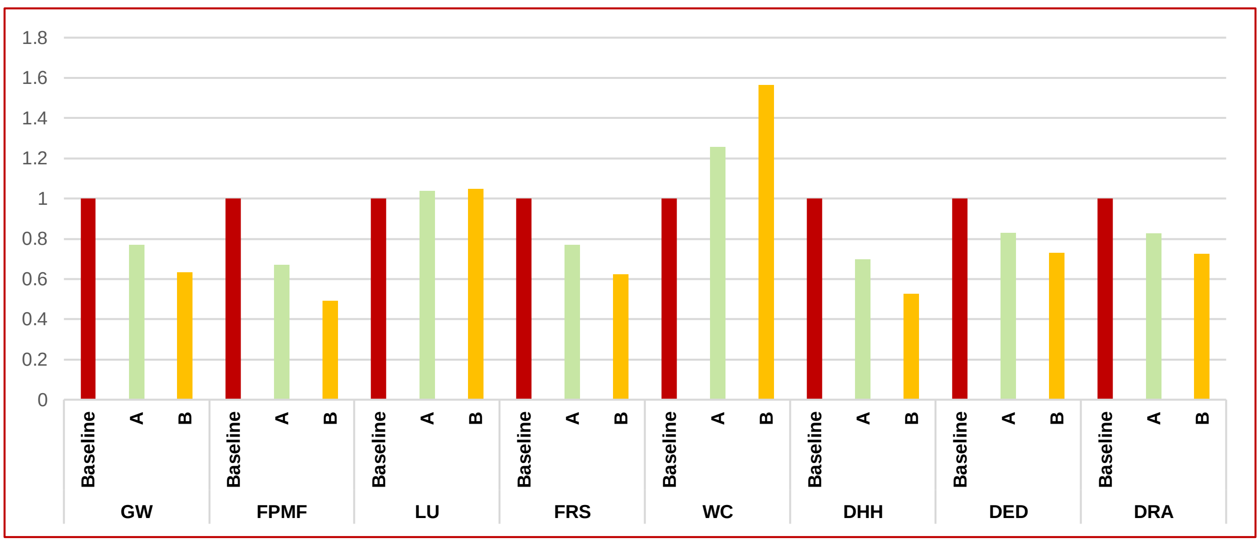


Figure 21, where values lower than 1 indicate an improvement of the assessed impact category versus the baseline.

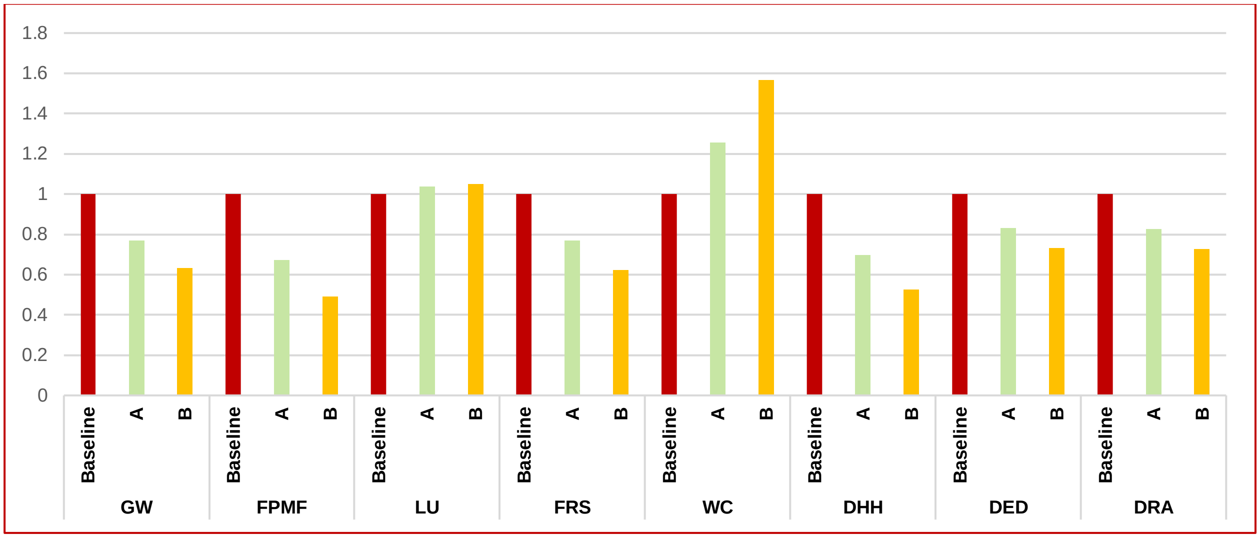


Figure 21. Comparison of scenarios varying the electricity mix used to process tomato into tomato juice. The baseline scenario values are fixed to 1 for each category.

Tomato sauce

Similar results are obtained for tomato sauce (**Table 14**, **Figure 22**).

Table 14. Environmental impacts of tomato sauce production process for different electricity mix scenarios. The functional unit is 300mL of tomato sauce produced plus its corresponding packaging.

Impact category		Scenario	Environmental impacts
Midpoint impact categories	Global warming (GW)	**Baseline**	1.97E+00
		A	1.49E+00
		B	1.21E+00
	Fine particulate matter formation (FPMF)	**Baseline**	1.29E-02
		A	8.57E-03
		B	6.23E-03
	Land use (LU)	**Baseline**	1.83E-01
		A	1.91E-01
		B	1.93E-01
	Fossil resource scarcity (FRS)	**Baseline**	4.99E-01
		A	3.77E-01
		B	3.00E-01
	Water consumption (WC)	**Baseline**	2.91E-02
		A	3.91E-02
		B	5.05E-02
Endpoint impact categories	Damage to Human health (DHH)	**Baseline**	1.00E-05
		A	6.91E-06
		B	5.16E-06
	Damage to Ecosystems Diversity (DED)	**Baseline**	1.03E-08
		A	8.42E-09
		B	7.33E-09
	Damage to Resources Availability (DRA)	**Baseline**	1.00E-01
		A	8.14E-02
		B	7.03E-02

In the same way as for the tomato juice, the categories GW, FPMF, FRS, DHH, DED, DRA show a reduction of between 30 and 50% of the environmental impacts for the scenario B. Impacts in the category WC increase by 75% in case of using 50% more of renewable energies. Like for the tomato juice case, LU category sees its environmental impacts rising slightly.

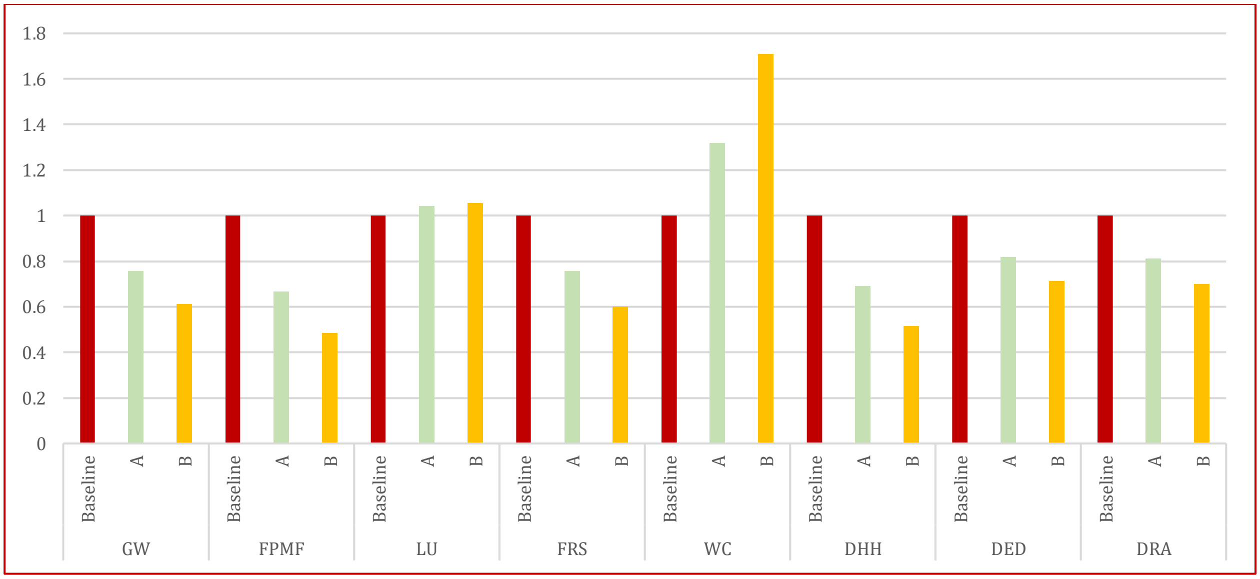


Figure 22. Comparison of scenarios varying the electricity mix used to process tomato into tomato sauce. The baseline scenario values are fixed to 1 for each category.

Overall, using a more renewable energy mix is favourable to reduce environmental impacts of tomato juice and sauce production processes. Nevertheless, it is important to consider that water use can be a critical point for Mediterranean countries affected by drought, such as Türkiye. The electricity production part removed from fossil fuels could be added to other renewable energy sources to mitigate this effect, although another assessment should be carried out to determine if impacts are displaced to other categories.

Sensitivity analysis on the packaging

The second hotspot identified was the glass packaging, for both tomato juice and sauce. Indeed, glass manufacturing is highly energy intensive. A research group carried out a LCA study of a bottle of wine and they noted that for every 10% increase in recycled glass content in bottles, the GW potential would be reduced by 2% (Amienyo, Camilleri, and Azapagic 2014). However, by modelling a higher amount of recycled material in the bottles, going from 57% (content in the baseline item) to 70% of recycled glass content, we could not obtain the same results. In our model, the energy needed to grind the glass, to melt it and to manufacture new bottles is major and hinders eventual improvements.

Table 15 presents the environmental impacts of the baseline, the tomato juice packed in a glass bottle made with 57% recycled glass, compared to the same product in a 70% recycled glass bottle. The variations are minor, going from -4% in the categories land use and water consumption to +1% in damage to ecosystem diversity. This is clearly shown in the plot of **Figure 23**, where the baseline is set at 1 of relative impact and worst performant impact categories surpass this value.

Table 15. Environmental impacts of tomato juice glass bottle, comparing baseline with 70% recycled glass content bottle scenario. The functional unit is 225mL of tomato juice produced plus its corresponding packaging.

Impact category		Scenario	Environmental impacts
Midpoint impact categories	Global warming (GW)	**Baseline**	1.40E+00
		70% recycled glass	1.41E+00
	Fine particulate matter formation (FPMF)	**Baseline**	8.82E-03
		70% recycled glass	8.79E-03
	Land use (LU)	**Baseline**	1.37E-01
		70% recycled glass	1.32E-01
	Fossil resource scarcity (FRS)	**Baseline**	3.55E-01
		70% recycled glass	3.56E-01
	Water consumption (WC)	**Baseline**	2.50E-02
		70% recycled glass	2.39E-02
Endpoint impact categories	Damage to Human health (DHH)	**Baseline**	6.91E-06
		70% recycled glass	6.92E-06
	Damage to Ecosystems Diversity (DED)	**Baseline**	7.51E-09
		70% recycled glass	7.51E-09
	Damage to Resources Availability (DRA)	**Baseline**	7.42E-02
		70% recycled glass	7.44E-02

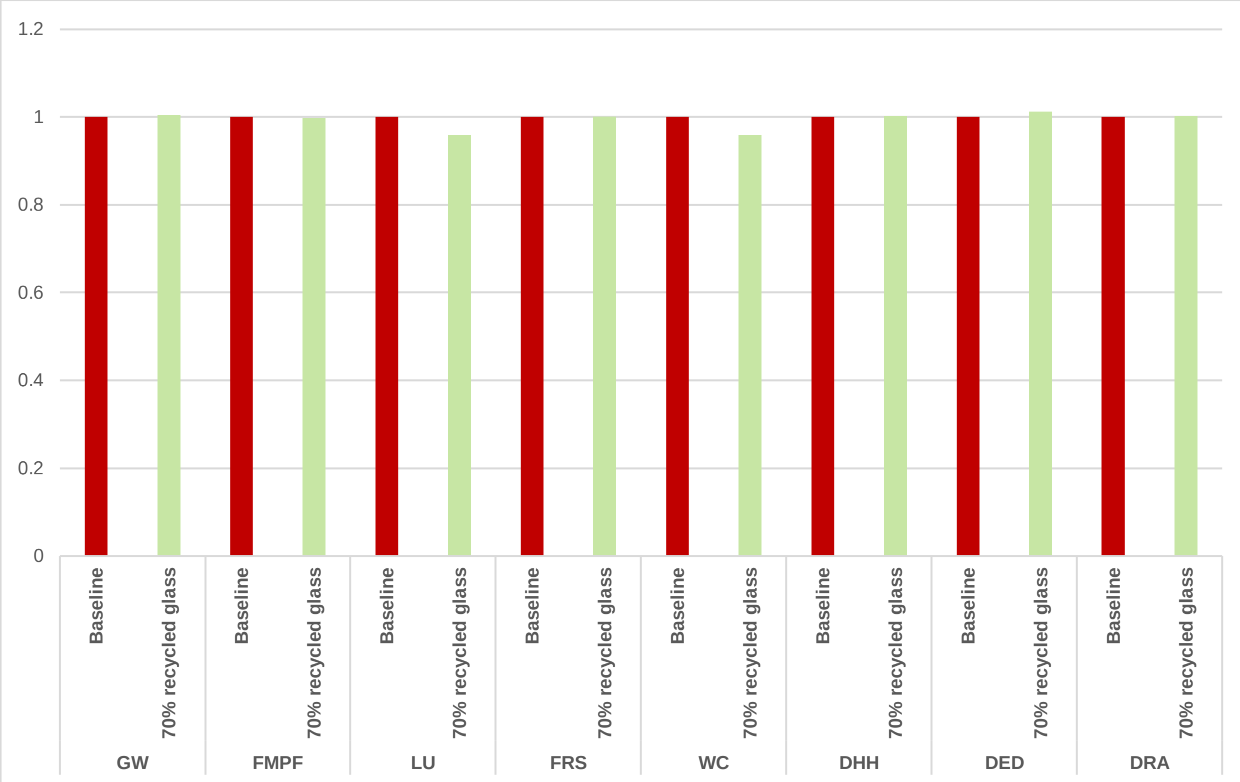


Figure 23. Comparison of scenarios varying the tomato juice glass bottle composition. The baseline scenario values are fixed to 1 for each category.

Following this model, the increase in recycled glass content in the model would not be a solution to reduce the impacts of this hotspot. However, further research on other types of packaging could reveal more environmentally friendly options. In a study conducted by Brock and Williams (2020), the environmental impacts of various packaging options for beverage were compared. They analysed a glass bottle, a theoretical 100% recycled glass bottle, a PET bottle or a Tetra Pak carton. Among these options, the glass bottle consistently showed the highest environmental impacts across almost all categories. Even when made entirely from recycled materials, the glass bottle still had a greater impact than the PET bottle or Tetra Pak. According to this study, Tetra Pak cartons are the preferable choice for fruit juices from an environmental perspective.

In the case of FunTomP, it was decided to compare the tomato juice packed in a glass bottle (baseline) with tomato juice packed in a beverage carton for juice. Results from this assessment are compiled in **Table 16**.

Table 16. Environmental impacts of tomato juice packed in a glass bottle compared with the same product packed in a beverage carton. The functional unit is 225mL of tomato juice produced plus its corresponding packaging. The inventory for the juice beverage carton is based on a 1L capacity.

Impact category		Scenario	Environmental impacts
Midpoint impact categories	Global warming (GW)	**Baseline**	1.40E+00
		Beverage carton	1.15E+00
	Fine particulate matter formation (FPMF)	**Baseline**	8.82E-03
		Beverage carton	8.16E-03
	Land use (LU)	**Baseline**	1.37E-01
		Beverage carton	1.41E-01
	Fossil resource scarcity (FRS)	**Baseline**	3.55E-01
		Beverage carton	3.01E-01
	Water consumption (WC)	**Baseline**	2.50E-02
		Beverage carton	2.27E-02
Endpoint impact categories	Damage to Human health (DHH)	**Baseline**	6.91E-06
		Beverage carton	6.32E-06
	Damage to Ecosystems Diversity (DED)	**Baseline**	7.51E-09
		Beverage carton	6.19E-09
	Damage to Resources Availability (DRA)	**Baseline**	7.42E-02
		Beverage carton	5.55E-02

The results indicate a 10-25% reduction in impacts across various categories, with the exception of land use, as better illustrated in **Figure 24**. The increase in land use impact can be attributed to the trees planted for producing the paper used in certain layers of the carton. Overall, the beverage carton appears to be a more environmentally friendly option compared to the glass bottle, despite the moderate improvements.

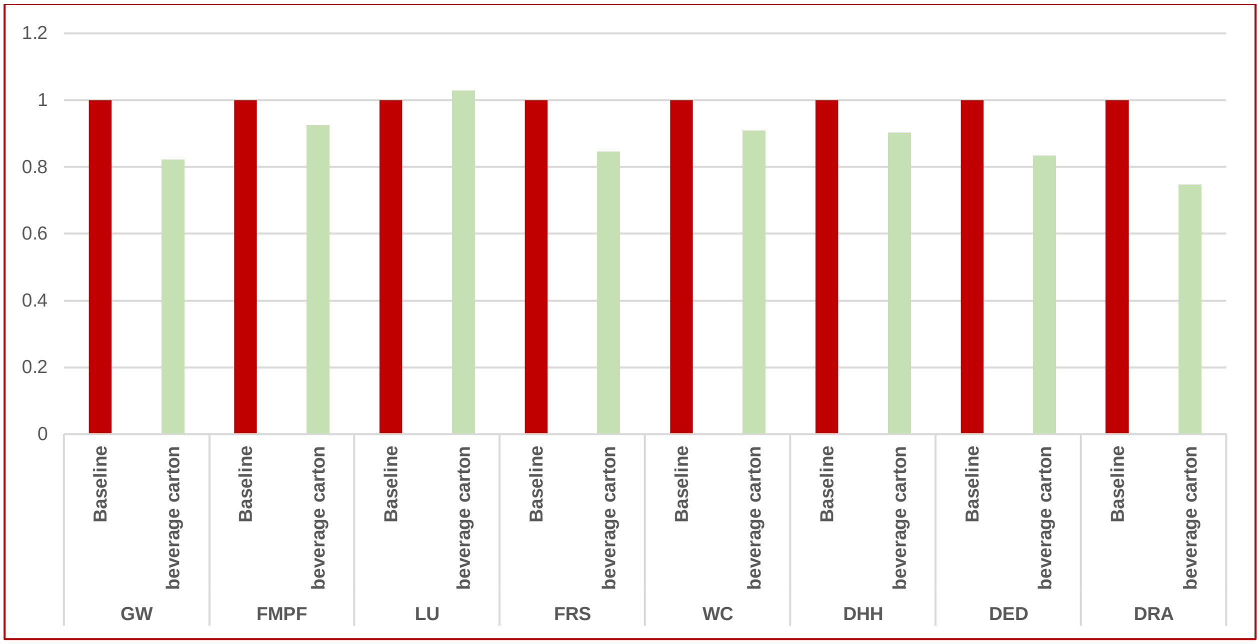


Figure 24. Comparison of scenarios varying the packaging used for tomato juice. The baseline scenario values are fixed to 1 for each category. The inventory for the juice beverage carton is based on a 1L capacity.

In summary, the sensitivity analysis indicates that several improvements can be made to mitigate certain impacts. Enhancing the energy mix by incorporating more renewable sources, such as installing solar panels on the factory roof, is one potential solution. Additionally, choosing alternative packaging, such as beverage cartons, could further improve the environmental profile of the overall product.

4. LIFE CYCLE COSTING

An LCC analysis is integrated with the LCA results. The LCC will identify, quantify, and compare all costs, including their variations over time, taking into account the benefits of the innovative technology. The analysis will cover operational and maintenance costs, investment costs, raw material supply, storage and transport, resources (energy and water), waste management, and taxes. The resulting economic indicators will enable the final price estimation of the FunTomP technology.

4.1. LCC goal and scope definition

Concerning the LCC study, the boundaries and scope are the same as the LCA. Nevertheless, the goal is to evaluate the total costs associated with the two products throughout their entire life cycle.

To deal with the scale issue, a projected industrial-scale LCC was proposed for the present study, being the modelled industrial manufacturing plant compiled in **Figure 2** and **Figure 4**, for juice and sauce, respectively. Both systems are similar regarding the production steps. The selected functional units are: 225 mL tomato juice and 300 mL of tomato sauce, adding the packaging in both cases.

The following relevant upscaling aspects were considered:

- Full integration of the industrial production chain, reducing storage needs, freezing or drying steps and avoiding long transportation distances.

- Replacement of laboratory processes with more resource-efficient industrial processes. Appropriate machinery and scaled-up data coming from equipment manufacturers and literature was employed, ultimately validated by project partners (mainly, the industrial Kraft Heinz).

- Freeze drying is applied at the end of olive powder process performed at laboratory scale. Even if freeze drying is not commonly used at industrial scale because of high energy consumption (and hence costs), it will be used in this project to keep nutraceutical properties of the functional products in accordance with industrial partner's recommendations. Other less energy intensive techniques have been investigated but they led to a lower quality product, alteration of taste and colour and loss of phenolic compounds.

4.2. Life cycle cost inventory analysis

LIFE CYCLE COST INVENTORY ANALYSIS FOR TOMATO JUICE PRODUCTION

Since both processes are similar, a common approach has been conducted to estimate costs and revenue. Primary data was prioritized when available, and it was completed by secondary data estimated by LOMARTOV according to literature on the topic to fulfil the gap for the required information.

Each model considers the same 3 production lines, namely: the principal production line, where tomato juice or tomato sauce is the final product; and two side lines which produce olive powder and tomato peel powder from the peel and seeds of the tomatoes. Particularly, the juice manufacturing process will have a by-product (pellet), which is the outcome from a centrifugation phase. This by-product is sold for cattle feedstock and constitutes an extra revenue.

For all money conversion needed in the cost structure calculation an exchange rate of 0.028 €/Turkish Lyra (TRL) and 0.92 €/USD were taken into account. Furthermore, it was considered that both production lines will have the same production scheme: 6 days a week, discounting Sundays, with 2 shifts per day, 8 hours per shift and operating the 12 months of the year. This is equivalent to 5 008 hours per year.

It is important to highlight that **due to limitations on primary industrial data availability**, several **operational units** related to auxiliary services such as, boilers, heat exchangers, storage and cooling **could not be estimated and there were not considered.**

Costs of Equipment

For the equipment costs calculation, no industrial primary data was given. Therefore, LOMARTOV estimated them through the flow diagram of both industrial applications (**Figure 2** and **Figure 4**), literature review, and mass balances validated by partners.

Equipment specifications were made aligned with the required design parameters. Technical parameters and prices were gathered on commercial websites such as *“Alibaba”* (Alibaba 2024) and *“Made In China”*(Made In China 2024). Since the prices were informed as Free on Board (FOB), delivery costs were included from several ports of China depending on the supplier’s location to the factory location. For this matter, the website *“Freightos Marketplace”*(Freightos Marketplace 2024) has been used. Freightos provides the cost of insurance, freight and broker for a certain load by informing total cost, total load, total volume and ports of origin and destination. **Table 17** shows the estimated costs for each equipment in accordance with the industrial scale for tomato juice production line. **Table 18** and **Table 19** detail the estimated costs for olive powder and tomato powder production lines.

Table 17. Purchased equipment cost estimation for FunTomP tomato juice production line.

Process	Equipment	Amount	Unitary Price-FOB (USD)	Origin	Destination	Freight & Insurance (€)	Unitary Price CIF (€)	Total Cost (€)
Sorting and washing	Conveyor	1	1 200	Shanghai, China	Istanbul, Türkiye	430	1 546	1 546
	Sorting and washing	4	5 990	Qingdao, China	Istanbul, Türkiye	1 067	6 638	26 550
Crushing hot/cold break tomatoes	Turbo Extractor	8	1 500	Shanghai, China	Istanbul, Türkiye	441	1 836	14 688
Centrifugation	Centrifuge	1	98 300	Jiangsu, China	Istanbul, Türkiye	1 024	92 443	92 443
Deaeration	Vacuum Degassing	2	7 400	Shanghai, China	Istanbul, Türkiye	666	7 548	15 096
High Pressure Homogenization	HPH	1	55 000	Shanghai, China	Istanbul, Türkiye	1 821	52 971	52 971
Packing of Tomato Sauce	Bottle Juice filler	1	100 000	Jiangsu, China	Istanbul, Türkiye	9 380	102 380	102 380
	Labeller	2	12 200	Shanghai, China	Istanbul, Türkiye	718	12 064	24 128
Pasteurization	Pasteurizer	3	24 600	Jiangsu China	Istanbul, Türkiye	5 786	28 664	85 992
Packaging	Cardboard machine	1	48 000	Jiangsu China	Istanbul, Türkiye	2 216	46 856	46 856
Auxiliary services	Palletiser	1	4 999	Jiangsu China	Istanbul, Türkiye	669	5 318	5 318
	Storage tank	10	8 888	Jiangsu, China	Istanbul, Türkiye	2 269	10 534	105 348
							SUBTOTAL	**573 317**

Table 18. Estimated equipment cost for olive powder production cost.

Process	Equipment	Amount	Unitary Price-FOB (USD)	Origin	Destination	Freight & Insurance (€)	Unitary Price CIF (€)	Total Cost (€)
Blending	Conveyor	1	500	Shanghai, China	Istanbul, Türkiye	462	927	927
	Crushing	2	13 937	Jiangsu, China	Istanbul, Türkiye	705	13 667	27 333
	Mixer	1	2 772	Shanghai, China	Istanbul, Türkiye	601	3 179	3 179
High Pressure Homogenization	High Pressure Homogenizer	1	55 000	Shanghai, China	Istanbul, Türkiye	1 821	52 971	52 971
Freezing/Freeze Dryer	Freeze dryer	1	10 500	Guangdong, China	Istanbul, Türkiye	2 324	12 089	12 089
Grinding	Grinder	1	5 800	Guangdong, China	Istanbul, Türkiye	866	6 260	6 260
Auxiliary services	Storage tank	1	889	Jiangsu, China	Istanbul, Türkiye	227	1 053	1 053
							SUBTOTAL	**102 986**

Table 19. Estimated equipment cost for tomato powder production cost.

Process	Equipment	Amount	Unitary Price-FOB (USD)	Origin	Destination	Freight & Insurance	Unitary Price CIF (€)	Total Cost (€)
Drying	Drier	1	5 000	Jiangsu, China	Istanbul, Türkiye	869	5 519	5519
Grinding	Grinder	1	5 800	Guangdong, China	Istanbul, Türkiye	866	6 260	6 260
Auxiliary services	Storage Tank	1	2 104	Jiangsu, China	Istanbul, Türkiye	537	2 493	2 493
							SUBTOTAL	**14 272**

Cost of Raw Materials

For the needed raw materials, quantities and prices have been also estimated. Regarding the juice, production capacity was established as 4 000 L/h. Taking into account the density of the product (1 kg/L) the mass rate production equals 4 000 kg/h.

To estimate raw material prices, a similar approach to equipment estimation cost has been conducted. Potential suppliers have been identified through different Mediterranean and European countries and the FOB prices were added to cost of insurance and freight (CIF) using Freightos Marketplace website.

Annual raw materials costs were calculated aligned with these production values. In **Table 20** annual raw material cost list can be consulted for the sauce production line.

Table 20. Annual raw material costs for tomato juice production.

Raw Material	Price (€/kg)	Amount (·10^6kg/year or ·10^6units/year)	Cost (M€)
Tomatoes	0.34	35.6	12.1
Pea Protein	9.35	0.2	2.0
Olive without seeds	1.16	0.2	0.2
Tap Water	4.9E-4	71.2	0.03
Glass Jar & Tap Tins	0.06	94.3	5.3
Cardboard Boxes	0.40	0.13	0.05
Cardboard separators	0.40	4.40	1.8
Pallets	25.71	0.01	0.2
Salt	1.36	0.21	0.3
TOTAL ANNUAL COST			21.9

Operating labour costs

For the operating labour costs, no primary data was obtained. Therefore, estimations were made based on bibliographic resources. The consulted bibliography suggests a graphic method where the operators by shift can be determined by knowing the production capacity, the number of shifts, the steps of the process and the technological innovation of the facility (Peters et al. 2004).

It was assumed that the line was operating in 2 daily shifts, each shift lasting 8 hours, according to information provided by the industrial partner. Furthermore, since the production plant is located in Türkiye, local wages were taken into account. A manufacturing operator earns 283 TRL per hour (equivalent to 7.92 € per hour), according to the consulted bibliography(Institute ERI of Economic Research 2024). **Table 21** compiles the annual operating labour expenditures costs for juice production line.

Table 21. Annual operating labour costs for juice and sauce production.

Product	Daily Operators	Wage (€/h)	Operating Labor Costs (M€/year)
Tomato Juice	24	7.92	0.97

For further information, LCC Annex details the calculation steps to achieve the total operators per shift.

Utilities

A utility cost estimation was needed, since no utilities primary data was available. Utilities estimations were done using the technical datasheets from the purchased equipment. Electrical consumption was estimated according to the annual hour production schedule and the amount of equipment needed to comply with the daily production rate. **Other utilities were not taken into account, since information was limited or null**. Electricity prices were taken from Eurostat for 1 kWh Turkish non-household at a fee price of 0.09 €/kWh (Eurostat 2024). **Table 22** shows the annual cost of utilities for the juice production line. In the LCC Annex, electricity consumption can be consulted from Table 61 to Table 64.

Table 22. Annual total utility cost for juice production.

Product	Annual electricity consumption (kWh/year)	Annual Utility Cost (M €/year)
Tomato Juice	16 923 133	1 523

Total Product Cost

Total product cost (TPC) has been calculated following the guidelines from the consulted bibliography(Peters et al. 2004). Crucial economic indicators have been estimated such as: operating supervision, maintenance and repairs, operative supplies, and laboratory changes among other relevant production costs. **Table 23** collects the total product costs for tomato juice.

Table 23. TPC for FunTomP tomato juice.

Item	Cost (M €)
Raw materials	22.0
Operating labour	1.0
Operating supervision	0.10
Utilities	1.50
Maintenance and repairs	0.20
Operating supplies	0.03
Laboratory charges	0.10
Royalties	0.30
Taxes on properties	0.06
Insurance	0.03
Fixed Charges	0.09
Plant Overhead	0.80
Administration	0.30
Distribution & selling	1.40
Research & Development	1.20
General Expense	2.90
TOTAL PRODUCT COST (TPC)	**29.0**

Depreciation

For juice production the depreciation of equipment has been estimated as indicated in **Table 24**.

Table 24. Annual depreciation factors.

Annual depreciation factor									
Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10

Taxes, Inflation and minimum acceptable rate of return

Taxes, inflation and minimum acceptable rate of return were determined using secondary data, and the results from the literature review was applied to both of the products.

Since the factory is located in Türkiye, taxes were established according to the taxation guidelines of this country. According to the consulted bibliography (BDO-Global 2024), the taxation for manufacturing facilities is 20% of the total income rate.

Regarding inflation, three different types of inflation were determined to apply in the LCC analysis:

1. <u>Construction Inflation:</u> The percentage of construction inflation has been stablished at 65%. This value is the inflation accumulated for the entire period of 2023.The values for this estimation were taken from Turkish Institute of Statistics (TIS) [12].

2. <u>Product Inflation:</u> Was set at 17% yearly from the datasets consulted from Eurostat.(Eurostat 2024)

3. <u>TPC Inflation:</u> Was set at 20% yearly from the dataset consulted from Eurostat. (Eurostat 2024)

Regarding the minimum acceptable rate of return (m_{ar}) the guidelines provided by the *"Plant Design & Economics for Chemical Economics"* were considered (Peters et al. 2004). **Figure 25** gathers the different rates recommended by the bibliography.

Investment description	Level of risk	Minimum acceptable return m_{ar} (after income taxes), percent/year
Basis: Safe corporate investment opportunities or cost of capital	Safe	4–8
New capacity with established corporate market position	Low	8–16
New product entering into established market, or new process technology	Medium	16–24
New product or process in a new application	High	24–32
Everything new, high R&D and marketing effort	Very high	32–48+

Figure 25. Suggested values for risk and minimum acceptable return on investment.(Peters et al. 2004)

The juice production has a safe corporative investment opportunity, meaning that the product will be released to an already developed market which is expected to rapidly incorporate the product by the demand. In this situation, it is accurate to set the level of risk as "*Safe*"; therefore, the m_{ar} has been established at 8%.

Revenues

Annual production has been estimated according to the production scheme before mentioned. Annually, the factory will be operative 5 008 hours. The production rate is 4 240 kg/h, therefore the annual production rate will be 21.2 million kg per year. According to the information the partners have provided, a by-product is generated in the centrifugation step of the juice production (Menrad 2003). This product is a pellet of tomato that is commercialized as cattle feedstock.

Since no primary data regarding sale prices was achieved, several commercial websites and market reports were reviewed in order to establish a sale price for the functional sauce and juice. According to the consulted bibliography, functional dairy products can be sold for 30% to 50% more than the regular product(Menrad 2003). Extrapolating this margin to the vegetable-based products field, the functionalized tomato products will be charged with an increase of 40%.

Regular tomato juice price is 1.055 USD/kg which is equivalent to 0.97 €/kg (Institute Trade Center 2024). Hence, the functional tomato sale price is set to 1.34 €/kg.

The price for the pellet by-product has been established according to the international market prices from *Trade Map*, at 0.30 €/kg (Institute Trade Center 2024). **Table 25** presents the revenues generated annually by the juice production line.

Table 25. Annual juice revenue

Product	Sale price (€/kg)	Annual production (M kg/year)	Annual Revenues (M €/year)
Juice Production	1.34	21.2	28.5
Peel and seeds and pellet	0.30	13.2	3.9

LIFE CYCLE COST INVENTORY ANALYSIS FOR TOMATO SAUCE PRODUCT

As mentioned before, a similar approach has been taken for the production of sauce and juice, because of the similarities behind the processes. Yearly hours for the production schedule are maintained and fixed at **5 008 hours**, distributed in 2 shifts per day, 6 days a week for 12 months a year. A remarkable difference between the processes are sale prices and by-product, since there is no by product in the sauce production.

Costs of equipment

The same approach than the juice case has been used for the equipment estimation of the sauce production line. **Table 26** compiles the purchased equipment cost estimation for the sauce production case.

Table 26. Purchased equipment cost estimation for FunTomP sauce production line.

Process	Equipment	Amount	Unitary Price-FOB (USD)	Origin	Destination	Freight & Insurance (€)	Unitary Price CIF (€)	Total Cost (€)
Sorting and washing	Conveyor	1	1 200	Shanghai, China	Istanbul, Türkiye	430	1 546	1 546
	Sorting and washing	2	5 990	Qingdao, China	Istanbul, Türkiye	1 067	6 637	13 275
Hot breaking- Pulp Production-Peel and seed separation	Turbo Extractor	8	1 500	Shanghai, China	Istanbul, Türkiye	446	1 841	14 728
Sterilizer	Industrial Cooker	5	9 900	Shanghai, China	Istanbul, Türkiye	521	9 728	48 640
High Pressure Homogenization	High Pressure homogenizer	1	55 000	Shanghai, China	Istanbul, Türkiye	1 821	52 971	52 971
Packing of Tomato Sauce	Jar Juice filler	1	14 000	Shanghai, China	Istanbul, Türkiye	740	13 760	13 760
	Labeller	4	12 200	Gundogan, China	Istanbul, Türkiye	348	11 694	46 776
Pasteurization	Pasteurizer	3	24 600	Jiangsu, China	Istanbul, Türkiye	5 876	28 754	86 262
Packaging	Cardboard machine	2	48 000	Jiangsu, China	Istanbul, Türkiye	2 216	46 856	93 712
Drying	Dryer-Big	2	24 800	Gundogan, China	Istanbul, Türkiye	3 313	26 377	52 754
	Dryer-Small	1	6 200	Gundogan, China	Istanbul, Türkiye	2 040	7 806	7 806
Grinding	Grinder	4	5 800	Gundogan, China	Istanbul, Türkiye	866	6 260	25 040
Auxiliary services	Palletiser	1	4 999	Jiangsu, China	Istanbul, Türkiye	781	5 430	5 430
	Storage tank	10	8 888	Jiangsu, China	Istanbul, Türkiye	2 269	10 535	105 348
SUBTOTAL								**568 049**

Costs of raw materials

In this case, productivity rate was set in 4 000 L/h or 4 384 kg/h, since density is 1.096 kg/L. **Table 27** compiles the estimated amount and costs for annual production of tomato sauce.

Table 27. Annual raw material cost for FunTomP tomato sauce.

Raw Material	Price (€/kg)	Amount (·10^6kg/year or ·10^6units/year)	Cost (M €)
Tomatoes	0.37	21.12	7.79
Pea Protein	9.51	0.40	3.80
Olive without seeds	1.18	0.22	0.26
Tap Water	0.001	47.55	0.02
Glass Jar & Tap Tins	0.06	80.21	4.51
Cardboard Boxes	0.40	0.89	0.36
Cardboard separators	0.40	3.86	1.55
Pallets	25.95	0.01	0.20
Total Annual Cost (TCP)			**18.51**

Operating labour costs

For the tomato sauce case, the same estimation has been taken as in the juice case. Guidelines from the consulted bibliography was utilized in order to estimate the operative labour costs (Peters et al. 2004). **Table 28** presents the operating labour costs for the tomato sauce production.

Table 28.Operating labour costs of tomato sauce production

Product	Daily Operators	Wage (€/h)	Operating Labor Costs (M€/year)
Tomato Sauce	30	7.92	1 191

For further information, LCC Annex details the calculation steps to achieve the total operators per shift.

Utilities

As in the tomato juice production, the only utility assessed due lack of industrial consumption information was the electricity consumed by the equipment. **Table 29** details the cost of utilities per year.

Table 29. Annual utilities for the sauce production.

Process	Annual electricity consumption (kWh/year)	Annual Utility Cost (M€/year)
Tomato Sauce	20 370 391	1.83

Total Product cost

TPC for the tomato sauce production has been estimated by the same tool and focus as in the tomato juice case. **Table 30** details the TPCs to be afforded.

Table 30. TPC for FunTomP tomato sauce.

Item	Cost (M€/year)
Raw materials	18.5
Operating labour	1.2
Operating supervision	0.2
Utilities	1.8
Maintenance and repairs	0.2
Operating supplies	0.03
Laboratory charges	0.18
Royalties	0.26
Taxes	0.07
Insurance	0.03
Plant overhead	0.95
Administration	0.31
Distribution & selling	1.30
Research & Development	1.04
General Expense	2.66
Total Product Cost (TPC)	**26.11**

Depreciation

Regarding depreciation, the same model as in the juice production has been set. It can be consulted in **Table 24**.

Taxes, Inflation, and minimum acceptable rate of return

Regarding the taxes, inflation and minimum acceptable rate of return, the same approach and values have been taken as in the juice tomato production. For further details it is recommended to consult the **section 3.3.1**.

Revenues

The same guideline as in the tomato juice production was taken. In accordance with the consulted bibliography, regular tomato sauce price range is between 46.84 and 110.00 TRL/kg. Average value range was set in 78.42 TRL/kg which is equivalent to 2.19 €/kg (Selina Wamucii 2024). A 40% of increase is set for the functionalized sauce price, compared to traditional tomato sauce. Therefore, the functional tomato sauce will be sold at 3.07 €/kg. **Table 31** highlights the total annual incomes of the sauce production line.

Table 31. Annual revenues for FunTomP tomato sauce.

Product	Price (€/kg)	Annual Production (M kg/year)	Annual Incomes (M €/annual)
Sauce Production	3.01	21.9	67.5

4.3. Life cycle cost impact assessment

The conducted assessment has been split in three sections: CAPEX, OPEX and Financial Indicators. This separation was made in order to properly monitors the indicators that will enable to evaluate and compare the feasibility of the tomato juice and sauce production lines. With the crafted LCC inventory, calculations were made in order to estimate the economic viability for a period of **10 years**.

Indicators such as OPEX, CAPEX, ROI, PP, NPV and DCFR were obtained as results from the assessment.

LIFE CYCLE COST IMPACT ASSESSMENT FOR TOMATO JUICE PRODUCTION

CAPEX

The estimated CAPEX value for the tomato juice production line under the conditions of the assessment has been determined at 3.4 million euros. **Table 32** and **Figure 26** highlight the cost distribution for the CAPEX estimation.

Table 32. CAPEX detail for the tomato juice production scheme.

CAPEX		
Item	**Cost (M €)**	**Percentage Contribution**
Purchased Equipment	0.69	19.9%
Purchased equipment installation	0.26	7.8%
Instrumentation& Controls	0.18	5.2%
Piping	0.21	6.2%
Electrical system	0.69	2.0%
Buildings	0.20	5.8%
Yard improvements	0.08	2.4%
Service facilities	0.38	10.9%
Engineering and supervision	0.22	6.4%
Construction expenses	0.23	6.8%
Legal expenses	0.003	0.8%
Contractor's fee	0.13	3.8%
Contingency	0.25	7.4%
Working capital	0.52	14.9%
TOTAL CAPEX	**3.50**	**100.0%**

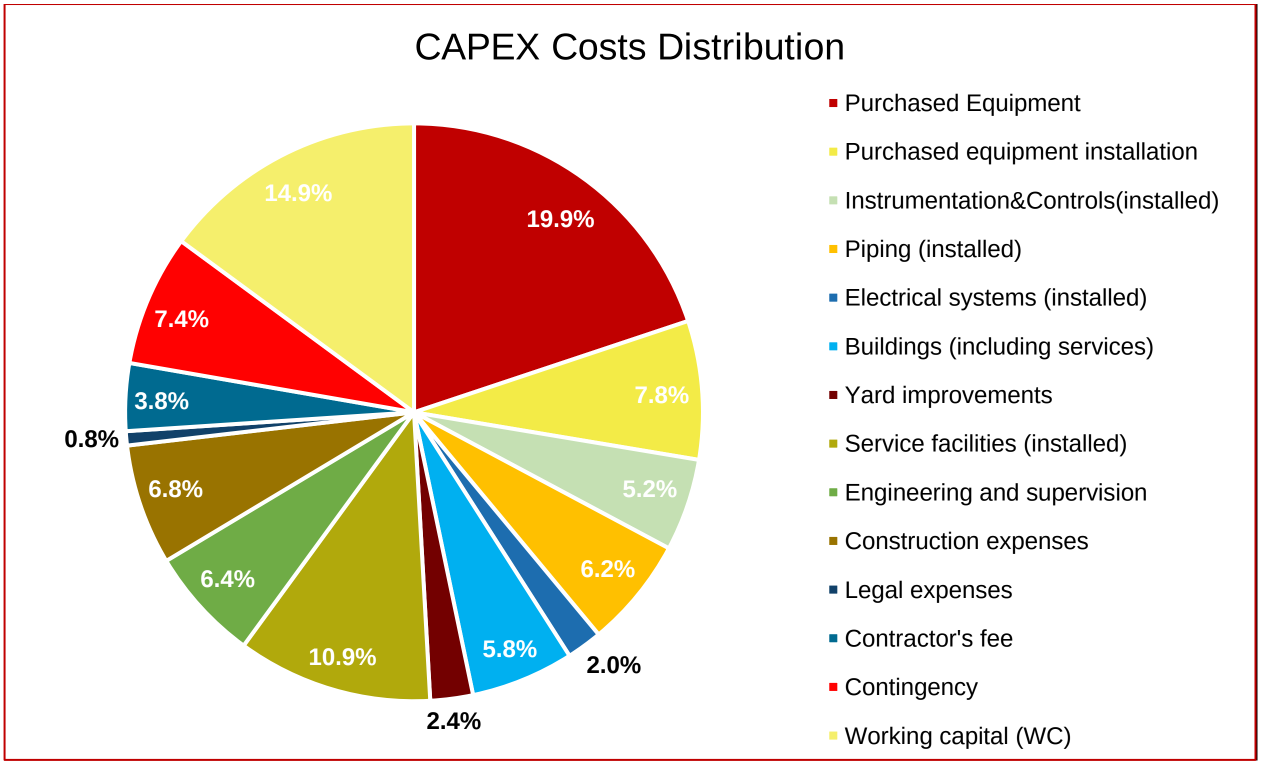


Figure 26. CAPEX percentage contribution of the tomato juice production line.

According to the **Figure 26** the main cost is related to "Purchased equipment", with a contribution of 19.9%, followed by its installation. The 3rd most significant cost is the Service Facilities category. These three categories represent almost 46% of the overall CAPEX.

OPEX

The estimated OPEX value for the tomato juice production line under the conditions of the assessment has been calculated at 29 million euros per year **Table 33** and **Figure 27** detail the cost distribution for the OPEX estimation.

Table 33. OPEX detail for the juice production scheme.

OPEX		
Item	**Cost (M€)**	**Percentage Contribution**
Tomatoes	12.10	41.8%
Pea Protein	2.00	6.8%
Olive without seeds	0.20	0.8%
Tap Water	0.03	0.1%
Glass Jar & Tap Tins	5.30	18.2%
Cardboard Boxes	0.05	0.2%
Cardboard separators	1.80	6.1%
Pallets	0.24	0.8%
Salt	0.29	1.0%
Operating Labor	0.97	3.3%
Utilities	1.50	5.3%
Operating supervision	0.14	0.5%
Maintenance and repairs	0.20	0.6%
Operating supplies	0.03	0.1%
Laboratory charges	0.10	0.5%
Royalties	0.30	1.0%
Taxes on properties	0.06	0.2%
Insurance	0.03	0.1%
Plant overhead	0.80	2.7%
Administration	0.23	0.9%
Distribution & selling	1.40	5.0%
Research & Development	1.50	4.0%
TOTAL OPEX	**28.90**	**100.0%**

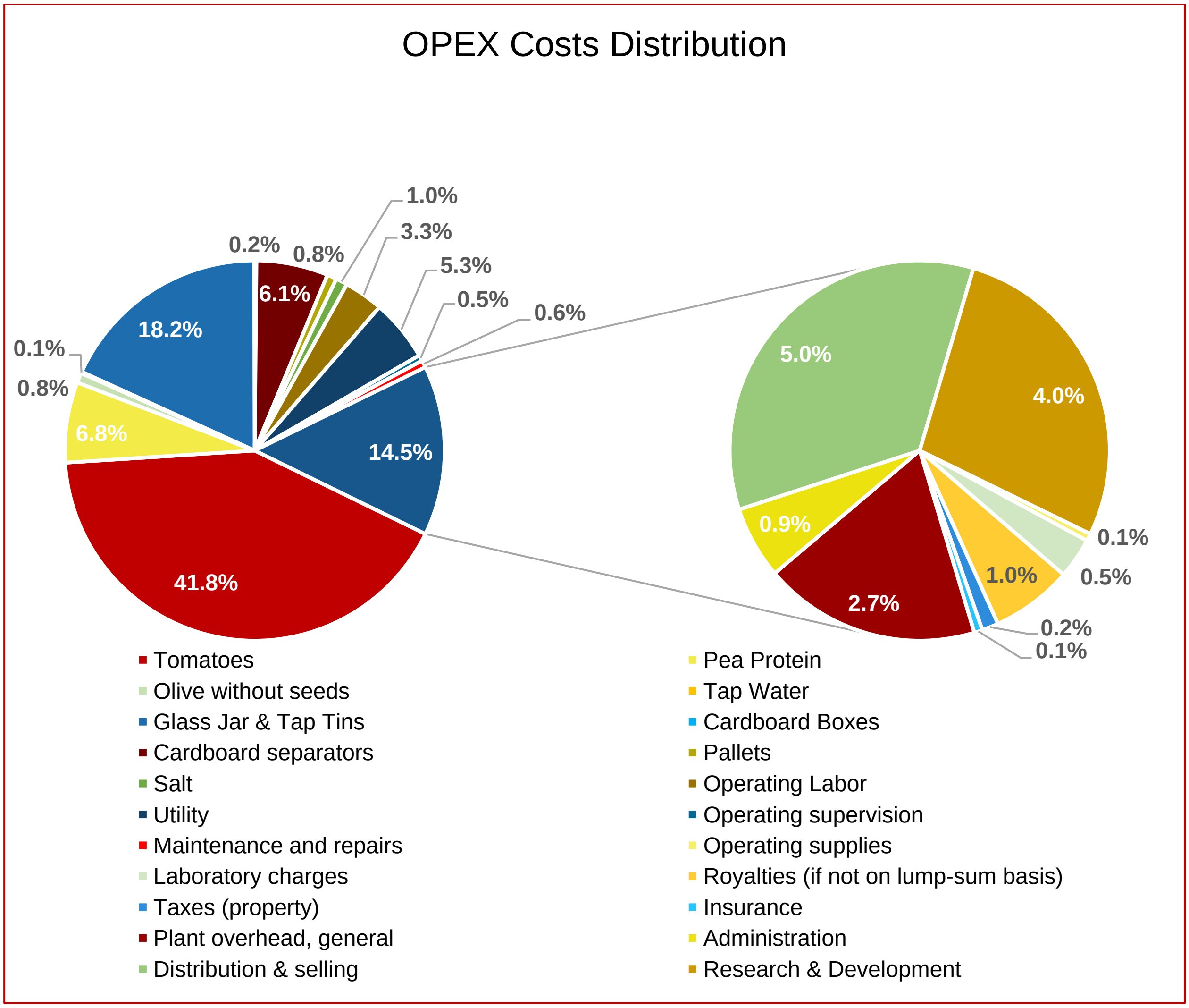


Figure 27. OPEX percentage contribution of the juice production line.

According to **Figure 27** the principal cost is related to “Tomatoes” consumption, with a contribution of 41.8%. The next most important cost corresponds to the “Glass Bottle & Jar” category, with 18.2%. Finally, “Pea Protein” category appears as cost hotspot, accounting a 6.8% of total OPEX cost.These three categories represent almost the 66.8% of the overall OPEX.

Assessment of main financial indicators

An economic assessment was carried out to evaluate the feasibility of the FunTomP tomato juice industrialisation, using the cost inventory data. The outcome of the assessment includes several financial indicators, such as Return on the Investment (ROI), Payback Period (PP), Net Present Value (NPV) and Discounted Cash Flow Rate of Discount (DCFR), calculated according to the equations presented in 2.2. **Figure 28** and **Table 34** collect the economic and financial results of FunTomP industrial tomato juice production.

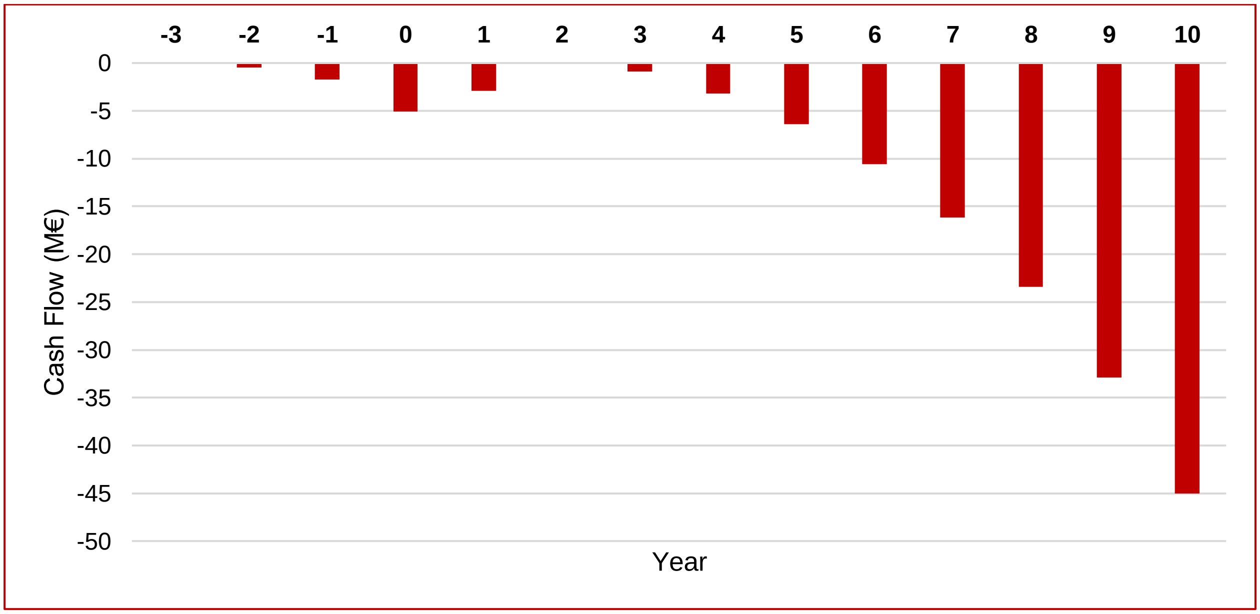


Figure 28. Accumulated cash flow for the juice production at industrial scale at a sale price of 1.34 €/kg of juice and 0.30 €/kg of pellets by-product.

Table 34. Financial indicators result for the juice production at a sale price of 1.34 €/kg and 0.30 €/kg of pellets by-product.

Indicator	Value
ROI (%)	-203
PP (years)	N/A
NPV (M€)	-86.97
DCFR (%)	N/A

As it is shown, the results reflect a bad economic performance. The sale price has been selected to be the adjustable variable to maximize the revenues. Informed CAPEX and OPEX in **Table 32** and **Table 33** were achieved after a thorough price research for industrial scale demand of equipment and consumables. This research was done prioritizing the lowest possible cost. Therefore, the structure and equipment costs constitute a more rigid variable in the analysis here presented. Hence, a new sale price was calculated with the same cost structure in order to get a 3-year PP. The recalculated price was 1.57 €/kg. **Table 35** and **Figure 29** highlight the accumulated cash flow and the economic indicators through the project's lifespan.

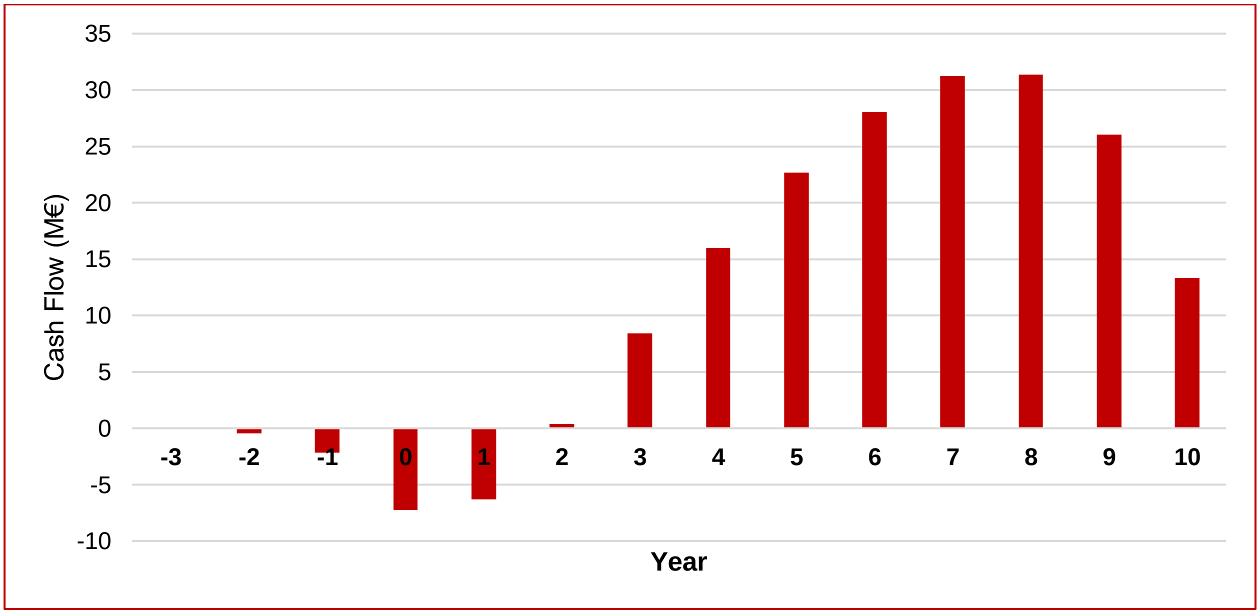


Figure 29. Accumulated cash flow for the juice production line with a sale price of juice of 1.57 €/kg and 0.30 €/kg of pellets by-product.

Table 35. Financial indicators result for the juice production at a sale price of 1.57€/kg and 0.30 €/kg of pellets by-product.

Indicator	Value
ROI (%)	19.9
PP (years)	3.0
NPV (M€)	12.9
DCFR (%)	40.5

Figure 29 shows to differentiated trends. First of all, the increase from year 0 till year 3 of the facility is explained by the increment of the production. During these years, the production will start at 50% capacity, passing to 90% at the second year and 100% at the third year. After this recovery, there is a decreasing cash flow generation explained by the difference between the inflation of the product itself (17%) and the TPC consumables (20%). Therefore, the relative

acceleration of the TPC inflation towards the product makes a cost overcome, aggravating year by year.

Sensitivity Analysis

A sensitivity analysis has been conducted modifying the sale price of the tomato juice solely. For this, it has been taken into account the recalculated price, introduced in the previous section. Two additional scenarios have been planned. On the one hand, a **pessimistic scenario** was created, where the functional product sale price is just a 30% more of the regular product sale price. This is translated to a sale price of 1.46 €/kg. On the other hand, an **optimistic scenario** has also been proposed. In this case, the sale price for the functionalized tomato juice will be 50% more than the regular juice. The price is settled in 1.68 €/kg. **Table 36** summarizes the different scenarios under assessment.

Table 36. Sale price of the tomato juice aligned with each case scenario

Sensitivity Scenario	Price (€/kg)
Pessimistic	1.46
Average	1.57
Optimistic	1.68

Figure 30 and **Table 37** present the performance of the economic activity for the three cases.

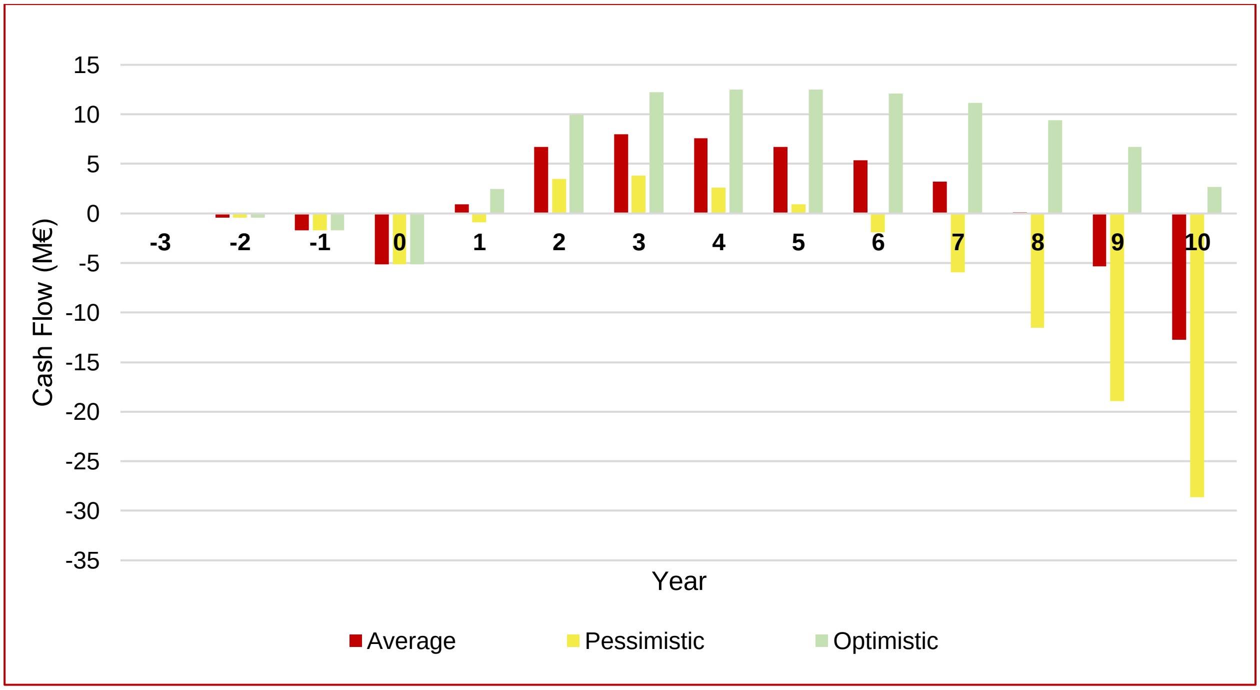


Figure 30. Accumulated cash flow for the three proposed scenarios: Average, Pessimistic, Optimistic.

Table 37. Financial indicators for the three proposed scenarios: Average, Pessimistic, Optimistic.

Financial Indicator	Case		
	Pessimistic	Average	Optimistic
Sale Price (€/kg)	1.46	1.57	1.68
ROI (%)	-87.0	19.9	117.9
PP (years)	-1.1	3.0	0.7
NPW(M€)	-34.7	12.9	56,7
DCFR (%)	No value	40.5	57.1

As it is informed in **Table 37** the production of tomato juice is sensitive to small price variations. As expected, all the economic and financial indicators improve upon increasing the product selling costs. Nevertheless, none of the assessed options is sustained financially over time as a consequence of the misalignment between the input/output inflation percentages.

In the Annex, from **Table 52** to **Table 55**, the sensitivity analysis calculations are presented for further consideration.

LIFE CYCLE COST IMPACT ASSESSMENT FOR TOMATO SAUCE PRODUCTION

CAPEX

CAPEX has been calculated for the tomato sauce production line. The estimated value under the conditions of the assessment has been determined at 4.06 million euros. **Table 38** and **Figure 31** detail the cost distribution for the CAPEX estimation.

Table 38. CAPEX detail for the sauce production scheme.

CAPEX		
Item	**Cost (M€)**	**Percentage Contribution**
Purchased Equipment	0.68	16.9%
Purchased equipment installation	0.32	7.9%
Instrumentation & Controls	0.25	6.1%
Piping	0.47	11.5%
Electrical systems	0.07	1.9%
Buildings	0.12	3.0%
Yard improvements	0.07	1.7%
Service facilities	0.48	11.8%
Engineering and supervision	0.23	5.6%
Construction expenses	0.28	6.9%
Legal expenses	0.03	0.7%
Contractor's fee	0.15	3.7%
Contingency	0.30	7.4%
Working capital	0.61	15.0%
TOTAL CAPEX	**4.10**	**100.0%**

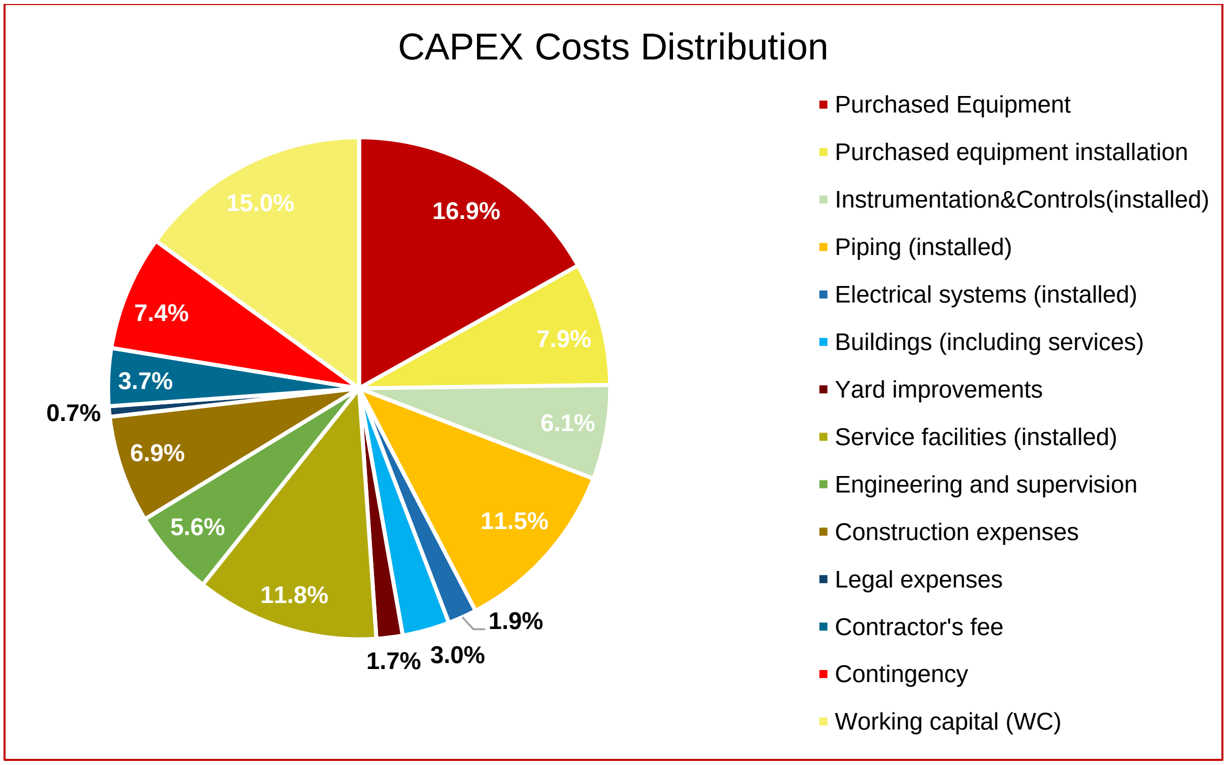


Figure 31. CAPEX percentage contribution of the sauce production line.

Figure 31 details de CAPEX for the sauce production line with the respective shares of the costs. The most contributive is the Purchased Equipment with 16.9 %, followed by the PURCHASED Equipment Installation with 15%. With 11.8% & 11.5%, Services Facilities and Pipping, respectively, have the highest cost shares.

OPEX

OPEX has been calculated for the tomato sauce production line. The estimated value under the conditions of the assessment has been calculated at 26 million euros per year. **Table 39** and **Figure 32** compile the cost distribution for the OPEX estimation.

Table 39. OPEX detail for the sauce production scheme

OPEX		
Item	**Cost**	**Percentage Contribution**
Tomatoes	7.80	29.9%
Pea Protein	3.80	14.6%
Olive without seeds	0.26	1.0%
Tap Water	0.02	0.1%
Glass Jar & Tap Tins	4.50	17.3%
Cardboard Boxes	0.36	1.4%
Cardboard separators	1.50	6.0%
Pallets	0.20	0.8%
Operating Labor	1.20	4.6%
Utilities	1.80	7.0%
Operating supervision	0.18	0.7%
Maintenance and repairs	0.21	0.8%
Operating supplies	0.03	0.1%
Laboratory charges	0.18	0.7%
Royalties	0.26	1.0%
Taxes	0.07	0.3%
Insurance	0.03	0.1%
Plant overhead	0.94	3.6%
Administration	0.31	1.2%
Distribution & selling	1.30	5.0%
Research & Development	1.00	4.0%
TOTAL OPEX	**26.11**	**100.0%**

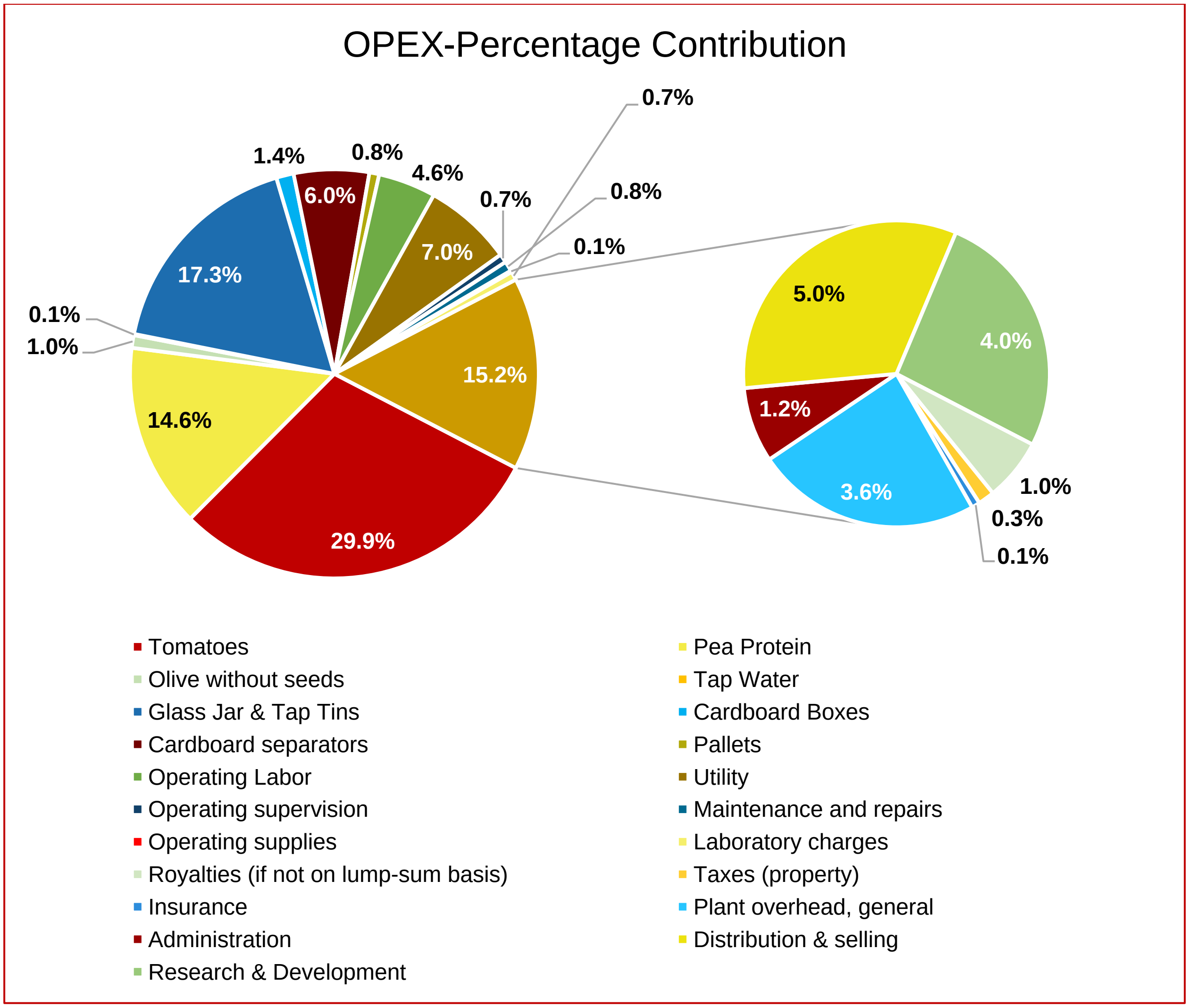


Figure 32.OPEX percentage contribution of the sauce production line.

Figure 32 details the different shares of the OPEX for the sauce production line. The most contributive share is given by the Tomato supply, with a 29.9% of the expenditure. In second place, Glass Jar & Bottles contributes with the 17.7%. At the same time, the Pea Protein purchase corresponds to the 14.6%.

Assessment of main financial indicators

As in the juice production case, an economic assessment was carried out to evaluate the feasibility of FunTomP sauce production. The same economic and financial indicators considered for the juice production case have been utilized for the sauce case. **Figure 33** and **Table 40** show the accumulated cash flow and the economic & financial indicators throughout all the lifespan of the project.

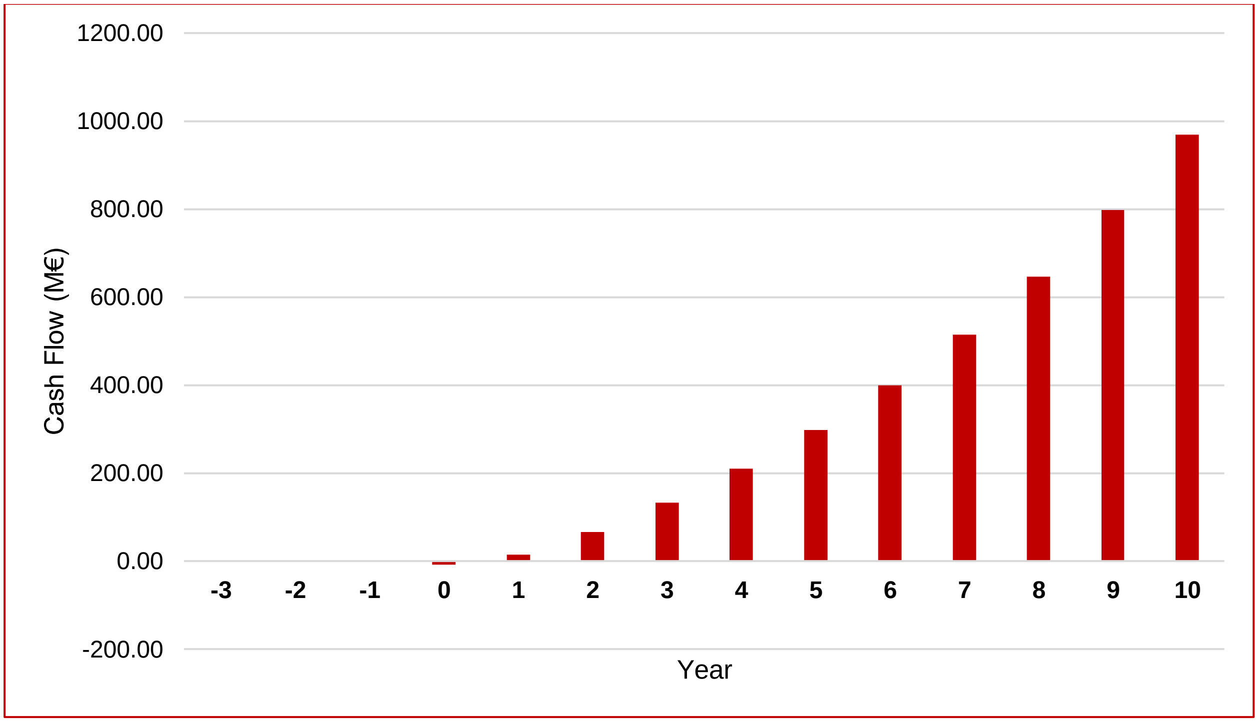


Figure 33. Accumulated cash flow for sauce production case at a sale price of 3.07 €/kg.

Table 40. Financial indicators result for the sauce production at a sale price of 3.07 €/kg.

Indicator	Value
ROI (%)	1144.1
PP (years)	0.074
NPV (M€)	607.0
DCFR (%)	111.1

Figure 33 and **Table 40** inform the economic results for the sauce production. Asi it can be seen in **Figure 33**, a short time (less than a year) is needed to recover the initial investment, which is followed by a positive accumulated cash flow trend. Furthermore, **Table 40** details the good economic performance of the business case with interesting financial and economic indicators, characterised by short PP and high rates of DCFR.

Sensitivity Analysis

A sensitivity analysis has been conducted by acting on the sale price of the tomato sauce given the good results for the average case. For the sale price calculation, a range of prices between 1.30 €/kg - low price - and 3.07 €/kg - high price - was taken. From these two prices an average tomato regular sauce sale price was calculated (2.19 €/kg), and a 40% recharge was added, due the functionalized properties, being 3.07 €/kg.(Menrad 2003)

Five scenario cases were assessed. First, a very-pessimistic scenario was built at a sale price of 1.71 €/kg. This price is composed of the lowest regular price product with a 30% of additional charge due the functionalized properties of the sauce. Second, a pessimistic scenario was planned where the functional product sale price is 30% more of the regular product sale price. This is translated to a sale price of 2.85 €/kg. Then, two positive scenarios were proposed: optimistic- at a sale price of the functionalized tomato juice a 50% higher than the regular juice sale price (3.29 €/kg); and very optimistic, at a sale price considering the higher price range value for the regular product plus a 50% charge (4.62 €/kg) (Selina Wamucii 2024) (Menrad 2003). **Table 41** summarises the price scenario for each sensitivity analysis case.

Table 41. Sale price of the tomato sauce aligned with each case scenario

Sensitivity Scenario	Price (€/kg)
Very Pessimistic	1.71
Pessimistic	2.85
Average	3.07
Optimistic	3.29
Very Optimistic	4.62

Figure 34 and **Table 42** show the performance of the economic activity for the five cases Average, Very Pessimistic, Pessimistic and Optimistic and Very Optimistic. In the LCC Annex from **Table 57** to **Table 60** are displayed the sensitivity analysis calculations for further consideration.

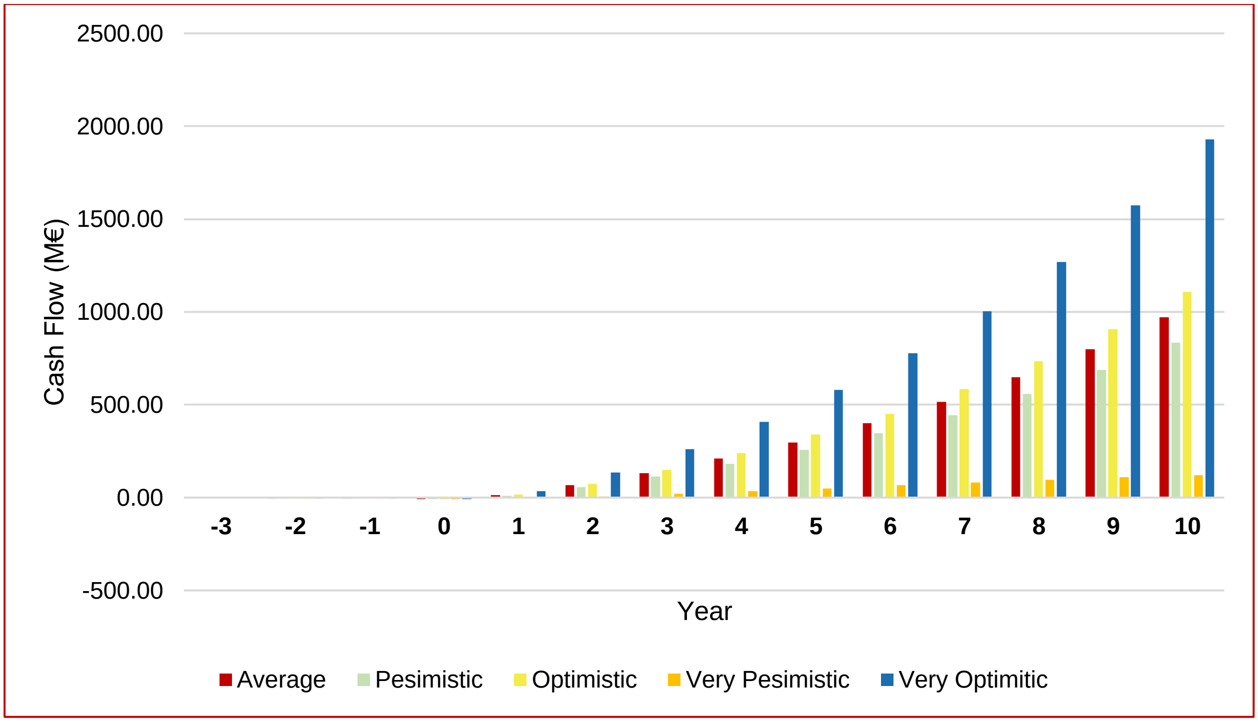


Figure 34. Accumulated cash flow for sauce production case at Very Pessimistic, Pessimistic, Average, Optimistic and Very Optimistic cases.

Table 42.Financial indicators for the sauce production line with the five proposed scenarios Average, Pessimistic, Optimistic, Very Pessimistic and Very Optimistic.

Financial Indicator	Case				
	Very Pessimistic	Pessimistic	Average	Optimistic	Very Optimistic
Sale Price	1.70	2.85	3.07	3.29	4.62
ROI (%)	145.0	983.8	1 144.1	1 304.4	2 272.6
PP (years)	0.5	0.1	0.1	0.1	0.04
NPV (M €)	78.4	522.2	607.0	607.0	1 203.7
DCFR (%)	74.7	106.2	111.1	115.5	134.7

Figure 34 and **Table 42** show the good results obtained from the sensitivity analysis for the tomato sauce production. As it can be inferred in **Figure 34** all the 5 cases have good positive accumulated cash flow throughout the lifespan of the project, and a fast investment recovery. **Table 42** compiles the positive economic financial indicators calculated for all the cases, even for

the very pessimistic scenario. With the information herein provided, it can be assured that the production of sauce under this cost and sale structure is not just feasible but robust.

4.4. INTERPRETATION OF LCC RESULTS

LCC RESULTS FOR TOMATO JUICE PRODUCTION

FunTomP tomato juice production has demonstrated to be unfeasible from the economic and financial point of view, with the current cost structure and sale price. The reason of this output is defined by several parameters: sale price, tomato cost and inflation rates.

The sale price of the tomato juice has demonstrated not being able to cover the needed costs. To guarantee the viability of the production line, the sale price should pass from 1.34 to 1.52 €/kg, which represents 13.43 % of increment. Since the regular tomato juice price is 0.97 €/kg, 50% increase on the value would turn out in a sale price of 1.45 €/kg for the upper limit value product. Since the recalculated sale price is 1.52 €/kg there is a risk of being pushed out of the market since the factory would sell outside the market's value.

Tomato cost resulted to be the main economic hotspot for the tomato juice production, representing 41.8% of the OPEX for the juice production with an expenditure of 12 million euros per year. This is the major asset in the OPEX followed by the "Glass Jar & Tin Tap" accounting for 18.1%. Therefore, efforts must be made to decrease as possible the tomato consumption and/or price. Reducing tomato consumption might be achieved by using more efficient processing techniques, lowering the wastes generated. Moreover, the possibilities to add value to the byproduct might be explored in order to have a second production line with a higher sale price.

Furthermore, tomato price is an asset to consider. According to the price found, Türkiye produces the cheapest tomatoes at sale price of 0.34 €/kg (Asad et al. 2023). This price might be lowered by two approaches: exploring cheaper non-European markets (with a consequent rise of carbon footprint in the product, due to transportation) or to produce the tomato by the company itself. Both strategies might lead a lower tomato price. Regarding the production of tomato by the company, the Turkish government has a battery of measures to encourage tomato cropping, where fertilizer, fuel and agricultural practices certificates among other expenditures are subsidized. (Turkish Goods 2024)

Sensitivity analysis has demonstrated that the case assessed could not accept a drop of the juice selling price from 1.57 to 1.46 €/kg. Under this scheme, the investment could not be recuperated since the ROI and PP have negative values. Furthermore, the NPV would turn out to be an investment loss. With a drop loss of 7%, the economic sustainability of the project is compromised. Therefore, the analysis demonstrates that the model lacks robustness when price tends to decrease.

Inflation rate has been a key parameter throughout the model. Since the TPC inflation rate is higher than the product inflation rate, expenditures are higher year by year when comparing to the incomes. This phenomenon, produce a decrease of the future cashflows throughout the lifespan of the project when the amounts are capitalized.

LCC RESULTS FOR TOMATO SAUCE PRODUCTION

FunTomP tomato functional sauce production has demonstrated to have good results for the model assessed. Financial and economic indicators have a good performance. At a sale price of 3.07 €/kg positive outputs have been obtained. ROI is set 1104% with a fast PP and interesting rates of DCFR above 100% and NPV for 607 million euros.

The sensitivity analysis has demonstrated a robust economic viability for the 5 cases assessed. Price variation between the average case and the very pessimistic case, set at a 45% different, has still returned positive results. When comparison is made between the tomato juice and tomato paste, the differences are remarkable. This is explained by three following model considerations: first, because the density of tomato sauce is slightly higher than that of tomato juice, it results in increased production rates measured in kilograms per hour, leading to a higher annual production rate for the sauce. Since sales prices are calculated per kilogram, this density difference positively affects profitability; second, the price difference is remarkable, the tomato sauce sale price is 2.3 times higher than the tomato juice's one; third, the efficiency for the tomato processing is higher in the tomato sauce production case than in the juice production case. For 1 gram of sauce, according to the LCA inventory 0.964 grams of raw tomato is needed, while in the juice case this ratio is 1.67 grams of tomato per gram of juice. This fact leads to higher consumption costs regarding tomatoes, which represents 29.9% and 41% of the total OPEX for sauce and juice production respectively.

5. SOCIAL LIFE CYCLE ASSESSMENT

In the current section, the S-LCA is detailed. The assessment was conducted in accordance with the methodology before mentioned in **section 2.3**.Hence, goal and scopes have been defined for both tomato juice and tomato sauce. For both products a S-LCI has been crafted, aligned to the Life cycle costing inventory. With each S-LCI and the SHDB the social assessment could be developed obtaining results for the social footprints through 5 impact categories and 25 impact sub-categories. Finally, a discussion of the results is detailed, providing remarkable hotspots identification and possible mitigation measures.

5.1. S-LCA goal and scope

This study aims to calculate the social footprint of the FunTomP proposed products, namely: a functionalized tomato juice and sauce.

The goal of the study is twofold:

1-To quantify the social impact that has the production of the sauce and juice

2-To identify the main social hotspots of the production of the sauce and juice

The scope of the S-LCA study includes the supply chain of the target products, assessing their potential social impacts from **'farm to gate'** (Figure 5). This boundary selection considers the production upstream of all the raw materials and energy required such as tomatoes, olives, and electricity. Production steps within the manufacture process are also considered with the respective back processes such as machinery and operating labour required, among others. The transportation of raw materials has not been considered since is supposed as negligible. Furthermore, the distribution of the products, use stage and end-of-life stages are, also excluded from the S-LCA study under this farm-to-gate approach.

As defined previously in the LCA, the considered **functional units** are 225 ml functionalized tomato juice and 300 ml of functionalized tomato sauce. Both products are ready for distribution, and their corresponding packaging (bottle and jar for juice and sauce, respectively) are included as part of the functional unit.

5.2. Social life cycle inventory (S-LCI)

The S-LCI herein provided for both products is based on the LCC inventory informed in the present report. This inventory is for industrial scale production and has the same data challenges as in the LCC section.

For both products, the S-LCI was developed considering the total costs calculated through the LCC study. With the mentioned total costs, the unitary production cost for each item has been calculated, including one bottle of tomato juice and one jar of tomato sauce. Since the Social Hotspot Database (SHDB) has its datasets expressed in 2011 USD, the unitary costs were corrected by inflation and expressed from Euros to American Dollars (USD). An exchange rate of 1.369 USD/€ has been considered. This rate is based on the average value of the year 2011 according to the consulted bibliography [20]. On the other hand, inflation rate has been calculated. **Table 43** compiles the calculation of the inflation in the period 2011-2024 for the three countries with relevant specific sectors in the value chain of the FunTomP products.

Table 43. Inflation rate for China, Türkiye and Spain in the period 2011-2024

Country	Inflation rate 2011-2024
China (CN)	32.2%
Türkiye (TUR)	735.7%
Spain (SP)	27.9%

It is important to note that several gaps were fulfilled by literature review in the LCC inventory. Since the S-LCI is based on the LCC inventory, the cost uncertainties impact the final S-LCA results.

S-LCI of Tomato Juice and Tomato Sauce

The items for the S-LCI have been gathered in different subgroups and groups in order to enable an easier analysis and identification for the result dissertation. Furthermore, groups, sub-groups and Country Specific Sector (CSS) are highlighted for each item. **Table 44** and **Table 45** compile the SLC-I for the juice and for the sauce productions, respectively.

Table 44. S-LCI for FunTomP juice production.

Group	Sub-Group	Item	Industrial Sector	Country	Cost per FU (Cents @ 2011)	Cost Group Distribution (%)
Materials	Packaging	Pallets	Chemical, rubber, plastic	China	2.6E-1	82.40%
		Cardboard Boxes	Manufacturer nec	China	6.0E-2	
		Glass Jar & Tap Tins	Manufacturer nec	China	6.0E0	
		Cardboard separators	Manufacturer nec	China	1.9E0	
	Raw Materials	Olive without seeds	Food Products	Spain	2.8E-1	
		Salt	Food Products	Türkiye	5.0E-2	
		Tomatoes	Vegetable, fruits, nuts	Türkiye	2.1E-1	
		Tap Water	Water	Türkiye	6.1E-3	
		Pea Protein	Food Products	China	2.2E0	
Labour force	Labour force	Administration	Food Product/TUR	Türkiye	4.0E-2	2.86%
		Research & Development	Food Product/TUR	Türkiye	2.0E0	
		Operating supervision	Food Product/TUR	Türkiye	2.0E-2	
		Operating Labor	Food Product/TUR	Türkiye	1.7E-1	
Utilities	Utilities	Utilities	Electricity	Türkiye	2.6E-1	1.72%
Infrastructure and equipment	Construction	Buildings	Construction	Türkiye	3.0E-2	9.97%
		Construction expenses	Construction	Türkiye	4.0E-2	
		Contingency	Construction	Türkiye	4.0E-2	
	Construction	Contractor's fee	Construction	Türkiye	2.0E-2	
		Engineering and supervision	Construction	Türkiye	4.0E-2	
		Legal expenses	Construction	Türkiye	4.8E-3	
		Service facilities	Construction	Türkiye	7.0E-3	
		Working capital	Construction	Türkiye	9.0E-3	

Group	Sub-Group	Item	Industrial Sector	Country	Cost per FU (Cents @ 2011)	Cost Group Distribution (%)
Infrastructure and equipment		Yard improvements	Construction	Türkiye	1.4E-3	
	Equipment including maintenance	Taxes	Financial Services	Türkiye	1.0E-3	
		Electrical systems	Electronic equipment	Türkiye	1.2E-3	
		Instrumentation & Controls	Machinery and Equipment	Türkiye	3.0E-2	
		Operating supplies	Machinery and Equipment	Türkiye	4.6E-3	
		Piping (installed)	Metals	Türkiye	4.0E-2	
		Purchased Equipment	Machinery and Equipment	China	1.0E00	
		Purchased equipment installation	Machinery and Equipment	Türkiye	5.0E-2	
		Maintenance and repairs	Machinery and Equipment	Türkiye	3.0E-2	
Financial, business, distribution and trade services	Financial, business, distribution and trade services	Distribution & selling	Trade	Türkiye	2.5E-1	2.16%
		Laboratory charges	Business services	Türkiye	2.0E-2	
		Royalties	Financial Services	Türkiye	5.0E-2	
		Insurance	Insurance	Türkiye	5.1E-3	
Plant Overhead	Plant Overhead	Plant overhead	Food Products	Türkiye	1.3E-1	0.88%

Table 45. S-LCI for FunTomP sauce production

Group	Sub-Group	Item	Industrial Sector	Country	Cost per juice bottle (USD Cents @ 2011)	Cost Group Distribution (%)
Materials	Packaging	Pallets	Chemical, rubber, plastic	China	4.0E-2	73.11%
		Cardboard Boxes	Manufacturer nec	China	4.6E-1	
		Glass Jar & Tap Tins	Manufacturer nec	China	5.8E0	
	Raw Materials	Cardboard separators	Manufacturer nec	China	3.2E-1	
		Olive without seeds	Food Products	Spain	3.5E-1	
		Tomatoes	Vegetable, fruits, nuts	Türkiye	1.6E0	
		Tap Water	Water	Türkiye	5.0E-3	
		Pea Protein	Food Products	China	7.8E-1	
Labour force	Labour force	Administration	Food Product/TUR	Türkiye	6.0E-2	4.35%
		Research & Development	Food Product/TUR	Türkiye	2.1E-1	
		Operating supervision	Food Product/TUR	Türkiye	4.0E-2	
		Operating Labor	Food Product/TUR	Türkiye	2.4E-1	
Utilities	Utilities	Utility	Electricity	Türkiye	3.7E-1	2.92%
Infrastructure and equipment	Construction	Buildings (including services)	Construction	Türkiye	2.0E-2	12.77%
		Construction expenses	Construction	Türkiye	6.0E.2	
		Contingency	Construction	Türkiye	6.0E.2	
Infrastructure and equipment	Construction	Contractor's fee	Construction	Türkiye	3.0E-2	
		Engineering and supervision	Construction	Türkiye	5.0E-2	
		Legal expenses	Construction	Türkiye	6.0E-2	
		Service facilities	Construction	Türkiye	1.0E-1	
		Working capital	Construction	Türkiye	1.2E-1	
		Yard improvements	Construction	Türkiye	1.0E-2	
		Taxes	Financial Services	Türkiye	1.0E-2	

Group	Sub-Group	Item	Industrial Sector	Country	Cost per juice bottle (USD Cents @ 2011)	Cost Group Distribution (%)
	Equipment including maintenance	Electrical systems	Electronic equipment	Türkiye	1.0E-2	
		Instrumentation & Controls	Machinery and Equipment	Türkiye	5.0E-2	
		Operating supplies	Machinery and Equipment	Türkiye	9.0E-2	
		Piping	Metals	Türkiye	900E-2	
		Purchased Equipment	Machinery and Equipment	China	8.8E-1	
		Purchased equipment installation	Machinery and Equipment	Türkiye	7.0E-2	
		Maintenance and repairs	Machinery and Equipment	Türkiye	4.0E-2	
Financial, business, distribution and trade services	Financial, business, distribution and trade services	Distribution & selling	Trade	Türkiye	2.7E-1	5.34%
		Laboratory charges	Business services	Türkiye	4.0E-2	
		Royalties	Financial Services	Türkiye	3.4E-1	
		Insurance	Insurance	Türkiye	4.0E-2	
Plant Overhead	Plant overhead	Plant overhead	Food Products	Türkiye	1.0E-1	1.51%

5.3. Social life cycle impact assessment (S-LCIA)

The main results of the S-LCIA are shown in this section, including social hotspots identification. The results will be informed separately by product. For both products, the social impact categories will be informed firstly by the groups determined in **Table 44** and **Table 45**, showing the total impacts and the share of each group. Shares will be analysed in order to establish social hotspots, comparing the results for the SHI versus the share of the cost reported for each group. Furthermore, the sub-categories will be also assessed for the different groups within the S-LCI.

Juice production S-LCA results

Table 46 and **Figure 35** depict the social impact of the production of one bottle of functionalized tomato juice.

Table 46. Category social impact per group for the production of one bottle of tomato juice.

Group	Labor Rights & Decent Work	Health & Safety	Human Rights	Governance	Community	Total
Materials	5.46E+00	5.53E+00	3.09E+00	7.45E+00	4.06E+00	**2.56E+01**
Labour force	7.59E-02	6.49E-02	4.51E-02	1.03E-01	5.85E-02	**3.48E-01**
Utilities	4.11E-04	2.73E-03	7.95E-04	2.91E-03	3.42E-04	**7.19E-03**
Infrastructure and equipment	4.96E-01	5.07E-01	2.64E-01	6.47E-01	3.28E-01	**2.24E+00**
Financial, business, distribution and trade services	6.28E-02	4.00E-02	3.46E-02	8.32E-02	4.46E-02	**2.65E-01**
Plant Overhead	2.99E-02	2.11E-02	1.70E-02	4.12E-02	2.32E-02	**1.32E-01**
Total	**6.12E+00**	**6.16E+00**	**3.45E+00**	**8.33E+00**	**4.51E+00**	**2.86E+01**

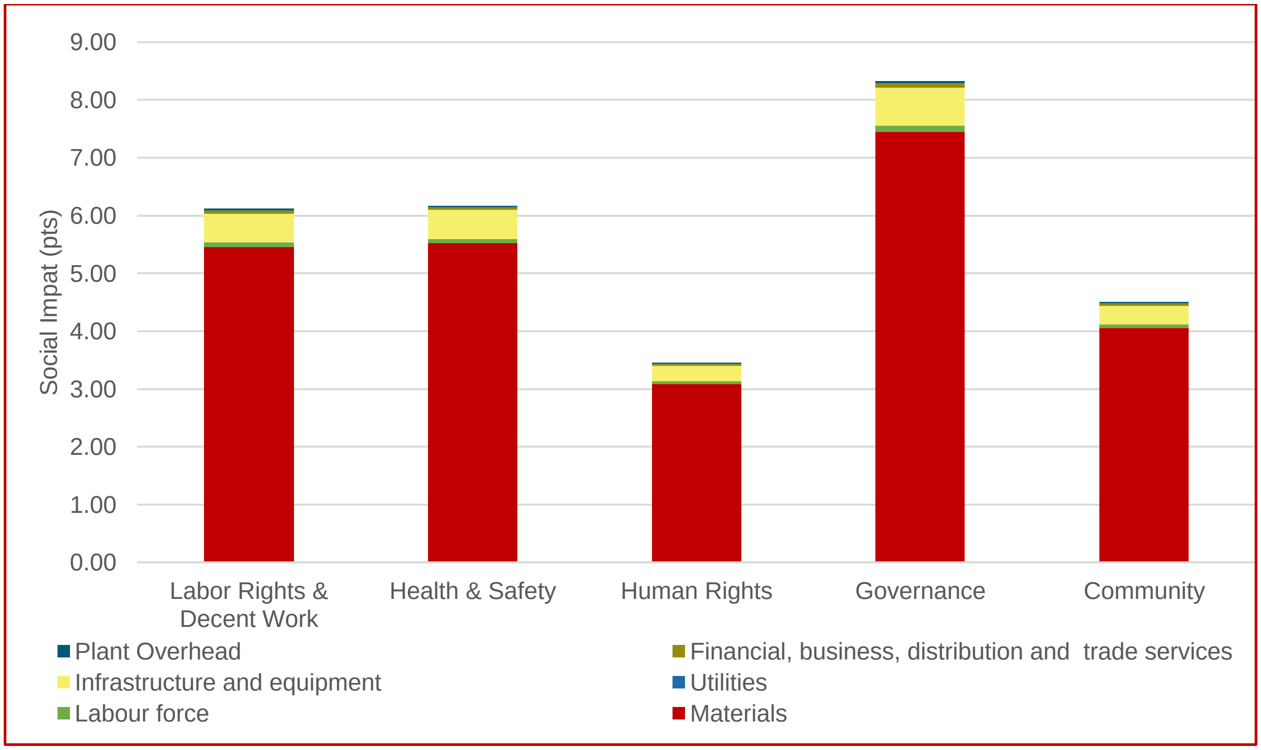


Figure 35. Contribution of each group within the social impacts for the production of one bottled juice.

Furthermore, the social impact sub-categories have also been assessed in order to recognise critical social issues and their origin. **Figure 36** illustrates the contribution that each life cycle component has to the social impact for each social sub-category of the of S-LCI items for juice production.

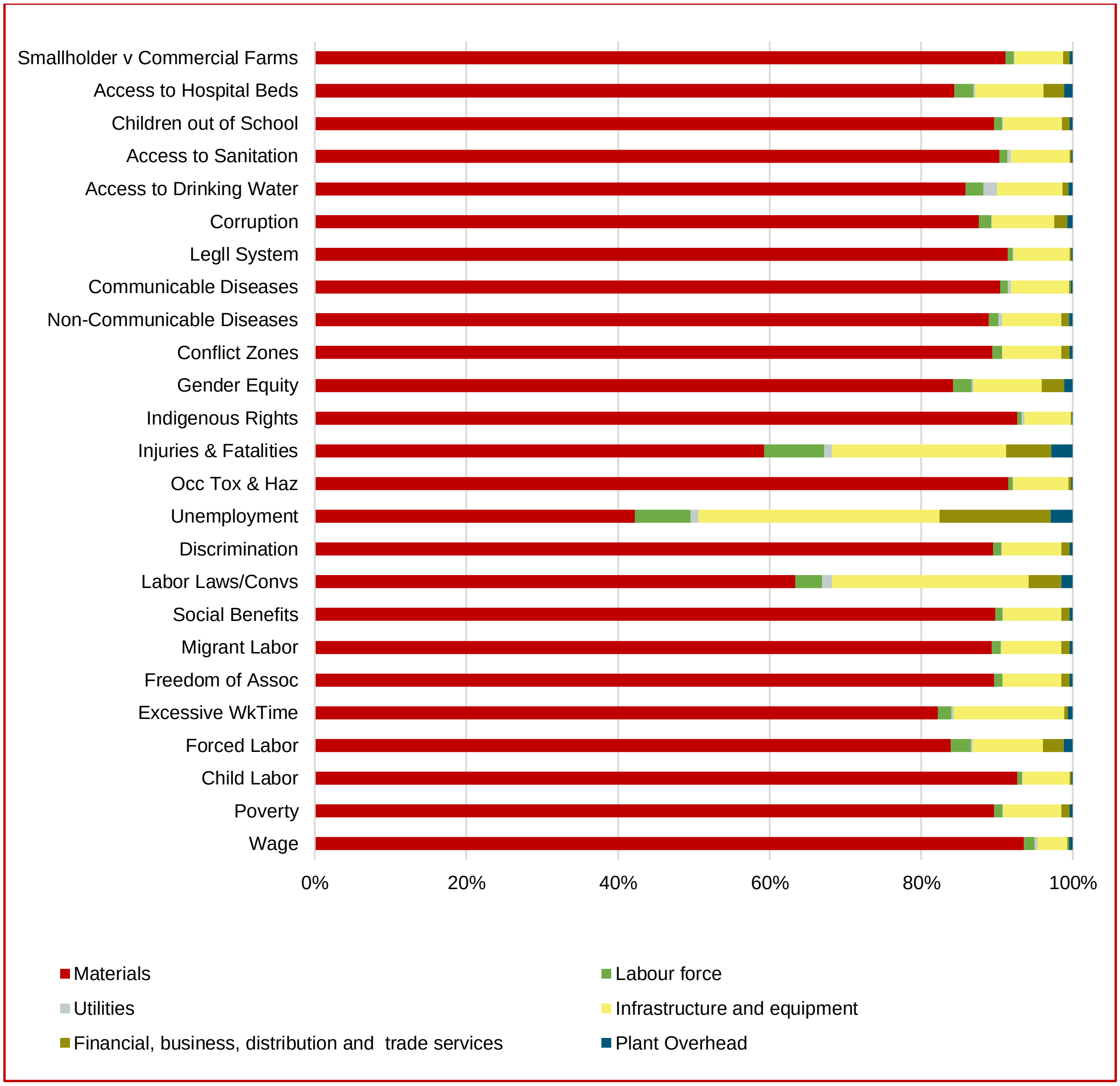


Figure 36. Contribution of the life cycle components to the social impact subcategories for one bottled and packed tomato juice.

Finally, SHI share and cost share are compared. The main interest in comparing these two shares is to assess if the generated social impacts are higher than the cost share destinated to that particular S-LCI component. Since the SHI share is based on the cost share, when the SHI share is higher than the cost shares the CSSs within the S-LCI component have remarkable social risks. **Figure 37** details the share of SHI and share cost that every life cycle component has.

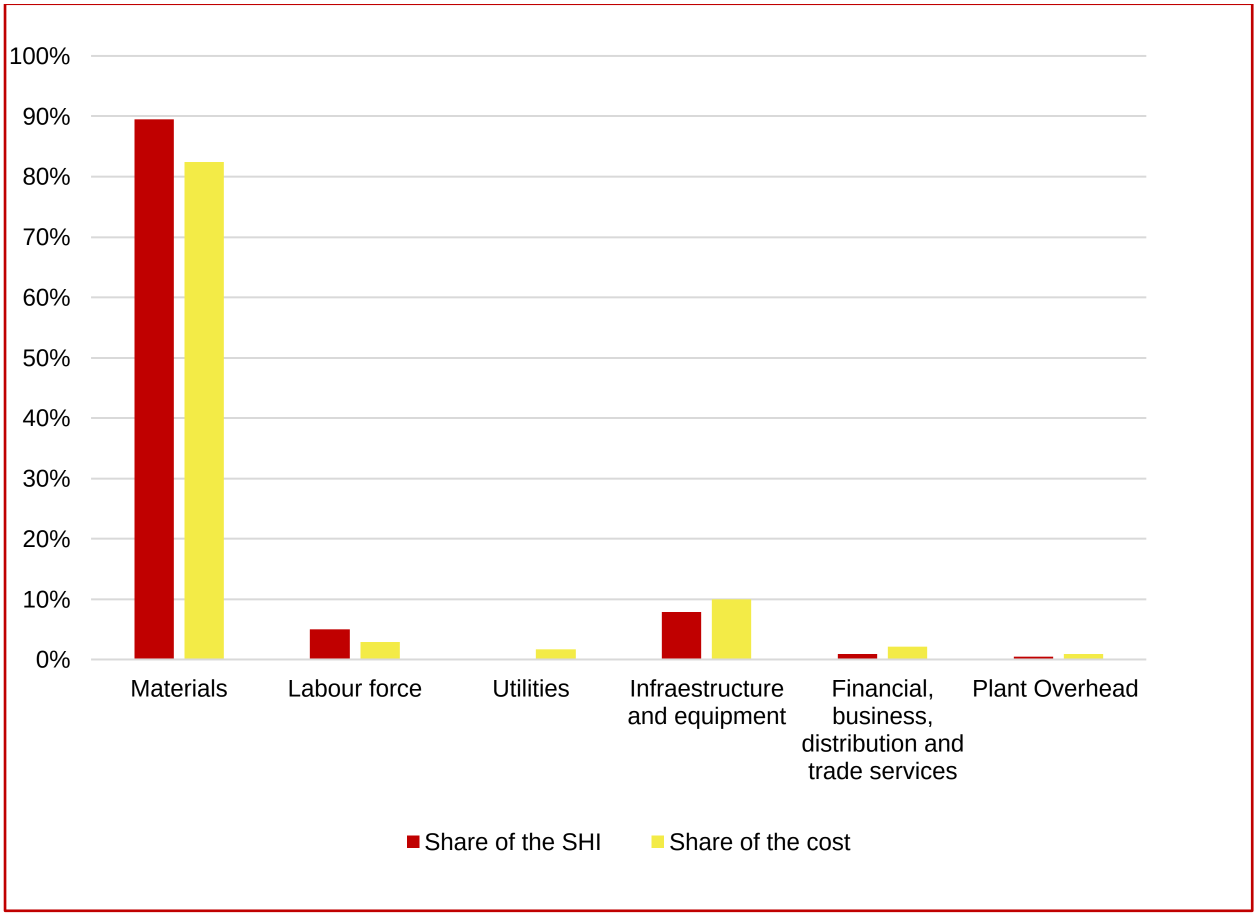


Figure 37. Share of SHI vs share of cost for juice production.

As it can be inferred by both **Table 46** and **Figure 35** the most impacting life cycle components within the social impact categories are: Materials, Infrastructure & Equipment (I&E) and, in a lesser extent, Labour Force (LF). Furthermore, **Figure 36** highlights the most significant contributions from the life cycle components regarding the social sub-category's indicators. **Figure** 37completes the previous analysis by showing the share cost and the share of SHI for each life cycle component. Materials are clearly the most important, with a contribution that averages 89% throughout all the impact categories. Similarly, the impact contribution of the Materials is the highest throughout all the sub-categories informed in **Figure 37**. Materials impacts ranges between 42%-95% depending on the sub-category considered. This was expected due to the high-cost shares that Packaging and Raw materials have, particularly, the tomato consumption. Furthermore, since the share of SHI is higher than the share of costs, Materials are considered a social hotspot.

I&E ranks as the second most important impact category for the tomato juice production. Nevertheless, the impact level is one order of magnitude lower when it is compared to Materials, as it ranges between 7-8%. Its impact share values are aligned with the cost share of 10%, represented in the **Figure 37**. Regarding the sub-categories, I&E ranges between 5%-30% depending on the sub-categories considered. Once again, the cost share is aligned with share informed in **Figure 37**. Few exceptions such as Unemployment sub-category are above the cost share with almost 30% of contribution. I&E has a higher cost share than its SHI share, thus not constituting a remarkable social hotspot.

Lastly, LF is the third main component in the social impact categories with a contribution of 1% throughout all the impact categories. Regarding the sub-category analysis, the LF component impacts vary from 1% to 8% depending on the sub-category, being these values in line with the share costs of the same percentage. Since the SHI share is higher than the share cost, LF can be considered a relevant social hotspot.

Categories such as Utilities, Financial, Business, Distribution & Trade services and Plant Overhead Costs do not represent a social threat according to the reported information.

Since materials have demonstrated to be the most important contributing component in the juice production, an analysis of CSS within the Material group has been conducted in order to establish which CSS contributes the most to the impacts. **Figure 38** details the CSS contribution towards the total SHI of the Material group.

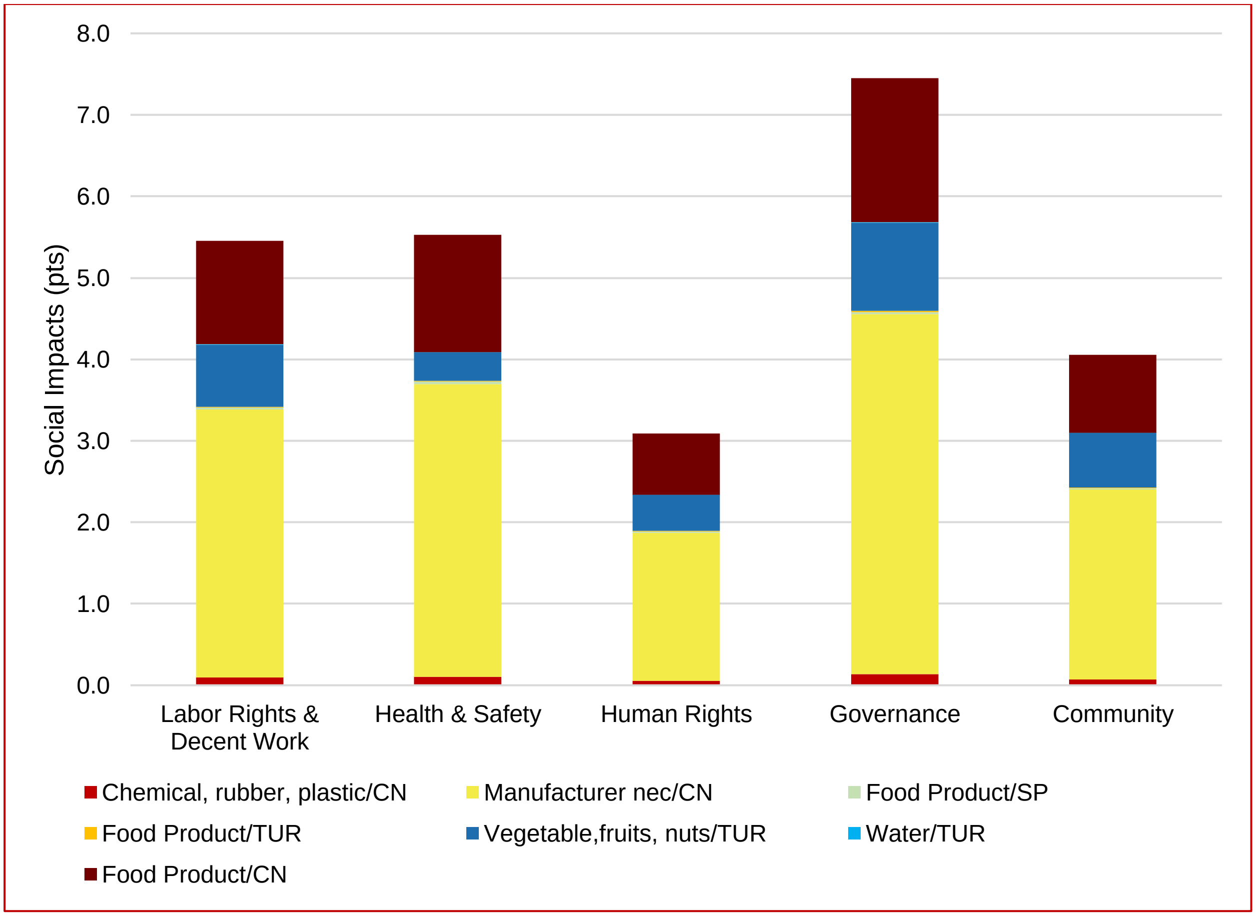


Figure 38. CSS contribution within Material group for one bottled and packed sauce production.

Within Material group, the most relevant CSS are the Packaging (Cardboard Boxes, Cardboard Separator and Glass Bottles & Jars). Packaging is represented by the Chinese Manufacturer (yellow colour). The second most relevant group is the Raw Materials (Pea Protein & Tomatoes), represented by the Chinese Food Products sector (shown in brown) and the Vegetable, Fruit & nuts Turkish sector (dark blue).

For the category Labour Force, no further chart was plotted, since 100% of the impact is all from the same CSS Turkish sector.

Sauce Production S-LCA Results

Table 47 and **Figure 39** depict the social impact of the production of one already packed bottle of functionalized tomato sauce.

Table 47. Social impact categories per group for bottle and packed sauce production

Group	Labor Rights & Decent Work	Health & Safety	Human Rights	Governance	Community	Total
Materials	3.86E+00	3.89E+00	2.17E+00	5.28E+00	3.21E+00	**1.84E+01**
Labour force	8.92E-02	7.45E-02	5.35E-02	1.21E-01	6.96E-02	**4.08E-01**
Utilities	6.18E-02	6.95E-02	3.88E-02	8.90E-02	4.64E-02	**3.06E-01**
Infrastructure and equipment	5.26E-01	5.19E-01	2.76E-01	6.75E-01	3.44E-01	**2.34E+00**
Financial, business, distribution and trade services	1.34E-01	7.65E-02	7.60E-02	1.84E-01	9.85E-02	**5.69E-01**
Plant Overhead	4.30E-02	3.04E-02	2.45E-02	5.92E-02	3.33E-02	**1.90E-01**
Total Per Group	**4.71E+00**	**4.66E+00**	**2.64E+00**	**6.41E+00**	**3.81E+00**	**2.22E+0€€1**

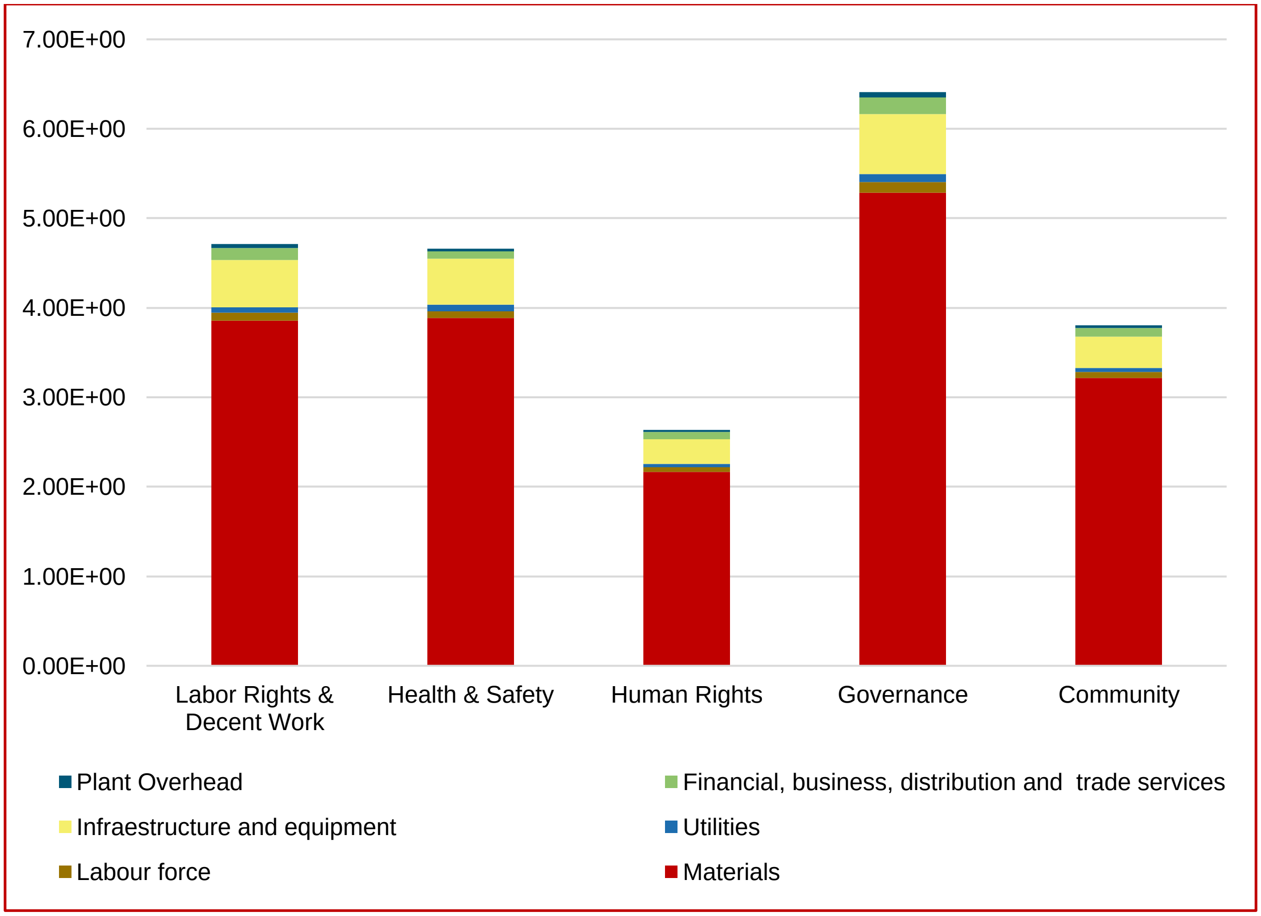


Figure 39. Contribution of each group within the social impacts to produce one bottled and packed sauce production.

Furthermore, the social impact subcategories have also been assessed in order to recognise major social impact contributions (**Figure 40**).

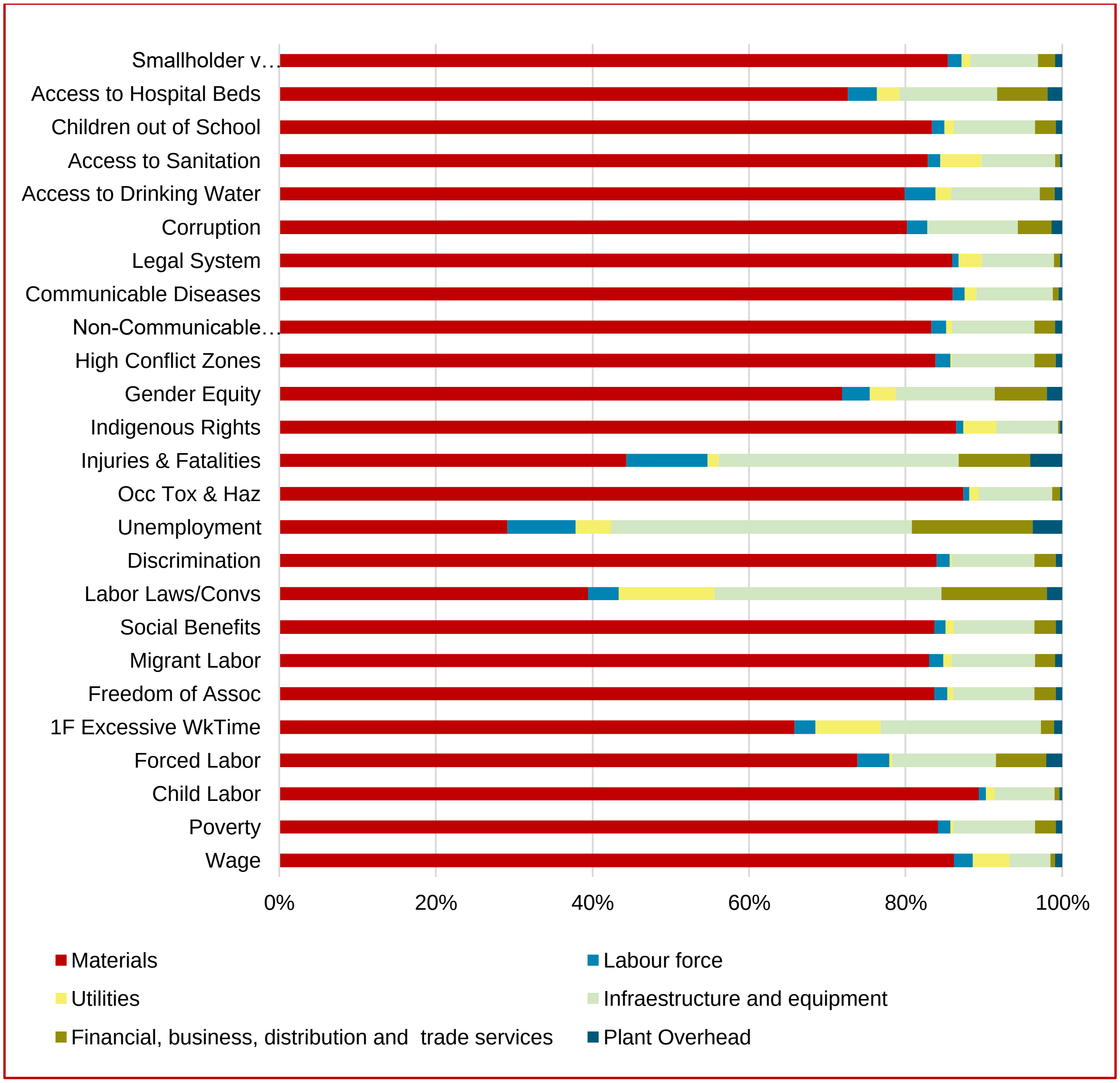


Figure 40. Share contribution of the sub-categories per group for the production of one bottled and packed sauce

Analogously to **Figure 37**, the **Figure 41** presents the comparison between the SHI share and the cost share, in order to identify social hotspots.

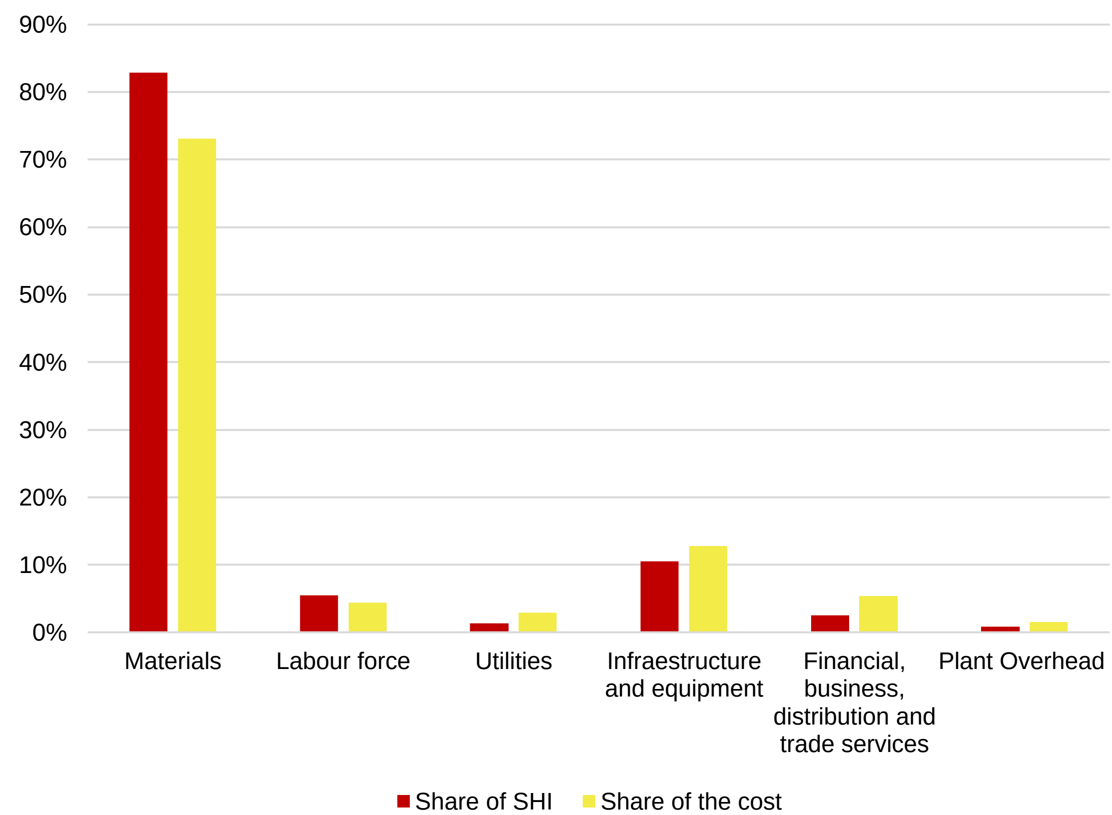


Figure 41. Share of SHI vs share of cost for the production of one bottled and packed sauce.

Similar to the juice case, the sauce production has the Materials component as the major social impact contributor, followed by I&E and LF. **Table 47** & **Figure 39** highlight the relevance of the Materials group related to the other categories. Furthermore, **Figure 40** shows the impact distribution for one packed sauce jar regarding the sub-categories, where the Materials group is, once again, the largest contributor.

Similarly to the tomato juice case production, Materials are the highest impact components throughout all the impact categories. Materials average a contribution between 82-84 %. Furthermore, materials are the most relevant components in the sub-category group with a contribution that ranges from 25% to 90% depending on the category. Once again, the results are justified according to the expenditure levels of this item, and Material components constitute a clear social hotspot.

I&E is the second most component for the sauce production. Throughout all the social categories, the I&E has an impact that ranges from 9%-11% depending on the category. Furthermore, for the subcategories, the same tendency as in the juice production case is observed. The contribution ranges from 8% to 30% depending on the sub-category under assessment. Unemployment is the most contributing sub-category. I&E is not considered as a social hotspot according to the outputs shown in **Figure 41**.

LF is considered as the third most relevant component within the S-LCI for the sauce. LF has an average contribution of 1% within all the categories. Within the subcategories, LF constitutes the 1-2% of the social impacts. Nevertheless, the LF is considered as a social hotspot, since the SHI share is lower than the share cost.

Categories such as Utilities, Financial, Business, Distribution & Trade services and Plant Overhead Costs do not represent a social threat due to their low impact.

Since the Materials are, as in the juice case, the major impact contributor, a detailed analysis of the CSS was made. **Figure 42** shows the impact of each CSS within the Material category.

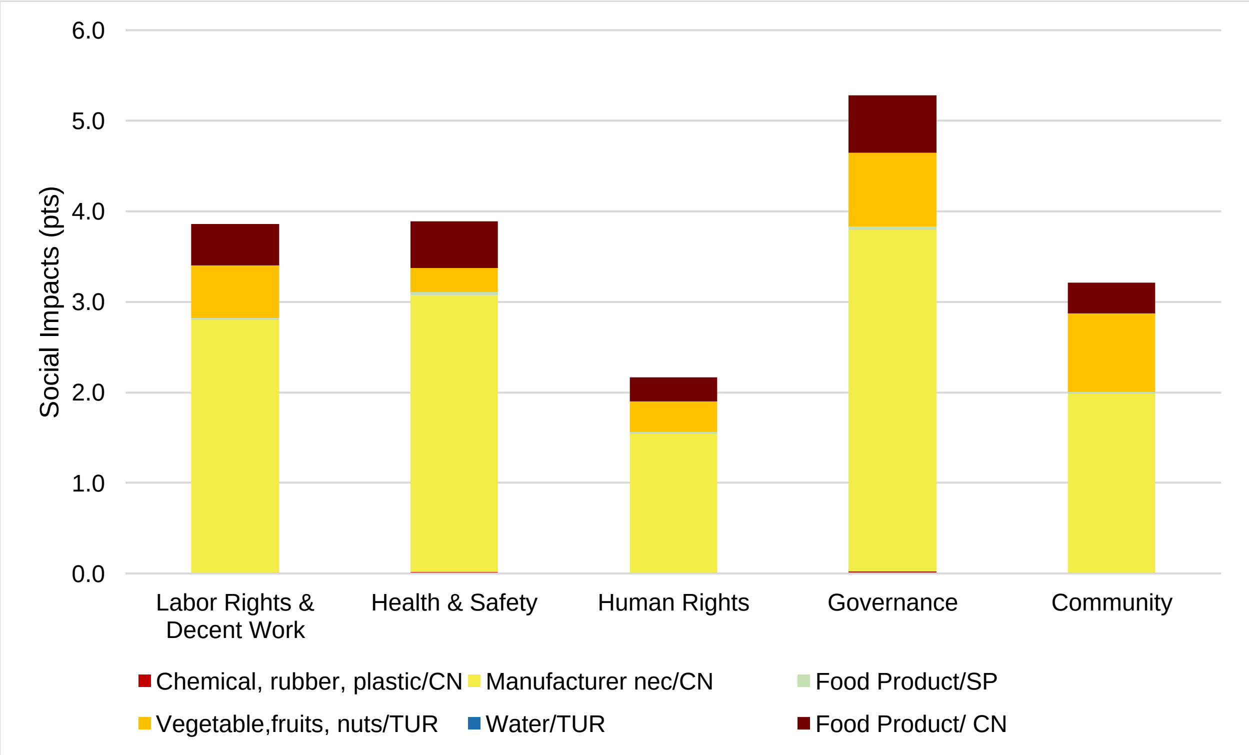


Figure 42. CSS contribution within Materials group for one bottled and packed sauce production.

As in the tomato juice case, Packaging (Cardboard boxes, Cardboard Separators and Glass Bottles & Jars) and Raw Materials (Pea Protein and Tomatoes) are the most relevant components when assessing at the production of the sauce.

For the Labour Force, no further chart was designed, since 100% of the impact corresponds to the selected Turkish CSS.

5.4. Interpretation of the results

The results obtained in the section 5.3 are analysed and interpreted in this section. Since both products have similar results, such as hotspots and crucial CSS, the interpretation has been done at the same time, resembling the differences between both cases.

Results have clearly demonstrated that the major social threat within the process is the Materials group, where two sub-groups are considered for both products: Raw Materials and Packaging. Furthermore, Labour Force and Construction will also be assessed briefly as they were also found to be social hotspots to a lesser extent.

Raw materials

Raw Materials has demonstrated to be a crucial asset within the current SLCA. The percentage contribution to the Raw Material category is 15%,14% and 16% for Governance, Human Rights and Community, respectively. In the case of the sauce, it is split into a 15%, 15% and 27%, respectively.

Pea protein is one of the most relevant items in terms of social impacts within the Materials group. Pea protein ranges throughout the impact categories with a contribution between 24-26%, in the juice case, and 12-14%, in the case of the sauce. Since the pea protein is produced in China, the Chinese manufacturing sector has been assessed from a labour and social approach.

Chinese labour market has several limitations towards the quality of the employee-employer bond. Several enterprises avoid having a formal labour relationship. Different techniques such as: registration as independent self-employed workers, signing agreements that are not real labour contracts, or labour outsourcing are common practices in the Chinese work market. These actions impact on the taskforce mass at a level of health and safety insurance, retirement wages or access to loans. [21]

Food manufacturing tends to reallocate the population. Hence, massive internal migration waves have occurred in China, affecting and stressing the supply chain from the farms to the cities. By 2010, according to Chinese census, 261 million people were not working at their birthplaces [22].

Since the access to detailed information towards working conditions in the Chinese pea protein industry was not accesible, limited recommendations can be made. FunTomP should assure that their protein suppliers fulfil rigorous work contracts in line with the international status. This way several impacts might be mitigated such as: Governance and Labour Rights & Decent Work for both products. If the case is so, more reliable sources of protein might be tested for implementation within the project.

The second most contributing impact is related to tomato production, which has been modelled as the agricultural Turkish economic sector. The relevant impact is mainly due to the high consumption of tomatoes planted in Türkiye, since annual consumption rate is around 20 000 tonnes for both products. Commonly, the agricultural sectors are prone to enable low quality work conditions due to the nature of the work arrangements done within the field. Social security benefits, formal jobs, avoided taxation and low paid wages are some of the most common problems within agriculture job market [23].

The Turkish agricultural sector is not the exception to this reality. 85% of the agricultural employment in Türkiye is informal, while the global average is 30%. Furthermore, the migrations of Syrians due the civil war occurring in their country offers a taskforce in the need for income with no minimal requirements for a high-quality job [23].

Wage within the agricultural Turkish field is also a crucial matter. For Turkish male workers the wage is surrounding 130 TRL per hour (3.64 € per hour) while the national minimum is 140 TRL per hour (3.98 € per hour). Furthermore, gender gap also persists regarding the salary. Women are reported to earn 9.1 TRL per hour (0.25 € per hour) less than men per day on average. Furthermore, this situation is even worse for the refugees working on the farms [23].

This reality is reflected throughout all the categories of the social indicators herein informed, where the tomatoes have a higher impact than other raw materials, like the olives. Within the Raw Materials, the Governance indicator is an important impact category. For the total Raw Material social impact on the governance category 37% is attributed to the tomatoes. While in the sauce represents 55% of the Raw Material contribution in the same impact category. This high impact for the tomatoes might come from tax's unpayments from the agricultural sector due the arrangements between the employers and employees. Additionally, the underpayment of work tasks might contribute to a high social footprint.

The impact of the tomato production may be diminished if it would have certain guarantees for the taskforce. Purchasing tomatoes produced with all the legal and economic measured aligned with the government and international policies could be translated into a better social footprint. This is applicable to both of the products.

Specifically, these measures may lead to a diminish in relevant impact categories within the Materials such as: Governance, Human Rights and Community.

Packaging

The Packaging group has a major impact. This group is formed by items like Pallets, Cardboard Boxes, Glass Bottle & Jars and Cardboard Separators. Carboard and Glass represent 97% of the Packaging impact in the juice case, and 99% of the Packaging impact in the sauce case. These items are mainly manufactured Chinese goods. Therefore, they have been modelled under the CSS Manufacturer nec/CN.

As beforementioned, at a general view, manufacture good production in China has challenges regarding the working conditions. However, no clear information regarding the Glass and Cardboard manufacturing sector has been found, therefore approximations were considered in other to fulfil the gap. China Labor Watch (CLW) has written a report where the cartridge sector has several challenges such as: employment of underage workers, discrimination of ethnic groups, denying of earned wages and sick leaves, unpaid overtime, inadequate health and safety conditions, among other violations [24]. This report is just one example of China Labor Watch's work to increase transparency of supply chains in China and defend workers' rights. In the context of FunTomP, it is recommended to check rigorously the packaging suppliers to ensure that national and international labour laws are respected.

Labour Force

Labour force has been determined as another hotspot. This was established since the share of the SHI is higher than the cost share for the juice (4.98% vs 2.86%) and sauce (5.49% vs 4.34%). In this case, 100% of the contribution has been allocated to the Turkish manufacturing sector.

Türkiye has challenges when it comes to working conditions. As mentioned before, low wages are present in the agricultural sector and the average informal labour is at a high rate, near 30% [23]. Nevertheless, this assessment is based on average values of CSS from the SHDB, therefore this should be taken as indicator rather than a conclusion.

The recommended upcoming step is to fulfil a specific assessment to check if the before mentioned risks are real. If so, mitigation steps should be taken in accordance with the discussion herein provided.

Infrastructure and Equipment

Despite not being a social hotspot, the Infrastructure and Equipment group has relevance since is the second biggest expenditure after the Materials, for both products. In the case of the sauce, it represents 10.5% of the SHI share and 12.8% for the cost share. While in the case of the juice, SHI share is 7,84% and the share cost is 9.97%. Infrastructure and Equipment have two contributors: Construction and Equipment sub-groups. Turkish construction/ sector and financial services sector represents the Construction sub-group. On the other hand, Equipment is represented as machinery production from China and Türkiye, metal production in Türkiye and insurance Turkish sector. The most important sectors are Turkish construction sector and machinery and equipment Chinese sector throughout all the impact categories, for Construction and Equipment sub-groups.

Turkish construction field has several challenges to be highlighted. According to the consulted bibliography, task force has struggled with several social threats in the workplace. Issues like unfair salary, overtime working hours, equality, discrimination, health and safety are social matters that had been identified in accordance with the consulted author.[25]

From the employers' side, access to beneficial state policies is not reachable for every entrepreneur. This aspect added to the high inflation experienced in the construction field, might impact negatively in the work generation within the sector and the conditions of the offered jobs.[25]

Manufacture working conditions were considered for the equipment and machinery sector in China. As depicted in Packaging and Raw materials sub-group, informal labour, low wages and health and safety issues were identified. [23] [20]

These assets impact directly in the social categories herein assessed and should be taken into account at the moment of selecting suppliers of construction services in Türkiye or the equipment purchasing in China. The selection of suppliers that grant freedom of association, decent job and decent wages should be prioritized. Categories like, Labour Rights & Decent Work and Health & Safety could reduce their social footprint with a responsible approach taken.

6. CONCLUSIONS

The present document has assessed the three dimensions of the sustainability in order to identify challenges, barriers and opportunities for the FunTomP project, aligning with the ISO 14040/14044 methodology.

After completing the full LCA analysis at a laboratory scale, main hotspots were identified within the selected impact categories. Main **environmental impacts** were found to be attributed to the electricity consumption and the glass packaging, for both tomato liquid products. Several processing steps, including crushing and heating (hot break and cold break), freeze drying of the olive powder and the HPH contribute significantly to the environmental impacts due to their high electricity demand. Glass packaging, including the bottle and the jar, also plays a major role in the overall impacts. As an example, within these processes, HPH, glass production and olive powder production were the most contributively ones with 0.42, 0.27 and 0.23 kg-eq $CO_{2,}$ per 225 ml bottle, respectively.

Regarding the tomato sauce case, a similar approach has been developed, resulting in similar outcomes. Once again HPH, olive powder production and glass jar are the main contributor processes. Hot break tomato process appears as a particular relevant asset of the sauce production. For HPH and hot breaking, electricity is the main contributor asset. Since olive powder production is the same as the in the juice production the impacts are equivalent. In numbers, global warming impact category for HPH, hot breaking, olive powder an jar glasses were accounted at: 0.53, 0.50 ,0.30 and 0.17 kg-eq $CO_{2,}$ per 300 ml jar, respectively.

Tomato production has also been a relevant asset for cold and hot tomato break within the LU and WC category. Such impacts are translated to endpoint category damage ecosystems. Specifically, regarding the WC negative values have been identified related to the washing treatment of tomatoes. This water will be treated and reuse in downstream process and therefore has a negative contribution to environmental impacts

Furthermore, a sensitivity analysis was crafted for both products. This sensitivity analysis was based on two main relevant assets: electricity and packaging selection. For electricity, a dataset with more sustainable energy source was modelled with interesting results. Particularly, for a replacement of 50% of the fossil fuel by hydropower in the juice production, a sustained reduction between 20-50% was observed throughout the assessed impact categories. In the tomato sauce case, the observed reduction under the same scenario was between 30%-50%. The only exception for both cases was the WC, since the selected renewable energy source was hydropower technology.

Regarding recycled glass higher contribution to jars, an increase from 57-70% has been modelled, not offering promising results. Therefore, as an exercise for the tomato juice case, the glass bottle was substituted with a Tetra Pak packaging, with showed relevant improvements.

To sum up, a thorough analysis has been made from an environmental point of view for both products. Similar results were obtained for both products, being electricity and glass the major assets impacting throughout the categories. Processes like cold/hot baking of tomatoes, HPH, and olive powder where also hotspots within the analysis. Finally, it is recommended to replace fossil fuel-based electricity with renewable source electricity, since interesting environmental results can be achieved. Furthermore, the glass bottling has demonstrated to be unsatisfactory from the environmental point of view and alternative packaging should be considered within FunTomP project, such as Tetra Pak.

Economic sustainability of the FunTomP project has been assessed within the LCC methodology at an industrial case scenario. With a sale price of 1.34 €/kg for the tomato juice all scenarios proved an unprofitable performance of all the economic indicators assessed (ROI, NPV, DCFR and PP). Therefore, a sale price re-calculation was made in order to estimate a sale price that will enable to yield a PP of 3 years. The result is a price sale set in 1.57 €/kg. Tomato Sauce case was also assessed, with a sale price of 3.07 €/kg. In the sauce case, good performance indicators where obtained.

The study was complemented with a sensitivity analysis was conducted for both products. In the tomato juice case, the optimistic case was set with a sale price of 1.68 €/kg. On the other hand, the pessimistic case was set in a tomato juice sale price of 1.46 €/kg. The results showed that the optimistic case demonstrated interesting ROI rates, high NPV and consistent DCFR at the same time PP was shorter than one year. Therefore, a good economic performance was achieved. By contrast, the pessimistic case showed bad economic performance, with unsustainable results.

Therefore, despite the showing good performances at sale prices above 1.57 €/kg, economic performance is compromised when slight down price variations occur.

In the same line, a sensitivity analysis was also conducted for the tomato sauce production case. Since good results were obtained for the Average case, five cases were assessed for the sauce production. Very Optimistic, with a sale price of 4.62 €/kg, Optimistic with a sale price of 3.29 €/kg, Pessimistic with a sale price of 2.85 €/kg and Very Pessimistic with a sale price of 1.70. The results were satisfactory, showing robustness towards sale price variation.

After the economic analysis was completed, the industrial partners provided the actual sale price for both products. Tomato juice has a sale price of 1.87 €/kg, and the tomato sauce has a sale price of 3.9 €/kg. Therefore, the expected economic results for the LCC should be similar to the Optimistic tomato juice case and the Very Optimistic tomato sauce case.

In conclusion, the results underscore a twofold result. First, the unprofitability of the juice production at the sale price of 1.34 €/kg from all the indicators herein assessed. Furthermore, despite the proposed sale price of 1.57 €/kg is economically feasible, the sensitivity analysis has not furthered robustness toward sale price variation. Regarding the sauce production, all the indicators have demonstrated to have a good economic performance, which is translated to good financial results.

In the same line, **social dimension** has been measured with a S-LCA approach. The S-LCA has been conducted for the two products with similar outcomes when impacts and social hotspots are compared. Both products have shown high social impact shares related to Materials. These impacts are mainly given by three assets: glass bottles & Jars, cardboard production, and tomatoes. Working conditions have been proved to be the main cause of these three assets to impact so highly on the social footprint of tomato juice and tomato sauce. Unpayment of salaries, informality of the employer-employee relationship, underage taskforce hiring, or refugees' exploitation are some of the main issues these items have.

Furthermore, Labour Force related to the food manufacturing sector has been highlighted as a social hotspot in Türkiye. This is given by low salary, gaps on the gender equality in the workplace and high rates of informal unemployment.

Infrastructure & Equipment sector has also barriers and challenges to overcome. Despite not being a social hotspot, the cost share of the I&E is not negligible. Construction sector has issues related to unfair salaries, inequality, and excessive working hours. Furthermore, purchased equipment has a relevant social footprint due the working conditions in China.

Therefore, FunTomP project should prioritize not only the environmental and economic performance of the value chain, but also the social impacts at the background process of its supply chain. Since the characterization factors and the data from the SHDB is established as average values for each CSS, it is highly recommended to assess the supplier process to identify social risks and act in accordance to mitigate the social footprint. Efforts should be conducted towards economic already mentioned sector from China and Türkiye.

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8. ANNEXES

8.1. LCA Annex

Table 48. Overview of the ReCiPe midpoint impact categories and characterisation factors not presented in this work.

Impact category		Characterisation factors	Unit
Midpoint	Stratospheric ozone depletion	Ozone depletion potential	kg CFC-11 eq to air
	Ionizing radiation	Ionising radiation potential	kBq Co-60 eq to air
	Ozone formation, Human health	Ozone formation pot.: humans	kg NOx eq to air
	Ozone formation, Terrestrial ecosystems	Ozone formation pot.: ecosystems	kg NOx eq to air
	Terrestrial acidification	Terrestrial acidification potential	kg SO2 eq to air
	Freshwater eutrophication	Freshwater eutrophication potential	kg P eq to freshwater
	Marine eutrophication	Marine eutrophication potential	kg N eq to marine water
	Terrestrial ecotoxicity	Terrestrial ecotoxicity potential	kg 1,4-DCB eq to industrial soil
	Freshwater ecotoxicity	Freshwater ecotoxicity potential	kg 1,4-DCB eq to freshwater
	Marine ecotoxicity	Marine ecotoxicity potential	kg 1,4-DCB eq to marine water
	Human carcinogenic toxicity	Human toxicity potential	kg 1,4-DCB eq to urban air
	Human non-carcinogenic toxicity	Human toxicity potential, non-cancer effects	kg 1,4-DCB eq to urban air
	Mineral resource scarcity	Surplus ore potential	kg Cu eq

Table 49. Life cycle impacts obtained for tomato juice for the other ReCiPe categories. Functional unit: 225 mL of juice + packaging

Input/Output	Midpoints												
	SOD	IR	OFHH	OFTE	TA	FEu	MEu	TEc	FEc	MEc	HCT	HNCT	MRS
	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg Cu eq
Washing water	5.97E-10	1.02E-05	1.90E-06	1.94E-06	2.87E-06	5.18E-08	7.53E-09	1.28E-04	4.55E-08	1.46E-07	7.02E-07	4.70E-06	6.44E-06
Tomato powder	2.64E-08	6.98E-05	1.96E-04	1.97E-04	3.83E-04	9.49E-06	3.33E-07	3.07E-03	1.36E-06	3.91E-06	1.93E-06	8.94E-05	3.72E-05
Pea protein	1.33E-08	3.45E-06	4.68E-06	4.73E-06	3.35E-06	2.73E-07	8.35E-06	4.45E-03	1.47E-05	3.95E-05	1.99E-07	4.96E-06	3.11E-06
Olive powder	1.94E-07	3.08E-04	8.20E-04	3.00E-04	1.620E-03	1.31E-05	8.60E-05	1.63E-01	1.00E-04	3.56E-04	6.08E-05	4.49E-02	1.79E-04
Tomatoes – Cold break – Tomato pulp + supernatant	2.63E-07	2.16E-04	2.98E-04	3.01E-04	4.90E-04	1.31E-05	8.60E-05	1.63E-01	1.00E-04	3.56E-04	6.08E-05	4,49E-02	1,79E-04
Salt	1.548E-08	4.110E-05	1.152E-04	1.160E-04	2.255E-04	5.589E-06	1.738E-07	1.793E-03	7.786E-07	2.231E-06	1.120E-06	4.137E-05	2.187E-05
Packaging material – Glass bottle	1.66E-07	1.46E-03	8.54E-04	8.64E-04	1.47E-03	1.67E-04	2.67E-05	1.35E-01	9.43E-05	1.17E-04	1.20E-04	2.18E-03	2,01E-03
Packaging material – Tin lid	1.01E-08	1.65E-04	1.10E-04	1.14E-04	1.42E-04	1.60E-06	6.70E-07	2.72E+00	1.02E-04	2.37E-03	6.05E-03	2.16E-02	3,38E-03
Centrifugation	1.55E-08	4.11E-05	1.15E-04	1.16E-04	2.25E-04	5.59E-06	1.74E-07	1.79E-03	7.79E-07	2.23E-06	1.12E-06	4.14E-05	2.19E-05
Blending	1.29E-09	3.42E-06	9.60E-06	9.67E-06	1.88E-05	4.66E-07	1.45E-08	1.49E-04	6.49E-08	1.86E-07	9.33E-08	3.45E-06	1.82E-06
HPH	1.24E-07	3.29E-04	9.22E-04	9.28E-04	1.80E-03	4.47E-05	1.39E-06	1.43E-02	6.23E-06	1.78E-05	8.96E-06	3.31E-04	1.75E-04
Pasteurisation	3.10E-08	8.22E-05	2.30E-04	2.32E-04	4.51E-04	1.12E-05	3.48E-07	3.59E-03	1.56E-06	4.46E-06	2.24E-06	8.27E-05	4.37E-05
Transportation of fresh tomato/tomato juice	5.26E-09	4.45E-05	1.75E-05	1.77E-05	1.26E-05	7.70E-07	3.04E-09	1.05E-01	1.59E-05	7.51E-05	3.38E-06	1.48E-03	4.50E-07
Peel and seeds	6.22E-11	3.22E-08	3.80E-08	3.84E-08	5.58E-08	1.50E-09	2.22E-08	1.46E-05	2.16E-08	7.22E-08	1.45E-08	1.12E-05	3.98E-08
Tomatoes washing wastewater	1.65E-09	1.76E-05	7.25E-07	7.27E-07	2.16E-06	9.73E-07	4.67E-06	2.66E-05	2.86E-08	1.61E-04	6.22E-08	1.13E-05	1.26E-07
Pellet from centrifugation	4.51E-11	6.84E-08	1.66E-07	1.67E-07	3.20E-07	7.94E-09	8.11E-09	1.64E-05	1.38E-08	3.56E-08	7.98E-09	4.10E-06	4.18E-08

Table 50. Life cycle impacts obtained for tomato sauce for the other ReCiPe categories. Functional unit: 300 mL of sauce + packaging

Input/Output	Midpoints												
	SOD	**IR**	**OFHH**	**OFTE**	**TA**	**FEu**	**MEu**	**TEc**	**FEc**	**MEc**	**HCT**	**HNCT**	**MRS**
	kg CFC11 eq	**kBq Co-60 eq**	**kg NOx eq**	**kg NOx eq**	**kg SO_2 eq**	**kg P eq**	**kg N eq**	**kg 1,4-DCB**	**kg 1,4-DCB**	**kg 1,4-DCB**	**kg 1,4-DCB**	**kg 1,4-DCB**	**kg Cu eq**
Washing water	4.72E-10	8.07E-06	150E-06	1.53E-06	2.27E-06	4.09E-08	5.95E-09	1.01E-04	3.60E-08	1.15E-07	5.55E-07	3.71E-06	5.09E-06
Tomato powder	1.34E-08	3.41E-05	9.46E-05	9.53E-05	1.85E-04	4.59E-06	3.85E-07	2.12E-03	9.48E-07	2.97E-06	1.09E-06	1.63E-04	1.83E-05
Pea protein	3.33E-08	8.66E-06	1.18E-05	1.19E-05	8.41E-06	6.85E-07	2.10E-05	1.12E-02	3.70E-05	9.90E-05	4.98E-07	1.25E-05	7.81E-06
Olive powder	4.44E-07	7.06E-04	1.86E-03	1.88E-03	3.71E-03	8.99E-05	4.04E-05	1.01E-01	1.62E-04	1.83E-04	9.02E-05	2.82E-02	4.04E-04
Tomatoes – Hot break – Tomato pulp	2.20E-07	2.20E-04	3.16E-04	3.19E-04	5.34E-04	1.42E-05	6.81E-05	1.86E-01	8.83E-05	3.23E-04	5.05E-05	3.63E-02	1.56E-04
Packaging material – Glass jar	1.84E-07	1.62E-03	9.49E-04	9.61E-04	1.63E-03	1.86E-04	2.97E-05	1.50E-01	1.05E-04	1.30E-04	1.34E-04	2.42E-03	2.24E-03
Packaging material – Tin lid	1.88E-08	3.06E-04	2.05E-04	2.11E-04	2.64E-04	2.97E-06	1.24E-06	5.04E+00	1.90E-04	4.41E-03	1.12E-02	4.01E-02	6.28E-03
Blending	1.78E-09	4.72E-06	1.32E-05	1.33E-05	2.59E-05	6.42E-07	2.00E-08	2.06E-04	8.94E-08	2.56E-07	1.29E-07	4.75E-06	2.51E-06
HPH	1.56E-07	4.13E-04	1.16E-03	1.17E-03	2.27E-03	5.62E-05	1.75E-06	1.80E-02	7.83E-06	2.24E-05	1.13E-05	4.16E-04	2.20E-04
Pasteurisation	4.27E-08	1.13E-04	3.18E-04	3.20E-04	6.21E-04	1.54E-05	4.79E-07	4.94E-03	2.15E-06	6.15E-06	3.09E-06	1.14E-04	6.03E-05
Transportation of fresh tomato/tomato juice	6.96E-09	5.90E-05	2.31E-05	2.34E-05	1.67E-05	1.02E-06	4.03E-09	1.39E-01	2.11E-05	9.94E-05	4.48E-06	1.96E-03	5.95E-07
Peel and seeds	7.67E-10	7.67E-07	1.10E-06	1.11E-06	1.86E-06	4.94E-08	2.37E-07	6.48E-04	3.07E-07	1.12E-06	1.76E-07	1.26E-04	5.41E-07
Tomatoes washing wastewater	1.30E-09	1.39E-05	5.73E-07	5.74E-07	1.70E-06	7.68E-07	3.69E-06	2.10E-05	2.26E-08	1.27E-04	4.91E-08	8.93E-06	9.93E-08

8.2. LCC Annex

Operating labour costs

For both production cases. the operational labour costs were estimated from Figure 43Figure 43. For both juice and sauce processes. the total production per day was calculated and according to the type of process several employees was estimated. Figure 43 highlights the estimation with the chart.

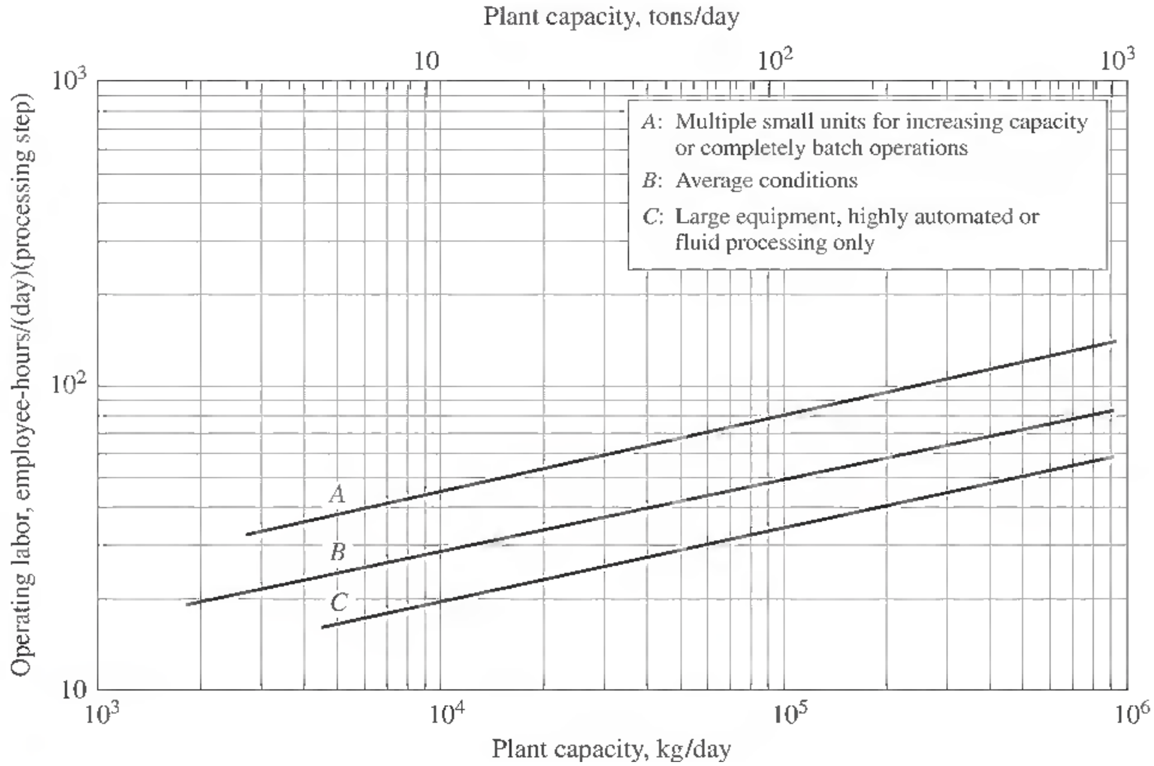

Figure 43. Operating labour expressed in employees-hour/day-step.(Peters et al. 2004)

Table 51. Employees-production correlation fused for the taskforce estimation.

Process	Type of process	Production (kg/day)	Employees-hours/day-steps
Tomato Juice	A	64 000	60
Tomato Sauce	A	70 144	80

JUICE PRODUCTION CASH FLOWS

Table 52. Cash flow calculation for the tomato juice production at a sale price of 1.37 €/kg.

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land (M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment	-0.44	-1.71	-4.02											-6.17
3. Working Capital (M€)			-1.08										1.08	0.00
4. Salvage Value(M€)													0.00	0.00
5. Total Capital Investment(M€)	-0.44	-1.71	-5.10											-7.25
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.62										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				26.09	55.02	71.62	83.90	98.29	115.14	134.88	158.01	185.10	216.84	1144.89
10. Annual Total Product Cost. depreciation <u>not</u> included (M€)				-28.36	-55.10	-72.51	-87.11	-104.65	-125.72	-151.04	-181.44	-217.98	-261.86	-1285.78
11. Annual depreciation factor				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.62	1.11	0.89	0.71	0.57	0.45	0.40	0.40	0.40	0.61	6.17
13. Annual Gross Profit (M€)				-3.49	-1.19	-1.78	-3.92	-6.94	-11.04	-16.56	-23.84	-33.28	-45.63	-147.69
14. Annual Net Profit (M€)				-3.49	-1.19	-1.78	-3.92	-6.94	-11.04	-16.56	-23.84	-33.28	-45.63	-147.69
15. Annual operating cash Flow (M€)				-2.88	-0.08	-0.89	-3.21	-6.37	-10.59	-16.16	-23.44	-32.88	-45.03	-141.51
16. Total annual cash flow (M€)	-0.44	-1.71	-5.10	-2.88	-0.08	-0.89	-3.21	-6.37	-10.59	-16.16	-23.44	-32.88	-45.03	-148.77
17. Cumulative cash position (M€)	-0.44	-2.15	-7.25	-10.13	-10.21	-11.10	-14.32	-20.68	-31.27	-47.42	-70.86	-103.74	-148.77	

Table 53. Cash flow calculation for the tomato juice production at a sale price of 1.57 €/kg.

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land (M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment (M€)	-0.44	-1.71	-4.02											-6.17
3. Working Capital (M€)			-1.08										1.08	0.00
4. Salvage Value (M€)													0.00	0.00
5. Total Capital Investment (M€)	-0.44	-1.71	-5.10											-7.25
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.62										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				29.98	63.22	82.29	96.40	112.93	132.29	154.97	181.54	212.67	249.13	1315.41
10. Annual Total Product Cost. depreciation not included (M€)				-28.36	-55.10	-72.51	-87.11	-104.65	-125.72	-151.04	-181.44	-217.98	-261.86	-1285.78
11. Annual depreciation factor				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.62	1.11	0.89	0.71	0.57	0.45	0.40	0.40	0.40	0.61	6.17
13. Annual Gross Profit (M€)				0.39	7.01	8.88	8.57	7.70	6.11	3.53	-0.31	-5.71	-13.34	22.84
14. Annual Net Profit (M€)				0.31	5.61	7.11	6.86	6.16	4.89	2.82	-0.31	-5.71	-13.34	14.40
15. Annual operating cash flow (M€)				0.93	6.72	8.00	7.57	6.73	5.34	3.23	0.10	-5.31	-12.73	20.57
16. Total annual cash flow(M€)	-0.44	-1.71	-5.10	0.93	6.72	8.00	7.57	6.73	5.34	3.23	0.10	-5.31	-12.73	13.32
17. Cumulative cash position (M€)	-0.44	-2.15	-7.25	-6.32	0.39	8.39	15.96	22.69	28.03	31.26	31.36	26.05	13.32	

Table 54.Cash flow calculation for the tomato juice production at pessimistic case (1.46 €/kg).

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land(M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment (M€)	-0.44	-1.71	-4.02											-6.17
3. Working Capital (M€)			-1.08										1.08	0.00
4. Salvage Value (M€)													0.00	0.00
5. Total Capital Investment (M€)	-0.44	-1.71	-5.10											-7.25
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.62										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				28.07	59.18	77.03	90.24	105.71	123.83	145.06	169.94	199.08	233.21	1231.34
10. Annual Total Product Cost. depreciation not included (M€)				-28.36	-55.10	-72.51	-87.11	-104.65	-125.72	-151.04	-181.44	-217.98	-261.86	-1285.78
11. Annual depreciation factor				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.62	1.11	0.89	0.71	0.57	0.45	0.40	0.40	0.40	0.61	6.17
13. Annual Gross Profit (M€)				-1.52	2.97	3.63	2.41	0.49	-2.35	-6.38	-11.91	-19.30	-29.26	-61.23
14. Annual Net Profit (M€)				-1.52	2.37	2.90	1.93	0.39	-2.35	-6.38	-11.91	-19.30	-29.26	-63.13
15. Annual operating cash flow (M€)				-0.91	3.48	3.79	2.64	0.96	-1.89	-5.97	-11.51	-18.90	-28.65	-56.96
16. Total annual cash flow (M€)	-0.44	-1.71	-5.10	-0.91	3.48	3.79	2.64	0.96	-1.89	-5.97	-11.51	-18.90	-28.65	-64.21
17. Cumulative cash position (M€)	-0.44	-2.15	-7.25	-8.16	-4.68	-0.89	1.75	2.71	0.82	-5.15	-16.66	-35.56	-64.21	

Table 55. Cash flow calculation for the tomato juice production at optimistic case (Sale price:1.68 €/kg).

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land (M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment(M€)	-0.44	-1.71	-4.02											-6.17
3. Working Capital (M€)			-1.08										1.08	0.00
4. Salvage Value (M€)													0.00	0.00
5. Total Capital Investment (M€)	-0.44	-1.71	-5.10											-7.25
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.62										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				31.90	67.26	87.55	102.56	120.14	140.74	164.87	193.14	226.26	265.05	1399.48
10. Annual Total Product Cost. depreciation not included (M€)				-28.36	-55.10	-72.51	-87.11	-104.65	-125.72	-151.04	-181.44	-217.98	-261.86	-1285.78
11. Annual depreciation factor				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.62	1.11	0.89	0.71	0.57	0.45	0.40	0.40	0.40	0.61	6.17
13. Annual Gross Profit (M€)				2.31	11.05	14.14	14.73	14.92	14.56	13.43	11.29	7.88	2.59	106.91
14. Annual Net Profit (M€)				1.85	8.84	11.32	11.79	11.94	11.65	10.75	9.04	6.30	2.07	85.53
15. Annual operating cash flow (M€)				2.46	9.95	12.20	12.50	12.51	12.11	11.15	9.44	6.71	2.68	91.70
16. Total annual cash flow (M€)	-0.44	-1.71	-5.10	2.46	9.95	12.20	12.50	12.51	12.11	11.15	9.44	6.71	2.68	84.45
17. Cumulative cash position (M€)	-0.44	-2.15	-7.25	-4.79	5.16	17.36	29.86	42.37	54.47	65.62	75.06	81.77	84.45	

SAUCE PRODUCTION CASH FLOWS

Table 56. Cash flow calculation for the tomato sauce production at a sale price of 3.07 €/kg.

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land (M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment (M€)	-0.52	-1.99	-4.70											-7.21
3. Working Capital (M€)			-1.27										1.27	0.00
4. Salvage Value (M€)													0.00	0.00
5. Total Capital Investment (M€)	-0.52	-1.99	-5.97											-8.49
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.72										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				54.25	114.39	148.90	174.43	204.33	239.37	280.41	328.49	384.81	450.79	2380.18
10. Annual Total Product Cost. depreciation <u>not</u> included (M€)				-25.85	-49.71	-65.33	-78.48	-94.28	-113.26	-136.06	-163.45	-196.36	-235.90	-1158.68
11. Annual depreciation factor				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.72	1.30	1.04	0.83	0.66	0.53	0.47	0.47	0.47	0.71	7.21
13. Annual Gross Profit (M€)				26.96	63.38	82.53	95.12	109.39	125.58	143.88	164.56	187.98	214.18	1213.56
14. Annual Net Profit (M€)				21.56	50.71	66.03	76.09	87.51	100.46	115.10	131.65	150.38	171.35	970.85
15. Annual operating cash flow (M€)				22.29	52.00	67.07	76.93	88.18	100.99	115.57	132.12	150.85	172.06	978.06
16. Total annual cash flow (M€)	-0.52	-1.99	-5.97	22.29	52.00	67.07	76.93	88.18	100.99	115.57	132.12	150.85	172.06	969.58
17. Cumulative cash position (M€)	-0.52	-2.51	-8.49	13.80	65.80	132.87	209.79	297.97	398.97	514.54	646.66	797.52	969.58	

Table 57. Cash flow calculation for the tomato sauce production at very pessimistic case (Sale price: 1.70 €/kg)

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land (M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment (M€)	-0.52	-1.99	-4.70											-7.21
3. Working Capital (M€)			-1.27										1.27	0.00
4. Salvage Value (M€)													0.00	0.00
5. Total Capital Investment (M€)	-0.52	-1.99	-5.97											-8.49
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.72										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				30.09	63.45	82.58	96.74	113.33	132.76	155.53	182.19	213.43	250.02	1320.12
10. Annual Total Product Cost. depreciation not included (M€)				-25.85	-49.71	-65.33	-78.48	-94.28	-113.26	-136.06	-163.45	-196.36	-235.90	-1158.68
11. Annual depreciation factor				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.72	1.30	1.04	0.83	0.66	0.53	0.47	0.47	0.47	0.71	7.21
13. Annual Gross Profit (M€)				2.79	12.43	16.22	17.43	18.39	18.97	18.99	18.26	16.59	13.42	153.51
14. Annual Net Profit (M€)				2.24	9.95	12.98	13.95	14.71	15.18	15.19	14.61	13.27	10.73	122.81
15. Annual operating cash flow (M€)				2.96	11.25	14.01	14.78	15.38	15.71	15.67	15.08	13.75	11.44	130.02
16. Total annual cash flow (M€)	-0.52	-1.99	-5.97	2.96	11.25	14.01	14.78	15.38	15.71	15.67	15.08	13.75	11.44	121.53
17. Cumulative cash position (M€)	-0.52	-2.51	-8.49	-5.53	5.72	19.73	34.51	49.89	65.59	81.26	96.34	110.09	121.53	

Table 58. Cash flow calculation for the tomato sauce production at pessimistic case (Sale price: 2.85 €/kg)

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land (M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment (M€)	-0.52	-1.99	-4.70											-7.21
3. Working Capital (M€)			-1.27										1.27	0.00
4. Salvage Value (M€)													0.00	0.00
5. Total Capital Investment (M€)	-0.52	-1.99	-5.97											-8.49
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.72										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				50.38	106.22	138.26	161.97	189.74	222.27	260.38	305.03	357.33	418.59	2210.16
10. Annual Total Product Cost. depreciation not included (M€)				-25.85	-49.71	-65.33	-78.48	-94.28	-113.26	-136.06	-163.45	-196.36	-235.90	-1158.68
11. Annual depreciation factor				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.72	1.30	1.04	0.83	0.66	0.53	0.47	0.47	0.47	0.71	7.21
13. Annual Gross Profit (M€)				23.08	55.21	71.90	82.66	94.80	108.48	123.85	141.10	160.49	181.99	1043.55
14. Annual Net Profit (M€)				18.46	44.17	57.52	66.13	75.84	86.78	99.08	112.88	128.39	145.59	834.84
15. Annual operating cash flow (M€)				19.19	45.47	58.56	66.96	76.50	87.32	99.55	113.35	128.86	146.30	842.05
16. Total annual cash flow (M€)	-0.52	-1.99	-5.97	19.19	45.47	58.56	66.96	76.50	87.32	99.55	113.35	128.86	146.30	833.57
17. Cumulative cash position (M€)	-0.52	-2.51	-8.49	10.70	56.17	114.72	181.68	258.18	345.50	445.05	558.40	687.27	833.57	

Table 59. Cash flow calculation for the tomato sauce production at optimistic case (Sale price: 3.29 €/kg)

Item	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment (M€)	-0.52	-1.99	-4.70											-7.21
3. Working Capital(M€)			-1.27										1.27	0.00
4. Salvage Value(M€)													0.00	0.00
5. Total Capital Investment(M€)	-0.52	-1.99	-5.97											-8.49
6. Annual Investment(M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost(M€)				-0.72										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales(M€)				58.13	122.56	159.53	186.89	218.93	256.47	300.44	351.95	412.30	482.99	2550.19
10. Annual Total Product Cost. depreciation not included(M€)				-25.85	-49.71	-65.33	-78.48	-94.28	-113.26	-136.06	-163.45	-196.36	-235.90	-1158.68
11. Annual depreciation factor. 1/y				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation(M€)/y				0.72	1.30	1.04	0.83	0.66	0.53	0.47	0.47	0.47	0.71	7.21
13. Annual Gross Profit(M€)				30.83	71.55	93.17	107.58	123.99	142.68	163.91	188.03	215.46	246.38	1383.57
14. Annual Net Profit(M€)				24.66	57.24	74.53	86.06	99.19	114.14	131.13	150.42	172.37	197.11	1106.86
15. Annual operating cash flow.$10^6$$				25.39	58.54	75.57	86.89	99.85	114.67	131.60	150.89	172.84	197.82	1114.07
16. Total annual cash flow(M€)	-0.52	-1.99	-5.97	25.39	58.54	75.57	86.89	99.85	114.67	131.60	150.89	172.84	197.82	1105.59
17. Cumulative cash position(M€)	-0.52	-2.51	-8.49	16.90	75.44	151.01	237.91	337.76	452.43	584.03	734.93	907.77	1105.59	

Table 60. Cash flow calculation for the tomato sauce production at a very optimistic case (Sale price: 4.62 €/kg)

	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Sum
1. Land (M€)	0.00	0.00	0.00										0.00	0.00
2. Fixed Capital Investment (M€)	-0.52	-1.99	-4.70											-7.21
3. Working Capital (M€)			-1.27										1.27	0.00
4. Salvage Value (M€)													0.00	0.00
5. Total Capital Investment (M€)	-0.52	-1.99	-5.97											-8.49
6. Annual Investment (M€)				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. Start-up cost (M€)				-0.72										
8. Operating rate. fraction of capacity				0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
9. Annual sales (M€)				81.53	171.92	223.78	262.15	307.09	359.75	421.43	493.69	578.33	677.50	3577.16
10. Annual Total Product Cost. depreciation not included (M€)				-25.85	-49.71	-65.33	-78.48	-94.28	-113.26	-136.06	-163.45	-196.36	-235.90	-1158.68
11. Annual depreciation factor. 1/y				0.10	0.18	0.14	0.12	0.09	0.07	0.07	0.07	0.07	0.10	
12. Annual depreciation (M€)				0.72	1.30	1.04	0.83	0.66	0.53	0.47	0.47	0.47	0.71	7.21
13. Annual Gross Profit (M€)				54.24	120.91	157.41	182.84	212.15	245.96	284.90	329.76	381.50	440.89	2410.54
14. Annual Net Profit (M€)				43.39	96.73	125.93	146.27	169.72	196.77	227.92	263.81	305.20	352.71	1928.44
15. Annual operating cash flow. (M€)				44.11	98.03	126.97	147.10	170.39	197.30	228.39	264.28	305.67	353.42	1935.65
16. Total annual cash flow (M€)	-0.52	-1.99	-5.97	44.11	98.03	126.97	147.10	170.39	197.30	228.39	264.28	305.67	353.42	1927.16
17. Cumulative cash position. (M€)	-0.52	-2.51	-8.49	35.63	133.65	260.62	407.72	578.11	775.40	1003.79	1268.07	1573.74	1927.16	

Table 61. Annual electricity consumption for olive powder production line

Olive Powder Production					
Process	**Equipment**	**Amount**	**Power Needed (kW)**	**Time Used (h/year)**	**Energy(kWh)**
Blending	Conveyor	1	3.2	16 025	51 282
	Crushing	2	7.5	37 560	563 400
	Mixer	1	11	55 088	605 968
High Pressure Homogenization	High Pressure Homogenizer	1	4	20 032	80 128
Freezing/Freeze Dryer	Freeze dryer	1	16.5	82 632	136 3428
Grinding	Grinder	1	35.8	179 286.4	6 418 453
SUB-TOTAL					**9 082 659**

Table 62. Annual electricity consumption for tomato powder line

Tomato Powder Production					
Process	**Equipment**	**Amount**	**Power Needed (kW)**	**Time Used (h/year)**	**Energy(kWh)**
Drying	Drier	1	7.5	37 560	281 700
Grinding	Grinder	1	35.80	179 286.4	6 418 453
Auxiliary services	Storage Tank	1	0	0	0
SUB-TOTAL					**6 700 153**

Table 63. Annual electricity consumption for tomato juice production

Process			Power (kW)	Hours(h/year)	Energy Consumed (kWh)
Sorting and washing	Conveyor	1	11.3	5008	56 590.4
	Sorting and Washer	4	3.2	5008	64 102.4
Crushing hot/cold break tomatoes	Turbo Extractor	8	2.2	5008	88 140.8
Centrifugation	Centrifuge	1	45	5008	225 360
Deration	Vacuum Degassing	2	4.5	5008	45 072
High Pressure Homogenization	High Pressure homogenizer	1	43	5008	215 344
Packing of Tomato Sauce	Bottle Juice filler	1	3	5008	15 024
	Labeller	2	17	5008	170 272
Pasteurization	Pasteurizer	3	15	5008	225 360
Packaging	Cardboard machine	1	5.5	5008	27 544
Auxiliary services	Pelletizer	1	1.5	5008	7 512
SUB-TOTAL					**1 140 284**

Table 64. Annual electricity consumption for tomato sauce production.

Process	Equipment	Amount	Power Needed (kW)	Time Used (h/year)	Energy(kWh)
Sorting and washing	Conveyor	1	11.3	5 008	56 590
	Sorting and washing	2	3.2	5 008	32 051
Hot breaking	Turbo Extractor	8	2.2	5 008	88 140.8
Sterilizer	Industrial Cooker	5	3.7	5 008	92 648
High Pressure Homogenization	High Pressure homogenizer	1	43	5 008	215 344
Packing of Tomato Sauce	Jar Juice filler	1	1.8	5 008	9 014
	Labeller	4	17	5 008	340 544
Pasteurization	Pasteurizer	3	15	5 008	225 360
Packaging	Cardboard machine	2	5.5	5 008	55 088
Drying	Dryer-Big	2	7.5	5 008	75 120
	Dryer-Small	1	7.5	5 008	37 560
Grinding	Grinder	4	138	5 008	2 764 416
Auxiliary services	Palleteizer	1	1.5	5 008	7 512
SUB-TOTAL					**3 999 389**

8.3. S-LCA Annex

SOCIAL LIFE CYCLE INVENTORY

TOMATO JUICE S-LCIA

Table 65. S-LCI of tomato juice production

Group	Sub-Group	Item	Industrial Sector	Country	Cost per FU (Cents @ 2011)	Cost distribution (%)	Subgroup Cost Distribution (%)	Cos Group Distribution (%)
Materials	Packaging	Pallets	Chemical. rubber. plastic	China	0.26	1.69%	52.34%	82.40%
		Cardboard Boxes	Manufacturer nec	China	0.06	0.37%		
		Glass Jar & Tap Tins	Manufacturer nec	China	6.0	37.64%		
		Cardboard separators	Manufacturer nec	China	1.9	12.65%		
	Raw Materials	Olive without seeds	Food Products	Spain	0.28	1.82%	30.06%	
		Salt	Food Products	Türkiye	0.050	0.33%		
		Tomatoes	Vegetable. fruits. nuts	Türkiye	0.21	13.69%		
		Tap Water	Water	Türkiye	6.1E-03	0.04%		
		Pea Protein	Food Products	China	2.2	14.19%		
Labour force	Labour force	Administration	Food Product/TUR	Türkiye	0.04	0.29%	2.86%	2.86%
		Research & Development	Food Product/TUR	Türkiye	0.2	1.31%		
		Operating supervision	Food Product/TUR	Türkiye	0.025	0.16%		
		Operating Labor	Food Product/TUR	Türkiye	0.17	1.09%		
Utilities	Utilities	Utilities	Electricity	Türkiye	0.26	1.72%	1.72%	1.72%
Infrastructure and equipment	Construction	Buildings	Construction	Türkiye	0.03	0.23%	2.32%	9.97%
		Construction expenses	Construction	Türkiye	0.04	0.27%		
		Contingency	Construction	Türkiye	0.04	0.29%		
	Construction	Contractor's fee	Construction	Türkiye	0.023	0.15%		
		Engineering and supervision	Construction	Türkiye	0.04	0.25%		
		Legal expenses	Construction	Türkiye	4.8E-03	0.03%		
		Service facilities	Construction	Türkiye	7.0E-3	0.43%		
		Working capital	Construction	Türkiye	9.0E-3	0.59%		
		Yard improvements	Construction	Türkiye	1.4E-3	0.09%		
Infrastructure and equipment	Equipment including maintenance	Taxes	Financial Services	Türkiye	1.0E-3	0.07%	7.65%	
		Electrical systems	Electronic equipment	Türkiye	1.2E-3	0.08%		
		Instrumentation & Controls	Machinery and Equipment	Türkiye	0.03	0.20%		
		Operating supplies	Machinery and Equipment	Türkiye	4.6E-03	0.03%		
		Piping (installed)	Metals	Türkiye	0.04	0.24%		

Group	Sub-Group	Item	Industrial Sector	Country	Cost per FU (Cents @ 2011)	Cost distribution (%)	Subgroup Cost Distribution (%)	Cos Group Distribution (%)
		Purchased Equipment	Machinery and Equipment	China	1.0	6.53%		
		Purchased equipment installation	Machinery and Equipment	Türkiye	0.05	0.30%		
		Maintenance and repairs	Machinery and Equipment	Türkiye	0.03	0.20%		
Financial. business. distribution and trade services	Financial. business. distribution and trade services	Distribution & selling	Trade	Türkiye	0.25	1.64%	2.16%	2.16%
		Laboratory charges	Business services	Türkiye	0.02	0.16%		
		Royalties	Financial Services	Türkiye	0.05	0.33%		
		Insurance	Insurance	Türkiye	5.1E-03	0.03%		
Plant Overhead	Plant Overhead	Plant overhead	Food Products	Türkiye	0.13	0.88%	0.88%	0.88%

TOMATO SAUCE S-LCI

Table 66. S-LCI of tomato sauce production

Group	Sub-Group	Item	Industrial Sector	Country	Cost per FU (Cents @ 2011)	Cost distribution (%)	Subgroup Cost Distribution (%)	Cost Group Distribution (%)
Materials	Packaging	Pallets	Chemical. rubber. plastic	China	0.04	0.32%	51.87%	73.11%
		Cardboard Boxes	Manufacturer nec	China	0.46	3.61%		
		Glass Jar & Tap Tins	Manufacturer nec	China	5.82	45.45%		
	Raw Materials	Cardboard separators	Manufacturer nec	China	0.32	2.48%		
		Olive without seeds	Food Products	Spain	0.35	2.72%	21.24%	
		Tomatoes	Vegetable. fruits. nuts	Türkiye	1.59	12.42%		
		Tap Water	Water	Türkiye	5.0E-3	0.04%		
		Pea Protein	Food Products	China	0.78	6.06%		
Labour force	Labour force	Administration	Food Product/TUR	Türkiye	0.06	0.50%	4.35%	4.35%
		Research & Development	Food Product/TUR	Türkiye	0.21	1.66%		
		Operating supervision	Food Product/TUR	Türkiye	0.04	0.28%		
		Operating Labor	Food Product/TUR	Türkiye	0.24	1.90%		
Utilities	Utilities	Utility	Electricity	Türkiye	0.37	2.92%	2.92%	2.92%

Group	Sub-Group	Item	Industrial Sector	Country	Cost per FU (Cents @ 2011)	Cost distribution (%)	Subgroup Cost Distribution (%)	Cost Group Distribution (%)
Infrastructure and equipment	Construction	Buildings (including services)	Construction	Türkiye	0.02	0.20%	3.62%	12.77%
		Construction expenses	Construction	Türkiye	0.06	0.45%		
		Contingency	Construction	Türkiye	0.06	0.48%		
Infrastructure and equipment	Construction	Contractor's fee	Construction	Türkiye	0.03	0.24%		
		Engineering and supervision	Construction	Türkiye	0.05	0.36%		
		Legal expenses	Construction	Türkiye	6.0E-2	0.04%		
		Service facilities	Construction	Türkiye	0.10	0.76%		
		Working capital	Construction	Türkiye	0.12	0.97%		
		Yard improvements	Construction	Türkiye	0.01	0.11%		
	Equipment including maintenance	Taxes	Financial Services	Türkiye	0.01	0.11%	9.16%	
		Electrical systems	Electronic equipment	Türkiye	0.01	0.12%		
		Instrumentation & Controls	Machinery and Equipment	Türkiye	0.05	0.39%		
		Operating supplies	Machinery and Equipment	Türkiye	0.09	0.05%		
		Piping	Metals	Türkiye	0.09	0.74%		
		Purchased Equipment	Machinery and Equipment	China	0.88	6.90%		
		Purchased equipment installation	Machinery and Equipment	Türkiye	0.07	0.51%		
		Maintenance and repairs	Machinery and Equipment	Türkiye	0.04	0.33%		
Financial. business. distribution and trade services	Financial. business. distribution and trade services	Distribution & selling	Trade	Türkiye	0.267	2.08%	5.34%	5.34%
		Laboratory charges	Business services	Türkiye	0.04	0.28%		
		Royalties	Financial Services	Türkiye	0.34	2.63%		
		Insurance	Insurance	Türkiye	0.04	0.35%		
Plant Overhead	Plant overhead	Plant overhead	Food Products	Türkiye	0.19	1.51%	1.51%	1.51%