AccelWater

Accelerating Water Circularity in Food and Beverage Industrial Areas around Europe

WP7: AccelWater System of Systems

Deliverable 7.3: *"Models for measuring AccelWater solutions performance"*

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Partners

Beneficiary		**Country**	**Logo**
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Executive Summary

This deliverable summarises all the activities of Task 7.7 “Performance management and sustainability measurement of AccelWater systems and testing” related to models developed for measuring the performance of AccelWater solutions with respect to principles of green production, low energy, low carbon and maximisation of process capability with regard to equipment/asset capacity, utilisation and reliability. Sustainability assessments were developed taking into consideration wastewater, waste and by-products quantities, costing parameters and impact. LCA, Cost analysis, social LCA and water energy Nexus of methodologies were applied along the project and the demonstrators. The results along with the related models are being integrated in the AccelWater monitoring and controlling platform (developed in T7.5) where users will be able to visually drill down to detail performance of each site, to view the relevant data about system’s performance and develop some potential simulations.

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Table of Abbreviations

Abbreviation	Explanation
AI	Artificial Intelligence
CE	Circular Economy
CO	Confidential
DPO	Data Protection Officer
EC	European Commission
ERP	Enterprise Resource Planning
EU	European Union
GA	Grant Agreement
GHG	Green House Gas
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communication Technology
IoT	Internet of Things
IS	Industrial Symbiosis
LIDAR	Light Detection And Ranging
MS	Milestone
R	Report
RFID	Radio Frequency Identification
RTO	Research and Technology Organisation
TBD	To be discussed
UHF	Ultra-High Frequency
WP	Work Package
WWTP	Wastewater Treatment Plant

1 Introduction

1.1 Purpose of the deliverable

This deliverable summarises all the activities of Task 7.7 "Performance management and sustainability measurement of AccelWater systems and testing" related to developed models for measuring the performance of AccelWater solutions. A part of the results, mainly concerning interactive analysis, are integrated in the AccelWater's monitoring and controlling platform (developed in T7.5) where users can view relevant data and different scenarios.

1.2 Relation with other Tasks/Deliverables

Deliverable 7.3 in relation with other project Tasks and deliverables:

- is based on the work performed in WP8.
- is prerequisite for the completion of Task 7.5.
- will complete the assessments module of AccelWater platform.

2 Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and WWE nexus approach

2.1 Modelling of demonstrators

For the modelling of demonstrators regarding the measuring of AccelWater solutions performance in terms of environmental and economic impact **LCA, LCC** and a **Waste-Water-Energy Nexus** approach **(WWEN)** was applied. For this purpose, and in accordance with the requirements of WP8, all relevant data were captured in the four studied demonstrators prior and after the implementation of AccelWater solutions and technologies. The developed methodology takes into account the outputs of the LCA and LCC analyses, along with the efficient application of energy and mass balances across the production chain for all demonstrators. Specifically, for the LCA results, each process related to the demonstrators was separately evaluated in terms of environmental impact and the overall environmental footprint of each demonstrator was evaluated by coupling all the relevant processes. For the LCC analysis, all relevant economic flows were considered. Additionally, the results of the LCA and LCC analyses were utilized to calculate the selected WWEN indicators (from WP8), prior and after the implementation of AccelWater. Moreover, two different approaches were adopted regarding the evaluation of the AccelWater solutions; interactive and static analysis, which will be further described in the following subsections.

		m3	tn	m3	kg	tn	tn	kWh	GJ	m3	kg
		WWTP	AWP	UF	AgProd (C)	SGP	Transp	Elec (C)	Therm (C)	Water (C)	Protein (C)
2	ReCiPe 2016 v1.1 Endpoint (H) - Climate change Freshw Ecosystems, default, excl biogenic carbon [species.yr]	3,80E-14	3,28E-12	8,85E-15	-7,29E-15	1,70E-11	2,95E-13	2,95E-14	-5,46E-12	-2,58E-14	-3,26E-14
2	ReCiPe 2016 v1.1 Endpoint (H) - Climate change Freshw Ecosystems, incl biogenic carbon [species.yr]	5,30E-14	3,28E-12	8,87E-15	5,06E-16	1,70E-11	2,96E-13	2,96E-14	-5,46E-12	-2,64E-14	8,06E-14
1	ReCiPe 2016 v1.1 Endpoint (H) - Climate change Human Health, default, excl biogenic carbon [DALY]	4,60E-07	3,97E-05	1,07E-07	-8,85E-08	2,06E-04	3,58E-06	3,58E-07	-6,62E-05	-3,13E-07	-3,96E-07
1	ReCiPe 2016 v1.1 Endpoint (H) - Climate change Human Health, incl biogenic carbon [DALY]	6,40E-07	3,98E-05	1,08E-07	6,14E-09	2,06E-04	3,59E-06	3,59E-07	-6,62E-05	-3,20E-07	9,78E-07
2	ReCiPe 2016 v1.1 Endpoint (H) - Climate change Terrest Ecosystems, default, excl biogenic carbon [species.yr]	1,40E-09	1,20E-07	3,24E-10	-2,67E-10	6,23E-07	1,08E-08	1,08E-09	-2,00E-07	-9,46E-10	-1,19E-09
2	ReCiPe 2016 v1.1 Endpoint (H) - Climate change Terrest Ecosystems, incl biogenic carbon [species.yr]	1,90E-09	1,20E-07	3,25E-10	1,85E-11	6,23E-07	1,08E-08	1,08E-09	-2,00E-07	-9,67E-10	2,95E-09
1	ReCiPe 2016 v1.1 Endpoint (H) - Fine Particulate Matter Formation [DALY]	8,30E-07	2,17E-06	5,05E-08	-1,18E-07	1,49E-05	1,68E-06	1,68E-07	-3,73E-06	-3,73E-07	-4,69E-07
3	ReCiPe 2016 v1.1 Endpoint (H) - Fossil depletion [$]	2,60E-02	4,83E+00	2,10E-03	-6,69E-03	2,43E+01	7,01E-02	7,01E-03	-8,06E+00	-1,70E-02	-2,83E-02
2	ReCiPe 2016 v1.1 Endpoint (H) - Freshwater Consumption, Freshw Ecosystems [species.yr]	-1,60E-12	-3,92E-14	9,83E-17	-4,14E-14	1,80E-14	3,28E-15	3,28E-16	-3,59E-15	-1,73E-12	-1,39E-13
1	ReCiPe 2016 v1.1 Endpoint (H) - Freshwater Consumption, Human Health [DALY]	-2,00E-06	-4,99E-08	6,73E-10	-5,29E-08	6,07E-08	2,24E-08	2,24E-09	-3,80E-09	-2,21E-06	-1,77E-07
2	ReCiPe 2016 v1.1 Endpoint (H) - Freshwater Consumption, Terrest Ecosystems [species.yr]	-1,20E-08	-3,06E-10	2,87E-12	-3,21E-10	2,75E-10	9,55E-11	9,55E-12	-2,17E-11	-1,34E-08	-1,08E-09
2	ReCiPe 2016 v1.1 Endpoint (H) - Freshwater ecotoxicity [species.yr]	5,50E-09	-5,63E-09	5,94E-15	-5,63E-09	3,40E-12	1,98E-13	1,98E-14	-9,88E-13	-5,14E-09	-2,34E-08
2	ReCiPe 2016 v1.1 Endpoint (H) - Freshwater Eutrophication [species.yr]	7,50E-10	-1,18E-11	3,43E-13	-1,36E-11	3,23E-11	1,14E-11	1,14E-12	-2,36E-12	-1,84E-10	-9,99E-11
1	ReCiPe 2016 v1.1 Endpoint (H) - Human toxicity, cancer [DALY]	6,20E-07	7,60E-09	1,89E-10	-1,60E-08	1,31E-07	6,30E-09	6,30E-10	-3,90E-08	-1,56E-07	-9,89E-08
1	ReCiPe 2016 v1.1 Endpoint (H) - Human toxicity, non-cancer [DALY]	7,00E-07	-3,25E-08	5,00E-10	-5,65E-08	1,54E-07	1,67E-08	1,67E-09	-3,91E-08	-1,23E-07	-7,84E-08
1	ReCiPe 2016 v1.1 Endpoint (H) - Ionizing Radiation [DALY]	4,80E-10	4,76E-11	3,28E-11	-1,81E-11	2,57E-09	1,09E-09	1,09E-10	-5,48E-11	-1,13E-09	-1,24E-10
2	ReCiPe 2016 v1.1 Endpoint (H) - Land use [species.yr]	2,50E-10	-1,00E-09	1,89E-10	-1,33E-09	1,46E-08	6,30E-09	6,30E-10	-2,41E-10	-8,51E-11	-2,33E-08
2	ReCiPe 2016 v1.1 Endpoint (H) - Marine ecotoxicity [species.yr]	7,90E-10	-7,95E-10	3,25E-15	-7,95E-10	1,44E-12	1,08E-13	1,08E-14	-4,02E-13	-7,31E-10	-3,31E-09
2	ReCiPe 2016 v1.1 Endpoint (H) - Marine Eutrophication [species.yr]	1,00E-11	-3,53E-13	7,78E-15	-3,89E-13	7,08E-13	2,59E-13	2,59E-14	-4,61E-14	-3,59E-14	-3,05E-12
3	ReCiPe 2016 v1.1 Endpoint (H) - Metal depletion [$]	2,00E-03	1,86E-03	2,76E-05	-1,55E-04	1,20E-02	9,21E-04	9,21E-05	-3,31E-03	-5,22E-04	-7,46E-04
2	ReCiPe 2016 v1.1 Endpoint (H) - Photochemical Ozone Formation, Ecosystems [species.yr]	2,40E-10	3,05E-09	2,57E-11	-5,48E-11	1,73E-08	8,55E-10	8,55E-11	-5,13E-09	-9,46E-11	-2,64E-10
1	ReCiPe 2016 v1.1 Endpoint (H) - Photochemical Ozone Formation, Human Health [DALY]	1,70E-09	2,12E-08	1,80E-10	-3,81E-10	1,20E-07	5,99E-09	5,99E-10	-3,57E-08	-6,58E-10	-1,83E-09
1	ReCiPe 2016 v1.1 Endpoint (H) - Stratospheric Ozone Depletion [DALY]	7,50E-10	2,96E-09	1,63E-11	-2,94E-10	1,74E-08	5,45E-10	5,45E-11	-5,40E-09	-8,44E-11	-2,57E-09
2	ReCiPe 2016 v1.1 Endpoint (H) - Terrestrial Acidification [species.yr]	7,80E-10	2,16E-09	5,22E-11	-1,33E-10	1,50E-08	1,74E-09	1,74E-10	-3,73E-09	-3,22E-10	-3,42E-10
2	ReCiPe 2016 v1.1 Endpoint (H) - Terrestrial ecotoxicity [species.yr]	4,10E-08	-4,14E-08	4,24E-13	-4,15E-08	1,73E-10	1,41E-11	1,41E-12	-4,73E-11	-3,81E-08	-1,73E-07
	ReCiPe 2016 v1.1 Midpoint (H) - Climate change, default, excl biogenic carbon [kg CO2 eq.]	4,90E-01	4,28E+01	1,16E-01	-9,54E-02	2,22E+02	3,86E+00	3,86E-01	-7,13E+01	-3,38E-01	-4,27E-01
	ReCiPe 2016 v1.1 Midpoint (H) - Climate change, incl biogenic carbon [kg CO2 eq.]	6,90E-01	4,29E+01	1,16E-01	6,62E-03	2,22E+02	3,87E+00	3,87E-01	-7,13E+01	-3,45E-01	1,05E+00
	ReCiPe 2016 v1.1 Midpoint (H) - Fine Particulate Matter Formation [kg PM2.5 eq.]	1,30E-03	3,45E-03	8,02E-05	-1,87E-04	2,37E-02	2,67E-03	2,67E-04	-5,94E-03	-5,93E-04	-7,46E-04
	ReCiPe 2016 v1.1 Midpoint (H) - Fossil depletion [kg oil eq.]	1,50E-01	1,61E+01	4,02E-02	-2,84E-02	8,32E+01	1,34E+00	1,34E-01	-2,68E+01	-1,63E-01	-1,01E-01
	ReCiPe 2016 v1.1 Midpoint (H) - Freshwater Consumption [m3]	-8,90E-01	-2,09E-02	1,01E-03	-2,38E-02	8,39E-02	3,37E-02	3,37E-03	-3,21E-03	-9,95E-01	-7,97E-02
	ReCiPe 2016 v1.1 Midpoint (H) - Freshwater ecotoxicity [kg 1,4 DB eq.]	3,40E-02	-2,16E-03	8,54E-06	-3,02E-03	4,89E-03	2,85E-04	2,85E-05	-1,42E-03	-1,03E-02	-2,03E-02
	ReCiPe 2016 v1.1 Midpoint (H) - Freshwater Eutrophication [kg P eq.]	1,10E-03	-1,76E-05	5,12E-07	-2,02E-05	4,81E-05	1,71E-05	1,71E-06	-3,52E-06	-2,74E-04	-1,49E-04
	ReCiPe 2016 v1.1 Midpoint (H) - Human toxicity, cancer [kg 1,4-DB eq.]	1,90E-01	2,29E-03	5,69E-05	-4,83E-03	3,95E-02	1,90E-03	1,90E-04	-1,18E-02	-4,71E-02	-2,98E-02
	ReCiPe 2016 v1.1 Midpoint (H) - Human toxicity, non-cancer [kg 1,4-DB eq.]	3,00E+00	-7,83E-02	2,19E-03	-1,83E-01	6,75E-01	7,31E-02	7,31E-03	-1,71E-01	-4,79E-01	-7,55E-02
	ReCiPe 2016 v1.1 Midpoint (H) - Ionizing Radiation [Bq C-60 eq. to air]	5,60E-02	5,60E-03	3,86E-03	-2,13E-03	3,03E-01	1,29E-01	1,29E-02	-6,44E-03	-1,33E-01	-1,46E-02
	ReCiPe 2016 v1.1 Midpoint (H) - Land use [Annual crop eq.-y]	2,90E-02	-1,13E-01	2,13E-02	-1,50E-01	1,64E+00	7,09E-01	7,09E-02	-2,71E-02	-9,58E-03	-2,62E+00
	ReCiPe 2016 v1.1 Midpoint (H) - Marine ecotoxicity [kg 1,4-DB eq.]	4,50E-02	-1,49E-03	3,09E-05	-3,82E-03	1,38E-02	1,03E-03	1,03E-04	-3,83E-03	-1,33E-02	-2,65E-02
	ReCiPe 2016 v1.1 Midpoint (H) - Marine Eutrophication [kg N eq.]	6,20E-03	-2,18E-04	4,71E-06	-2,39E-04	4,27E-04	1,57E-04	1,57E-05	-2,73E-05	-2,20E-05	-1,87E-03
	ReCiPe 2016 v1.1 Midpoint (H) - Metal depletion [kg Cu eq.]	8,80E-03	8,05E-03	1,20E-04	-6,69E-04	5,18E-02	3,99E-03	3,99E-04	-1,43E-02	-2,26E-03	-3,23E-03
	ReCiPe 2016 v1.1 Midpoint (H) - Photochemical Ozone Formation, Ecosystems [kg NOx eq.]	1,90E-03	2,36E-02	1,99E-04	-4,25E-04	1,34E-01	6,63E-03	6,63E-04	-3,98E-02	-7,33E-04	-2,05E-03
	ReCiPe 2016 v1.1 Midpoint (H) - Photochemical Ozone Formation, Human Health [kg NOx eq.]	1,80E-03	2,33E-02	1,98E-04	-4,19E-04	1,32E-01	6,58E-03	6,58E-04	-3,93E-02	-7,23E-04	-2,01E-03
	ReCiPe 2016 v1.1 Midpoint (H) - Stratospheric Ozone Depletion [kg CFC-11 eq.]	1,40E-06	5,58E-06	3,08E-08	-5,53E-07	3,28E-05	1,03E-06	1,03E-07	-1,02E-05	-1,59E-07	-4,84E-06
	ReCiPe 2016 v1.1 Midpoint (H) - Terrestrial Acidification [kg SO2 eq.]	3,70E-03	1,02E-02	2,46E-04	-6,26E-04	7,09E-02	8,21E-03	8,21E-04	-1,76E-02	-1,52E-03	-1,61E-03
	ReCiPe 2016 v1.1 Midpoint (H) - Terrestrial ecotoxicity [kg 1,4-DB eq.]	3,30E+00	2,20E+00	3,72E-02	-3,28E-01	1,52E+01	1,24E+00	1,24E-01	-4,15E+00	-9,81E-01	-1,73E+00
	ReCiPe 2016 v1.1 Endpoint (H) - Damage to human health [DALY]	1,25E-06	8,16E-05	2,67E-07	-3,26E-07	4,27E-04	8,90E-06	8,90E-07	-1,36E-04	-3,50E-06	-2,46E-07
	ReCiPe 2016 v1.1 Endpoint (H) - Damage to ecosystems [species.yr]	4,06E-08	1,96E-07	9,20E-10	-5,00E-08	1,29E-06	3,06E-08	3,06E-09	-4,09E-07	-6,00E-08	-2,23E-07
	ReCiPe 2016 v1.1 Endpoint (H) - Damage to resource availability [$]	2,80E-02	4,83E+00	2,13E-03	-6,85E-03	2,43E+01	7,10E-02	7,10E-03	-8,06E+00	-1,75E-02	-2,90E-02

FIGURE 1 LCA RESULTS MODELLING

2.1.1 Industrial Symbiosis (Greek Demonstrator)

Description

Industrial Symbiosis (IS) is located in the Industrial Area of Patras, Greece, and comprises of a brewery (Athenian Brewery), a dairy (Friesland Campina Hellas), and a food processing industry (REZOS). Prior to AccelWater implementation, wastewater generated by the dairy and brewery industries was treated within the boundaries of the industry, and subsequently transferred to a municipal wastewater treatment plant for further treatment. Moreover, the generated solid wastes (brewer's spent grains (BSG) and acid whey (AW) for AB and FCH, respectively) were valorized by other industries. BSG's were predominantly used for the production of animal feed, while AW was used to produce biogas. The following image depicts the state of the IS prior its induction to the AccelWater project.

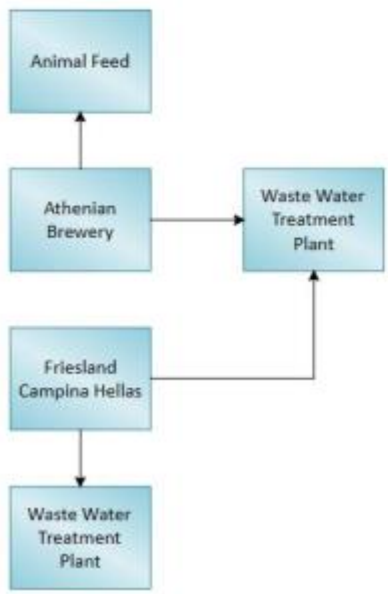


FIGURE 2 FLOWCHART OF IS BEFORE ACCELWATER

The main processes introduced due to AccelWater project include:

- Ultrafiltration of AW
  - Ultrafiltration operates on the principle of size exclusion, utilizing a semipermeable membrane to selectively retain larger molecules, such as acid whey proteins, while allowing smaller molecules and solvents to pass through, thereby achieving effective separation and concentration of the desired proteins.
- Spray-drying of AW retentate to obtain AW protein isolate
  - Spray-drying of acid whey retentate involves atomizing the concentrated protein solution into a hot air chamber, where rapid evaporation of water occurs, leaving behind fine, dry particles of acid whey protein isolate, which are then collected as a high-purity protein isolate powder.
- Ultrafiltration to purify the wastewater of AB and FCH

  - Ultrafiltration is employed to treat the wastewater of the brewery and dairy industries by using a semipermeable membranes to retain suspended solids, bacteria, and larger molecules, while allowing water and smaller solutes to pass through, resulting in cleaner effluent while minimising the overall environmental impact.
- Rainwater collection in REZOS facilities
  - Rainwater collection in REZOS facilities involves capturing and storing rainwater from rooftop surfaces, which can provide a sustainable and cost-effective water source.
- Irrigation using the purified AB and FCH wastewater and the harvested rainwater
  - Irrigation using the treated wastewater, along with harvested rainwater, leverages these treated water sources to efficiently and sustainably irrigate crops, reducing reliance on freshwater resources and promoting environmental sustainability in agricultural practices
- Extraction of BSG to obtain BSG protein isolate
  - The extraction of BSGs involves processing the grain through methods such as alkaline or enzymatic hydrolysis to extract proteins, followed by purification steps like ultrafiltration or precipitation to isolate BSG protein, resulting in a high-quality protein isolate suitable for various applications.
- Gasification of AW and BSGs residues to produce H_2
  - Gasification of AW and BSGs residues involves thermochemically converting these organic materials at high temperatures in the presence of a controlled amount of oxygen or steam, resulting in the production of H_2 gas, which can be harnessed as a clean and renewable energy source.

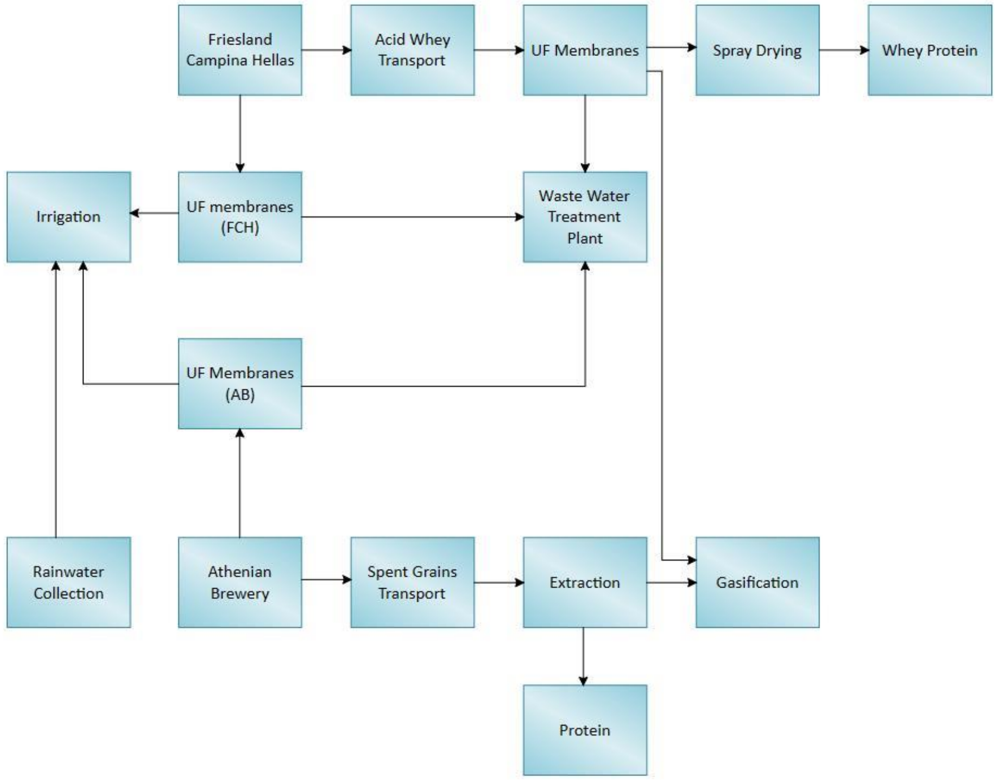


FIGURE 3 FLOWCHART OF IS AFTER ACCELWATER

2.1.2 Spanish Demonstrator

Description

Spanish demonstrator is located in Sant Joan de Vilatorrada, Spain, and the involved sector is a meat processing industry. Prior to AccelWater implementation, wastewater generated by the industry were treated within the boundaries of the industry, and subsequently transferred to a municipal wastewater treatment plant for further treatment. Moreover, the generated solid wastes were either sold to external companies to be valorized or external subcontractors were employed to safely handle the hazardous solid wastes. The following images depict the state of the Spanish Demonstrator prior to the beginning of the AccelWater project.

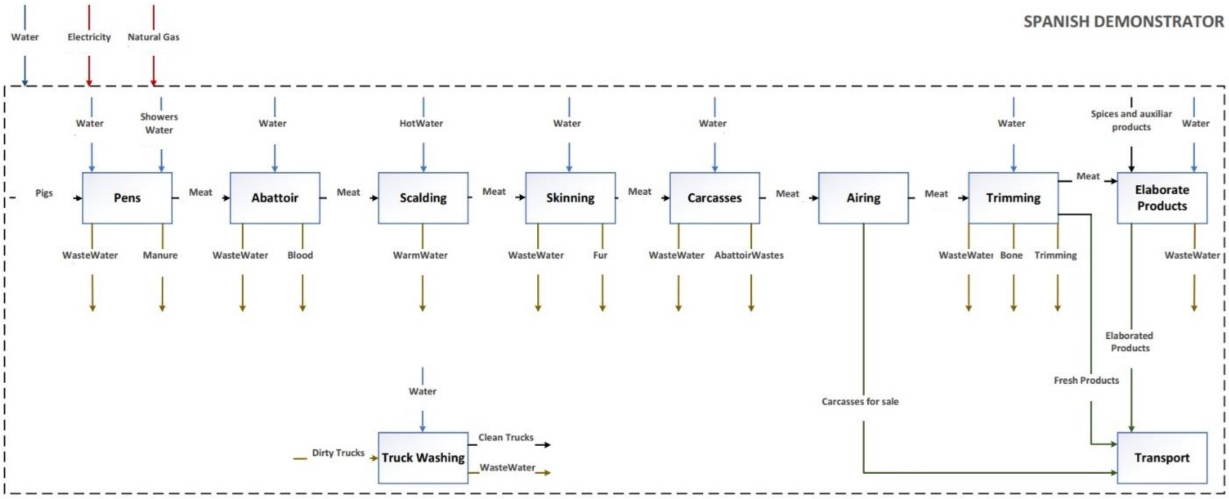


FIGURE 4 FLOWCHART OF THE PRODUCTION LINE OF SPANISH DEMONSTRATOR BEFORE ACCELWATER

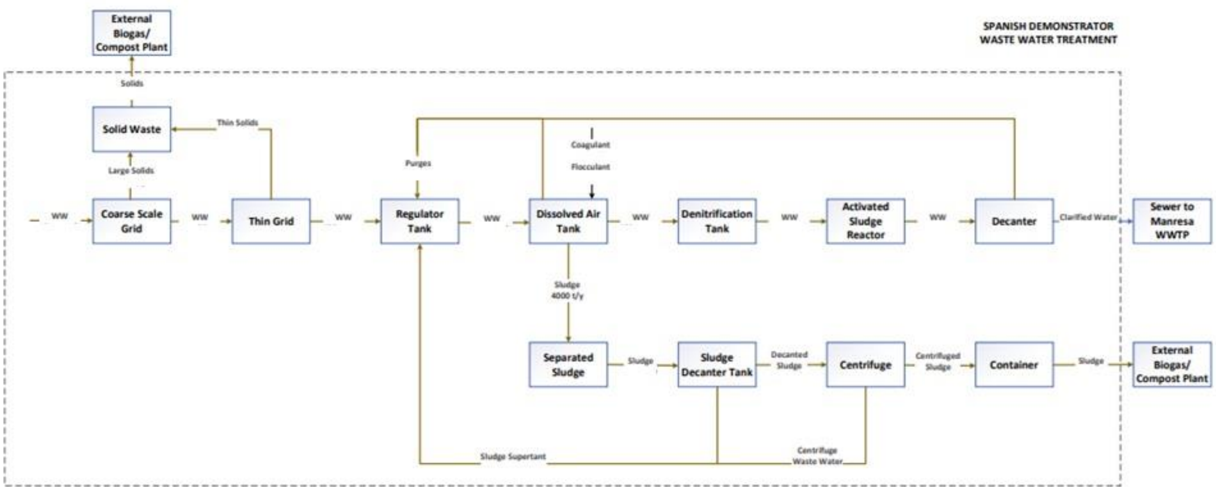


FIGURE 5 FLOWCHART OF THE WASTEWATER TREATMENT OF SPANISH DEMONSTRATOR BEFORE ACCELWATER

The main processes that are introduced by AccelWater include:

- Membrane bioreactor for wastewater treatment
  - A membrane bioreactor (MBR) combines biological treatment with membrane filtration, effectively removing organic matter, suspended solids, and microorganisms from wastewater, resulting in high-quality effluent suitable for reuse or further purification.
- Electrodialysis as a second step following the membrane bioreactor process
  - Electrodialysis, implemented after the membrane bioreactor process, utilizes an electric field to drive ions through selective membranes, further refining the treated wastewater by removing dissolved salts and other ionic impurities
- Freeze Concentration for biostimulants production

    - Freeze concentration involves selectively freezing water from a biostimulant solution, allowing the ice crystals to be removed, thereby concentrating the active ingredients and enhancing the efficacy and stability of the biostimulants.
- UV treatment as the final process for wastewater purification
    - UV treatment, used as the final step in wastewater purification, employs ultraviolet light to disinfect and eliminate remaining pathogens and microorganisms, ensuring the treated water is safe for discharge or reuse.
- Anaerobic digestion for the solid wastes with high organic content to produce biogas
    - Anaerobic digestion treats waste flows with high organic content in the absence of oxygen. This process results in the decomposition of the organic matter and the production of biogas, which is a renewable energy source consisting mainly of methane and carbon dioxide.
- Solid state fermentation of the digestate for biostimulants production
    - Solid state fermentation of the digestate, meaning the residue from anaerobic digestion, involves microbial cultivation on solid substrates to convert the digestate into valuable biostimulants, promoting plant growth and soil health.
- Biodrying for the solid wastes with low organic content to produce biomass fuel
    - Biodrying involves partially drying solid wastes with low organic content through controlled biological activity, reducing moisture content and producing biomass fuel that can be used for energy generation.

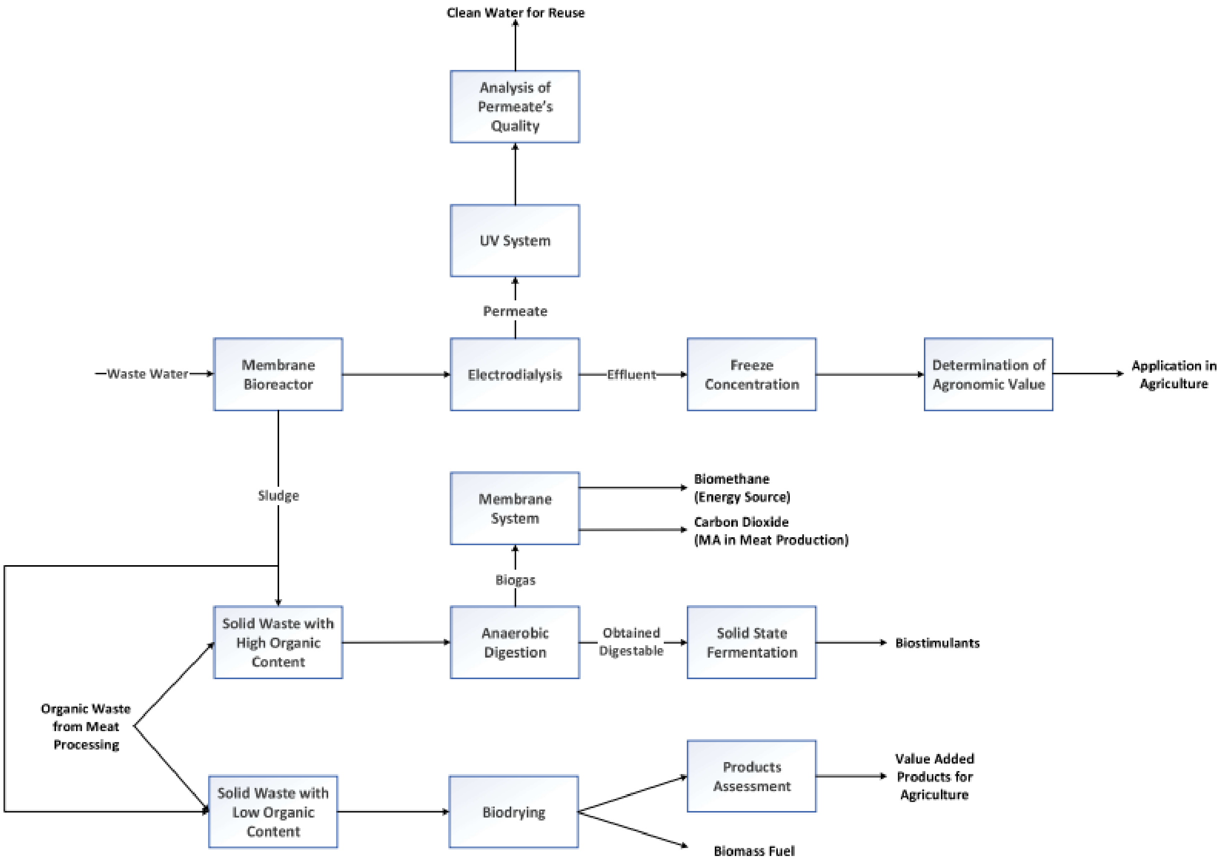


FIGURE 6 FLOWCHART OF THE WASTEWATER AND SOLID WASTES VALORIZATION OF SPANISH DEMONSTRATOR AFTER ACCELWATER

2.1.3 Italian Demonstrator

Description

Italian demonstrator is located in Castel San Giorgio, Italy, and the involved sector is a tomato processing industry. The main hinder of the Italian Demonstrator's efficiency was the substantial amount of water and energy consumption during the peeling of the tomatoes. Therefore, the utilization of pulsed electric fields (PEF) as a cutting-edge technology before the peeling process is proposed and implemented within the AccelWater framework. PEF technology in tomato processing involves applying short bursts of high voltage to tomatoes, disrupting cell membranes and facilitating easier peeling, which optimizes the peeling process by reducing energy consumption, improving yield, and preserving the quality of the tomatoes. The following figures depict the state of the Italian Demonstrator prior to the beginning of the AccelWater project and after the implementation of PEF.

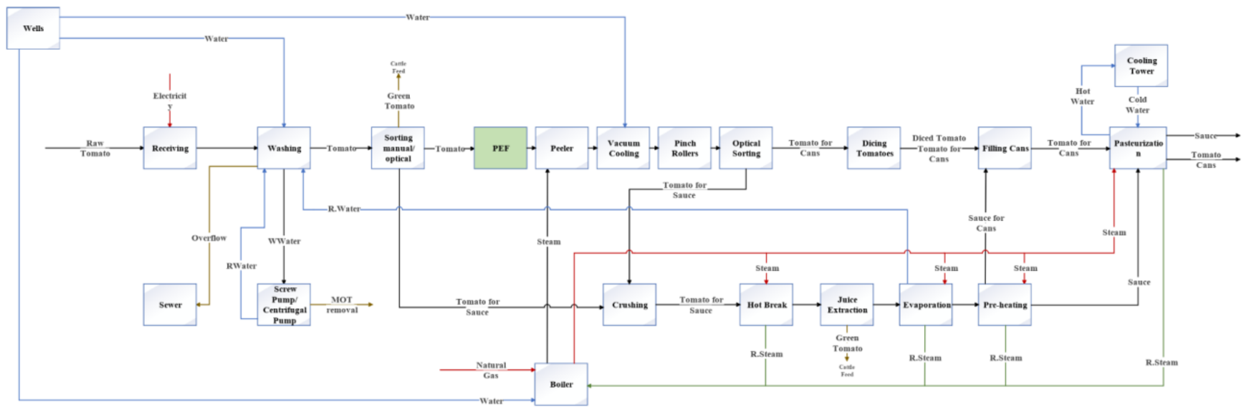


FIGURE 7 FLOWCHART OF THE ITALIAN DEMONSTRATOR AFTER ACCELWATER

2.1.4 Icelandic Demonstrator

Description

Icelandic demonstrator involves a fish processing industry and more specifically fish processing facilities that are located in Akureyyri. During the production stages in the fish processing facilities, various side-streams with high protein content are generated, thus AccelWater interventions are mainly focused on the valorization of the aforementioned streams to recover the corresponding proteins. The following figures depict the state of the Icelandic Demonstrator prior to the beginning of the AccelWater project and after the utilization of the proposed technologies for protein recovery.

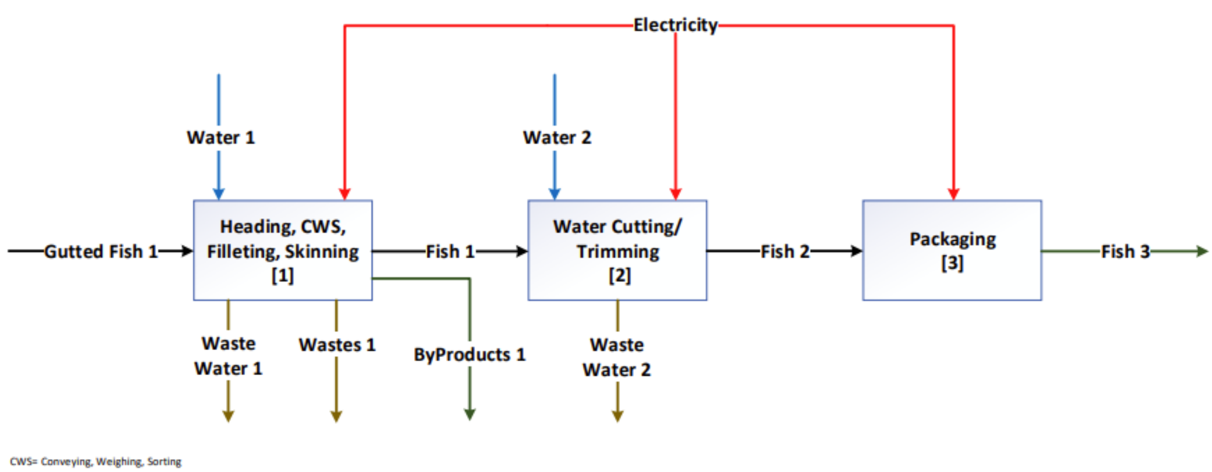


FIGURE 8 FLOWCHART OF ICELANDIC DEMONSTRATOR BEFORE ACCELWATER

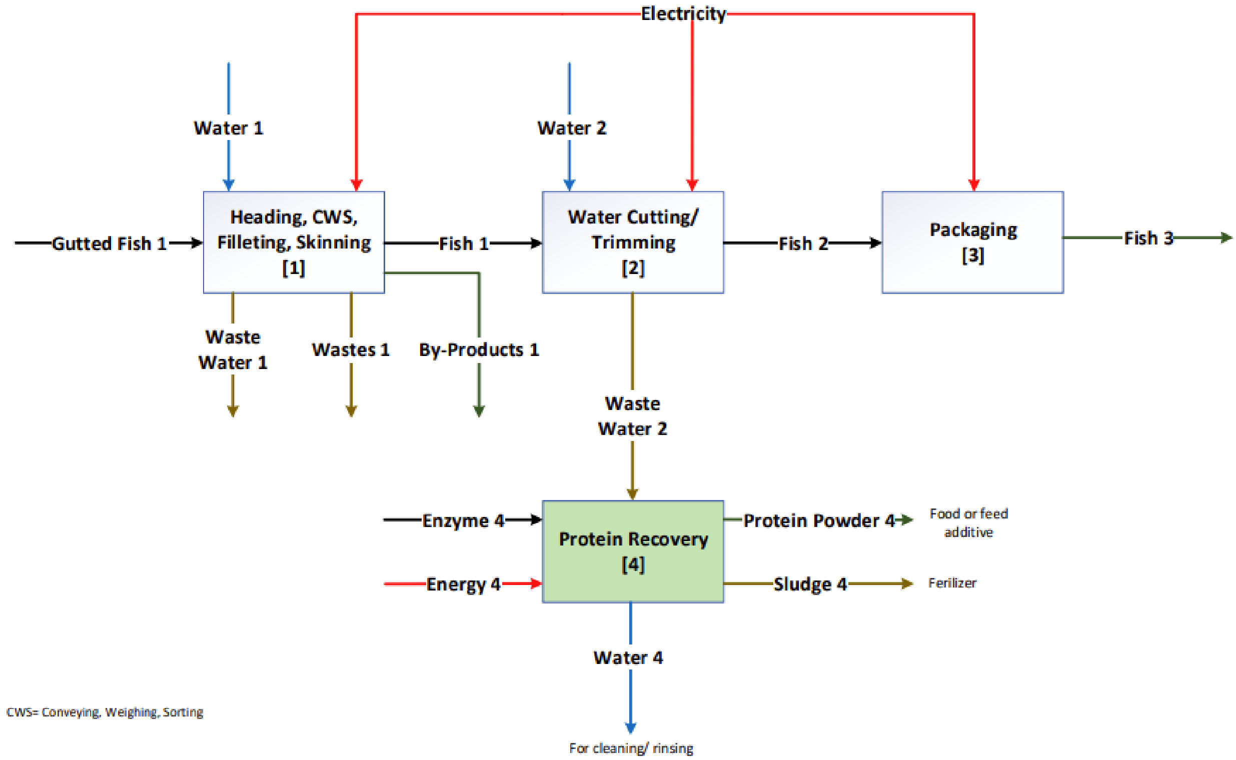


Figure 9 Flowchart of Icelandic Demonstrator after AccelWater

2.2 Interactive analysis

The interactive analysis for the AccelWater solutions allows users to manually enter data of some inputs to evaluate the solutions based on Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and the Waste-Water-Energy (WWE) nexus, with users being able to provide specific details about their resource's usage and costs. Subsequently, the platform then processes this data to provide insights into the sustainability and cost-effectiveness of AccelWater technologies. This user-friendly approach helps stakeholders make informed decisions and optimize their water, waste, and energy management by tailoring the evaluation to their specific needs and conditions. In the following subsections, the user interface along with the results of each demonstrator are presented.

2.2.1 Industrial Symbiosis (Greek Demo)

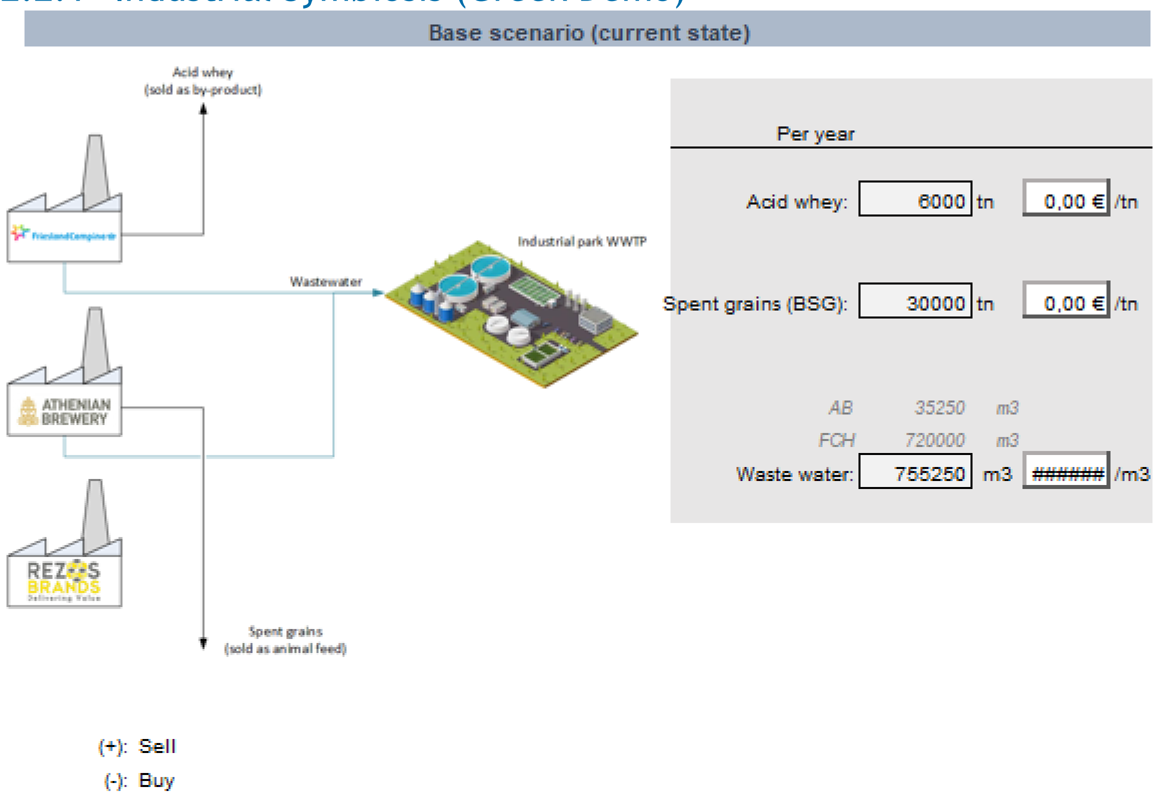


FIGURE 10 BASIC INPUTS AND OUTPUTS OF IS BEFORE ACCELWATER

The basic flows of the IS before the implementation of AccelWater consist of the basic by-products from the dairy and the brewing industry, which are the acid whey and the BSGs, respectively. These by-products are not further exploited by the industries, but are handled by external companies. Finally, the other main output of the IS is the generated wastewater, while REZOS prior to AccelWater did not have any interaction with the other industries.

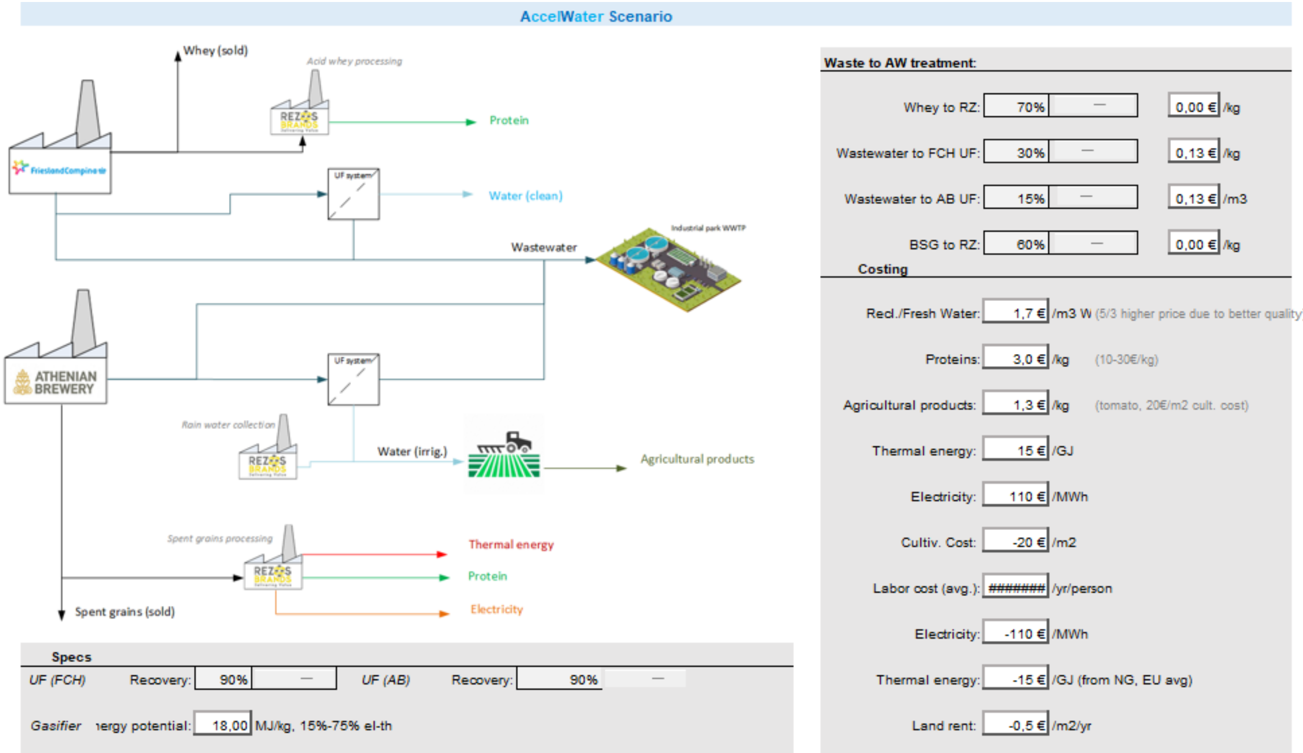


FIGURE 11 BASIC INPUTS AND OUTPUTS OF IS AFTER ACCELWATER

The basic flows of the IS after the implementation of AccelWater also consist of the basic by-products from the dairy and the brewing industry, which are the acid whey and the BSGs, respectively. A quantity of the aforementioned compounds is transported to the facilities of REZOS for protein extraction and production of H_2 via gasification. Regarding the relevant cost flows these consist of the costs associated with the valorization of the solid wastes, the treatment of the wastewater and the exploitation of the generated products, such as protein isolates and energy.

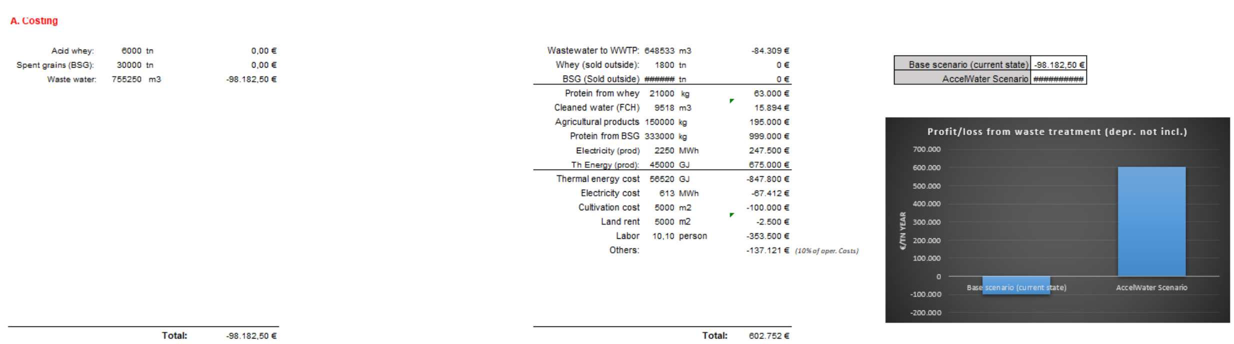
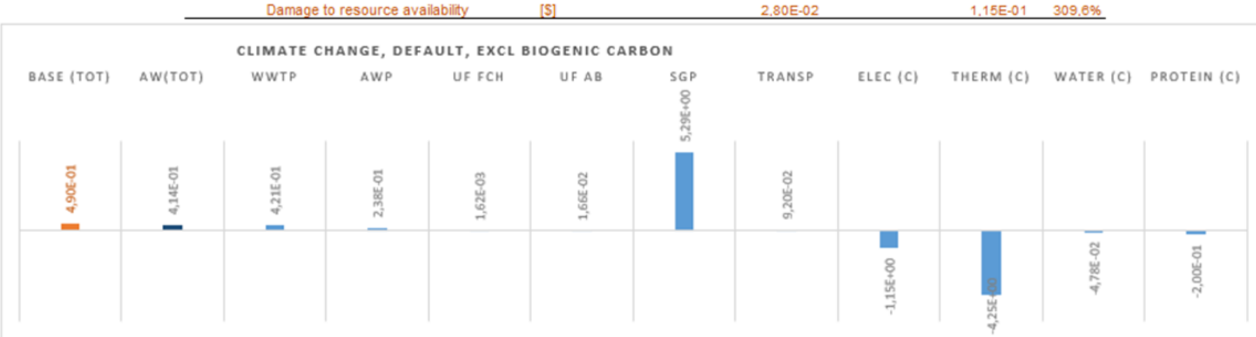


FIGURE 12 LCC RESULTS OF IS BEFORE AND AFTER ACCELWATER

According to the LCC analysis of the IS before and after AccelWater, before the beginning of the project a total cost of -98,182.60€/year is depicted, primarily due to the costs associated with treating wastewater and handling acid whey and BSG. However, the economic evaluation of the proposed solutions and technologies demonstrated significant financial improvement with a total profit of 602,752€/year. This improvement stems from revenue generated by selling various by-products, including recovered proteins from acid whey and BSG, treated water, and agricultural products, as well as energy production.

B. LCA

FU: 0	0 per 1m3 of wastewater	Base scenario (current state)	AccelWater Scenario	% change
Climate change, default, excl biogenic carbon	[kg CO2 eq.]	4,90E-01	4,14E-01	-15,5%
Climate change, incl biogenic carbon	[kg CO2 eq.]	6,90E-01	1,27E+00	84,7%
Fine Particulate Matter Formation	[kg PM2.5 eq.]	1,30E-03	1,94E-04	-85,1%
Fossil depletion	[kg oil eq.]	1,50E-01	1,73E-01	15,4%
Freshwater Consumption	[m3]	-8,90E-01	-9,50E-01	-6,7%
Freshwater ecotoxicity	[kg 1,4 DB eq.]	3,40E-02	1,82E-02	-46,6%
Freshwater Eutrophication	[kg P eq.]	1,10E-03	8,32E-04	-24,3%
Human toxicity, cancer	[kg 1,4-DB eq.]	1,90E-01	1,42E-01	-25,1%
Human toxicity, non-cancer	[kg 1,4-DB eq.]	3,00E+00	2,46E+00	-18,0%
Ionizing Radiation	[Bq C-60 eq. to air]	5,60E-02	-5,43E-03	-109,7%
Land use	[Annual crop eq.·y]	2,90E-02	-1,36E+00	-4784,9%
Marine ecotoxicity	[kg 1,4-DB eq.]	4,50E-02	2,42E-02	-46,3%
Marine Eutrophication	[kg N eq.]	6,20E-03	4,41E-03	-28,9%
Metal depletion	[kg Cu eq.]	8,80E-03	5,08E-03	-42,3%
Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]	1,90E-03	-2,65E-04	-114,0%
Photochemical Ozone Formation, Human Health	[kg NOx eq.]	1,80E-03	-3,37E-04	-118,7%
Stratospheric Ozone Depletion	[kg CFC-11 eq.]	1,40E-06	-1,16E-06	-183,0%
Terrestrial Acidification	[kg SO2 eq.]	3,70E-03	6,94E-04	-81,2%
Terrestrial ecotoxicity	[kg 1,4-DB eq.]	3,30E+00	1,68E+00	-49,2%
Damage to human health	[DALY]	1,25E-06	5,90E-07	-52,9%
Damage to ecosystems	[species.yr]	4,06E-08	-7,88E-08	-294,1%
Damage to resource availability	[$]	2,80E-02	1,15E-01	309,6%



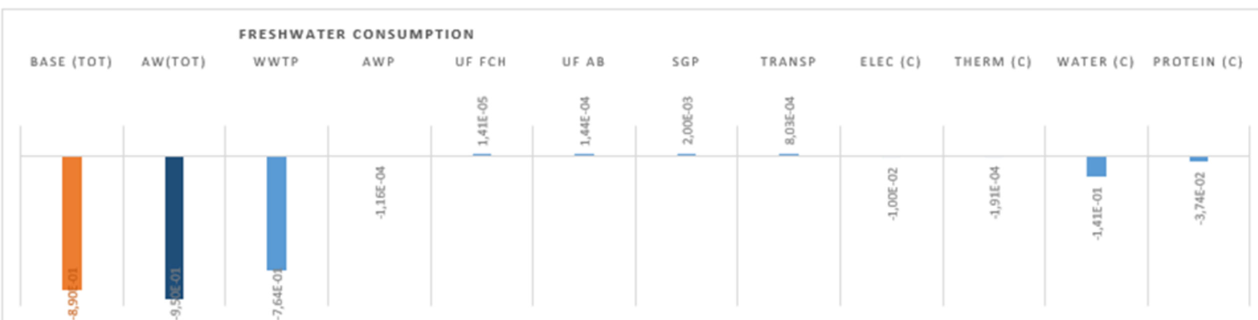


FIGURE 13 LCA RESULTS OF IS BEFORE AND AFTER ACCELWATER

According to the LCA analysis of the IS before and after implementing the AccelWater project, the base scenario indicates various environmental impacts and resource depletions associated with treating wastewater and handling acid whey and BSG. However, the AccelWater Scenario shows remarkable improvements across all these categories. More specifically, climate change impact reduces by 15.5%, freshwater consumption decreases by 6.7%, and human toxicity, related to cancer, is reduced by 25.1%.

The graphical representation further emphasizes these environmental benefits, showcasing substantial reductions in the studied impact categories compared to the base scenario.

C. Nexus

Index	Value	Base
Profit	7,1	1
CO2 red	0,2	0
Water reuse	0,6	0-1
Ele gain	0,0	0
Thermal En gain	0,0	0

FIGURE 14 NEXUS INDICATORS OF IS BEFORE AND AFTER ACCELWATER

According to the Nexus approach of the IS before and after the implementation of the AccelWater project, several key indices highlight the overall improvements. In terms of profit, the value is 7.1 compared to the base scenario of 1, indicating a cost-saving shift. CO_2 reduction has a significant value of 1.0, starting from a base of 0, showcasing substantial environmental benefits. Water reuse is also notable, with a value of 0.6 compared to a base range of 0-1, demonstrating enhanced water management. However, the electricity and thermal energy gain does not alter following the implementation of AccelWater, due to the utilization of both electricity and thermal energy in the valorization of solid wastes and the treatment of the generated wastewater.

2.2.2 Spanish Demonstrator

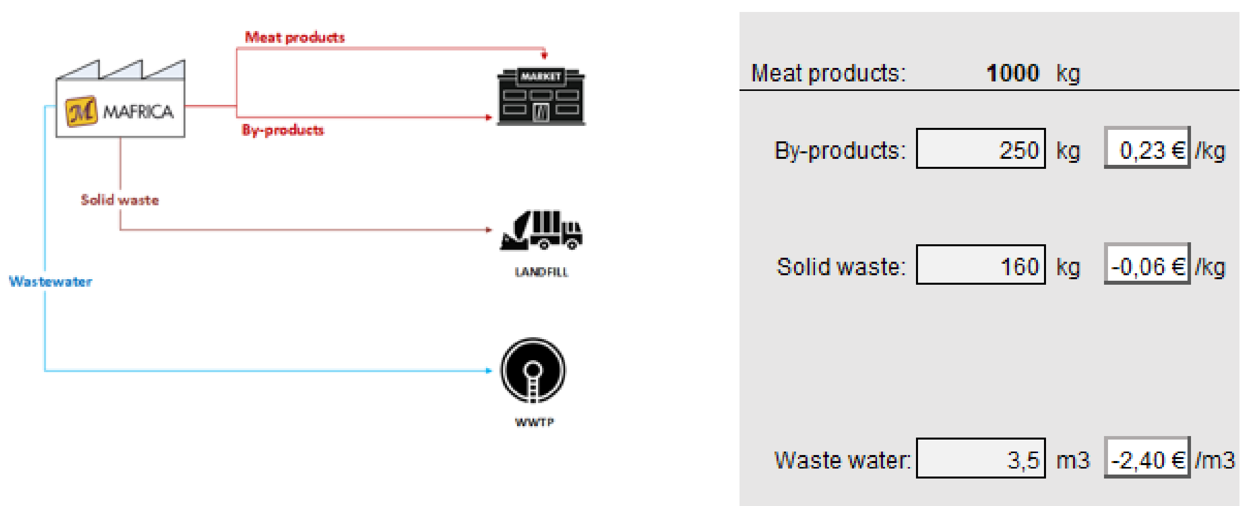


FIGURE 15 BASIC INPUTS AND OUTPUTS OF SPANISH DEMONSTRATOR BEFORE ACCELWATER

The basic flows of the Spanish demonstrator before the implementation of AccelWater consist of the non-hazardous by-products, which are sold to external industries, and the generated hazardous solid wastes and wastewater that their treatment and disposal constitutes an economic burden of the industry. Especially, for the hazardous solid wastes, their management is performed by external subcontractors

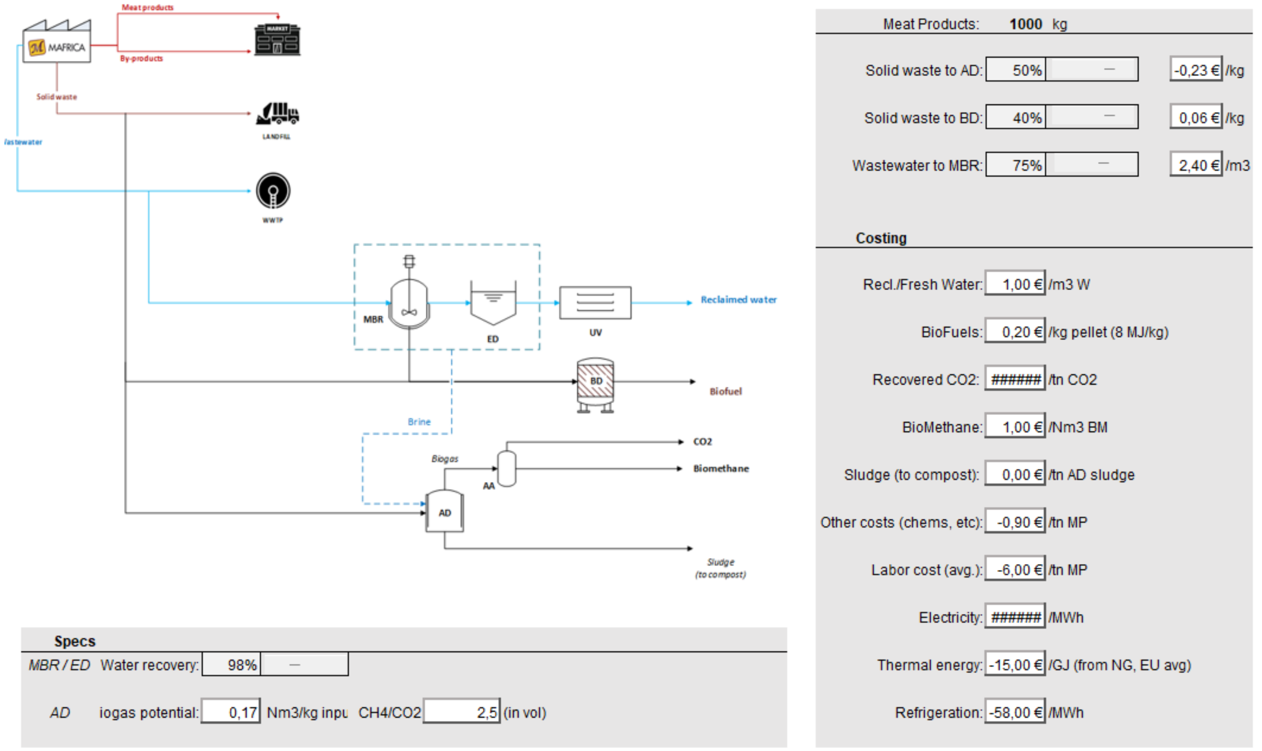


FIGURE 16 BASIC INPUTS AND OUTPUTS OF SPANISH DEMONSTRATOR AFTER ACCELWATER

The basic flows of the Spanish demonstrator after the implementation of AccelWater consist of the solid wastes that either are valorized via biordrying or anaerobic digestion and the wastewater that is treated in a membrane bioreactor. Regarding the relevant cost flows these consist of the costs associated with the valorization of the solid wastes, the treatment of the wastewater and the exploitation of the generated products, such as biomethane and biofuels.

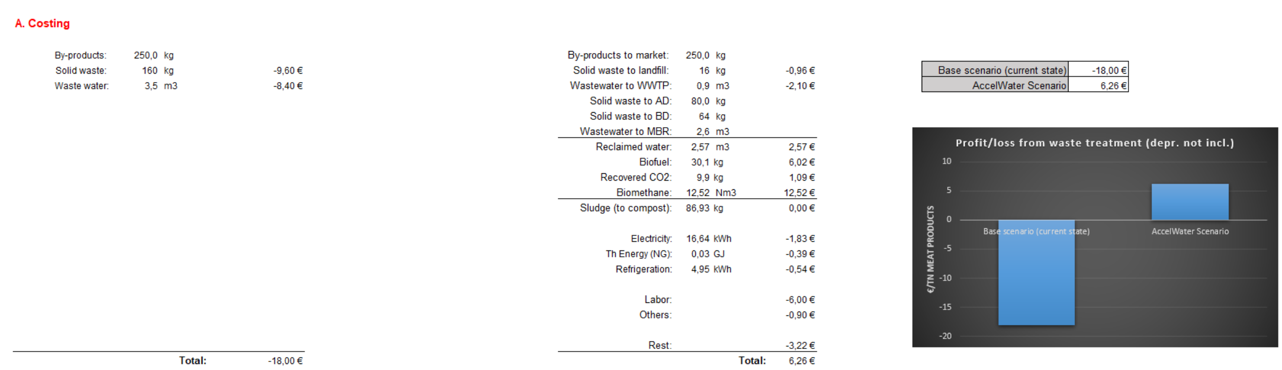


FIGURE 17 LCC RESULTS OF SPANISH DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the LCC analysis before and after the implementation of the new waste treatment strategy, the initial scenario depicts a total cost of -18.00€/tn of meat products. This cost is primarily due to expenses associated with managing the generated solid wastes and wastewater. However, the economic evaluation of the proposed improvements demonstrates a significant financial turnaround, resulting in a total profit of 6.26€/tn of meat products. This positive change is attributed to the effective handling and marketable use of by-products, such as reclaimed water, biogas, and other recovered materials.

B. LCA

FU: 1000 kg	Meat products:	Base scenario (current state)	AccelWater Scenario	% change
Climate change, default, excl biogenic carbon	[kg CO2 eq.]	1,51E+02	-5,43E+00	-103,6%
Climate change, incl biogenic carbon	[kg CO2 eq.]	1,94E+02	4,61E+01	-76,3%
Fine Particulate Matter Formation	[kg PM2.5 eq.]	2,06E-02	-2,57E-02	-224,9%
Fossil depletion	[kg oil eq.]	2,29E+00	-5,96E+00	-360,6%
Freshwater Consumption	[m3]	-3,05E+00	-3,21E+00	-5,3%
Freshwater ecotoxicity	[kg 1,4 DB eq.]	3,05E+01	2,50E+00	-91,8%
Freshwater Eutrophication	[kg P eq.]	1,01E-02	-4,95E-03	-149,1%
Human toxicity, cancer	[kg 1,4-DB eq.]	4,03E+00	-4,71E-01	-111,7%
Human toxicity, non-cancer	[kg 1,4-DB eq.]	1,43E+03	2,67E+02	-81,4%
Ionizing Radiation	[Bq C-60 eq. to air]	3,72E-01	-1,34E+00	-459,7%
Land use	[Annual crop eq.·y]	5,66E-01	-1,05E+01	-1961,1%
Marine ecotoxicity	[kg 1,4-DB eq.]	3,70E+01	3,00E+00	-91,9%
Marine Eutrophication	[kg N eq.]	1,32E-01	1,57E-02	-88,1%
Metal depletion	[kg Cu eq.]	4,58E-02	-7,03E-02	-253,3%
Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]	4,99E-02	1,45E+01	28993,3%
Photochemical Ozone Formation, Human Health	[kg NOx eq.]	4,79E-02	9,03E+00	18743,9%
Stratospheric Ozone Depletion	[kg CFC-11 eq.]	2,89E-05	1,81E-04	524,9%
Terrestrial Acidification	[kg SO2 eq.]	4,02E-02	-9,66E-03	-124,1%
Terrestrial ecotoxicity	[kg 1,4-DB eq.]	8,68E+01	-8,08E+01	-193,1%
Damage to human health	[DALY]	6,60E-04	8,11E-05	-87,7%
Damage to ecosystems	[species.yr]	2,48E-06	3,17E-07	-87,2%
Damage to resource availability	[$]	7,42E-01	-1,68E+00	-326,5%

FIGURE 18 LCA RESULTS OF SPANISH DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the LCA analysis of the Spanish demonstrator before and after implementing the AccelWater project, the base scenario indicates various environmental impacts and resource depletions associated with the generated wastewater and handling of the solid wastes. However, the AccelWater Scenario shows remarkable improvements across all these categories. More specifically, climate change impact reduces by 103.0%, freshwater consumption decreases by 41.1%, and human toxicity, related to cancer, is reduced by 497.1%. The graphical representation further emphasizes these environmental benefits, showcasing substantial reductions in the studied impact categories compared to the base scenario.

C. Nexus

Index	Value	Base
Profit	-0,3	1
CO2 red	1,0	0
Water reuse	0,7	0-1
Ele gain	2,7	0
Thermal En gain	18,2	0

FIGURE 19 NEXUS INDICATORS OF SPANISH DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the Nexus approach of the Spanish demonstrator before and after the implementation of the AccelWater project, several key indices highlight the overall improvements. CO_2 reduction has a significant value of 1.0, starting from a base of 0, showcasing substantial environmental benefits. Water reuse is also notable, with a value of 0.7 compared to a base range of 0-1, demonstrating enhanced water management. Electricity gain is 2.7, and thermal energy gain is 18.2, both starting from a base of 0, indicating considerable improvements in energy recovery and utilization.

2.2.3 Italian Demonstrator

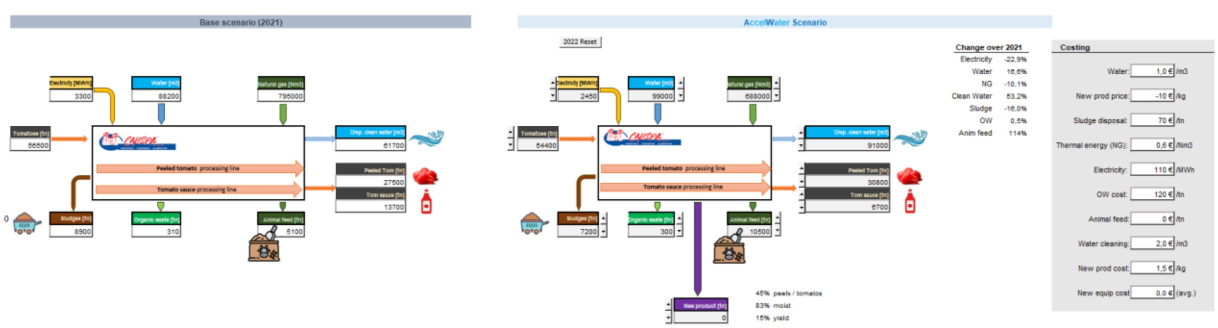


FIGURE 20 BASIC INPUTS AND OUTPUTS OF ITALIAN DEMONSTRATOR BEFORE AND AFTER ACCELWATER

The basic flows of the Italian demonstrator before and after the implementation of AccelWater consist of the by-products that are valorized to recover lycopene and cutin.

Base scenario (2021)

A. Costing (per tn tomato)

	Unit	Amount	Cost
Electricity	kWh	58,4	6,4 €
Water	m3	1,6	1,6 €
Natural gas	Nm3	14,1	8,4 €
Sludges	tn	0,2	11,0 €
OW	tn	0,0	0,7 €
Animal feed (dr.)	tn	0,02	0,0 €
Water cleaning	m3	1,1	2,2 €
New prod	tn	-	-
		Total:	30,30 €

AccelWater Scenario

	Unit	Amount	Cost
Electricity	kWh	45,0	5,0 €
Water	m3	1,8	1,8 €
Natural gas	Nm3	12,6	7,6 €
Sludges	tn	0,1	9,3 €
OW	tn	0,0	0,7 €
Animal feed (dr.)	tn	0,03	0,0 €
Water cleaning	m3	1,7	3,3 €
New prod	kg	0,0	0,0 €
7-year Depr. Equip			**0,0 €**
		Total:	28 €

Base scenario (2021)	30,30 €
AccelWater Scenario	27,63 €

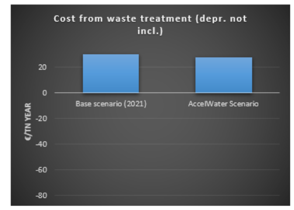
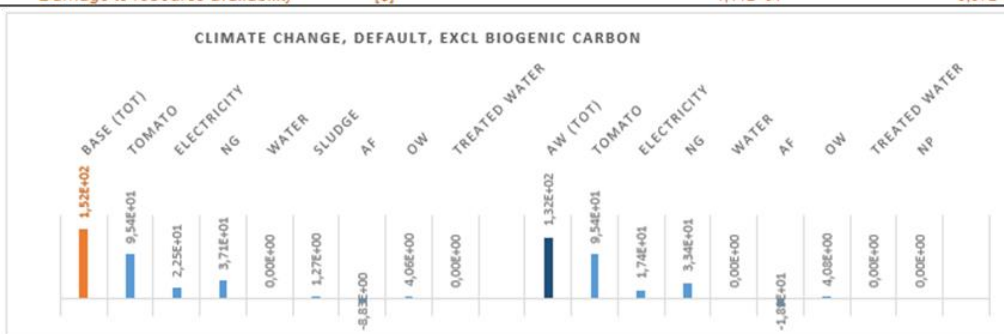


FIGURE 21 LCC RESULTS OF ITALIAN DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the LCC analysis before and after the implementation of the new waste treatment strategy, the initial scenario depicts a total profit of 30.30€/tn of tomatoes. This cost is primarily due to expenses associated with managing the generated solid wastes and wastewater. However, the economic evaluation of the proposed improvements demonstrates a significant reduction in costs, resulting in a total cost of 27.63€/tn of tomatoes. This positive change is attributed to reduction of energy and water consumption associated with the implementation of AccelWater.

B. LCA

FU: 1 tn fresh tomato		Base scenario (2021)	AccelWater Scenario	% change
Climate change, default, excl biogenic carbon	[kg CO2 eq.]	1,52E+02	1,32E+02	-12,6%
Climate change, incl biogenic carbon	[kg CO2 eq.]	7,41E+01	8,13E+01	9,7%
Fine Particulate Matter Formation	[kg PM2.5 eq.]	1,90E-01	1,67E-01	-12,4%
Fossil depletion	[kg oil eq.]	4,87E+01	4,33E+01	-11,2%
Freshwater Consumption	[m3]	2,28E+01	1,80E+01	-20,8%
Freshwater ecotoxicity	[kg 1,4 DB eq.]	2,71E+00	2,33E+00	-14,1%
Freshwater Eutrophication	[kg P eq.]	1,84E-02	1,58E-02	-14,5%
Human toxicity, cancer	[kg 1,4-DB eq.]	4,47E+00	3,99E+00	-10,7%
Human toxicity, non-cancer	[kg 1,4-DB eq.]	1,75E+02	1,65E+02	-5,9%
Ionizing Radiation	[Bq C-60 eq. to air]	2,73E+00	2,29E+00	-16,1%
Land use	[Annual crop eq.·y]	1,26E+02	9,21E+01	-26,7%
Marine ecotoxicity	[kg 1,4-DB eq.]	3,44E+00	2,96E+00	-14,0%
Marine Eutrophication	[kg N eq.]	1,98E-01	1,49E-01	-24,7%
Metal depletion	[kg Cu eq.]	6,72E-01	6,03E-01	-10,4%
Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]	1,17E+00	1,13E+00	-3,6%
Photochemical Ozone Formation, Human Health	[kg NOx eq.]	8,92E-01	8,49E-01	-4,8%
Stratospheric Ozone Depletion	[kg CFC-11 eq.]	4,46E-04	3,08E-04	-30,9%
Terrestrial Acidification	[kg SO2 eq.]	6,18E-01	5,28E-01	-14,6%
Terrestrial ecotoxicity	[kg 1,4-DB eq.]	3,04E+02	2,62E+02	-13,8%
Damage to human health	[DALY]	4,50E-04	4,09E-04	-9,1%
Damage to ecosystems	[species.yr]	4,76E-05	4,42E-05	-7,2%
Damage to resource availability	[$]	1,11E+01	9,97E+00	-10,0%



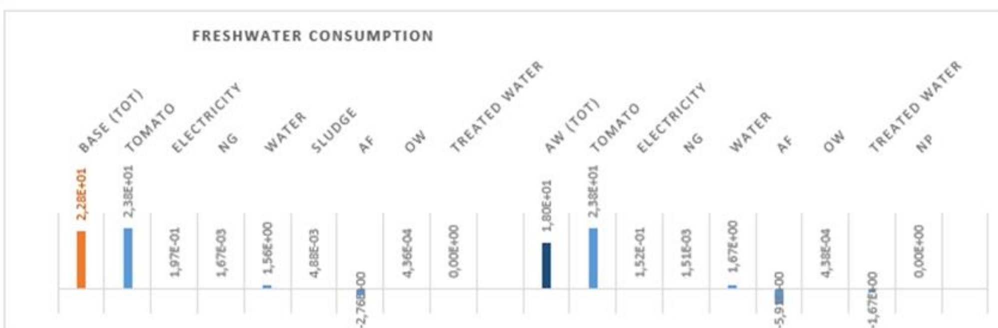


FIGURE 22 LCA RESULTS OF ITALIAN DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the LCA analysis of the Italian demonstrator before and after implementing the AccelWater project, the base scenario indicates various environmental impacts and resource depletions associated with the generated wastewater and handling of the solid wastes. However, the AccelWater Scenario shows remarkable improvements across all these categories. More specifically, climate change impact reduces by 12.6%, freshwater consumption decreases by 20.8%, and human toxicity, related to cancer, is reduced by 10.7%. The graphical representation further emphasizes these environmental benefits, showcasing substantial reductions in the studied impact categories compared to the base scenario.

C. Nexus

Index	Value	Base
Cost	0,9	1
CO2 red	1,1	1
Water claimed	1,3	1
Ele gain	0,0	0
Thermal En gain	0,0	0

FIGURE 23 NEXUS INDICATORS OF SPANISH DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the Nexus approach of the Italian demonstrator before and after the implementation of the AccelWater project, several key indices highlight the overall improvements. CO_2 reduction has a 10% increase, showcasing substantial environmental benefits. Moreover, water reuse is also notable, with a value of 1.3 compared to the basis value of 1.

2.2.4 Icelandic Demonstrator

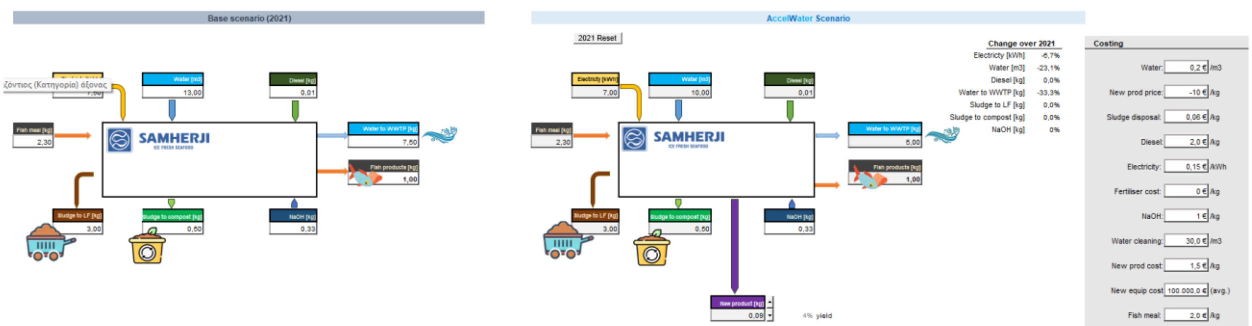


FIGURE 24 BASIC INPUTS AND OUTPUTS OF ICELANDIC DEMONSTRATOR BEFORE AND AFTER ACCELWATER

The basic flows of the Icelandic demonstrator before and after the implementation of AccelWater consist of the by-products that are valorized to obtain new products that can be subsequently sold.

A. Costing (per kg fish product)

	Unit	Amount	Cost
Electricity	kWh	7,5	1,1 €
Water	m3	13,0	2,6 €
Diesel	kg	0,01	0,0 €
Sludges	kg	3,0	0,2 €
Compost	kg	0,5	0,0 €
NaOH	kg	0,33	0,3 €
Water cleaning	kg	7,5	0,2 €
Fish meal	kg	2,3	4,6 €
New prod	kg	-	-
		Total:	9,08 €

	Unit	Amount	Cost
Electricity	kWh	7,0	1,1 €
Water	m3	10,0	2,0 €
Diesel	kg	0,01	0,0 €
Sludges	kg	3,0	0,2 €
Compost	kg	0,5	0,0 €
NaOH	kg	0,33	0,3 €
Water cleaning	kg	5,0	0,2 €
Fish meal	kg	2,3	4,6 €
New prod	kg	0,1	-0,8 €
7-year Depr. Equip			0,0 €
		Total:	7,55 €

Base scenario (2021)	9,08 €
AccelWater Scenario	7,55 €

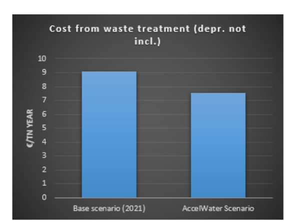
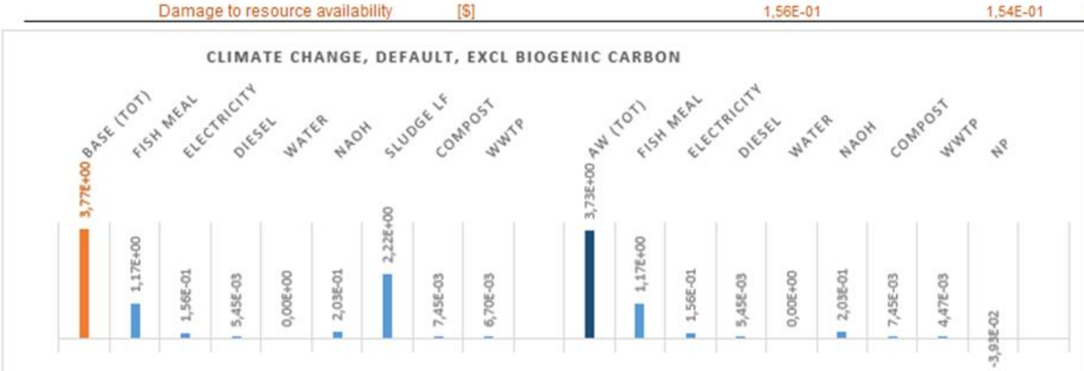


FIGURE 25 LCC RESULTS OF ICELANDIC DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the LCC analysis before and after the implementation of the new waste treatment strategy, the initial scenario depicts a total profit of 9.08€/kg of fish products. This cost is primarily due to expenses associated with managing the generated solid wastes and wastewater. However, the economic evaluation of the proposed improvements demonstrates a significant reduction in costs, resulting in a total cost of 7.55€/kg of fish products. This positive change is attributed to reduction of energy and water consumption associated with the implementation of AccelWater.

B. LCA

FU: 1 tn fresh tomato		Base scenario (2021)	AccelWater Scenario	% change
Climate change, default, excl biogenic carbon	[kg CO2 eq.]	3,77E+00	3,73E+00	-1,1%
Climate change, incl biogenic carbon	[kg CO2 eq.]	1,29E+00	1,38E+00	6,5%
Fine Particulate Matter Formation	[kg PM2.5 eq.]	2,17E-03	2,10E-03	-3,3%
Fossil depletion	[kg oil eq.]	4,36E-01	4,27E-01	-2,2%
Freshwater Consumption	[m3]	1,28E-01	1,29E-01	0,6%
Freshwater ecotoxicity	[illegible]	2,65E-03	7,63E-04	-71,3%
Freshwater Eutrophication	[illegible]	6,53E-04	6,36E-04	-2,6%
Human toxicity, cancer	[kg 1,4-DB eq.]	1,00E-03	-1,86E-03	-285,9%
Human toxicity, non-cancer	[kg 1,4-DB eq.]	-4,93E-01	-5,01E-01	-1,6%
Ionizing Radiation	Bq C-60 eq. to air]	8,25E-03	6,88E-03	-16,6%
Land use	Annual crop eq.·y]	6,29E+00	6,04E+00	-3,8%
Marine ecotoxicity	[kg 1,4-DB eq.]	3,58E-03	1,11E-03	-69,0%
Marine Eutrophication	[kg N eq.]	4,20E-03	4,03E-03	-4,2%
Metal depletion	[kg Cu eq.]	5,94E-02	5,95E-02	0,3%
Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]	1,66E+00	1,64E+00	-1,0%
Photochemical Ozone Formation, Human Health	[kg NOx eq.]	1,03E+00	1,02E+00	-1,0%
Stratospheric Ozone Depletion	[kg CFC-11 eq.]	1,21E-05	1,17E-05	-3,5%
Terrestrial Acidification	[kg SO2 eq.]	8,08E-03	7,93E-03	-2,0%
Terrestrial ecotoxicity	[kg 1,4-DB eq.]	3,65E-01	2,04E-01	-44,1%
Damage to human health	[DALY]	6,96E-06	6,92E-06	-0,6%
Damage to ecosystems	[species.yr]	2,86E-07	2,64E-07	-7,9%
Damage to resource availability	[$]	1,56E-01	1,54E-01	-1,7%



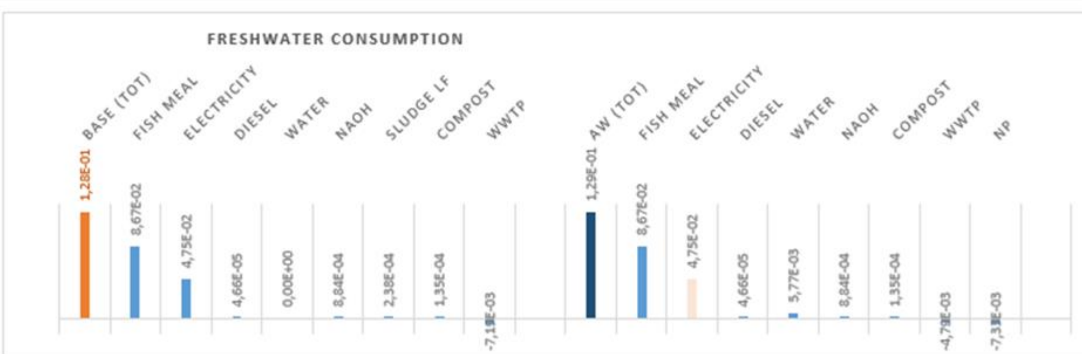


FIGURE 26 LCA RESULTS OF ICELANDIC DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the LCA analysis of the Icelandic demonstrator before and after implementing the AccelWater project, the base scenario indicates various environmental impacts and resource depletions associated with the generated wastewater and handling of the solid wastes. However, the AccelWater Scenario shows remarkable improvements across all these categories. More specifically, climate change impact reduces by 1.1%, freshwater consumption decreases by 0.6%, and human toxicity, related to cancer, is reduced by 285.9%.

C. Nexus

Index	Value	Base
Cost	**0,8**	1
CO2 red	**1,0**	1
Water claimed	**0,9**	1
Ele gain	0,0	0
Thermal En gain	0,0	0

FIGURE 27 NEXUS INDICATORS OF ICELANDIC DEMONSTRATOR BEFORE AND AFTER ACCELWATER

According to the results obtained Nexus approach of the Icelandic demonstrator before and after the implementation of the AccelWater project, several key indices highlight the overall improvements. More specifically, the decrease in the cost associated with the handling of solid wastes and the reclaimed water are depicted in the decrease of the corresponding indicators.

2.3 Static Analysis

The static analysis for evaluating AccelWater solutions is designed to systematically collect data from industrial demonstrators at regular intervals. This process ensures a comprehensive and continuous monitoring system that is critical for assessing the performance and sustainability of the implemented technologies. At the core of this system is the platform administrator, who is tasked with the crucial role of uploading collected data. This data encompasses detailed metrics on resource consumption, cost parameters, and other relevant variables that provide a holistic view of the operational efficiency and environmental impact. By utilizing the described methodology, the AccelWater platform processes this data to generate comprehensive reports. These reports are meticulously crafted to analyse the performance and sustainability of AccelWater technologies, offering stakeholders invaluable insights into their water, waste, and energy management practices. The reports are based on rigorous methodologies, including Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and the Waste-Water-Energy (WWE) nexus approach, all in strict compliance with the protocols outlined in Work Package 8 (WP8) of the project. This structured and automated approach ensures precise and reliable evaluations. By leveraging advanced data analytics and systematic data collection, the platform delivers critical insights into long-term trends, identifies hot-spots across the production chain and assesses the effectiveness of the AccelWater solutions. Stakeholders can rely on these reports to make informed decisions about resource management and to identify areas for further improvement.

Moreover, there is a provision for updating the results every six months. This is facilitated by the continuous collection of data through the installed sensors, ensuring that the evaluations remain current and reflective of the latest operational data. This biannual update capability is a significant feature that allows for dynamic and responsive management of resources, adapting to changes and improvements in real time. The results of the evaluation of the collected data over this six-month period will be available online (platform) in a PDF format report. This format ensures that the information is easily accessible, shareable, and archivable, allowing stakeholders to review the findings conveniently. The use of PDF format also ensures the integrity and security of the data presented. The methodology employed is based on Work Package 8 of the AccelWater project, which provides a robust framework for evaluating the environmental and economic impacts of the technologies, along with the interdependencies of critical parameters, such as energy and water consumption and wastes valorization, based on the developed Nexus approach. By adhering to WP8 guidelines (based on the ISOs 14040 & 14044), the evaluations maintain a high standard of accuracy and reliability, reinforcing the credibility of the findings. Furthermore, in this report, which will present the results of the evaluation of AccelWater’s solutions will include a comparative analysis of each demonstrator's performance following the implementation of the AccelWater project with the baseline performance data captured at the beginning of the project. This comparative analysis is crucial for quantifying the improvements achieved and for identifying the specific benefits brought about by the AccelWater solutions. In conclusion, the static analysis for evaluating AccelWater solutions is a comprehensive and systematic approach designed to provide continuous, reliable, and detailed insights into the performance of water, waste, and energy management practices. With the capability to update results biannually and present findings in a PDF format, this methodology ensures that stakeholders are well-informed and equipped to make data-driven decisions.

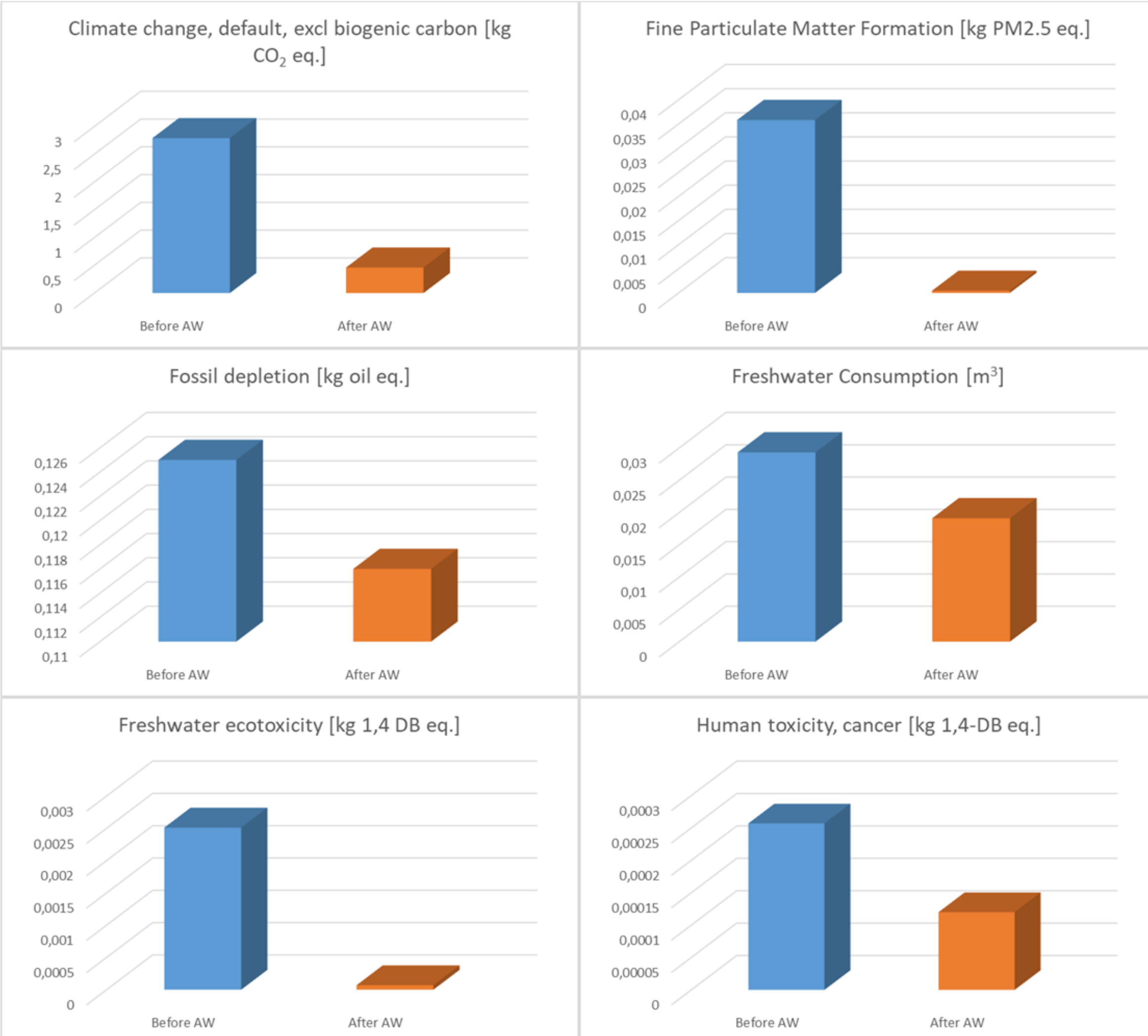


FIGURE 28 SNAPSHOT OF THE GENERATED REPORT (LCA ANALYSIS)

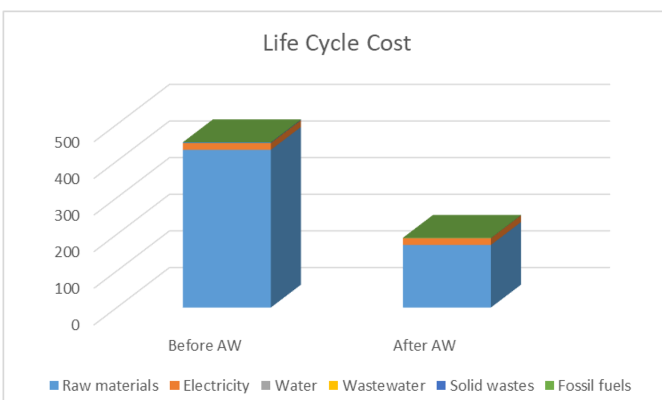


FIGURE 29 SNAPSHOT OF THE GENERATED REPORT (LCC ANALYSIS)

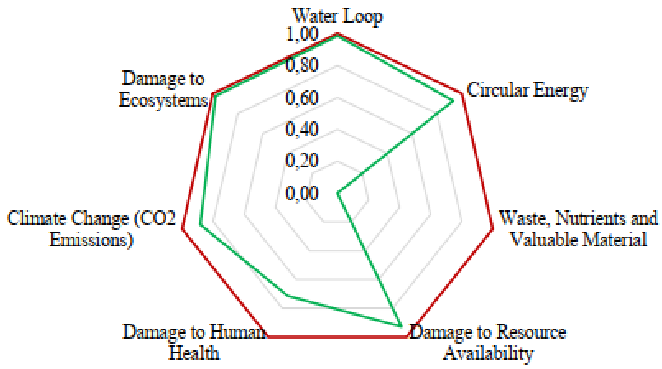


FIGURE 30 SNAPSHOT OF THE GENERATED REPORT (WWE-NEXUS APPROACH)

3 Social LCA

The Social Life Cycle Assessment (S-LCA) examines the various social dimensions of a product or a system, considering the influence related to the stakeholders: workers, value chain actors, society and local communities. This encompasses aspects such as labour conditions, human rights, community well-being, health and safety, social equity and more. Since the fundamental goal of S-LCA methodology is to promote improvement of social conditions throughout the life cycle of a product, human well-being is the central concept [1]. For this purpose, and in accordance with the requirements of WP8, all relevant data were captured in the studied demonstrators prior and after the implementation of AccelWater solutions and technologies.

The analysis is conducted in OpenLCA, which is a Life Cycle and Sustainability Assessment software. For the social assessment SOCA v2 database is utilized, which combines PSILCA v3 and Ecoinvent v3.7.1 databases [2]. Based on PSILCA database, SOCA covers social risks on the four stakeholders: workers, local communities, value chain actors and society and the social outcomes are provided as risk assessed indicators. As an impact assessment method for the social indicators evaluation Social Impact Weighting Method was used, which contains the characterization factors of the social indicator. In SOCA v2 database, the assessment is conducted using a risk scale with six different risk levels, since the indicators are measured in different, non-comparable units. The activity variable applied in this analysis is worker hours and is used to quantify the social risks. It is explained as the measure of a process activity which can be related to process output [3], [4]. The risk level of each indicator is scaled to medium risk hours, as this is the unit for the results depiction, as shown in Table 1. Characterization factors for the impact assessment method in PSILCA and SOCA [2], [4]

Risk Level	Factor
Very Low Risk	0.01
Low Risk	0.1
Medium Risk	1
High Risk	10
Very High Risk	100
No Risk	0
No Data	0.1

TABLE 1 CHARACTERIZATION FACTORS FOR THE IMPACT ASSESSMENT METHOD IN PSILCA AND SOCA

The social analysis considers the four main stakeholders of a process, the workers, the value chain actors, the local communities and the society. The impacts on these four stakeholders are classified in 17 subcategories. These subcategories include 53 indicators of social risks [2], out of these indicators the most relevant ones are selected to be assessed in the frameworks of AccelWater Project.

3.1 Interactive Analysis of Social Impact

3.1.1 Total Social Risk Assessment

A comprehensive Excel file has been developed to calculate the total social risk associated with an industry. This file evaluates the 16 most relevant social indicators, encompassing all four stakeholder groups. The risk assessment follows the scaling provided in the PSILCA handbook for each indicator.

For instance, the next table (Table 2) illustrates the risk assessment for the indicator 'Accident rate at workplace' concerning non-fatal accidents. The risk scaling provided by PSILCA is detailed in Table 2. The unit of measurement is cases per 100,000 employees per year. According to this scale, if there are 780 cases per 100,000 employees per year, the social risk for this indicator is considered low.

Indicator value y (cases per 100000 employees per year)	Risk Level
0<=y<750	Very Low Risk
750<=y<1500	Low Risk
1500<=y<2250	Medium Risk
2250<=y<3000	High Risk
3000<=y	Very High Risk
-	No Data

TABLE 2 RISK ASSESSMENT: RISK THAT WORKERS SUFFER NON-FATAL ACCIDENTS

In the Excel file https://1drv.ms/x/s!AjKNAlXomEDayETFtg7_-Dw0Hnxk?e=PbPD1G , the user should input data into columns F and G, ensuring they use the correct units of measurement as indicated in column E to obtain accurate results. The outcomes for each indicator are displayed in column H. For a comprehensive calculation of the total social impact, all indicators must have data entered. The final result of the total analysis is shown in cell H24.

Stakeholders	Subcategories	Indicators	Risk assessment	Units of Measurment	Pilot Case		
					Value		Risk Level
Workers	Fair salary	Living wage, per month	Risk that cost of living is high	USD	700		High Risk
		Minimum wage, per month	Risk that minimum wage is too low to permit a dignified life	USD	800		Low Risk
		Sector average wage, per month	Risk that salary is too low to permit a dignified life	USD	1000		Very Low Risk
	Working time	Hours of work per employee, per week	Risk of improper working hours	h	40		Low Risk
	Discrimination	Men in the sectoral labour force	Risk of men being underrepresented in specific sectors	ratio	0.3		High Risk
		Women in the sectoral labour force	Risk of women being underrepresented in specific sectors	ratio	0.7		Low Risk
		Gender wage gap	Risk of unequal wages	Percentage of inequalities in wages between the two genders (%)	15		Medium Risk
	Health and Safety	Accident rate at workplace	Risk that workers suffer non-fatal accidents	Cases per 100,000 employees per year	10		Very Low Risk
		Fatal accidents at workplace	Risk that workers suffer fatal accidents	Cases per 100,000 employees per year	42		Very High Risk
Value Chains Actors	Corruption	Active involvement of enterprises in corruption and bribery	Risk of involvement in foreign bribery	% of your sector	Manufacturing	8.0	Medium Risk
	Promoting social responsibility	Membership in an initiative that promotes social responsibility along the supply chain	Risk of unsustainable business practices	Number of companies	5		Medium Risk
Society	Prevention and mitigation of conflicts	Risk of conflicts	Risk of involvement in foreign bribery	Score of your country location	Switzerland	1.35	Very Low Risk
Local Community	Access to material resources	Level of industrial water use (related to total withdrawal)	Risk that industry accounts for a large share of water withdrawal	% of total water withdrawal	20		Medium Risk
		Level of industrial water use (related to renewable water resources)	Risk of a high pressure on renewable water resources	% of renewable water resources	1		Low Risk
		Certified environmental management systems (CMEs)	Risk of environmental damage	# CEMs (ISO 14001) in sector per 10,000 employees	1		Very Low Risk
	Safe and healthy living conditions	Contribution of the sector to environmental load	Risk of health and environmental risks due to different compounds	kg of CO2 equiv. per USD	0.0001		Low Risk

Dear User,
Welcome to the social impact assessment tool based on the 17 indicators from the PSILCA database.
To get started, please enter your data in columns F and G. The risk level for each indicator will be calculated automatically and displayed in column H.
For an overall analysis, the total risk level will be shown in cell H24.
Please note that the results in cell H24 are realistic only if all the indicator cells in columns F and G are completed. If you find that some indicator information is missing, please visit PSILCA documentation to locate the relevant indicator.
The PSILCA handbook includes suggested national databases where you can approximate any missing data.
If you have any questions or need further assistance, please do not hesitate to contact us at:
sofia.papadaki@dignity.com.gr
apetridi@dignity.com.gr

Total Social Impact: Low to Medium Risk

Figure 31 Excel file interface for the calculation of the Social Impacts of a process based on the selected Indicators

If direct data for any of the indicators is missing, it can be sourced through national databases as suggested in the PSILCA handbook for each indicator. By adjusting the values in the specified columns, the user can interactively observe how interventions in a process line affect the social impact of an industry. As the values change, the social impact of the industry will increase or decrease accordingly.

3.1.2 Social Impact level changes from AccelWater

Models for measuring AccelWater solutions' performance align with the Theory of Change (ToC) approach by mapping how specific interventions, such as waste valorization, energy production, and water reuse, lead to desired outcomes. The ToC framework helps identify key assumptions, risks, and solutions, ensuring that AccelWater's activities contribute effectively to sustainable industry transformation. Through ongoing evaluation and stakeholder consultation, these models ensure the interventions address real-world challenges and drive progress.

Theory of Change (ToC) is a method that describes the way in which an intervention, or a group of interventions, leads to a desired change. It describes how the various activities are expected to produce certain outcomes that will contribute to achieving the final intended change. A ToC must be driven by sound analysis, consultation with key stakeholders and learning on what works and what does not in diverse contexts drawn from experience. Additionally, a ToC can be used in order to determine any assumptions made for the intervention to happen and to identify solutions for various risks and problems that hinder the desired progress[1]. A ToC methodology is typically used for planning participation, management and evaluation, in order to promote a social change; a process whereby individuals and communities adjust or abandon customs and associated leading ideas, values and purposes to act differently in response to random (unique) or systemic factors. A ToC method can be developed for any level of intervention, from a single event up to an organization[2].

A ToC methodology can be represented by a diagram that depicts the relationships between the chosen strategies and the expected outcomes, usually as a series of boxes from inputs to outputs, outcomes and impacts (e.g. see Figure 33). Sometimes multiple boxes are shown for each stage and the relevant boxes linked to show how particular activities lead to particular outputs and how particular outputs lead to particular outcomes, always combined with the assumptions and risks made in each stage.

FIGURE 32 BASIC THEORY OF CHANGE METHODOLOGY DIAGRAM

There are four steps involved in the development of a ToC methodology. Briefly:

- Focus on the high-level change

[1] United Nation Development Group, THEORY OF CHANGE UNDAF CAMPANION GUIDANCE, https://unsdg.un.org/sites/default/files/UNDG-UNDAF-Companion-Pieces-7-Theory-of-Change.pdf

[2] Rogers, P. (2014). Methodological Briefs: Impact Evaluation No. 2, Theory of Change

- Define the goals and objectives of the study, identify the problem that ToC seeks to address, its causes and consequences.
- Search for opportunities (e.g. synergies with other initiatives, strengthening of existing resources).

➢ Develop the way to go to the desired situation from the current one

- How this change will come about.
- How the intervention will trigger this change.

➢ Define assumptions underpinning the ToC and possible risks

- Focus on things that are expected that will affect the intervention outcomes.
- Analysis of the risks involved.

➢ Identify partners & key actors

- Revisit each result, including the related risks and assumptions.

A theory of change implies a shift in focus to contribution rather than attribution, to acknowledge the role and inputs of partners and other actors both in achieving outcomes and in providing evidence for those outcomes. Concisely, a ToC explains how and why a sequence of logically linked events should lead to a desired outcome. This is achieved by articulating assumptions and the beliefs and hypotheses they rely on. It shows how short-, medium-, and/or long-term change happens in a specific context; and stipulating how early and intermediate outcomes contribute towards the long-term change, using indicators that describe how much of, for whom, and when each outcome is to be realized. The theory of change and the impact pathways have to be harmonized so that they contribute to the project targets. With an appropriate theory of change defined, indicators and baselines are needed so that the assumptions underlying them can be continuously tested and project's contributions checked for alignment and plausibility.

AccelWater's Theory of Change is designed to create substantial impact level changes through a strategic approach encompassing community building, employment, and education. At its core, the strategy focuses on engaging stakeholders and fostering industrial symbiosis, enhancing the Waste-Water-Energy Nexus, and promoting energy and water savings alongside waste minimization. These efforts are projected to yield significant economic benefits through the production of high-value products.

Community Building: AccelWater aims to increase participation across diverse demographics, ensuring active engagement from men, women, and businesses in decision-making processes and various activities. Success indicators include the number of participants, diversity of involvement, loyalty through returning users, and participation across multiple structures and programs.

Employment: By involving professionals in educational activities, AccelWater seeks to improve employability and skills. This is measured by the number of professionals trained, new job positions created, and the enhancement of participants' knowledge and skills.

Education: The educational impact is gauged through participants' skill assessments before and after engaging with AccelWater's e-learning modules, the number of training programs conducted, and the total employee participation. Additionally, diversity metrics such as gender ratio and age groups are monitored.

To achieve these outcomes, AccelWater provides high-quality educational materials, experienced trainers, and efficient budgets for training activities. The success of pilot cases and structured e-learning modules support these endeavors.

Impact Level Changes: The ultimate goals include improved industrial practices, increased safety and employability for workers, and enhanced societal well-being. Achieving these impacts requires preconditions such as the willingness of beneficiaries to participate, established local leadership, and stakeholder support.

AccelWater's Theory of Change outlines specific impact level changes that result from its strategic interventions. These impact level changes can be categorized into three main areas: industrial symbiosis, worker well-being, and societal benefits.

Industrial Symbiosis and Environmental Impact

1. **Waste-Water-Energy Nexus**:
    - **Energy and Water Savings**: Implementing technologies and practices that reduce energy and water consumption in industrial processes. This leads to more sustainable operations and lower utility costs for industries.
    - **Waste Minimization**: By optimizing waste management practices, industries can significantly reduce the amount of waste generated, leading to a cleaner environment and reduced disposal costs.
    - **Economic Benefits and High-Value Products**: Efficient resource utilization and waste reduction can create economic opportunities by converting waste into high-value products, enhancing profitability and market competitiveness.
2. **Industrial Symbiosis**:
    - **Resource Sharing**: Encouraging industries to share resources such as water, energy, and materials, which can lead to cost savings and more efficient resource use.
    - **Collaborative Innovation**: Promoting collaboration between different industries to develop innovative solutions for common challenges, leading to technological advancements and improved industrial practices.

3. Worker Well-Being and Employment

- **Skills Improvement and Safety**:
  - **Training and Education**: Providing high-quality training programs to improve the skills and knowledge of workers, making them more adept at handling modern, sustainable technologies and processes.
  - **Safety Enhancements**: Implementing safety protocols and training to ensure a safer working environment, which can reduce accidents and enhance worker satisfaction and productivity.
- **Employability**:
  - **Job Creation**: Through the introduction of new technologies and processes, AccelWater aims to create new job opportunities within the participating industries.
  - **Career Advancement**: Empowering workers with new skills and knowledge can lead to career growth and better job prospects, improving overall job satisfaction and economic stability for employees.

4. Societal Benefits and Resilience

- **Improved Well-Being**:
  - **Health and Environment**: Reducing industrial emissions and waste improves environmental quality, which directly benefits public health and community well-being.
  - **Community Engagement**: Encouraging active participation from community members in decision-making processes fosters a sense of ownership and responsibility towards sustainable practices.
- **Improved Products**:
  - **Quality and Innovation**: Developing high-value products from waste not only provides economic benefits but also ensures that the products meet high standards of quality and innovation, satisfying consumer demands and fostering market growth.
- **Resilience to Environmental Impact**:
  - **Sustainable Practices**: By adopting sustainable industrial practices, communities and industries become more resilient to environmental changes and disruptions, ensuring long-term stability and growth.
  - **Adaptation and Mitigation**: Implementing strategies that both adapt to and mitigate the effects of environmental changes helps industries and societies better withstand future challenges.

5. Preconditions for Achieving Impact

To achieve these impact level changes, several preconditions must be met:

- **Willingness of Beneficiaries**: The beneficiaries, including industries and workers, must be willing to participate in the interventions and adopt new practices.
- **Local Leadership Structure**: Effective local leadership is essential to guide and support the implementation of AccelWater initiatives.
- **Stakeholder Support**: Strong support from stakeholders, including government agencies, community organizations, and industry partners, is crucial for the success of the program.

By addressing these preconditions and implementing its strategic activities, AccelWater aims to drive significant impact level changes that contribute to a more sustainable, economically viable, and socially responsible industrial landscape.

The AccelWater partners can fill the questionnaire in this link https://form.typeform.com/to/jKkddM7w at least once and can update it as many times they consider that a significant change occurred and it is important to be noted. The results of this questionnaire will be available in a summary report in the following link https://form.typeform.com/report/jKkddM7w/meC0RB04YDc3LX5W . This report is automatically updated any time that new responses are collected. Moreover, this report will be available to the open-public function of the platform to anyone that would like to be informed about the impact level changes that AccelWater brought on a social level.

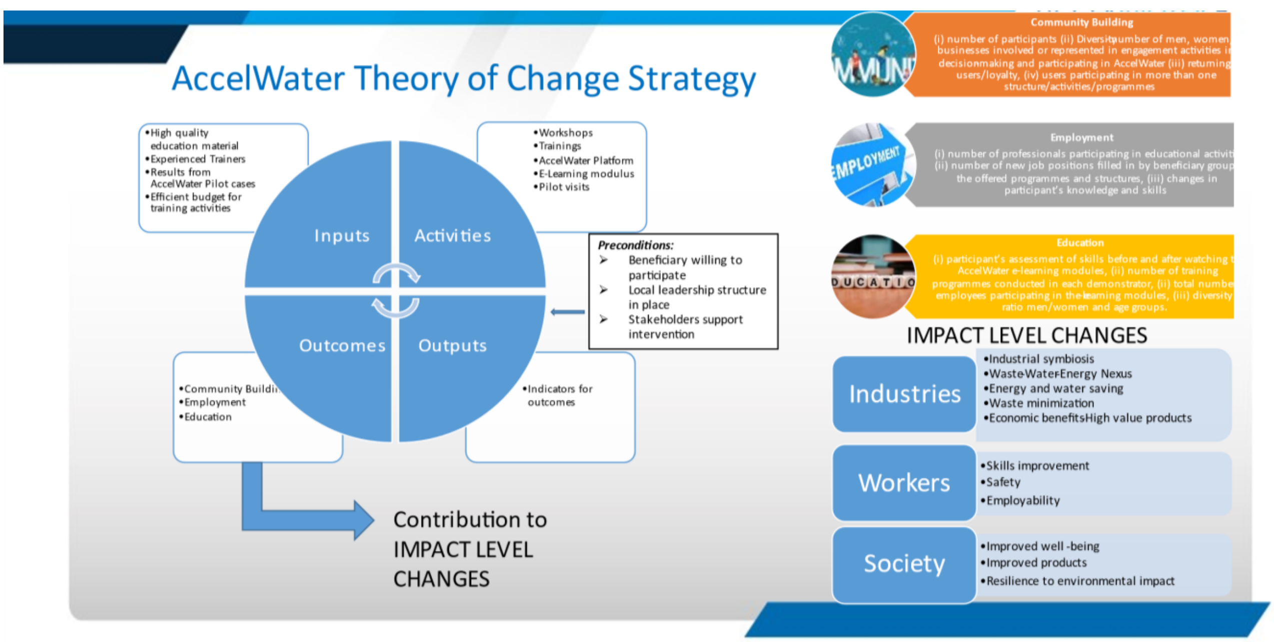


FIGURE 33 ACCELWATER TOC STRATEGY

3.2 Static Analysis of Social Impact

The social impacts of the demonstrators are actively calculated based on data provided by each demonstrator. It is expected that the results of the social analysis will be updated every six months. This updating process is facilitated by continuous data collection through installed sensors, ensuring that evaluations remain current and reflective of the latest operational data. This approach also allows for the timely update of any changes in social outcomes accumulated from the demonstrators. Initial results from the Spanish and Icelandic demonstrators are presented in the following sections, while comprehensive results for the Italian and Greek demonstrators are in progress and will be shared at the end of the project.

3.2.1 Spanish Demonstrator

Mafrica's production process, which is a meat industry specializing in pig products, located in Spain, is examined through social LCA. The examined meat industry plant consists of the production process plant and a Wastewater Treatment Plant (WWTP) installed on-site. The WWTP includes certain equipment, such as coarse scale grid, thin scale grid, regulator tank, dissolved air flotation, activated sludge reactor with nitrification-denitrification, sludge decanter tank and centrifuge. These processes are partially replaced by several innovative processes, aiming to mitigate the energy and water consumption, while at the same time valorizing wastes. The interventions that have been introduced in the abovementioned processes, under the framework of AccelWater project are: a wastewater reclamation system including a membrane bioreactor, electrodialysis, and UV disinfection processes. In addition, animal tissues and guts undergo now anaerobic digestion to produce biogas that could possibly be used for generating thermal and electrical energy through a Combined Heat and Power (CHP) System. Furthermore, sludge from the WWTP and sludge from the membrane bioreactor are bio-dried to produce solid biofuel. The process line for the base and the AccelWater scenario are also depicted in Figures 4-6.

The data for the social analysis of the Spanish Demonstrator were obtained through communication with industrial partners. The initial analysis compared the base situation of the Spanish Demonstrator with a scenario where 50% of wastewater was treated using the intervention system, while the remaining 50% was treated using the conventional system. The results revealed significant reductions in the most relevant social indicators: Gender Wage Gap by 36.0%, Fair Salary by 37.0%, Public Sector Corruption by 34.9%, and Biomass Consumption by 33.7%.

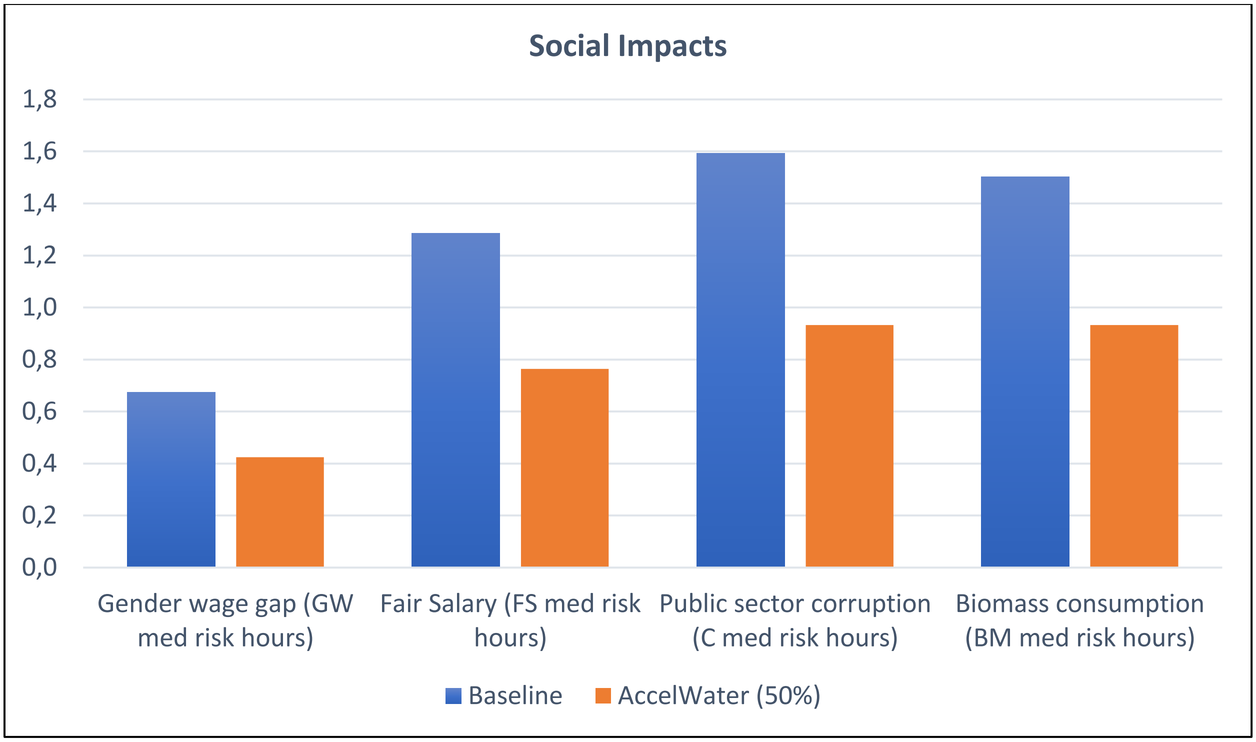


FIGURE 34 SOCIAL LCA RESULTS OF SPANISH DEMONSTRATOR BEFORE AND AFTER ACCELWATER

To further assess the effectiveness of the proposed AccelWater interventions, three different scenarios were studied, each varying in the proportion of water treated in the intervention system. The analysis demonstrated that increasing the use of the intervention system led to a corresponding reduction in social risks. These findings highlight the potential for substantial social benefits through the expanded implementation of the AccelWater interventions. The results are depicted in Figures 35-38.

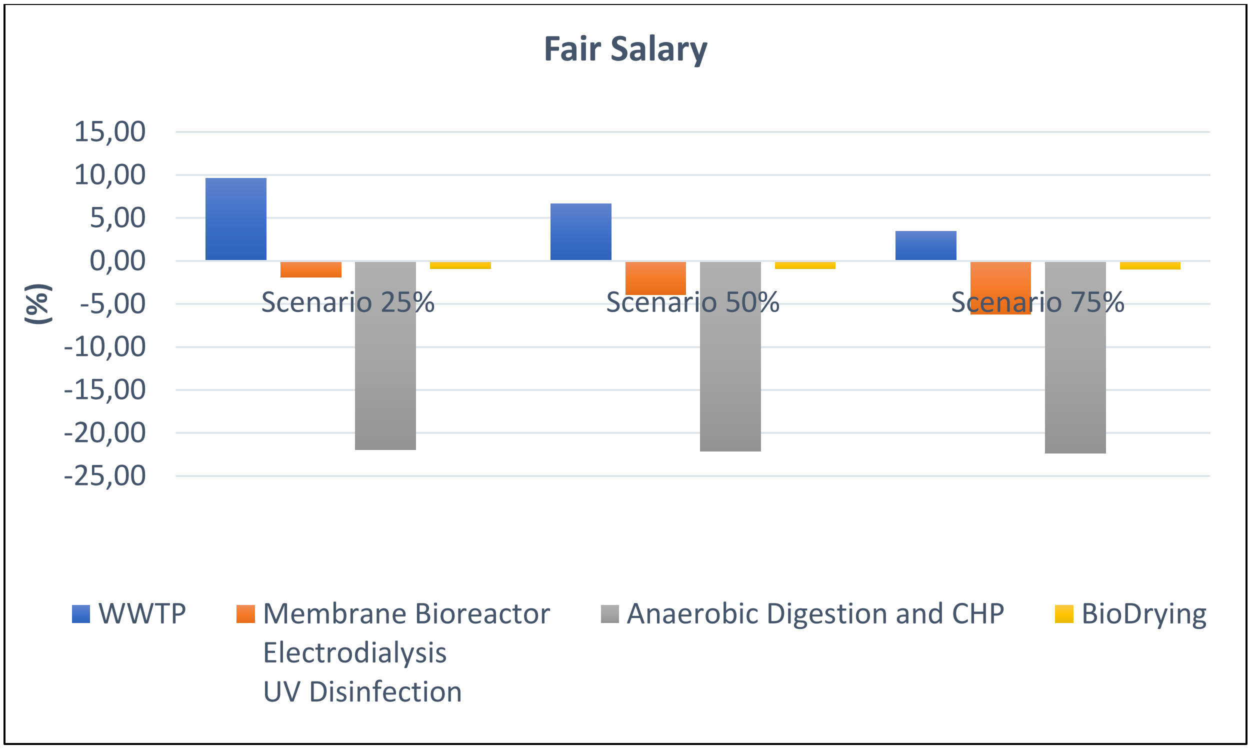


Figure 35 Social LCA results of Fair Salary Indicator of Spanish demonstrator For three different scenarios based on the quantity of water treated in the intervention system of the AccelWater

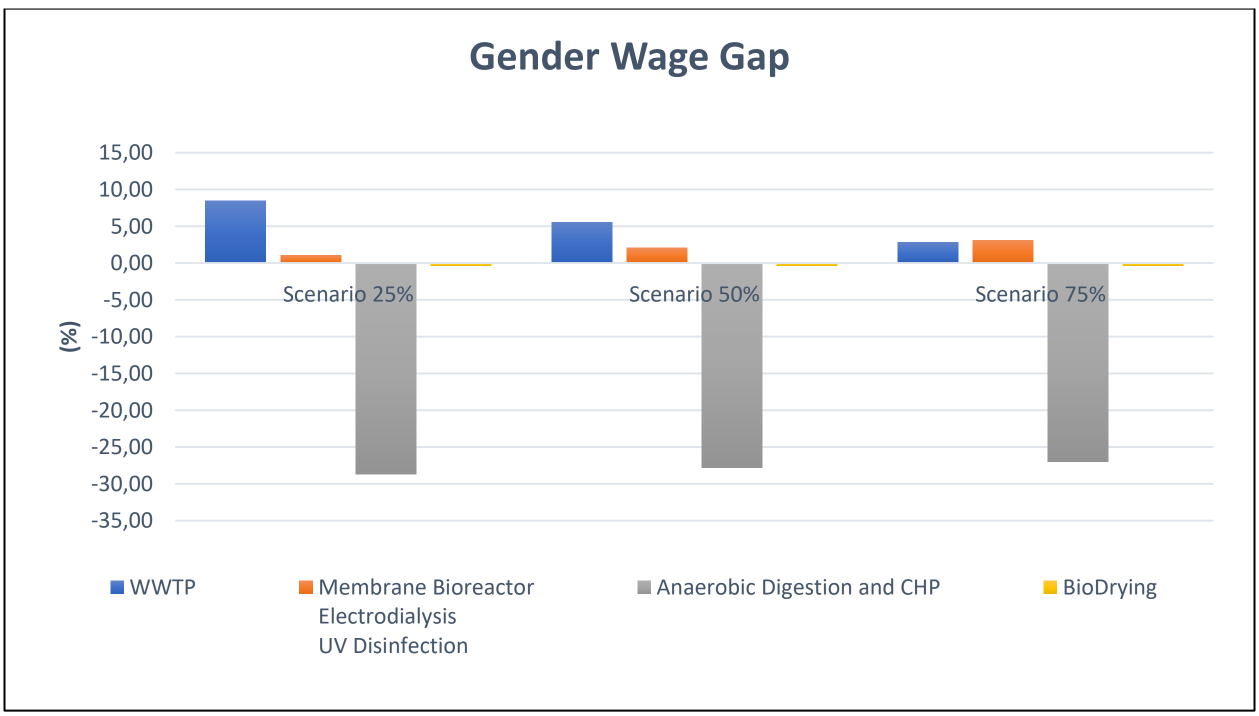


Figure 36 Social LCA results of Gender Wage Gap Indicator of Spanish demonstrator For three different scenarios based on the quantity of water treated in the intervention system of the AccelWater

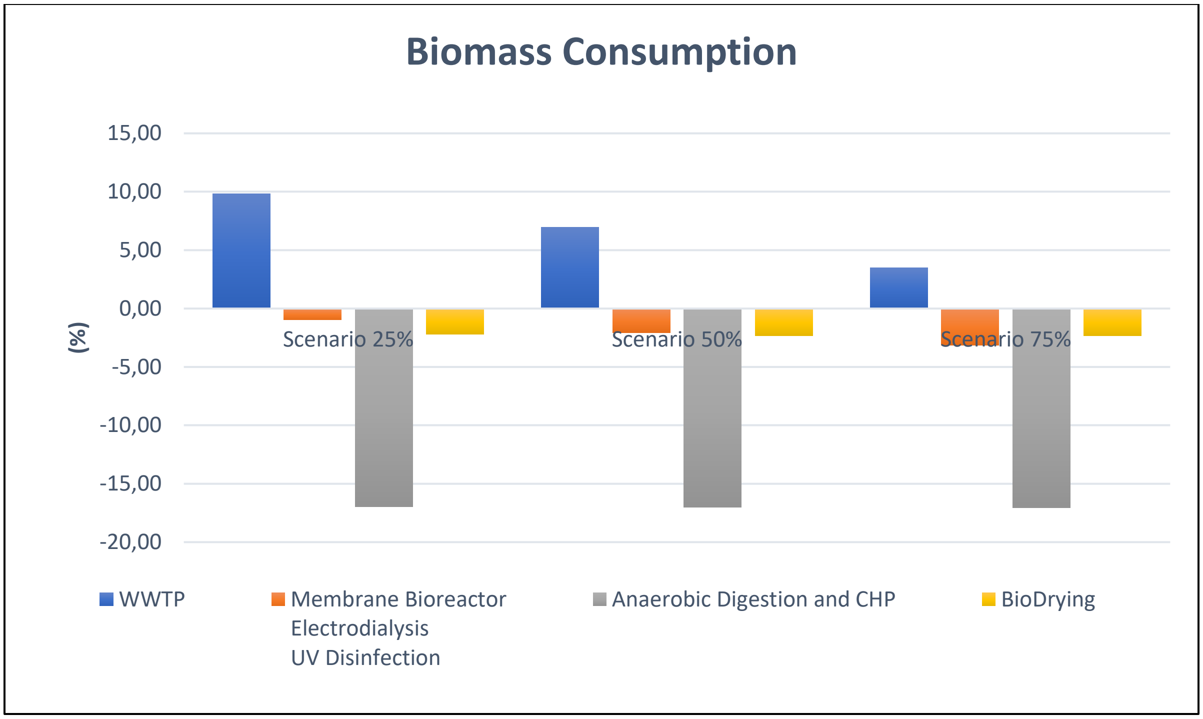


FIGURE 37 SOCIAL LCA RESULTS OF BIOMASS CONSUMPTION INDICATOR OF SPANISH DEMONSTRATOR FOR THREE DIFFERENT SCENARIOS BASED ON THE QUANTITY OF WATER TREATED IN THE INTERVENTION SYSTEM OF THE ACCELWATER

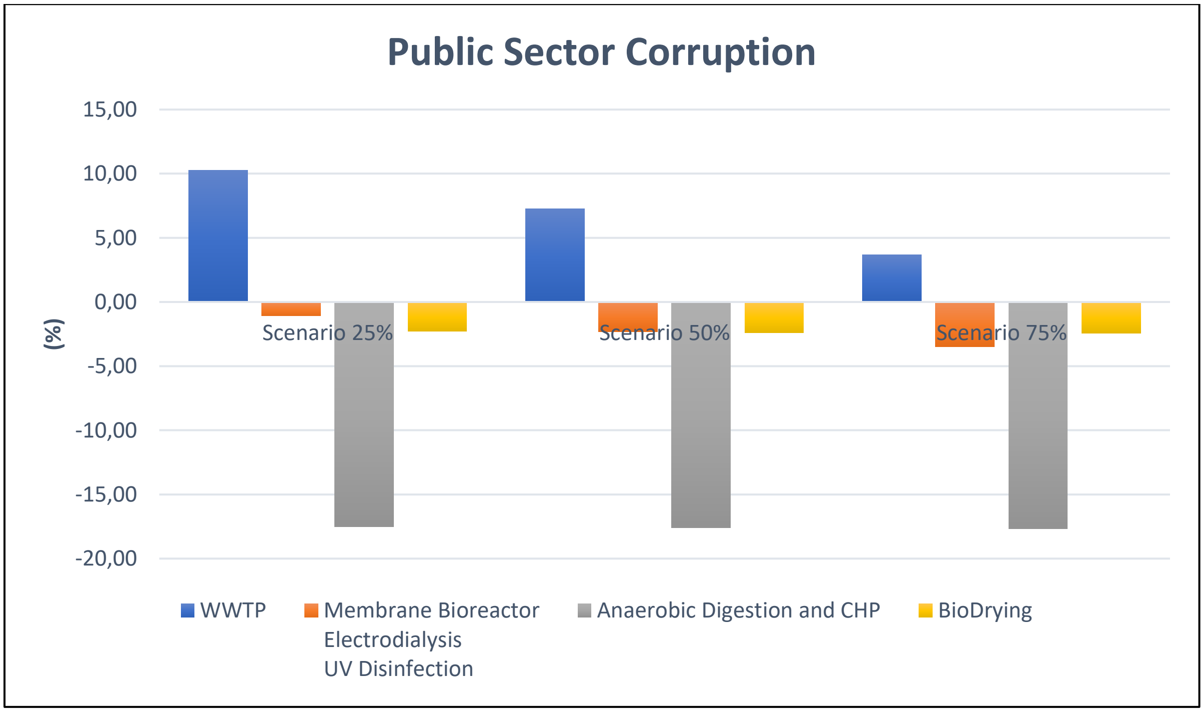


FIGURE 38 SOCIAL LCA RESULTS OF PUBLIC SECTOR CORRUPTION INDICATOR OF SPANISH DEMONSTRATOR FOR THREE DIFFERENT SCENARIOS BASED ON THE QUANTITY OF WATER TREATED IN THE INTERVENTION SYSTEM OF THE ACCELWATER

As expected, the degree of influence of each intervention system varies depending on the specific social risk, with different social categories exhibiting varying levels of sensitivity based on the risk associated with a process. In Table 3 the percentage difference of the social impact between the base and each scenario varying in the percentage of wastewater treated in the intervention system is assessed. The percentage change is calculated based on Equation 1.

$$\text{Percentage change of impacts} = \frac{\text{Value of the impact category for the scenario assessed} - \text{Value of the baseline scenario}}{\text{Value of the baseline scenario}} * 100\%, \quad (1)$$

As the proportion of wastewater treated in the intervention plant increases, the social impacts are accordingly reduced, proving that the interventions benefit the four social stakeholders: the workers, value chain actors, local communities and society.

Impact category	Reference unit	Base/25%	Base/50%	Base/75%
Fair Salary	FS med risk hours	-34.7%	-37.0%	-39.7%
Biomass consumption	BM med risk hours	-31.2%	-33.7%	-35.7%
Gender wage gap	GW med risk hours	-36.7%	-36.8%	-36.9%
Public sector corruption	C med risk hours	-30.8%	-33.3%	-35.6%

Table 3 Percentage difference of the environmental impact categories between the base and the three scenarios with the interventions

3.2.2 Icelandic Demonstrator

The aquaculture facilities of Silfurstjarnan in Iceland encompass several key components: the aquaculture and bleeding tanks, storage, and wastewater treatment facilities. The treatment facilities include drum filters and a degasser for recirculating part of the wastewater, as well as settling ponds for solid waste collection, as depicted in Figure 39.

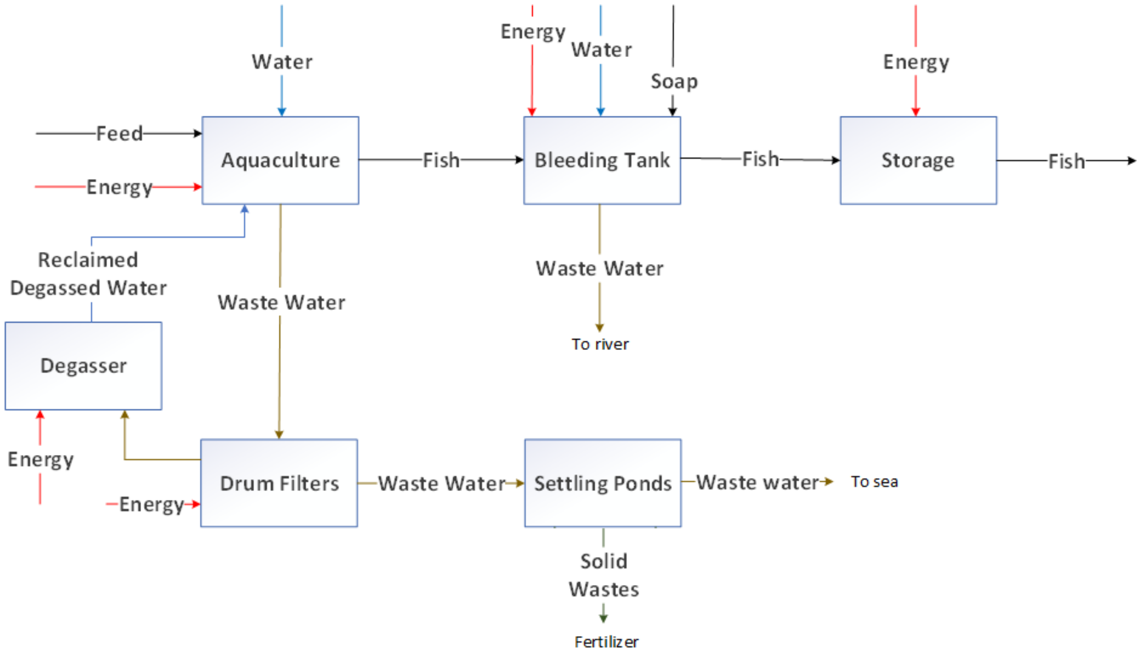


FIGURE 39 BASE PROCESS LINE OF THE AQUACULTURE FACILITIES IN SILFURSTJARNAN IN ICELAND

In the AccelWater scenario, a dry bleeding tank technology will be integrated prior to the conventional bleeding tank process. This approach facilitates the easy collection of fish blood, enabling its recovery to produce blood meal, which can be used as an animal food additive. Additionally, this method results in clearer water being released into the river, as it contains less blood. Belt filtration will replace settling ponds as a more efficient technology for water clarification and solid collection. All of the solid wastes will be repurposed as forestry fertilizer. The new aquaculture processing system, including these interventions, is depicted in Figure 40, with the interventions highlighted in green-coloured boxes.

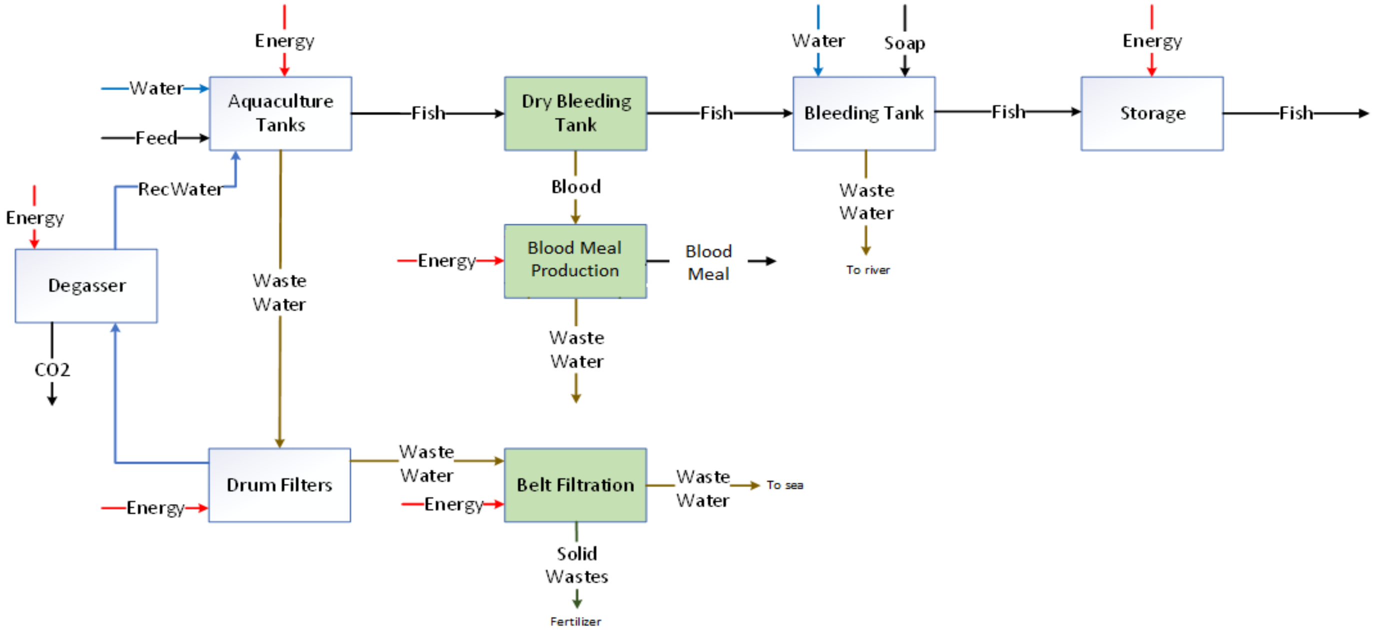


FIGURE 40 ACCELWATER PROCESS LINE OF THE AQUACULTURE FACILITIES IN SILFURSTJARNAN IN ICELAND

The social impact assessment of the aquaculture system focused on evaluating indicators with significant influence, leading to the detailed analysis of eight key metrics. Figure 41 illustrates that the implementation of new interventions within the aquaculture processing has resulted in a discernible decrease in social impacts. Although the reductions may not be dramatic, these findings underscore the positive contribution of the interventions to enhance overall social well-being. They also emphasize the importance of ongoing efforts to refine interventions and monitor their effects to further mitigate social impacts in aquaculture operations.

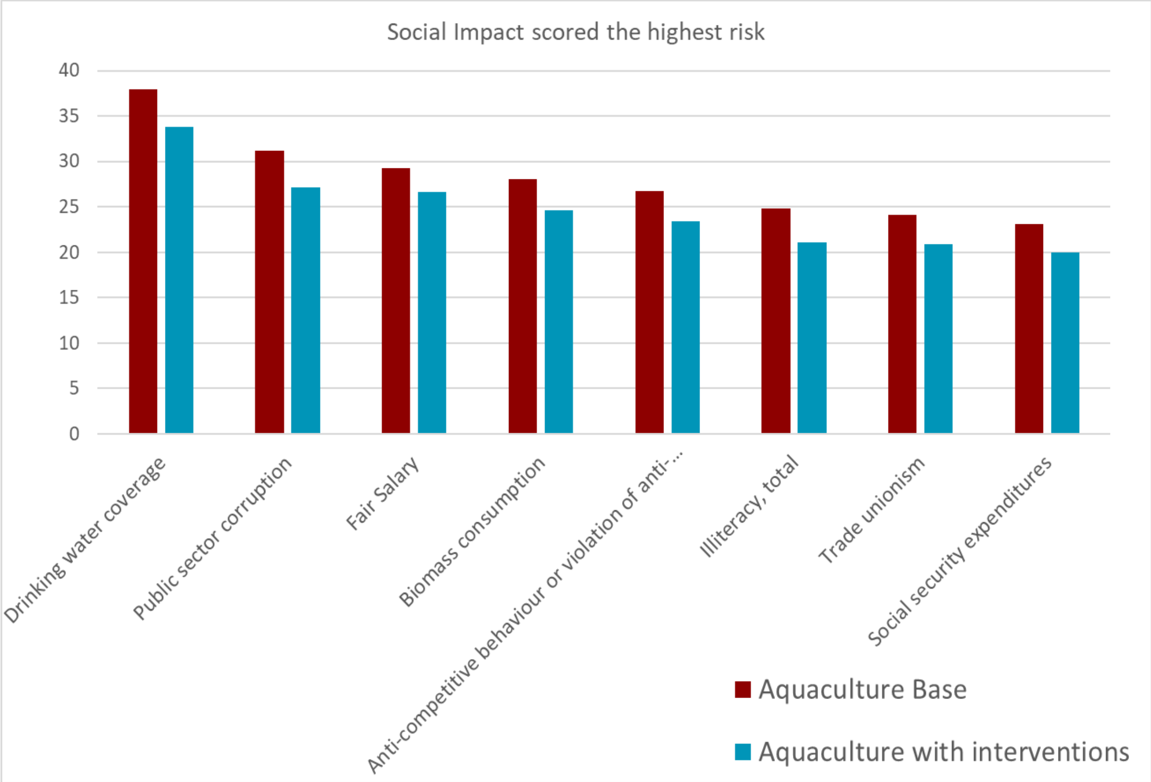


FIGURE 41 SOCIAL LCA RESULTS OF ICELANDIC DEMONSTRATOR BEFORE AND AFTER ACCELWATER

To realise from where the social risks are coming from the eight indicators were further analysed in order to reveal the hotspots.

From Figure 42 it is obvious that the main contributor of the social risks is fish feed production.

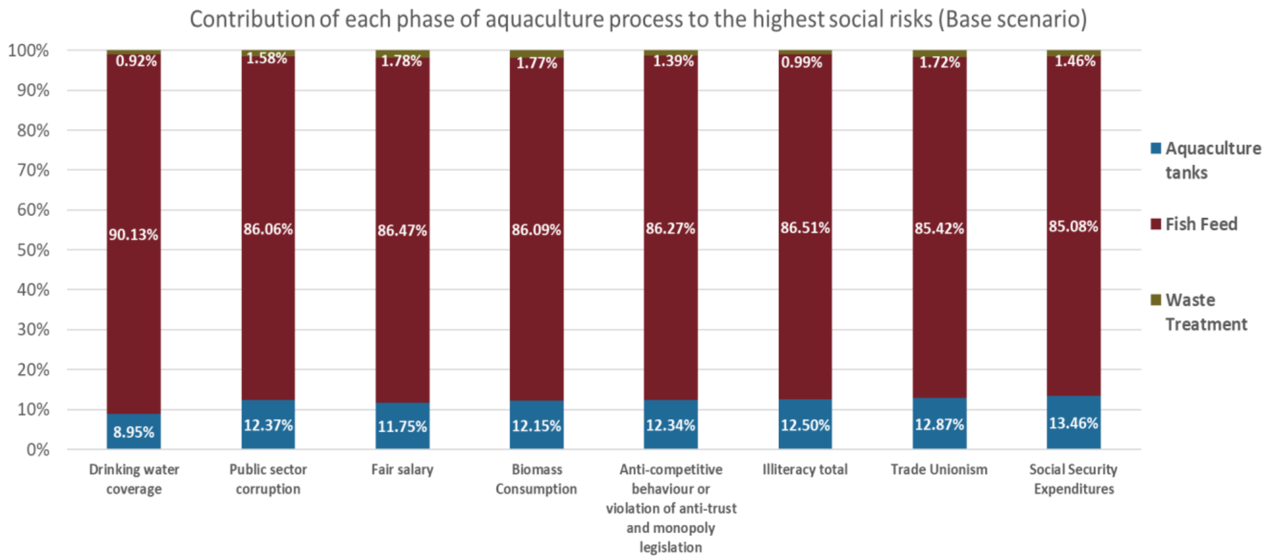


FIGURE 42 SOCIAL LCA RESULTS OF ICELANDIC DEMONSTRATOR BEFORE ACCELWATER, HOTSPOT IDENTIFICATION

This is further explained by the fact that components of the fish feed originate from countries with varying levels of social risk. Sources such as China and Brazil, identified as having high social risks [5], [6], contribute to the composition of the feed.

Consequently, sourcing fish feed from countries with higher social security would significantly reduce the social footprint associated with the fish product. Alternatively, varying the compositions of aquafeed could mitigate social impacts to a lesser degree. Understanding and adjusting these sourcing practices can play a pivotal role in improving the overall social sustainability of aquaculture operations. This approach not only addresses immediate social concerns but also aligns with broader sustainability goals within the industry.

3.3 Social LCA Literature

[1] C. Norris, B. Mazijn, and E. Andrews, "Guidelines for social life cycle assessment of products social and socio-economic LCA guidelines complementing environmental LCA and life cycle costing, contributing to the full assessment of goods and services within the context of sustainable development provided by the UNEP/SETAC Life Cycle Initiative," 2009, Accessed: Apr. 18, 2024. [Online]. Available: https://www.researchgate.net/publication/260418794_Guidelines_for_Social_Life_Cycle_Assessment_of_Products

[2] F. Eisfeldt, C. Rodríguez, and A. Ciroth, "SOCA-A database add-on for Life Cycle Sustainability Assessment."

[3] M. A. J. Huijbregts *et al.*, "ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level," *International Journal of Life Cycle Assessment*, vol. 22, no. 2, pp. 138–147, Feb. 2017, doi: 10.1007/s11367-016-1246-y.

[4] Kirill Maister, Claudia Di Noi, Andreas Ciroth, and Michael Srocka, "PSILCA v.3: A Product Social Impact Life Cycle Assessment database," Jun. 2020.

[5] C. M. de Freitas, I. V. de M. e Silva, and N. da C. Cidade, "COVID-19 AS A GLOBAL DISASTER: Challenges to risk governance and social vulnerability in Brazil," *Ambiente & Sociedade*, vol. 23, 2020, doi: 10.1590/1809-4422asoc20200115vu2020l3id.

[6] Y. Yan, "Food Safety and Social Risk in Contemporary China," *J Asian Stud*, vol. 71, no. 3, pp. 705–729, Aug. 2012, doi: 10.1017/S0021911812000678.

4 Traceability aspects

Digitization, traceability and tools to identify, collect and exchange data from different processes, stages and events throughout the value chain, are becoming increasingly necessary in modern management, production and distribution processes and the life cycle of the respective materials and products[3], their contribution to sustainable production and consumption[4,5], as well as the active involvement of consumers[6]. The digitalization and visualization of value chains offers key information and a greater degree of detail to those involved. Systems such as enterprise resource planning (ERP) are being improved by offering a digital display of processes. The creation of relevant functions and the collection of real-time data, face great challenges, both in terms of data availability, as well as in terms of design, integration and operation[7,8]. Traceability features can also enable the creation and use of Digital Product Passport in different value chains.

Tracking and traceability capabilities and the applicability of various tracking solutions such as Radio Frequency Identification (RFID) , Barcodes and GPS, were studied for AccelWater IS demonstrator in Patras. Upon design, traceability framework should be developed, including the definition of unit of material and the unit of product and the properties that are important in each study case. In this case, our main materials are spent grains and whey acid, their quantity is the main aspect, while quality is not easily trackable. To implement this traceability framework in the industrial park, thus developing a tracing solution that tracks and visualize the whole value chain of the spent grains and whey acid, the following components should be considered and combined:

4.1 Localization

Localization is the main methodology to track the costs and environmental impacts -mainly GHG emissions- and timelines, concerning the transportation of the resources involved in the symbiotic synergy. For our case there are 2 main routes, the transportation of acid whey from FCH to REZOS and

[3] T.S. Deepu, V. Ravi, A review of literature on implementation and operational dimensions of supply chain digitalization: Framework development and future research directions, International Journal of Information Management Data Insights, Volume 3, Issue 1, 2023, 100156, ISSN 2667-0968, https://doi.org/10.1016/j.jjimei.2023.100156.

[4] Vincenzo Varriale, Antonello Cammarano, Francesca Michelino, Mauro Caputo, The role of digital technologies in production systems for achieving sustainable development goals, Sustainable Production and Consumption, Volume 47, 2024, Pages 87-104, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2024.03.035.

[5] Xiongyong Zhou, Zhiduan Xu,Investigating circular procurement management and sustainability performance: The interactive moderating effects of digital traceability and collaboration, Journal of Purchasing and Supply Management, 2024, 100950, ISSN 1478-4092, https://doi.org/10.1016/j.pursup.2024.100950.

[6] Estrela Ferreira Cruz, A.M. Rosado da Cruz, Digital solutions for engaging end-consumers in the circular economy of the textile and clothing value chain - A systematic review,Cleaner and Responsible Consumption, Volume 11, 2023, 100138, ISSN 2666-7843, https://doi.org/10.1016/j.clrc.2023.100138.

[7] Mohd Javaid, Abid Haleem, Ravi Pratap Singh, Anil Kumar Sinha, Digital economy to improve the culture of industry 4.0: A study on features, implementation and challenges, Green Technologies and Sustainability, Volume 2, Issue 2, 2024, 100083, ISSN 2949-7361, https://doi.org/10.1016/j.grets.2024.100083.

[8] T.S. Deepu, V. Ravi, A review of literature on implementation and operational dimensions of supply chain digitalization: Framework development and future research directions, International Journal of Information Management Data Insights, Volume 3, Issue 1, 2023, 100156, ISSN 2667-0968.

the spend grains from AB to REZOS. There are 2 potential localization solutions that could be used in this case:

- Commercial GPS tracking devices embedded in the tracks used or alternatively
- Use of the GPS in the mobile phones of the drivers via a proper Mobile App integrated with AccelWater platform.

The exact locations and timestamps are very useful. In more complex cases, all the data collected could be used for optimization of the routes including taking into consideration traffic or other aspects.

FIGURE 43 FCH TO REZOS ROUTE

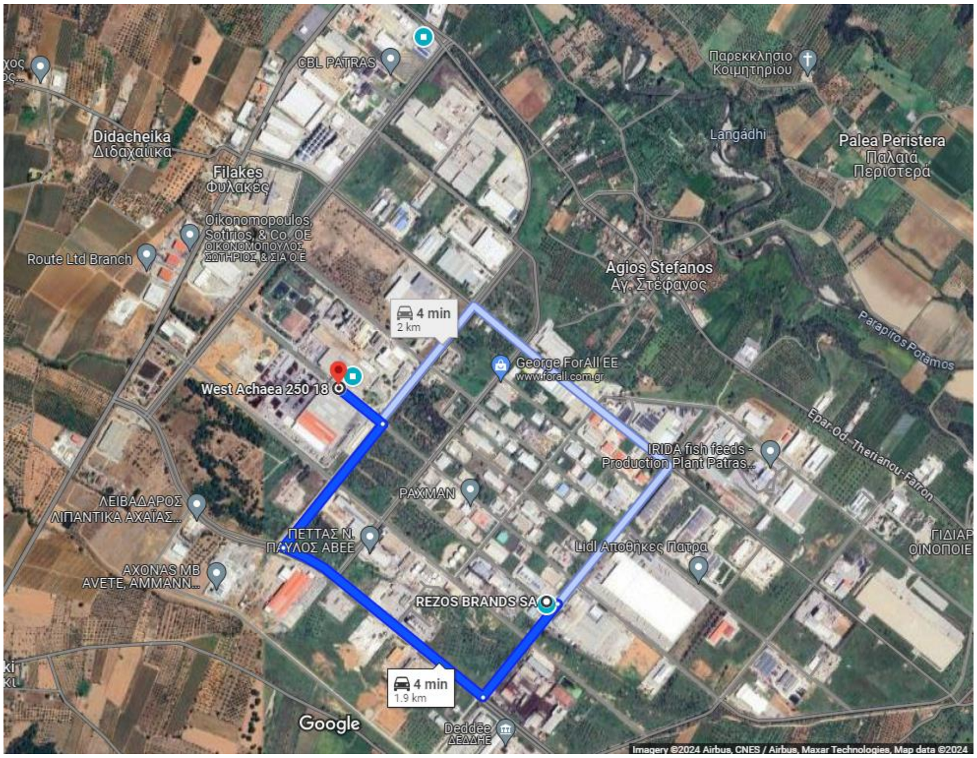


FIGURE 44 AB TO REZOS ROUTE

4.2 Definition of quantity and quality

The tracking of the resources exchange in terms of quality and quantity is the most crucial aspect of traceability modules. Along with localization, a full view of recourses exchange can be developed e.g. what type and quantity of materials are transported, when and where. Solutions that can be applied are:

- RFID solutions that include readers, tags and Antennas to retrieve the time, type and quantities of materials that are being transferred. For example, a package/batch of materials can be scanned -either by a user or by system automatically- to update the system, without a user to fill in any information manually, about the location, the quantity, the state, the progress and the changes of this item within the value chain. ICCS has already conducted experimental development of a similar system in its labs for internal research projects. ICCS' RFID system comprises the Ultra-high frequency (UHF) reader, wide and narrow beam antennas. The High-power UHF reader used, AdvanReader-160[9], is a high power (31.5 dBm), four ports, high performance UHF reader with an on-board microcomputer and a fully open Linux operating system. Thanks to its on-board microcomputer, the reader can work stand-alone without being connected to an external computer, therefore reducing equipment, installation and maintenance costs. This reader can work with batteries and at the same time control their level including also sleep mode for minimizing consumption. Therefore, it is ideal for mobile systems.

[9] https://keonn.com/components-product/advanreader-160/#

- Cameras combined with computer vision or LIDAR techniques (LIght Detection and Ranging) to identify material batches and quantities.
- Other solutions regarding tags such as smart tags (changing upon different stages and status of material), QR codes etc. functioning in the same logic as RFID.

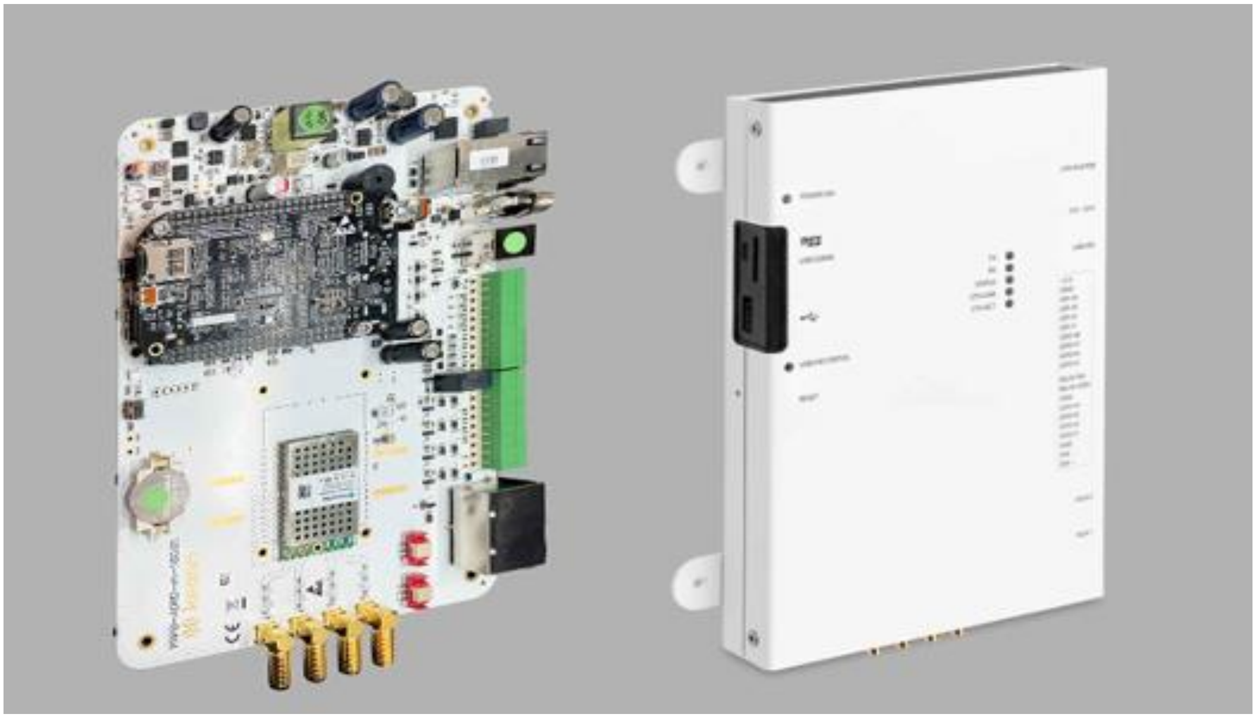


FIGURE 45 ADVANREADER-160

4.3 Enrichment of data from end users or existing systems

Other solutions can be applied, to enhance the information and include other stages of symbiosis (processing, sorting etc.) and retrieve changes of status or other events occurring. These could include:

- Manual input of data (e.g. change of states, actions, estimations) from the end users via a mobile Application in Laptops, Tablets or mobiles.
- Integration and collecting data e.g. quantities, quality, transportation timeline, special requirements, previous treatment etc. from existing systems such as ERPs or Scada.

5 Integration of Models in the Platform

Part of the results, mainly interactive models were integrated into the AccelWater Platform. Indicatively, the platform includes a dedicated module (Assessments Module) in which users can navigate and perform simulations and define potential scenarios based on the models developed in this document.

More details are presented in D7.7 : AI enabled AccelWater platform development for monitoring and controlling decentralised water-waste-energy management - Version 2.

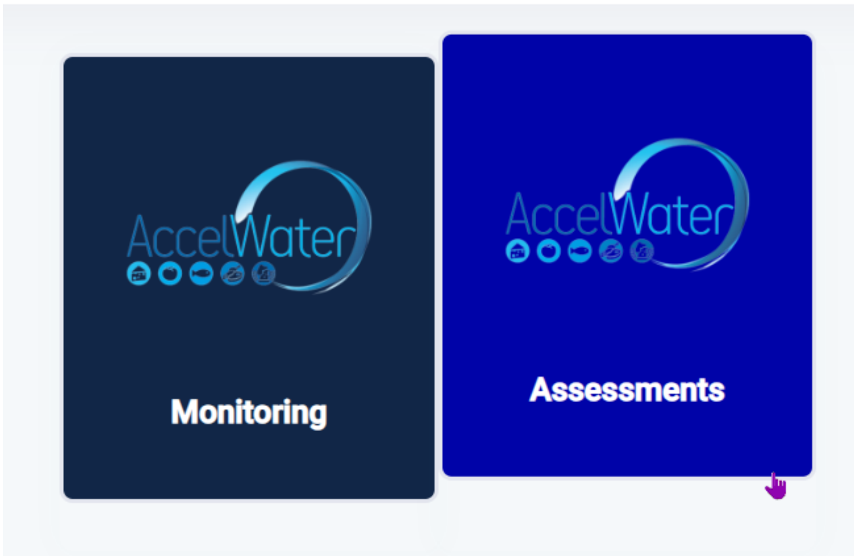


FIGURE 46 ASSESMENTS MODULE OF ACCELWATER PLATFORM

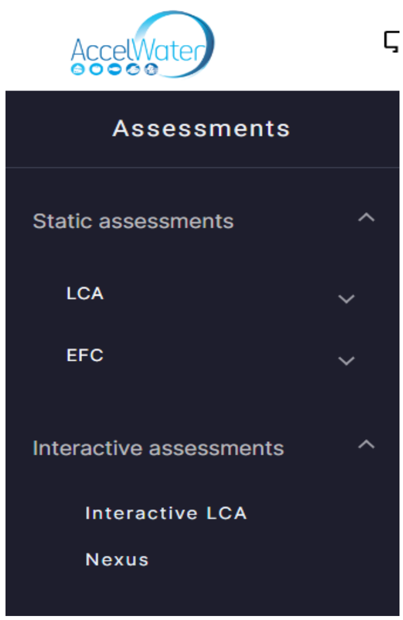


FIGURE 47 DIFFERENT MODELS INTEGRATED

6 Conclusion

This deliverable summarises all the activities of Task 7.7 presenting the models developed for measuring the performance of AccelWater solutions. Sustainability assessments were developed taking into consideration wastewater, waste and by-products quantities, costing parameters and impact. LCA, Cost analysis, social LCA and water energy Nexus of methodologies were applied along the project and the demonstrators. Traceability aspects were also examined. The results along with the related models are being integrated in the AccelWater platform to enable relevant features for the users to view data and develop potential scenarios to simulate the current state and the state after the end of AccelWater project.

The measurement of sustainability includes many different aspects and dimensions, including technical details regarding processes and their efficiency, environmental, economic and social impacts, as well as the nexus between all. To understand the total impact of the solutions applied, all the dimensions should be explored and combined. For the next steps, in order tomake decisions, different trade-offs are raising according to the priorities and the strategy of the different entities e.g. regional authorities, ministries, industries and society. For this purpose, the simulation of different scenarios is valuable.

The research conducted along with the results, methodologies and features will be exploited and enhanced to be used in on-going and future Horizon Europe projects.