This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 730398

REcovery and REcycling of nutrients TURNing wasteWATER into added-value products for a circular economy in agriculture

Grant Agreement No:	730398	**Project Acronym:**	Water2REturn
Project Title:	Recovery and Recycling of nutrients TURNing wasteWATER into added-value products for a circular economy in agriculture		
Funding scheme:	Horizon 2020 – Innovation Action		
Project Coordinator:	BIOAZUL		
Start date of the project:	01.07.2017	**Duration of the project:**	42 months
Contractual delivery date:	**30.06.2018**		
Actual delivery date:	**02.07.2018**		
Contributing WP:	**WP8: environmental, economic, social and risk assessments**		
Dissemination level:	**Public**		
Authors:	**2B**		
Contributors:	**ELO**		
Version:	**1.0**		

List of abbreviations

W2R	Water2REturn
WP	Work Package
D	Deliverable
EU	The European Union
EC	European Commission
EASME	European Agency for Small and Medium Enterprises
H2020	Horizon 2020
ADU	Anaerobic Digestion Unit
ATU	Aerobic Treatment Unit
CPH	Combined Power and Heat
ETV	Environmental Technology Verification
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
NRU	Nutrient Recovery and Upcycling
SBR	Sequencing Batch Reactor
SFU	Splitting Filtration Unit
S-LCA	Social Life Cycle Assessment
TEA	Techno-Economic Assessment

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1. Introduction

1.1 Project summary

Water2REturn proposes a full-scale demonstration process for integrated nutrients recovery from wastewater from the slaughterhouse industry using biochemical and physical technologies and a positive balance in energy footprint. The project will not only produce a nitrate and phosphate concentrate available for use as organic fertiliser in agriculture, but its novelty rests on the use of an innovative fermentative process designed for sludge valorisation which results in a hydrolysed sludge (with a multiplied Biomethane Potential) and bio-stimulants products, with low development costs and high added value in plant nutrition and agriculture [1].

This process is complemented by proven technologies such as biological aeration systems, membrane technologies, anaerobic processes for bio-methane production and algal technologies, all combined in a zero-waste-emission and an integrated monitoring control tool that will improve the quality of data on nutrient flows. The project will close the loop by demonstrating the benefits associated with nutrients recycling through the implementation of different business models for each final product. This will be done with a systemic and replicable approach that considers economic, governance and social acceptance aspects through the whole chain of water and targets essentially two market demands: 1) Demand for more efficient and sustainable production methods in the meat industry; and 2) Demand for new recycled products as a nutrient source for agriculture. Figure 1 illustrates the closed-loop approach of the **Water2Return** project in the light of Circular Economy [1].

***Figure 1: Water2REturn** closed-loop approach in the light of Circular Economy*

The **Water2REturn** project adopts a Circular Economy approach where nutrients present in wastewaters from the meat industry can be recycled and injected back into the agricultural system as new raw materials. The project fosters synergies between the food and sustainable agriculture industries and proposes innovative business models for the resulting products that will open new market opportunities for the European industries and SMEs in two key economic sectors [1].

1.2 Partners

The **Water2REturn** project consortium is a selection of SMEs and institutes that combine their different knowledge to reach the objectives established for this project. The project is coordinated by Bioazul S.L., Spain. The consortium includes 15 partners, spread out over 8 European countries (Spain, Portugal, Slovenia, Romania, Italy, Belgium, Germany and United Kingdom):

- 4 research institutes:
  - University of Seville, Spain (USE).
  - University of Cadiz, Spain (UCA).
  - Foundation Centre for the New Water Technologies, Spain (CENTA).
  - University of Ljubljana, Slovenia (UL).
- 2 associations:
  - European Livestock and Meat Trading Union, Belgium (UECBV).
  - European Landowners Organisation, Belgium (ELO).
- 9 SMEs:
  - Bioazul S.L., Spain (BIOAZUL).
  - Agroindustrial Kimitec S.L., Spain (KIMITEC).
  - Advanced Environmental Technologies Lda, Portugal (ADVENTECH).
  - Algen, Algal Technology Centre, Slovenia (ALGEN).
  - SC Slorom Srl, Romania (SLOROM).
  - Enco Consulting Srl, Italy (ENCO).
  - 2B Srl, Italy (2B).
  - Isitec GmbH, Germany (ISITEC).
  - Exergy Ltd, United Kingdom (EXERGY).

The 4 research institutes and organisations deal with technologies regarding recovery of organic waste, reduction or elimination of liquid and solid waste and wastewater treatment. The 2 associations represent the interest of landowners and meet the interests of livestock traders and meat companies.

The 9 SMEs deal with agriculture, wastewater treatment technologies, project management and market analysis, life cycle assessment and eco-design, automation systems and renewable energy.

Table 1: *Expertise and role of the **Water2REturn** project partners.*

No.	Short name	Expertise	Role
1	BIOAZUL	Process engineering, wastewater treatment, water reuse concepts, energy efficiency.	Project coordinator. Water line technological development. Manufacture of water line modules and market the **Water2REturn** wastewater treatment of the slaughterhouse.
2	USE	Process revaluation of organic waste by biological technologies.	Design and construction of the fermentation module.
3	UCA	Environmental technologies for the reduction or elimination of liquid and solid waste pollutant.	Design of the anaerobic digestion.
4	CENTA	Wastewater treatment for small communities, rural areas and decentralised treatment.	Design and construction of the wastewater biological treatment.
5	KIMITEC	Pharmacological approach development of R&D based solutions.	Production of the secondary raw material. Test, optimisation and validation of agriculture products.
6	ADVENTECH	Design, on-site installation, start-up and maintenance of treatment plants for industrial water and wastewater.	Energy production from the hydrolysed sludge. Design, construction and optimisation of the anaerobic digestion and energy production unit. Design and construction of the fermentation bioreactor.
7	ALGEN	Development and system integration of algae technology-based systems.	Design, construction and optimisation of the module for algae production. Algal bacterial treatment of biogas digestate.
8	UL	Natural research, soil science, environmental protection.	Preliminary tests for the design of the algae cultivation unit expected at demo scale. Laboratory and greenhouse experiments.
9	SLOROM	Agronomic experience.	Performing tests on site with the formulations produced within **Water2REturn** with regards to monitoring and validation.
10	ENCO	Management of international and national projects, dissemination and exploitation.	Extend business network and support emerging technologies in the most critical steps of their development.

No.	Short name	Expertise	Role
11	2B	LCA, LCC, eco-design, ecolabel, industrial ecology, environmental communication.	LCA, LCC and social assessment of technologies and final products.
12	UECBV	Representation of the needs of livestock traders and meat companies.	Provide first-hand information on requirements and challenges of the slaughterhouses and meat industry.
13	ISITEC	Development and delivery of innovative automation systems.	Control module. Provide the consortium with all the necessary information for optimised/site-specific prototype design.
14	EXERGY	Renewable energy, low carbon and sustainable development. Policy briefs and recommendations.	Provide recommendations for economic and energy process optimisation and will perform in depth analysis of regulatory barriers.
15	ELO	Representation of the interests of landowners, land and forest managers and rural enterprises.	Provide first-hand information on requirements and challenges of farmers, assess the project results.

1.3 Work packages

The **Water2REturn** project is organised in 11 work-packages, as illustrated in Figure 2. A short description of each work-package can be found below [1].

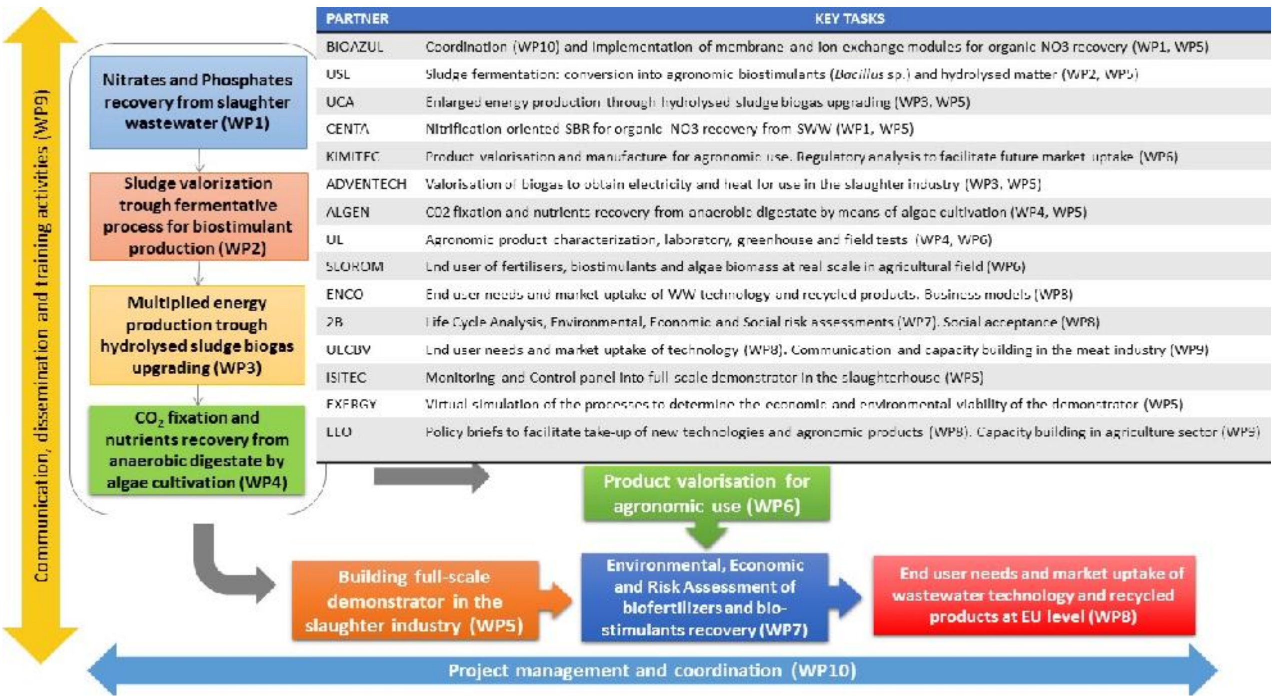


***Figure 2: Water2REturn** workplan consisting of 11 work packages (the 10 WPs shown in the figure + an additional one related to ethical issues).*

WP1: Ethics requirement (BIOAZUL)

This work package sets out the ethical requirements that the project must comply with. WP1 is entirely devoted to ethical issues and the WP leader is BIOAZUL.

WP2: Basis for implementation of Water2REturn concept: initial data and design of the water line oriented to NO_3 recovery (CENTA).

WP2 will focus on the water line of the process and recovery of organic origin NO_3 for its use in the formulation and manufacture of organic fertilizers. The WP leader is CENTA.

WP3: Fermentation for sludge valorisation (USE).

During WP3 sewage sludge generated in the water treatment line will be valorised through the fermentative process designed by USE. The valorisation process will result into two different products: solid agronomic bio-stimulant products, and liquid hydrolysed organic matter. The latter will be used as input in the process of anaerobic digestion for biogas production. The WP leader is USE.

WP4: Multiplied energy production through hydrolysed sludge biogas upgrading (ADVENTECH).

The use of biogas in co-generation engines and hydrogen fuel cells (after catalytic oxidations of CH_4) will lead to obtain electricity and heat. The WP leader is ADVENTECH.

WP5: Nutrients recovery from anaerobic digestate and CO_2 fixation by means of algae cultivation (ALGEN).

In WP5 the resulting CO_2 from WP4, the anaerobic digestate or additional wastewater (if required) will feed a micro-algae cultivation system. The harvested biomass will also be employed for agronomic purposes. The WP leader is ALGEN.

WP6: Building full-scale demonstrator in the slaughter industry (BIOAZUL).

WP6 will build and optimise the full-scale demonstrator in-situ in the slaughter industry including the inclusion of a monitoring and control tool. The WP leader is BIOAZUL.

WP7: Product valorisation for agronomic use (KIMITEC).

WP7 will serve to formulate solutions to valorise and recycle the resulting products from WP2, WP3 and WP5 into fertilisers from organic source and bio-stimulants of agronomic interest. The WP leader is KIMITEC.

WP8: Environmental, economic, social and risk assessment of organic sources fertilisers and bio-stimulants recovery from slaughter wastewater (2B).

WP8 will perform sustainability analyses (LCA, LCC, Social LCA) and Risk Assessment of potential hazards to the environment and human health. The WP leader is 2B.

WP9: End users' needs and market uptake of wastewater technology and recycled products at European level (ENCO).

WP9 is intended to analyse various target markets, propose evidence-based knowledge for policy makers and provide instruments to step towards market uptake. The WP leader is ENCO.

WP10: Communication, Dissemination and Exploitation (UECBV).

WP10 will provide the elements to ensure that the project activities reach its target groups: researchers, regulators, water industry, fertiliser manufacturers, farmers and final consumers. The WP leader is UECBV.

WP11: Management and coordination (BIOAZUL).

WP11 is dedicated to the general management of the project, ensuring the adoption of IPR provisions and the appropriate management of the innovation. The WP leader is BIOAZUL.

1.4 Objectives and tasks of WP8

WP8 concerns the environmental, economic, social and risk assessment of the recovery of fertilizers and bio-stimulants from slaughter wastewater.

The objectives of WP8 are:

1. Eco-efficiency assessment by means of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) of fertilizers and bio-stimulants recovery from slaughter wastewater.

2. Sustainability assessment of the **Water2REturn** system, comprising Social LCA in order to assess the positive and negative social impacts of the project.

3. LCA of the investigated processes and products of the **Water2REturn** project using primary data from the supply chain actors involved in the project in order to eco-design feedback and optimise the **Water2REturn** technologies according to the Circular Economy concept.

4. Comparative LCA in order to illustrate the specific advantages of the new technology compared with the traditional technology.

5. Safety, Health and Environment (SHE) evaluation of the **Water2REturn** technology in order to check and if needed prevent or minimise possible SHE risks.

6. Techno-economic assessment and verification by an external entity of the **Water2REturn** technologies in order to determine the economic, environmental and commercial feasibility of the proposed process and estimate the cost viability of the overall process within an expected future market.

WP8 has the same duration as the entire project, from month 1 to month 42, and is characterized as described in the following below paragraphs.

Task 8.1: Environmental Life Cycle Assessment

In this task, LCA is performed for all different technologies and final products involved in the **Water2REturn** project, following the ISO standards 14040-14044 [2, 3] and the ILCD handbook for LCA. The goal of the LCA is to evaluate the environmental performance of the innovative technologies as proposed in the **Water2REturn** process. Furthermore, a comparison will be made with traditional technologies and eco-design feedback will be provided to support process optimisation. The goal and scope of the LCA will be defined by setting the methodological LCA choices according to its step-wise approach: goal and scope, inventory, impact assessment, interpretation. In the inventory analysis, primary LCA data will be gathered for all core processes from technological partners of the project, while for the life cycle inventory of upstream or downstream processes, existing background data can be used (e.g. ELCD, Ecoinvent). The impact assessment will be performed with the ILCD method and at least one additional LCIA method to investigate the sensitivity of the results. The interpretation will be supported by contribution analysis, sensitivity analysis and uncertainty analysis. The main conclusions will focus on the expected reduced environmental burden of the **Water2REturn** process, with special attention to closing the loops of the water, energy and nutrients cycles (nutrient recovery) in the whole production and consumption value chain [1]. A critical review will be performed by project partners. Task leader: 2B, duration: M1-M39.

Task 8.2: Life Cycle Costing (LCC)

LCC will be performed in parallel to the LCA study in order to quantify the Life Cycle Costs of the different technologies involved in the **Water2REturn** project, following the guidelines of the SETAC handbook on Environmental Life Cycle Costing [4]. LCC will be performed on the basis of the same system boundaries, data inventory and the same scenarios of the LCA, in order to be able to put in parallel the environmental and the economic aspects in Task 8.4 (eco-efficiency) and to obtain consistent results. LCC results will be used also as an input for Task 8.6 (Techno-economic assessment) [1]. Task leader: 2B, duration: M1-M39.

Task 8.3: Social footprinting

Besides the environmental and economic impacts and benefits, also the social aspects will be investigated in the **Water2REturn** project. The social assessment will be done in a semi-quantitative/qualitative way, according to the principles of social footprinting, providing qualitative metrics on the social aspects of the **Water2REturn** project. Task 9.1 will contribute with the data gathered from social metrics (stakeholder engagement), providing information on end-users perceptions about the benefits of implementing individual key technologies, the **Water2REturn** process as a whole and the agronomic products, in the context of the Circular Economy. Social acceptance of the **Water2REturn** processes is crucial to ensure market success of the concept, which will be further investigated in Task 9.3. Furthermore, social footprinting results will be complemented with the LCA and LCC results in order to give insight in the sustainability assessment of the **Water2REturn** technologies (WP9) [1]. Task leader: 2B, duration: M1-M39.

Task 8.4: Quantification of eco-efficiency and eco-design recommendations

In this task the eco-efficiency of the different technologies involved in the overall **Water2REturn** process will be measured and quantified by means of indicators. Outcomes will be used along with the LCA in order to measure environmental impacts during the project execution. The main objectives will include to determine the reduction in consumption of resources, impacts on the environment and to measure the actual value of the final product (fertilizers) and the provided service (cleaning up wastewater streams) in comparison to traditional processes and practices which do not take into consideration the holistic Circular Economy concept. Eco-efficiency indicators will be set during the project execution and will be iteratively quantified according to the outcomes in other tasks (i.e. LCA, LCC). Some of the eco-efficiency indicators will be, but not limited to, for instance resource consumption, waste generation, emissions (including pollution), social costs and land use [1]. Task leader: 2B, duration: M16-M39.

Task 8.5: Quantitative risk assessment for humans and environment

The different risks for humans (health and safety) associated with the use of the final products as well as the overall process of **Water2REturn** will be analysed and quantified during the execution of this task. This will include mainly biological risks due to the possible, but rare, presence of bacteria during the different processes (risks of pathogens) as well as the risks associated with the use of microalgae and recovery of nutrients from slaughterhouses sewage, health risks related to the emissions and dangerous effluents generated along the process and all the potential risks associated to the plant operation. Apart from the risks assessment and their quantification, some recommendations will be given to prevent bad practices in the use of the final products as well as mitigation plans will be set where necessary. This risks assessment will be complemented with a HAZOP methodology where necessary [1]. Task leader: EXERGY, duration: M16-M40.

Task 8.6: Techno-economic assessment (TEA) of the overall process

In parallel to the LCC, a techno-economic assessment will be carried out in order to determine the economic and commercial feasibility of the proposed process, based on the premise that no similar process is currently being applied. This activity will be closely linked with the LCC and the outputs from the simulations of the upscaled process. Some sensitivity and risks analysis will be considered in order to evaluate different scenarios and which would make the commercialisation of the process and their products more profitable. Operational expenses such as energy consumption, catalysts, etc. will be taken into account as an important factor along with the material streams and capital expenses such as equipment and material investment, building, etc. for the evaluation of the overall effectiveness of the technology. These parameters will estimate the cost viability of the overall process within an expected future market share. End users will participate in this task to orientate the commercial feasibility of the products compared to the use of conventional chemical fertilizers. The third party Matadero del Sur, will also be involved in this task to provide feedback on the improvements in wastewater and energy consumption [1]. Task leader: EXERGY, duration: M19-M42.

Task 8.7: ETV technology verification

In order to boost the development of environmentally sound technology and to assure the successful penetration in the market by gaining more credibility on the **Water2REturn** performance indicators, the consortium will participate in the voluntary EU Environmental Technology Verification Pilot Programme (ETV). The consortium will firstly perform the eligibility check from a Verification Body. Following this first positive evaluation, a full ETV proposal will be developed [1]. Task leader: BIOAZUL, duration: M19-M42.

1.5 Objectives Deliverable 8.1

The aim of Deliverable 8.1, called "Report on goal and scope definition" due in month 12 of the project, is to provide a methodological basis for the work to be done in WP8. The goal and scope definition is the first step of LCA, LCC and Social LCA. It is therefore important to define the methodological choices related to these life cycle tools in a consistent way, allowing the tools to be uniformly applied to the **Water2REturn** project.

The outcomes of the tools are different, LCA analyses the potential environmental impacts, LCC analyses the life cycle costs, while Social LCA assesses the social impacts, but the methodological basis (e.g. object of study, functional unit, system boundaries) should be the same.

Deliverable 8.1 will provide this methodological basis for especially Task 8.1: Environmental Life Cycle Assessment, Task 8.2: Life Cycle Costing (LCC) and 8.3: Social footprinting. The other tasks of WP8 will be indirectly influenced by Deliverable 8.1 since these tasks will use the results of Task 8.1, Task 8.2 and Task 8.3 as an important input.

The work of WP8 will be performed by case studies, i.e. LCA of the baseline wastewater treatment situation, LCA of SBR (Sequencing Batch Reactor), LCA of NRU (Nutrient Recovery and Upcycling), LCA of

SFU (Splitting Filtration Unit), LCA of ADU (Anaerobic Digestion Unit), LCA of ATU (Aerobic Treatment Unit), LCA of algae plant, LCA of bio-fertilizers, LCA of bio-stimulants and the LCA of the overall technology.

One of the first LCA case studies that will be performed is the LCA of algae plant. In this LCA case study the digestate from the sludge line is treated in an algae pond, which is followed by treatment in the DAF (Dissolved Air Flotation) tank, to separate reclaimed water from the algae biomass flow. The algae biomass flow from the DAF is centrifuged, separating other reclaimed water from the algal biomass that is ready to be used in agriculture.

The methodological choices for the foreseen case studies in the **Water2REturn** project, can be found in this document, while case study specific methodological choices can be found in the case study documents.

Deliverable 8.1 shall function as a guidance document for all LCA, LCC and Social LCA elaborations during the project. Deliverable 8.1 is a living document that will be issued in month 12 of the project and updated whenever necessary during the further elaboration of the project by means of the case studies.

Besides the introduction to the **Water2REturn** project (§ 1), Deliverable 8.1 consists of the following sections:

- Description of the sustainability tools: LCA (§ 2.1), LCC (§ 2.2) and Social LCA (§ 2.3);
- Methodological choices for the **Water2REturn** project that will guide the elaboration of the LCA, LCC and Social LCA case studies: LCA choices (§ 3.1); LCC choices (§ 3.2); Social LCA choices (§ 3.3).

2. Sustainability tools: LCA, LCC and Social LCA

2.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is a well-known analytical tool, standardised in ISO 14040-14044 [2, 3] to assess potential environmental impacts of the entire life-cycle of a product, process or service. Key characteristics of LCA are:

- the “cradle to cradle” approach, analysing each stage of the life cycle of a product, from raw material, transport, production, distribution, use phase to recycling or final disposal;
- an assessment of a broad range of environmental burdens, including extraction of different types of resources, emissions of potentially hazardous substances, different types of land use, etc.;
- quantification in relation to a functional unit: the functional unit is a measure of the function of the studied system and it provides a reference to which the inputs and outputs can be related, enabling the comparison of different systems that fulfil the same function.

The LCA methodology consists of four phases:

1. Goal and scope: the first phase of an LCA, establishing the aim of the intended study, the functional unit, the reference flow, the product system(s) under study and the breadth and depth of the study in relation to this aim;

2. Life Cycle Inventory (LCI): the second phase of an LCA, in which the relevant inputs and outputs of the product system(s) under study throughout the life cycle are, as far as possible, compiled and quantified;

3. Life Cycle Impact Assessment (LCIA): the third phase of an LCA, concerned with understanding and evaluating the magnitude and significance of the potential environmental impacts of the product system(s) under study;

4. Interpretation: the fourth phase of an LCA, in which the results of the Inventory analysis and/or Impact assessment are interpreted in the light of the Goal and scope definition (e.g. by means of contribution, perturbation and uncertainty analysis, comparison with other studies) in order to draw up conclusions and recommendations.

The LCA methodology as defined and standardised by ISO 14040-14044 [2, 3], is illustrated in Figure 3. Main applications of LCA are eco-design to support product development and improvement, scenario analysis to support strategic planning and public policy making, and the calculation of environmental product information to support environmental communication and marketing (e.g. Environmental Product Declaration - EPD).

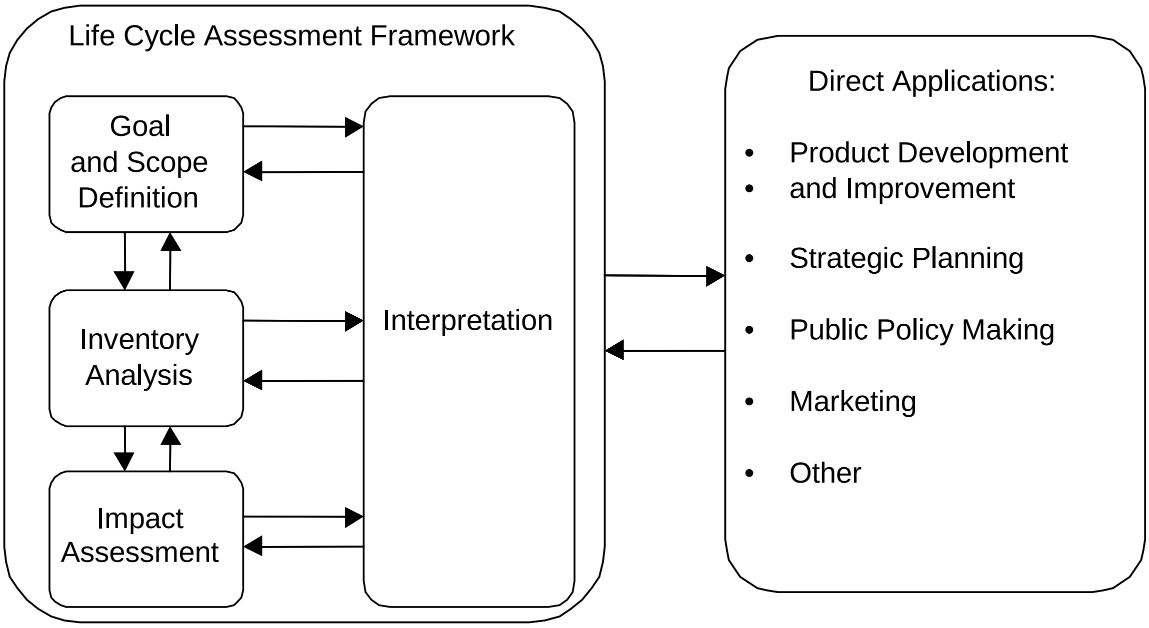


Figure 3: *LCA methodology according to ISO 14040/14044 [2, 3].*

2.2 Life Cycle Costing

Life Cycle Costing (LCC) is an economic assessment of all costs related to a product, process or service, over the entire life cycle, from raw materials, transport, production until use and disposal. Goal of LCC is to minimize overall costs, associated with all life cycle phases, providing economic benefits for all supply chain actors as a whole.

The SETAC publication on Life Cycle Costing distinguishes three types of LCC [4]:

- Conventional LCC: economic assessment of the life cycle of a product, often excluding one or more life cycle phases, like the disposal phase;
- Environmental LCC: economic assessment of the entire life cycle of a product, performed in parallel with an LCA study applying the same system boundaries but without monetisation of environmental impacts in order to avoid double counting with LCC results;
- Societal LCC: economic assessment of the entire life cycle of a product including external costs for society, like for instance through the monetisation of environmental impacts.

Like LCA, LCC follows the ISO standards 14040/14044 [2, 3]. At the moment, there are no general ISO standards available for LCC, but the SETAC publication on Life Cycle Costing is often used as a reference [4]. This handbook is written in the perspective of Environmental LCC and consequently advises to perform LCC in parallel with LCA, aligning the various methodological choices. Being conducted in parallel with LCA, LCC has the same functional unit and equivalent system boundaries as the LCA study. System boundaries are equivalent but may be not exactly the same, as different processes may have different relevance for the environment and for the cost part. For example, labor costs are usually not considered in an LCA, while they are commonly taken into account in LCC. Environmental LCC can be performed from the viewpoint of different life cycle actors, like suppliers, producers, consumers or end of life actors.

The LCC methodology has the same methodological phases as an LCA (Figure 3):

1. Goal and scope definition: the preliminary phase of an LCC, establishing the aim of the study, the functional unit, the system boundaries and the depth of the study in relation to its aim;
2. Inventory analysis: the phase that will quantify the costs of all processes within the system boundaries of the LCC;
3. Impact assessment: the phase that will aggregate all life cycle costs items of the inventory in one monetary unit expressing the overall costs of the entire life cycle of a product, if appropriate using discounting;
4. Interpretation: the phase that will interpret the LCC results in order to formulate conclusions and recommendations.

LCC has a long tradition in industry, especially for those products that have a long-life time and/or high maintenance, use or disposal costs. Motivation in these cases comes from both the user and the producer of these products. For the user, the purchase price is only a small share of all costs the product will have, and the overall costs are therefore more important for the purchase decision. For the producer, life cycle costs are a way to demonstrate that more effort for the production is convenient, by reduced use, maintenance costs or disposal costs [5].

In combination with an LCA that investigates the environmental impact of a product or service, LCC can serve to address the economic dimension of sustainability [6]. Furthermore, the assessment of the eco-efficiency analysis of the different options are implemented. In order to compare the different technology scenarios, it is necessary to combine environmental and economic results. In particular, taking into account these two performances at the same time, it is possible to define the most sustainable scenario in terms of eco-efficiency. Following the work of Huppes and Ishikawa [7], the combination of economic and environmental scores are employed in order to assess the eco-efficiency of each scenario.

2.3 Social LCA

Social Life Cycle Assessment (S-LCA) is a tool for the assessment of the social footprint, and complements LCA and LCC in the evaluation of sustainability.

The three pillars of sustainability are economic, environmental and social, for this reason LCA, LCC and S-LCA together provide a more comprehensive picture of the products' life cycle impacts [8].

A social and socio-economic Life Cycle Assessment is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal. S-LCA complements LCA with social and socio-economic aspects [8].

S-LCA assesses social and socio-economic impacts found along the life cycle (supply chain, including the use phase and disposal) with generic and site-specific data. Social and socio-economic aspects assessed in S-LCA are those that may directly affect stakeholders positively or negatively during the life cycle of a product. They may be linked to the behaviours of enterprises, to socio-economic processes, or to impacts on social capital. Depending on the scope of the study, indirect impacts on stakeholders may also be considered [8].

Social footprinting provides information about end-users' perceptions about the benefits of implementing individual key technologies, the whole process under study and the related products. The social acceptance of a process is a key to ensure market success of the concept [1].

The structure of the S-LCA corresponds to the structure of the LCA, thus it is subdivided in the typical four phases: goal and scope definition, inventory phase, life cycle impact assessment and interpretation phase. However, the contents may have some differences [8].

- In goal and scope definition, S-LCA encourages external stakeholders to be involved in providing input and outputs on impacts, within the assessment itself. In S-LCA, justification needs to be presented when a subcategory is not included in the study. The subcategories are classified both by stakeholder categories and by impact categories in S-LCA. S-LCA may require site-specific LCIA in some cases, and may also need information about "political" attributes, such as the country and its laws.

- As regards to the inventory phase, the activity variables data are collected and used more often in S-LCA than in LCA. The subjective data are sometimes in S-LCA the most appropriate information to use. The balance between quantitative, qualitative and semi-quantitative data will generally be different from the LCA. Furthermore, the data sources will differ (coming from stakeholders) and the data collection steps and methods vary.

- For the life cycle impact assessment, the use of performance reference points is specific to S-LCA and the social assessment encounters both positive and negative impacts of the product life cycle.

- For the interpretation the significant issues will differ and in S-LCA there is the addition of information on the level of engagement of stakeholders [8].

3. Methodological choices for the Water2REturn project

3.1 Life Cycle Assessment

In the goal and the scope definition, the objectives that characterise the LCA study shall be clearly defined and shall be consistent with the intended application. The goal and scope definition is a crucial phase in LCA studies, since different purposes require different methodological choices, or vice versa, different methodological choices respond to different questions [9].

During the **Water2REturn** project multiple LCA case studies shall be performed (i.e. LCA of the baseline wastewater treatment situation; LCA of SBR, LCA of NRU, LCA of SFU, LCA of ADU, LCA of ATU, LCA of algae plant, LCA of bio-fertilizers, LCA of bio-stimulants, LCA of the overall technology). The general methodological choices for the foreseen case studies can be found in this document, while case study specific methodological choices can be found in the case study documents. If necessary, the goal and scope definition shall be updated in case of important methodological choices made in the case studies.

The goal and scope definitions deals with the following aspects: intended application and reasons of the study, commissioner and target audience of the study, comparative assessment and critical review, classification of the decision-context and modelling approach, functional unit and reference flow, system boundaries, allocation and cut-off criteria, LCIA methods and associated impact categories, LCI data quality requirements, foreseen deliverables of the study, limitation and assumptions of the study.

Intended application and reasons of the study

In the **Water2REturn** project, LCA shall be applied in order to provide eco-design feedback to the projects partners, enabling the optimization of the **Water2REturn** technologies and to quantify the advantages and disadvantages of their implementation. In the broader context of circular economy, the **Water2REturn** project shall investigate the wastewater situation of the slaughterhouses in relation to the proposed wastewater treatment options and possibilities of nutrient recovery. LCA shall be performed in order to evaluate the environmental impacts and benefits in a system perspective contributing to the concept of circular economy.

Commissioner and target audience of the study

The commissioner of the **Water2REturn** project is the European Commission by means of the research programme Horizon2020. This research programme is for a small part based on co-financing by the project consortium, which means that also the consortium partners are partly co-financing.

The target audience of the study is represented by multiple stakeholders:

- Direct stakeholders represented by the project consortium and the European Commission comprising slaughterhouses, wastewater treatment companies, producers of bio-stimulants and fertilizers, agricultural companies, land-owners and the meat industry.
- Indirect stakeholders outside the project consortium comprising national and regional authorities in charge of agriculture, environment and water issues, and the consumer.

Comparative assessment and critical review

The goal and scope definition should states whether the study involves comparisons or comparative assertions across systems and whether these are foreseen to be disclosed to the public [10]. In case of the **Water2REturn** project, comparative LCAs are foreseen as different wastewater technologies shall be compared in order provide eco-design feedback to the consortium partners. This type of application concerns an internal LCA made for eco-design purposes. A critical review is therefore not compulsory, since the LCA shall not be disclosed to the public.

Nevertheless, dissemination activities like scientific publications and communications to the larger public of LCA results will take place during and after the **Water2REturn** project. It is therefore recommended to foresee critical review activities. In the **Water2REturn** project three partners have been assigned the task to review the LCA activities: Exergy, ELO and UECBV.

The LCAs shall be performed by 2B Srl while Exergy, ELO and UECBV although part of the consortium, have not been involved in the performance of the LCI/LCA study. This independency of the LCA reviewers is beneficial for the quality and credibility and hence value of the LCA study. In case of scientific publications and additional review is foreseen through the review and publication process of the scientific journal.

Classification of the decision-context and modelling approach

Two Life Cycle Assessment approaches can be distinguished, as defined by the UNEP/SETAC Shonan guidance on LCA [11]:

- Attributional approach*:* System modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system.
- Consequential approach: System modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change for the functional unit.

The decision-context of the **Water2REturn** project typically concerns the evaluation of existing and/or emerging technologies in relation to their actual state of development. This means that the evaluation shall be based on the average situation, corresponding to the attributional approach.

Moreover, the decision context of the **Water2REturn** project corresponds to a micro-level decision support. In the ILCD handbook the micro-level decision support is defined as follows: “Life cycle-based decision support on micro-level, i.e. typically for questions related to specific products. Micro-level decisions are assumed to have limited and no structural consequences outside the decision-context, i.e. they are supposed not to change available production capacity” [10]. Typical applications of micro-level decision support are hotspot analysis and eco-design which matches with the goals of the **Water2REturn** project. Micro-level decision support, corresponding to Situation A of the ILCD Handbook, requires the application of the attributional approach. The attributional life cycle model depicts its actual or forecasted specific or average supply-chain plus its use and end-of-life value chain. The existing or forecasted system is embedded into a static technosphere [10].

Functional unit and reference flow

The definition of the functional unit and its associated reference flow is a fundamental step in LCA since all the inputs and the outputs of the system are related to the functional unit, and as a consequence the

LCA result are quantified per functional unit, allowing the comparison between different product systems having the same functional unit.

In the **Water2REturn** project the choice of the functional unit shall be evaluated case by case and documented in the foreseen LCA case studies (i.e. LCA of the baseline wastewater treatment situation; LCA of SBR, LCA of NRU, LCA of SFU, LCA of ADU, LCA of ATU, LCA of algae plant, LCA of bio-fertilizers, LCA of bio-stimulants, LCA of the overall technology).

The choice of functional unit shall be related to the amount of treated slaughterhouse wastewater, expressed in volume (i.e. 1 m^3). Possible alternative functional units can be also related to the production of fertilizers (water line), bio-stimulants (sludge line) and algae biomass (algae line). Any deviation from the foreseen functional unit (volume of treated slaughterhouse wastewater), if applicable, shall be justified in the specific case study report.

System boundaries

The system boundaries determine which unit process shall be included within the LCA. The selection of the system boundaries shall be consistent with the goal of the study (§ 3.1), while the criteria used in establishing the system boundaries shall be identified, justified and clearly described in the LCA case study [2, 3].

The system boundaries of the **Water2REturn** project shall comprehend all the lines which result necessary in relation to the treatment of the slaughterhouse sewage water, like for instance the production of fertilizers, bio-stimulants and biogas for the energy self-efficiency of the slaughterhouse. A demonstrative example is represented by Figure 4 and a provisional diagram of the overall process is shown in Figure 6.

The system boundaries related to the functional unit of the wastewater treatment comprehend all slaughterhouse wastewater treatment processes, considering each process step, tank and reactor.

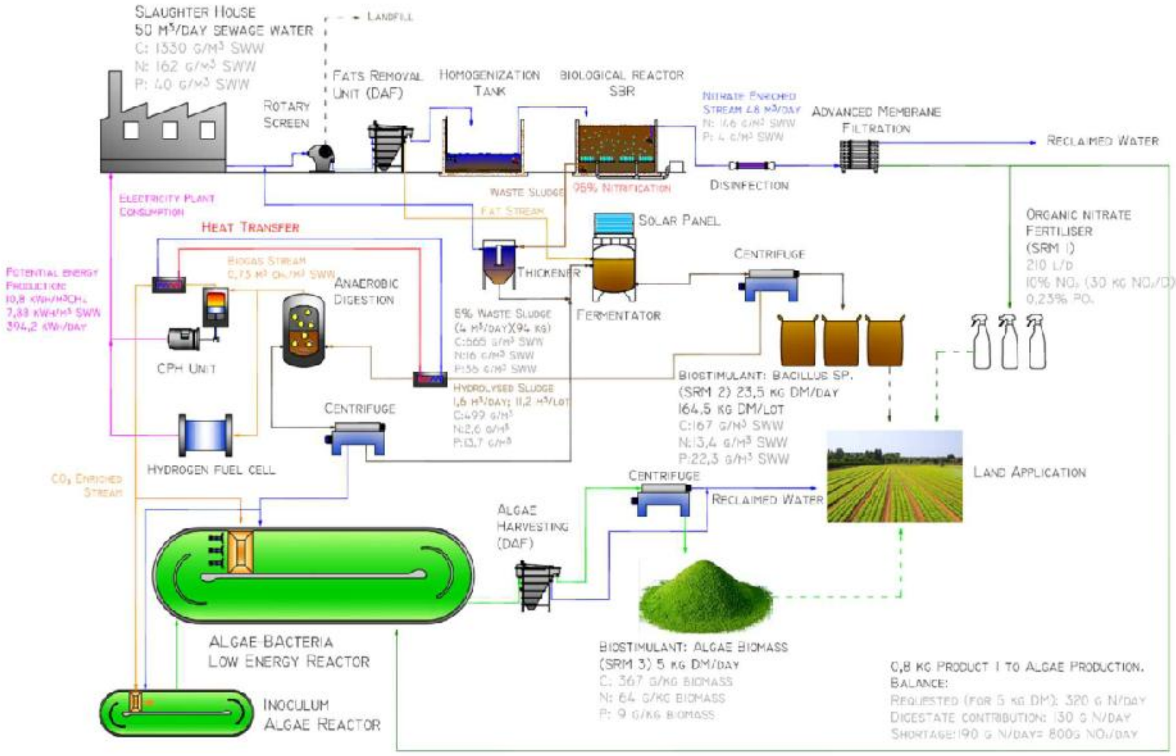


*Figure 4: System boundaries of **Water2REturn** project [1].*

Concerning the production of the nitrogen and phosphorous-based fertilizers, the specific line of the biological reactor has been considered. After being screened, the slaughterhouse wastewater goes to the fats removal unit. After homogenization the wastewater is uniform and goes to the biological reaction tank, where the nitrification process takes place. The nitrate enriched stream goes to the disinfection and then to the advanced membrane filtration to separate the reclaimed water and the organic nitrate fertiliser.

Concerning the production of the bacillus-based bio-stimulant the fermentation line has been considered. The sludge from the biological reaction tank enters the thickener. The waste sludge from the thickener and from the sludge line and the fats removed in the nitrification line enter the fermentation step. After the centrifugation the solid fraction, corresponding to the bacillus-based bio-stimulant, is obtained and ready to be use on the agronomic field.

The hydrolysed sludge from the centrifuge of the bacillus line is sent to the anaerobic digestion unit, consisting of one homogenization tank, two anaerobic sequential batch reactors for the anaerobic digestion, and one biogas tank (Figure 5). CO_2 enriched stream is sent to the algal line, while methane and hydrogen are used for the energy production in order to provide energy to the slaughterhouse.

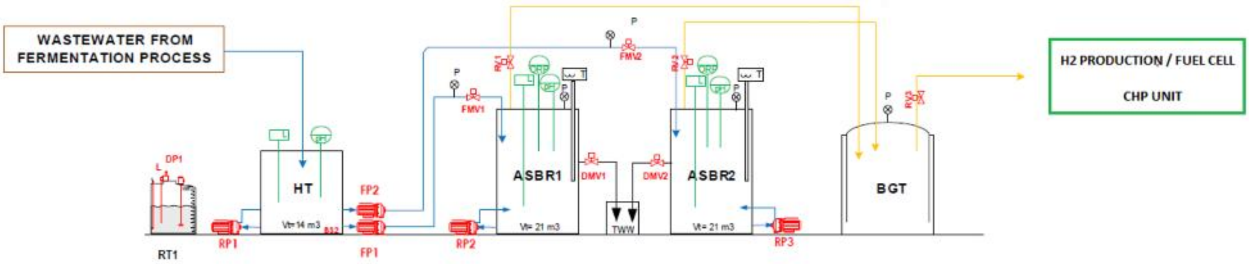


Figure 5: *Anaerobic digester and the energy production module 1.*

In the algal line, as represented by the green part of Figure 6, the CO_2 enriched stream and digestate from the sludge line enter the buffer tank B-3. Inputs from the water line, from the buffer tank B-1, the Disinfecter (U-3) and the Advanced Membrane Filter (U-4), and also from the centrifuge U-5, may enter the buffer tank B-3. The homogenised flow that exits B-3 enters both the inoculum pond (R-4) and the algae pond (R-5). Pump P-4 sends the algae solution from the algae pond to buffer tank B-4. The Dissolved Air Flotation (DAF) U-7 comes after the buffer tank B-4. It provides reclaimed water and an algae biomass flow that is sent to the U-5 centrifuge. This centrifuge separates other reclaimed water from the algae biomass. Both can be used in agriculture, together with fertilizers and a bacillus-based bio-stimulant.

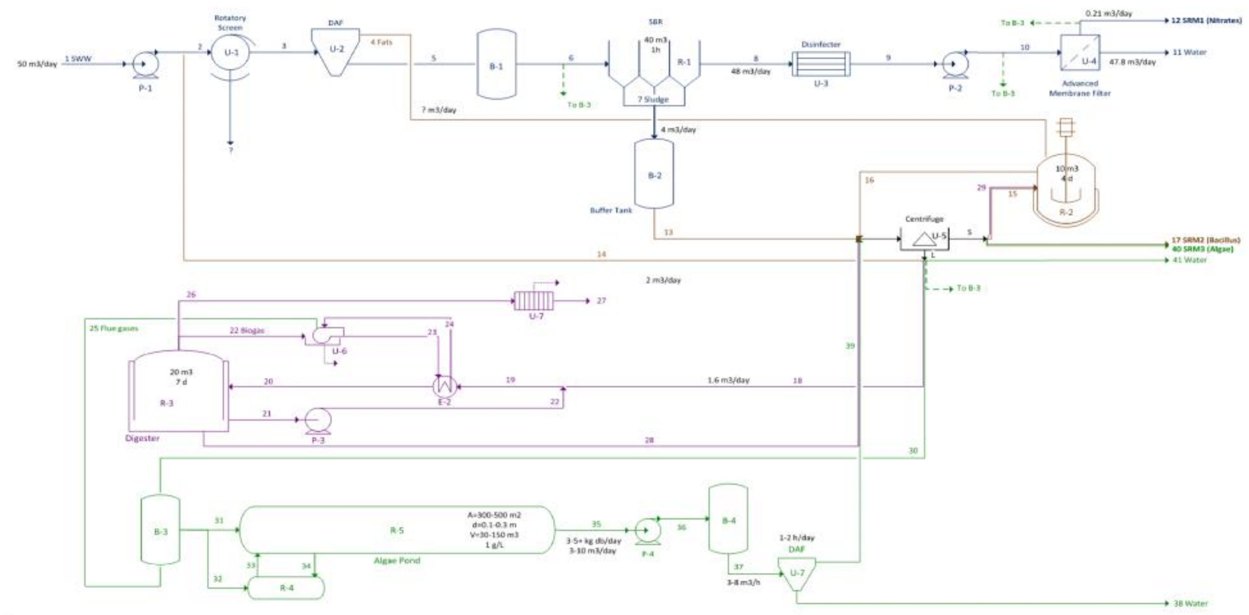


Figure 6: *Provisional plant diagram.*

Allocation and cut-off criteria

An allocation problem occurs when a process results in multiple output products and where there is only aggregate information available about the emissions. The priorities suggested by ISO 14040 shall be considered in the allocation procedure [3]:

- Whenever possible, allocation shall be avoided by dividing the unit process into two or more sub-processes and collecting the environmental data related to these sub-processes, or by means of system expansion, expanding the product system to include the additional functions related to the co-products.
- Where allocation cannot be avoided, the inputs and outputs of the system shall be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.
- Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

Concerning end-of-life allocation, the "cut-off" approach, or also called the "recycled content" approach, has been applied as a default. With this approach, outputs subject to recycling are considered as inputs to the next life cycle, and no environmental burdens nor environmental gains deriving from the recycling process are allocated to the waste stream. Waste collection and transport to the recycling facility are included. In the case of the **Water2REturn** project this means that the slaughter house waste water is free of any environmental burden.

Cut-off rules are intended to support an efficient calculation procedure. They shall not be applied in order to hide data. Processes and activities that contribute to less than 1% of the total environmental impact for any impact category may be omitted from the inventory analysis. Processes that are not included in the LCA shall be documented [12].

LCIA methods and associated impact categories

The impact assessment methods used in the performed LCAs during the **Water2REturn** project have been selected according to the ILCD handbook on Life Cycle Impact Assessment [10].

In order to give a more synthetic overview, the 16 impact categories of the ILCD method [13] have been reduced to a more limited set of 9 impact categories containing the most relevant indicators, identified as the "ILCD/INCOM" method: Climate change (biogenic CO_2 excluded due to the neutrality approach); Human toxicity, cancer effects; Human toxicity, non-cancer effects; Particulate matter; Acidification; Freshwater ecotoxicity; Land use; Water resource depletion; and mineral, fossil and renewable resource depletion.

Furthermore, the ReCiPe method [14] has been applied in order to use also an end-point LCIA method containing 17 impact categories that can be further aggregated into 3 damage categories (human health, ecosystem and resources) and eventually one single score (in ecopoints), by means an European set of normalization and weighting factors.

LCI data quality requirements

Primary data or foreground data of the technologies investigated in the **Water2REturn** project shall be provided by the consortium partners. LCA data will be collected through questionnaires, e-mail communications and project meetings. Primary data refer to pilot or demonstration scale. Secondary data or background data can be used for background processes and can originate from various LCA databases, but the ELCD database [15] and the ecoinvent database [16] are preferred. The use of secondary data derived from LCA databases older than from 1990 should be avoided.

A fundamental characteristic of the data collection in the **Water2REturn** project is that it proposes a full-scale demonstration process which allows to collect most of the primary data directly from the consortium partners.

Starting point for the data collection is the characterization of the slaughterhouse wastewater effluent provided in deliverable 2.1 [17]. Furthermore, detailed information, to be obtained through personalized questionnaires, is required on all processes of the **Water2REturn** project, like for instance fertilisers, bio-stimulants and all further processes involved in the water line, sludge line and algae line.

Primary data shall be used for the generation of electricity, if possible. If primary data is not available or if the electricity mix is not specified, the electricity mix used shall be approximated as the electricity mix of the specific country. The electricity mix shall be documented.

Transport of materials to manufacturer shall be based on actual transportation and distances from the supplier. The geographical and temporal system boundaries need to be specified in the LCA case studies, where the geographical system boundaries are determined by the actual location of the demonstration processes, or more generally Europe, and the reference year is the one in which the LCA data has been collected.

Limitation and assumptions of the study

The limitations and assumptions of the LCA case studies shall be clearly identified and described in the LCA case study reports. Limitations of the LCA case studies may be related to initial choices of the goal and scope definition, impact coverage limitations, methodological limitations, assumption limitations and limitations for the use of the LCA case study.

3.2 Life Cycle Costing

In the **Water2REturn** project LCC follows the ISO standards 14040/14044 [2, 3] and shall be performed according to SETAC's publication "Environmental Life Cycle Costing" [4]. This means that LCC shall be performed in parallel with an LCA study applying the same system boundaries but without monetization of environmental impacts in order to avoid double counting with LCC results.

In this sense, all methodological choices made section 3.1 are also valid for the LCC studies in the **Water2REturn** project, summarized in the following key choices:

- The choice of the **functional unit** shall be evaluated case by case and documented in the foreseen LCC case studies (i.e. LCC of the baseline wastewater treatment situation; LCC of SBR, LCC of NRU, LCC of SFU, LCC of ADU, LCC of ATU, LCA of algae plant, LCC of bio-fertilizers, LCC of bio-stimulants, LCC of the overall technology). The choice of functional unit shall be related to the amount of treated slaughterhouse wastewater, expressed in volume (i.e. 1 m^3). Possible alternative functional units can be also related to the production of fertilizers (water line), bio-stimulants (sludge line) and algae biomass (algae line). Any deviation from the foreseen functional unit (volume of treated slaughterhouse wastewater), if applicable, shall be justified in the specific case study report.

- The **system boundaries** of the **Water2REturn** project shall comprehend all the lines which result necessary in relation to the treatment of the slaughterhouse sewage water, like for instance the production of fertilizers, bio-stimulants and biogas for the energy self-efficiency of the slaughterhouse. A demonstrative example is represented by Figure 4 and a provisional diagram of the overall process is shown in Figure 6. The system boundaries related to the functional unit of the wastewater treatment comprehend all slaughterhouse wastewater treatment processes, considering each process step, tank and reactor. Additionally, also labour cost, research and development costs and capital costs are part of the system boundaries.

- The **LCC data** shall be based in primary cost data, coming directly from the technology owners, that is the partners in the project. For the LCC data collection personalized questionnaires will be developed in order to enhance the collection of LCC data among the partners in the consortium.

- In LCC, **Life Cycle Impact Assessment** (LCIA) is relatively simple since all costs will be aggregated in the same unit of currency, namely euro. If appropriate, discounting will be applied.

- The **eco-efficiency analysis** shall be performed in line with the work of Huppes and Ishikawa [7], where eco-efficiency results are illustrated in a portfolio presentation, plotting LCC results against LCA results. The eco-efficiency analysis requires the use of a single score. LCA results are expressed in terms of global warming potential according to IPCC 2013 [18] or alternatively the single score of the ReCiPe method [14]. LCC results automatically represent a single score, since they are expressed in euro.

3.3 Social LCA

The purpose of performing Life Cycle Assessment, Life Cycle Costing and Social LCA is to provide an assessment for eco-design purposes based on all three pillars of sustainability: environmental, economic and social.

For this reason, during the **Water2REturn** project Social LCA's will be performed for the same case studies assessed with LCA and LCC, i.e. Social LCA of the baseline wastewater treatment situation; Social LCA of SBR, Social LCA of NRU, Social LCA of SFU, Social LCA of ADU, Social LCA of ATU, Social LCA of algae plant, Social LCA of bio-fertilizers, Social LCA of bio-stimulants, Social LCA of the overall technology.

In the **Water2REturn** project Social LCA follows mainly the UNEP-SETAC Guidelines for Social Life Cycle Assessment of Products [8], also supported by the methodological approach of the Product Social Impact Assessment guidelines, PRé Consultants [19].

Intended application and reasons for the study

The specific function of Social LCA is to integrate the environmental and economic assessment with social criteria in the development of the innovative technologies as proposed in the **Water2REturn** process. The purpose is to support the optimisation process through the social assessment of advantages and disadvantages of the new technologies and a comparison with traditional ones, providing project partners with assessments to support informed choices.

Comparative assessment and critical review

Similarly to LCA, also the UNEP – SETAC Guidelines for Social LCA of Products state that it must be specified "whether the results are intended to be used in comparative assertions or intended to be disclosed to the public (ISO 14040, 2006)" [8]. In case of the **Water2REturn** project, comparative Social LCAs are foreseen as different wastewater technologies shall be compared in order to provide eco-design feedback to the consortium partners. This type of application concerns an internal Social LCA made for eco-design purposes. A critical review is therefore not compulsory, since the Social LCA shall not be disclosed to the public.

Nevertheless, dissemination activities like scientific publications and communications to the larger public of Social LCA results will take place during and after the **Water2REturn** project. As a critical review is not foreseen for these activities, comparative results will be restricted to eco-design purpose and internal use only, while communication to the larger public will focus on the **Water2REturn** technologies.

Functional unit and system boundaries

The Social LCA will be performed in parallel to LCA and LCC, with the same purpose and on the same studies. For consistency reasons, the same functional unit and the same system boundaries will be applied:

- The choice of the **functional unit** shall be evaluated case by case and documented in the foreseen Social LCA case studies (i.e. Social LCA of the baseline wastewater treatment situation; Social LCA of SBR, Social LCA of NRU, Social LCA of SFU, Social LCA of ADU, Social LCA of ATU, Social LCA of algae plant, Social LCA of bio-fertilizers, Social LCA of bio-stimulants). The choice of functional unit shall be related to the amount of treated slaughterhouse wastewater, expressed in volume (i.e. 1 m^3). Possible alternative functional units can be also related to the production of fertilizers (water line), bio-stimulants (sludge line) and algae biomass (algae line). Any deviation from the foreseen functional unit (volume of treated slaughterhouse wastewater), if applicable, shall be justified in the specific case study report.

The **system boundaries** of the **Water2REturn** project shall comprehend all the lines which result involved in the treatment of the slaughterhouse sewage water, like for instance the production of fertilizers, bio-stimulants and biogas for the energy self-efficiency of the slaughterhouse. A demonstrative example is represented by Figure 4 and a provisional diagram of the overall process is shown in Figure 6. The system boundaries related to the functional unit of the wastewater treatment comprehend all slaughterhouse wastewater treatment processes, considering each process step. For the Social LCA specifically, aspects related to workers, society, local communities, suppliers and consumers will be taken into consideration. The stakeholders will be identified in detail for each case study, as specified in the section "Roles of the organizations involved". The geographical scope will refer to Spain and the temporal scope will follow the methodological choices made for LCA and LCC and the data availability of economic projections.

Methodology

The methodology applied to this study follows the principles of relevance, accuracy, completeness, consistency and transparency, feasibility, adopting them from GHG Product Life Cycle Accounting and Reporting Standard [20] and Social Life Cycle Metrics for Chemical Products [21].

Relevance: ensure that the assessment reflects the actual social impacts of the life-cycle system as much as possible and serves the decision-making needs of users.

Accuracy: ensure that uncertainties are reduced as far as practicable and that sufficient care and meticulosity are guaranteed to enable users to make decisions with reasonable assurance as to the quality of the work.

Completeness: taking into account and reporting all social impacts related to the functional unit and within the system boundary.

Consistency: use a consistent methodology throughout all studies for meaningful comparisons.

Transparency: disclose all relevant assumptions and report relevant references to the methodologies and data sources used.

Feasibility: Ensure that the chosen approach can be executed within a reasonable timeframe and with a reasonable level of effort and cost.

Target audience of the study

The target audience of the study refers to the audience at which the study is aimed. For LCA and LCC studies the target audience is represented by multiple stakeholders:

- Direct stakeholders: European Commission (contractor promoting innovation in the EU); organizations of the project consortium, other organisations providing similar products or services, like slaughterhouses, wastewater treatment research centres, producers of bio-stimulants and fertilizers, agricultural companies, land-owners and the meat industry.
- Indirect stakeholders outside the project consortium comprising wastewater treatment companies, national and regional authorities in charge of agriculture, environment and water issues, and the consumer.

In the specific case of Social LCA, the five stakeholder groups listed by the UNEP/SETAC guidelines [8] have been considered and on a first assessment it seems appropriate to consider all of them:

- local communities: sewage water has an impact on the quality of the environment and a new technology may need consideration given its potential impacts on the communities living in the vicinity. There should be participatory engagement with the local community to gain their acceptance for the technology and the project on the whole, contributing to bigger societal goals.

- consumers: a possible relevant contact with consumers may happen at the use phase of the products and health and safety is a relevant aspect to assess. The SLCA – Methodological sheets by UNEP /SETAC [21] refer to health and safety as "Customers (end users) expect products and services to perform their intended functions satisfactorily and not pose a risk to their health and safety." It is also necessary to address the use of fertilizer and bio-stimulants of animal origin which may represent an issue for certain types of consumers which for personal, cultural, or religious reasons, do not consume food of animal origin.

- suppliers: The SLCA – Methodological sheets by UNEP /SETAC [21] refer to supplier relationships as relationships which also concern to "all mutual activities, co-operations, agreements that regulate the exchanges, trade and relation among organizations, bearing in mind that every organization in the value chain is responsible for complying with applicable laws and regulations". Being a circular economy project, relationships along the supply chain are important.

- society: the two topics applying are Contribution to economic development, important aspect to evaluate the economic impact of the new technology, and Technological development, considering that this is a EU-funded project and all partners also take part in the financing.

- employees: employees are crucial stakeholders; Introducing a new technology make it more important to provide appropriate training, reinforce self-confidence and skills among employees.

The stakeholder groups are considered along the whole value chain, comprising also the local communities and the employees, which are not considered as target audience of the LCA and LCC studies.

Furthermore, Social LCA is sensitive to location and the geographical aspect will influence the type of choices to be made.

Roles of the organizations involved

Modelling the system enables to better identify the companies involved within the consortium, the processes each one is involved in and the stakeholders involved in each line/phase. At this stage, the identification of stakeholders is based on the information available in the DoA [*1*]and a brief screening in literature but will need to be refined by means of questionnaires, interviews with the consortium partners involved, documents from the interested organizations and further literature analysis.

The role of each organization involved is specified, both for the baseline system actually in place and for the new **Water2REturn** technologies which are being developed. The principle for the inclusion of an organization in the following list is "relevance" as earlier specified. Only organizations affected in their operations, management or structure are included. In case an organization is not affected but can provide valuable information for the social assessment this will be specified.

<u>Baseline system</u>

The system actually in place, and which will be studied against the new **Water2REturn** system, is represented in Figure 7.

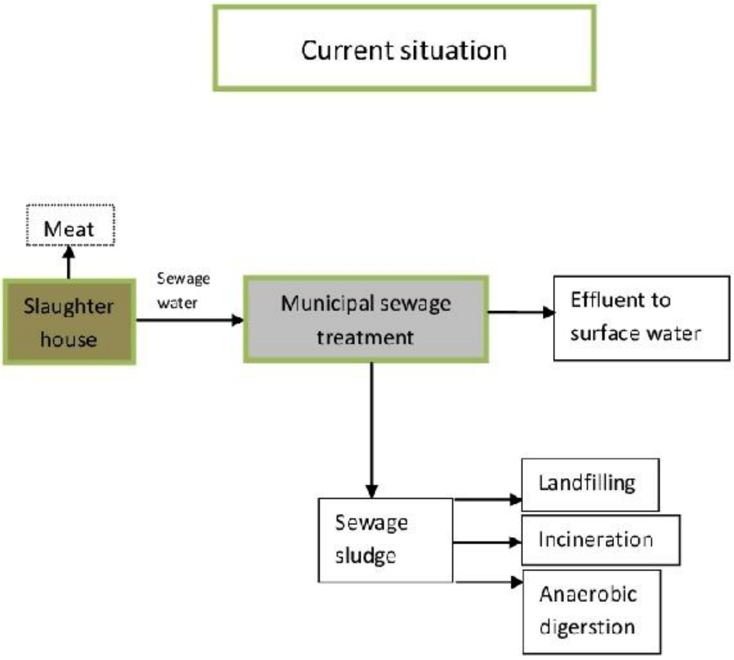


Figure 7: *System boundaries of the current situation – baseline.*

Table 2: *Organizations involved in the baseline and role within the project*

Organization	Location	Role within the project
Matadero del Sur	Seville (Spain)	Emission of sewage water to be treated
Municipality	Seville (Spain)	Sewage water treatment

<u>**Water2REturn** system</u>

The **Water2REturn** technologies are characterised by numerous interactions; to facilitate the identification of the stakeholders, the system has been divided into 5 phases, 2 of which are identified with companies and 3 with technology/production lines, as represented in Figure 8. Within each one of these phases and technology/production lines, all the organizations involved are identified, which will represent the bases for the identification of the stakeholders:

- Slaughterhouse, where livestock is slaughtered, and waste is produced.
- Water line, where organic nitrate fertiliser is produced.
- Sludge line, identified by the production of bio-stimulants and biogas.
- Algae line, for the production of algae biomass.
- Farmers for the land application of fertiliser and bio-stimulants.

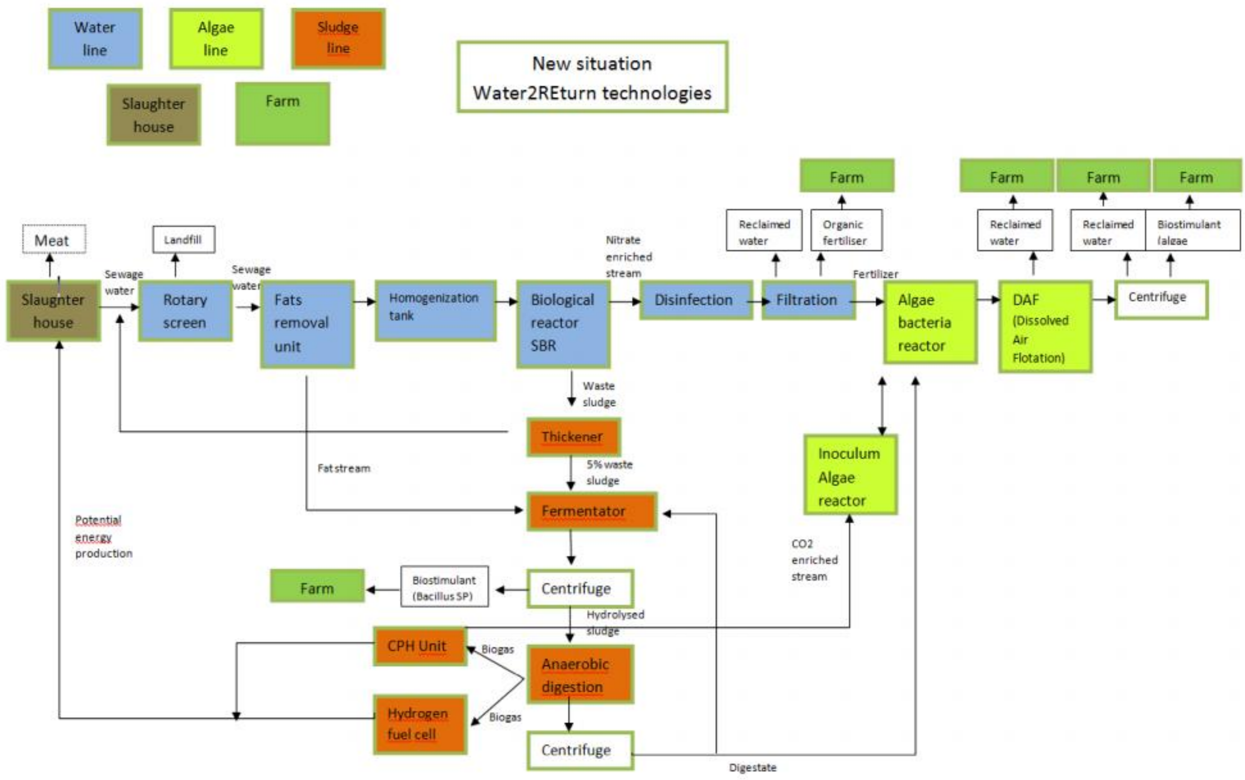
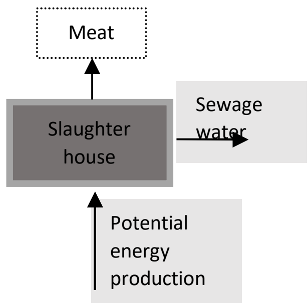
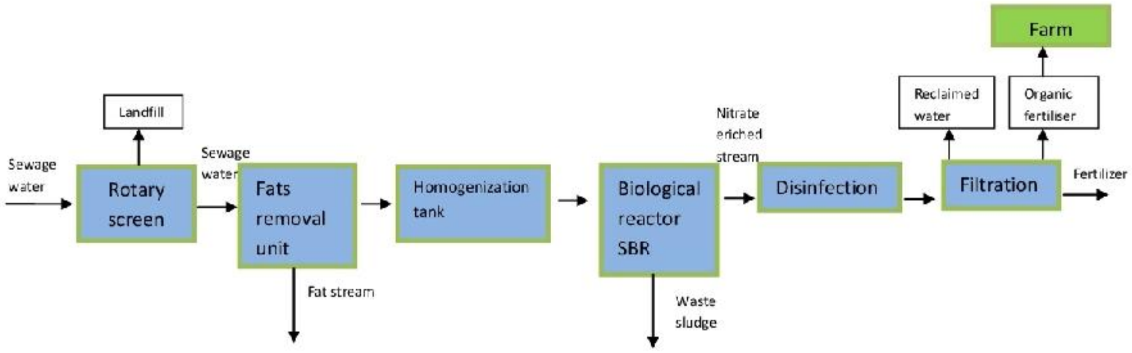


Figure 8: *System boundaries divided into 2 phases and 3 lines of production.*

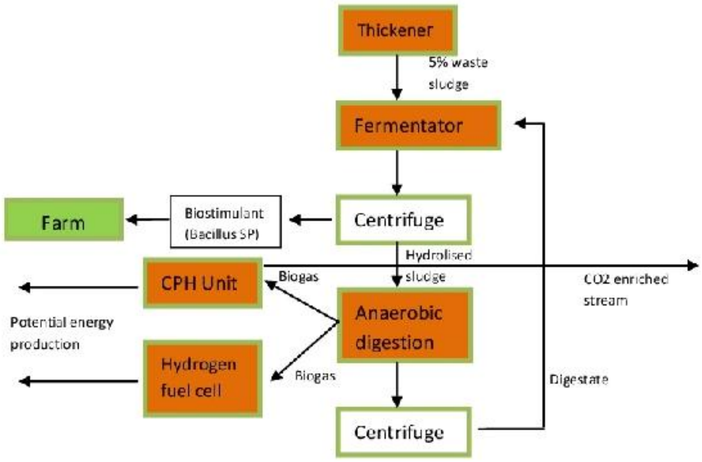
For consistency reasons, the description of the role of all organizations involved in the new system follows the 5 phases used to describe it.

Organization	Location	Role within the project
		
Matadero del Sur	Sevilla (Spain)	Emission of sewage water
UECBV – European Livestock and Meat Trades Union	Brussels (Belgium)	UECBV is not affected by the system in place and is only considered here for the role as provider of information.



Water line

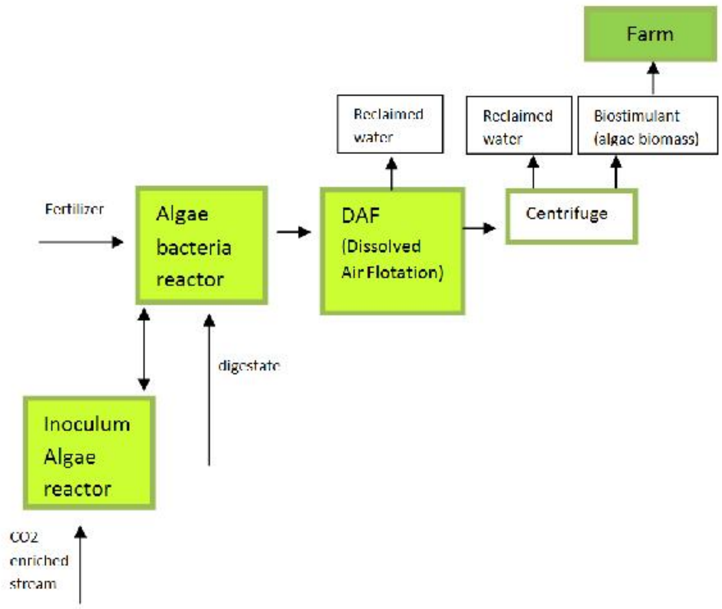
Bioazul	Malaga (Spain)	Implementation of membrane and ion-exchange modules for organic NO_3 recovery
Centa	Sevilla (Spain)	Nitrification-oriented SBR for organic NO_3 recovery from sewage water
KIMITEC	Almería (Spain)	Product valorisation and manufacture for agronomic use + regulatory analysis



Sludge line

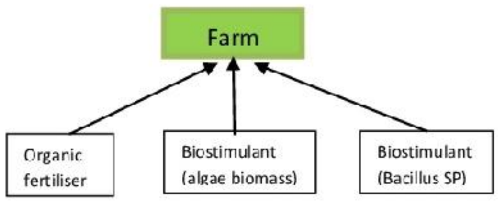
USE – University of Seville	Seville (Spain)	Sludge fermentation conversion into organic biostimulants and hydrolysed matter
UCA – University of Cadiz	Cadiz (Spain)	Enlarged energy production through hydrolysed sludge biogas upgrading
KIMITEC	Almería (Spain)	Product valorisation and manufacture for agronomic use + regulatory analysis

Adventech	Porto (Portugal)	Valorisation of biogas to obtain electricity and heat for use in the slaughterhouse industry



Algae Line

Algen	Ljubljana (Slovenja)	CO_2 fixation and nutrients recovery from anaerobic digestate by means of algae cultivation
UL – University of Ljubljana	Ljubljana (Slovenia)	Agronomic product characterization, laboratory, greenhouse and field tests



Farm

Slorom	Romania	End user of fertilizer, biostimulants and algae biomass at real scale in agriculture
ELO	**Brussels (Belgium)**	ELO is not affected by the system in place and is only considered here for the role as provider of information.

Identification of social topics

Following the principles earlier identified, the social topics are selected on the basis of relevance. Only social topics that might be affected in the transition from the baseline to the new technology have been chosen.

Table 3: *Organizations involved, stakeholders affected and relevant social topics.*

System phases	Organizations involved and country	Local communities	Employees	Society	Suppliers	Consumers
Slaughter house	• **Matadero del Sur** – Spain	Health and safety Community engagement	Training and education Job satisfaction and engagement	Contribution to economic development Technology development		
Water line	• **Bioazul** – Spain • **CENTA** – Spain • **KIMITEC** - Spain	Health and safety Community engagement Local employment	Training and education Job satisfaction and engagement	Contribution to economic development Technology development	Supplier relationships	
Sludge line	• **USE** – Spain • **KIMITEC** – Spain • **Adventech** - Portugal	Health and safety Community engagement Employment	Training and education Job satisfaction and engagement	Contribution to economic development Technology development	Supplier relationships	
Algae line	• **Algen** – Slovenja • **UL** - Slovenja	Health and safety Community engagement	Training and education Job satisfaction and engagement	Contribution to economic development Technology development	Supplier relationships	
Farm	▪ **Slorom** – Romania	Health and safety	Training and education Job satisfaction and engagement	Technology development	Supplier relationships	Health and safety

Impact categories

Table ***4*** presents a first draft of social topics combined with performance indicators. This choice will be validated by means of questionnaires, interviews with the consortium partners involved, documents from the interested organizations and further literature analysis.

Table 4: *Social topics and related performance indicators.*

Stakeholder group	Social topic	Performance indicator	Impact Assessment method	Results
Local community	Community engagement	▪ Number of activities in place to engage local community ▪ Diversity of community stakeholder groups that engage with the organization		
	Health and safety	▪ Presence of a strategy to mitigate negative impacts ▪ Actions in place to mitigate negative impacts		
	Local employment	▪ Number of jobs created, balance between job creation and job losses		
Employees	Training and education	▪ Number of hours of training ▪ Percentage of workers that have participated in training		
	Job satisfaction and engagement	▪ Percentage of workers who participated in a job satisfaction and engagement survey, and their level of satisfaction ▪ A non-formal survey is in place and results communicated to management		
Society	Contribution to economic development	▪ Contribution of the product/service/organization to economic progress (revenue, gain, paid wages, R+D costs in relation to revenue, etc.)		
	Technology development	▪ Partnerships in research and Development ▪ investments in technology development/ technology transfer		
Consumers	Health and safety	▪ The use of animal fertilizers/biostimulants is accepted by vegetarians/vegans		

4. Foreseen deliverables of WP8

The deliverables of WP8 are illustrated in Table 5. The first deliverable, D8.1, is represented by this document, which shall give guidance to the development of the second deliverable, D8.2, consisting of the final report on eco-efficiency and sustainability assessment (LCA, LCC and S-LCA).

The final report shall be based on all intermediate reports elaborated during the **Water2REturn** project. Examples of intermediate reports are the LCA case studies on the baseline wastewater treatment situation, SBR, NRU, SFU, ADU, ATU, bio-fertilizers, bio-stimulants and the overall technology. Other intermediate reports are the case studies on Life Cycle Costing (LCC) and Social LCA (S-LCA).

The case study reports have the function to identify the environmental, economic and social hotspots and to suggest improvement options in order to provide eco-design feedback on the eco-efficiency and sustainability of the technologies developed during the **Water2REturn** project. For this reason, it is important that the case studies are performed directly once the technology is demonstrated and LCA data can be gathered. In this way, the eco-design feedback can be still taken into account to optimize the technology.

Finally, WP8 will provide deliverables on the safety, health and environment regulations (D8.3), techno-economic assessment (D8.4) and ETV certification (D8.5). These other three deliverables are beyond the scope of this document, but will be indirectly influenced by Deliverable 8.1 since these deliverables will use the results of the D8.1 and D8.2 as an important input.

Table 5: *Overview of the deliverables of WP8.*

Deliverable number	Deliverable name	Lead beneficiary	Type	Dissemination level	Due date (in months)
D8.1	Report on LCA goal and scope definition	11 – 2B	Report	Public	12
D8.2	Final report on eco-efficiency and sustainability assessment (LCA, LCC, social foot printing, indicators and recommendations)	11 – 2B	Report	Confidential, only for members of the consortium (including the Commission Services)	39
D8.3	Report on safety, health and environment regulations	14 – EXERGY	Report	Public	40
D8.4	Report on techno-economic assessment	14 – EXERGY	Report	Confidential, only for members of the consortium (including the Commission Services)	42
D8.5	ETV certification	1 – BIOAZUL	Report	Public	42

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