LIFE Project Number

<LIFE18 ENV/ES/000165>

Mid-term / Final Report

Covering the project activities from 01/07/2019[1] to 30/06/2023

Reporting Date[2]

<30/09/2023>

LIFE PROJECT NAME or Acronym

<LIFE ULISES>

Data Project

Project location:	Andalucía
Project start date:	<01/07/2019>
Project end date:	<30/06/2022>
Total budget:	1,902,784€
EU contribution:	1,041,810€
(%) of eligible costs:	54.75%

Data Beneficiary

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Project Website:	https://life-ulises.eu/

[1] Project start date
[2] Include the reporting date as foreseen in part C2 of Annex II of the Grant Agreement

This table comprises an essential part of the report and should be filled in before submission

Please note that the evaluation of your report may only commence if the package complies with all the elements in this receivability check. The evaluation will be stopped if any obligatory elements are missing.

Package completeness and correctness check	
Obligatory elements	**✓ or N/A**
Technical report	
The correct latest template for the type of project (e.g. traditional) has been followed and all sections have been filled in, in English *In electronic version only*	✓
Index of deliverables with short description annexed, in English *In electronic version only*	✓
Mid-term report: Deliverables due in the reporting period (from project start) annexed Final report: Deliverables not already submitted with the MTR annexed including the Layman's report and after-LIFE plan Deliverables in language(s) other than English include a summary in English *In electronic version only*	✓
Financial report	
The reporting period in the financial report (consolidated financial statement **and** financial statement of each Individual Beneficiary) is the same as in the technical report with the exception of any terminated beneficiary for which the end period should be the date of the termination.	✓
Consolidated Financial Statement with all 5 forms duly filled in and signed and dated *On paper (signed and dated originals*) and in electronic version (pdfs of signed sheets + full Excel file)*	✓
Financial Statement(s) of the Coordinating Beneficiary, of each Associated Beneficiary and of each affiliate (if involved), with all forms duly filled in (signed and dated). The Financial Statement(s) of Beneficiaries with affiliate(s) include the total cost of each affiliate in 1 line per cost category. *In electronic version (pdfs of signed sheets + full Excel files) + in the case of the Final report the overall summary forms of each beneficiary on paper (signed and dated originals*)*	✓
Amounts, names and other data (e.g. bank account) are correct and consistent with the Grant Agreement / across the different forms (e.g. figures from the individual statements are the same as those reported in the consolidated statement)	✓
Mid-term report (for all projects except IPs): the threshold for the second pre-financing payment has been reached	**N/A**
Beneficiary's certificate for Durable Goods included (if required, i.e. beneficiaries claiming 100% cost for durable goods) *On paper (signed and dated originals*) and in electronic version (pdfs of signed sheets)*	✓
Certificate on financial statements (if required, i.e. for beneficiaries with EU contribution ≥750,000 € in the budget) *On paper (signed original) and in electronic version (pdf)*	✓
Other checks	
Additional information / clarifications and supporting documents requested in previous EASME letters (unless already submitted or not yet due) *In electronic version only*	✓
This table, page 2 of the Mid-term / Final report, is completed - each tick box is filled in *In electronic version only*	✓

**original signature by a legal or statutory representative of the beneficiary / affiliate concerned*

Instructions:

Please refer to the General Conditions annexed to your grant agreement for the contractual requirements concerning a Mid-term/Final Report.

Both Mid-term and Final Technical Reports shall report on progress from the project start-date. The Final Report must be submitted to the EASME no later than 3 months after the project end date.

Please follow the reporting instructions concerning your technical report, deliverables and financial report that are described in the document "Guidance on how to report on your LIFE 2014-2020 project", available on the LIFE website at: https://ec.europa.eu/easme/sites/easme-site/files/report-your-life-project.pdf. Please check if you have the latest version of the guidance as it is regularly updated. Additional guidance concerning deliverables, including the layman's report and after-LIFE plan, are given at the end of this reporting template.

Regarding the length of your report, try to adhere to the suggested number of pages while providing all the required information as described in the guidance per section within this template.

1. Table of contents

2. List of key-words and abbreviations

Key Word.	Meaning
CEC	Concerning Emergent Contaminant
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
DCMD	Direct contact membrane distillation
DO	Dissolved Oxygen
DS	Draw Solution
EC	Electrical Conductivity
EU	European Union
FO	Forward Osmosis
GHG	Green House Gas
HRT	Hydraulic Retention Time
IWA	International Water Association
KPI	Key Project Indicator
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MBR	Membrane Bioreactor
MD	Membrane Distillation
NEDC	New European Driving Cycle
OM	Organic Matter
ORP	Oxidation Reduction Potential
PA	Partnership Agreement
PAO	Polyphosphate Accumulating Organisms
PFD	Process Flow Diagram
PLC	Programmed Logic Controller
RDE	Real Driving Emissions
RO	Reverse Osmosis
RPR	Raceway Pond Reactor
SAP	Stakeholder Advisory Panel
SS	Sewage sludge
TS	Total Solids
TSS	Total Suspended Solids
UASB	Upflow Anaerobic Sludge Blanket
UV	Ultra-Violet
WLTP	World Wide Harmonized Light Vehicles Test Procedure
WW	Wastewater
WWT	Wastewater treatment
WWTP	Wastewater treatment plant

3. Executive Summary (maximum 2 pages)

LIFE ULISES aims to demonstrate an integral solution to improve resource efficiency of the water sector, minimizing energy consumption and promoting the safe reuse of nutrients and water. LIFE ULISES main objective is to demonstrate a novel shift of a conventional WWTP, from a high energy consumer and waste producer, into a resource efficient infrastructure (biorefinery), focusing on two main specific objectives: energy self-sufficiency in WWTP and “full recycling” concept. For that purpose, the project deals with the **3 main areas of a WWTP: gas line, water line and sludge line**. Regarding the gas line, the installation of a biogas scrubber (**ABAD Bioenergy®**) converts biogas into biomethane, allowing for the use of the surplus biogas which is currently burnt in torches. Furthermore, **PUSH anaerobic pretreatment** process, consisting of a modification of the traditional UASB reactor, increases biogas production by the degradation of organic matter from wastewater. Organic load is then reduced in this process, minimizing the energy requirements for the WWT. A **solar photo-fenton disinfection** was installed **as tertiary treatment**, the process aim to reduce the carbon footprint of the overall process. In the sludge line, two different processes are implemented to recover nutrients and obtain **biofertilizers**: an enzymatic hydrolysis for dewatered sludge and a direct osmosis precipitation system for struvite production from centrate. All these actions were performed simultaneously in the same facility (El Bobar WWTP, Almeria) in order to assess the overall impact of the demonstration on a real WWTP by a **Life Cycle Assessment**.

Preparatory Actions (A), which took place from M1 to M11, were dedicated to confirming El Bobar WWTP as demonstration site, obtaining permits to start works and fulfilling a complete characterization of streams needed for plants design. The configuration and the best location to implement all demo plants were also assessed (D.A.1.1). In February 2020, the Construction Project was finalized including the final design and technical specifications of each demo plant (D.A2.1).

Implementation Actions (B) started in January 2020 (M7) with **B1 Action**, as initially programmed. Tender and procurement took place during the first period and civil works were due to start on March 2020 (M9). However, the Covid-19 pandemic situation, that caused the complete lockdown in Spain during more than 3 months, delayed the start of the works until June 2020 (M12). This also affected the supply of certain equipment, causing a total delay of 6 months in Action B1. Mechanical and electric works took place from September to December 2020 (M15-18). In January 2021 all demo plants installation were finalized and ready for start-up and operation, so that **Actions B2, B3, B4 and B5** could start. Regarding **B6 Action: Replicability and Transferability**, it started in January 2021.

Monitoring Actions (C) have all started since the start of the project. Monitoring LIFE ULISES **Key Performance Indicators** (C1) have been especially reviewed updating all monitoring parameters from the different Actions in the corresponding Excel files. This revision is linked to **Life Cycle Assessment (LCA)** baseline scenario from El Bobar WWTP, which has been carried out using real and updated data from the full-scale plant operation (D.C.2.1). This is an activity from **Action C2**, which aims to evaluate the environmental impact of the whole LIFE ULISES concept in a WWTP. Therefore, these analyses will suppose the baseline or departing scenario to compare with the final project impacts. EnergyLab has followed the framework proposed by ISO 14040 and 14044 for LCA studies. Similarly, the background data was retrieved from the ecoinvent v3.6 LCI database, and ReCiPe 2016 v1.1 midpoint and Cumulative Energy Demand were the life cycle impact assessment methods implemented. Concerning socioeconomic impacts of LIFE ULISES project (C3), an initial assessment has been also performed considering local impacts of the project in Almería and the compilation of project investment costs.

Dissemination and Communication activities (D) have been carried out intensively since the beginning of the project to maximize visibility and reach a wide range of audience and stakeholders. Several actions have been carried out in order to raise public awareness and ensure dissemination of the project actions and results (D1). The development of a **Dissemination Plan** (D.D.1.1) has been carried out and several dissemination materials and media have been designed: project logotype, website, social media, brochures, merchandising, press releases, notice boards, project video… As well, several networking actions have been carried out in order to increase the outreach of the project and its target audience (D2), such as the participation in events or the contact with other LIFE and non-LIFE projects. However, the pandemic situation led to the cancellation of most of the planned events from 2020, among them the first LIFE ULISES seminar.

Regarding **Project Management (E)**, the consortium has kept continuous communication and the Action has progressed as expected. A project management guide (D.E.1.2) was developed at the start of the project and financial and technical documentation is collected and reviewed every 3 months by AQUALIA, supported by CETIM. This way, the Project Management Team has ensured an optimal advance of the technical and financial parts of the project. Nine **periodic project meetings** have been carried out. The Kick off meeting was held in Almería on September 2019. 2nd, 3rd and 4th Project meetings were developed by virtual mode. 5th and 6th Project meetings were held in Almería. 7th Project meeting was held in A Coruña. Finally, 8th Project meeting and final meeting were developed by virtual mode. Aqualia has kept continuous communication with the Neemo monitor and the first visit was carried out virtually on May 2020, the second visit was held in Almería on May 2022 and the third visit was carried out virtually on August 2023

Concerning project chronogram, an **extension of the project was required** due to the delays that demo plants construction have suffered due to Covid-19 situation. The LIFE ULISES project consortium made an amendment and obtained a prorogation of the project for one year.

4. Introduction (maximum 2 pages)

4.1. Description of background, problems and objectives

Over 40 billion m^3 of municipal wastewater (WW) are produced annually in the EU, leading to a high energy consumption, the emission of 27 Mt of CO_2eq and the production of 3.55 Mt of sewage sludge (SS) to be managed. Moreover, the electricity demand on water sector is expected to increase due to the population growth in the next years.

Despite of this, wastewater itself has a great energy potential (4-10 times the energy required for treatment). However, most of this potential remains in SS and it is partially recovered on biogas production. Several aspects of water depuration could still be updated in order to reach a more sustainable process that could ensure minimum energy requirements.

In this context, LIFE ULISES aims to demonstrate an integral solution to improve resource efficiency of water sector, minimizing energy consumption and the safe reuse of nutrients and water. Thus, LIFE ULISES main objective is to demonstrate a novel shift of a conventional WWTP, from a high energy consumer and waste producer, into a resource efficient infrastructure (biorefinery), focusing on two main specific objectives: energy self-sufficiency in WWTP and "full-recycling" concept.

For that purpose, the project deals with the 3 main areas of a WWTP: gas line, water line and sludge line. Regarding the gas line, the installation of a simplified biogas scrubber will convert biogas into biomethane, allowing the use of the surplus biogas which is currently burnt in torches. Furthermore, anaerobic pretreatment process will be included to increase biogas production. This anaerobic pretreatment, being a modification of the traditional Upflow Anaerobic Sludge Blanket (UASB) reactor, will also affect the water line. Organic load is reduced in this process, minimizing the energy requirements for the WWT. An advance aeration control system will be applied in the biological reactor as well as a solar disinfection as tertiary treatment. Both processes aim to reduce the carbon footprint of the overall process. According to the sludge line, two different processes will be implemented to recover nutrients and obtain biofertilizer as a valuable product. These technologies will affect both the solid phase and the liquid phase of the centrifugation process of the sludge. All these actions will be performed simultaneously in the same facility (El Bobar WWTP, Almeria) in order to assess the overall impact of the demonstration on a real WWTP.

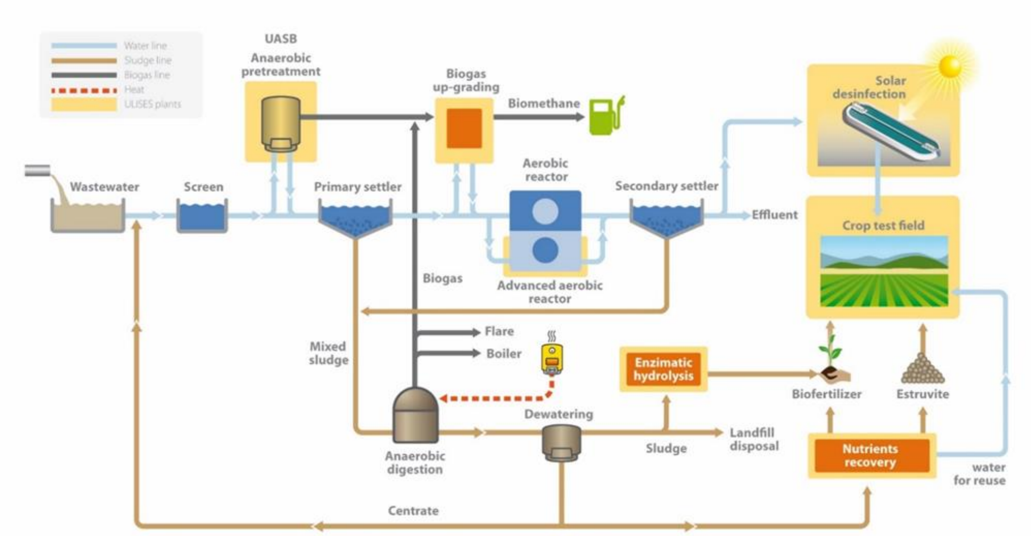

Figure 1: Scheme of the different technologies proposed for LIFE ULISES

By the implementation of these technologies, it is expected to produce:

- 10 Nm^3/h of biomethane, a vehicle biofuel, saving over 80% of GHG emissions compared to conventional fossil fuel.
- Treating up to 15 m^3/day of wastewater in a novel anaerobic reactor (PUSH) that converts COD into biogas.
- 30% less energy demand of aerobic biological processes by an advanced control system
- two high quality biofertilizers from sludge (struvite and hydrolysed dewatered sludge)
- up to 350 m^3/day of reclaimed water for irrigation using a solar photo-fenton reactor.

The implementation of these technologies in a full-scale plant would lead to an energy self-sufficient WWTP, with a carbon neutral footprint, and will allow the recovery of high amount of valuable resources: over 41 tonnes of nitrogen and 15 tonnes of phosphorous annually, almost 2,000 Nm^3 of CH_4 daily, and over 25,000 m^3/day of water for irrigation.

4.2. Expected longer term results

LIFE ULISES counts with different mechanisms to contribute to future persistence of the impacts of the project:

- Continuation after project's completion: Implementing 6 prototypes in the same WWTP managed by Aqualia would let the follow up and validation of demonstration trials after the project. Biogas, water and biosolids will be continuously produced in El Bobar WWTP, and its valorization will return some economic and environmental benefit.

- Replication of ULISES concept: Experience on the operation of the demonstration plants will be used to define a design for similar plants focusing on improving sustainability of already existing plants, but also in new construction ones.

- Transfer of ULISES technologies: All results will be transferred to the WWT services within Aqualia's operation (20 countries) and associate beneficiaries. In this sense, the know-how to apply these techniques would spread among the final users making easier its replication and future management. As well, a commercialization plan will be developed for the individual technologies to be included in the portfolio of Aqualia and the demonstration plant will be used as an example of the performance of the complete system for possible clients.

Concerning **policy and legislation implications**, the environment, water resources protection, its sustainable use, and efficient use of the energy and the development of new and renewable forms of it (as biogas) are some of the key pillars in the EU's policies. Other of the main goals is making the transition to a stronger and more circular economy where resources are used in a more sustainable way. In this context, the EU added value of LIFE ULISES and its actions will contribute to the development and the implementation of the European Union environmental legislation, especially to EU Water and Circular Economy Policy Areas, such as Directive 91/271/EEC for Urban Wastewater, Directive 86/278/EEC related to Sewerage sludge, Fertilizers Regulation or Water reuse new Directive. But also, a special relevance has the European Standard (EN 16723-2) that sets the quality requirements of biomethane to be used as transport fuel, which will directly affect the LIFE ULISES project.

5. Administrative part (maximum 1 page)

5.1. The project management process

The first step taken by the consortium was the elaboration of the partnership agreement which was signed in September 2019. The project started in July 1st 2019 and the approach followed for the management of the LIFE ULISES project is described in the deliverable D.E.1.2, "Project Management Guide".

The working method is based on a clear understanding of the roles and responsibilities of each partner (both from a technical and administrative point of view), as well as frequent meetings, approximately every 6 months (either face-to-face or virtual meetings) to share relevant information, track progress, answer questions and make decisions. Every 3 months, technical and financial documentation is collected and reviewed by AQUALIA, supported by CETIM. To assure the correct information exchange within the project a Sharepoint Project System has been available for all partners of LIFE ULISES. This system is being used for sharing all project documentation. The project's management structure is detailed in the following figure:

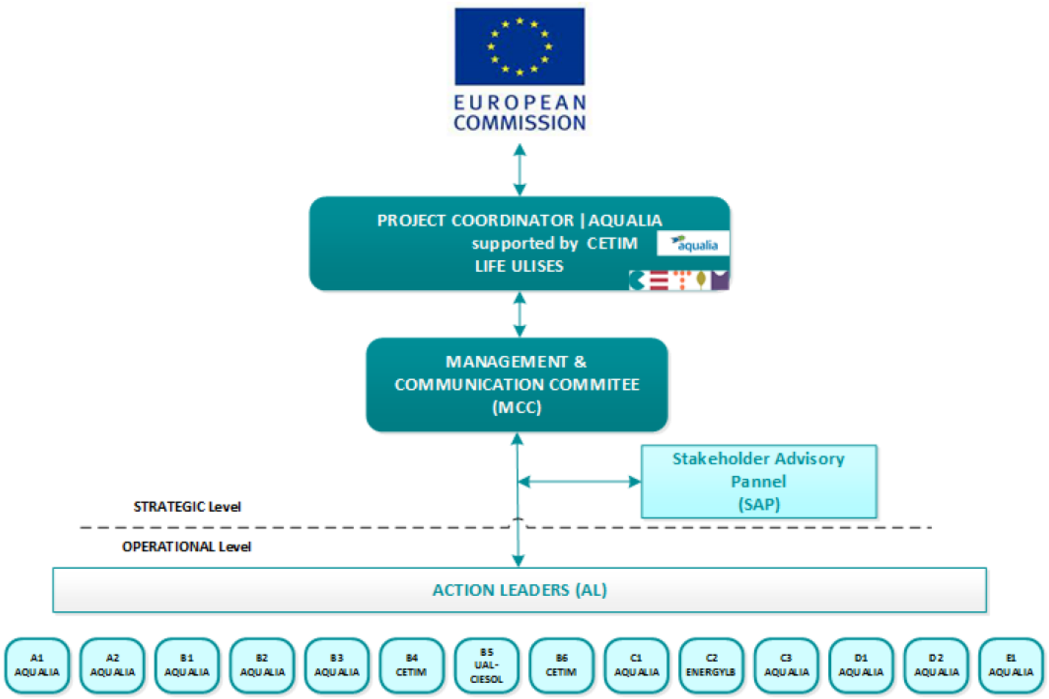

Figure 2: Project management structure of LIFE ULISES project

The main objective of this structure is to ensure the work of the consortium as a team in the spirit of cooperation, coordination and commonly understood procedures, and make sure that actions and objectives are performed successfully according to the contractual, technical and economical requirements.

5.2. Communication with EASME and Monitoring team

An active communication and feedback from the project monitor has been implemented in LIFE ULISES. AQUALIA has been in contact with the monitor for the different aspects of financial guidelines, administrative procedures and technical issues throughout the project and has informed timely of any deviation.

5.3. Changes due to amendments to the Grant Agreement

A year extension was approved by the amendment to the Grant Agreement.

6. Technical part (maximum 25 pages)

6.1. Technical progress, per Action

A1. Preliminary studies			
Status	COMPLETED		
Foreseen start date:	01/07/2019	Actual start date:	01/07/2019
Foreseen end date:	12/12/2019	Actual (or anticipated) end date:	31/05/2020

Activities Undertaken and outputs achieved

During the first months of the project the efforts focused on completing the preliminary studies needed to continue with the further activities proposed. Selection of the demonstrator´s site, authorization requests, licenses and permits were processed at that time. On the 31-09-2019 and 01-10-2019, the LIFE ULISES Project Kick-Off meeting was carried out in Aqualia facilities from Almeria, where the first project meeting and a site visit took place. Different technical aspects were discussed, specially focused on the configuration of each demo plant and the coordination of the oncoming works in El Bobar WWTP.

A.1.1. Selection of the demonstrator's site

As it was already described in the project proposal, LIFE ULISES Project takes place in El Bobar WWTP (Almeria). This plant is operated by Aqualia and treats municipal WW from Almeria city, with a treatment capacity of 30,000 m3/day, and provides service to 230,000 equivalent inhabitants. It is composed by a conventional WWT based on activated sludge.

A.1.2. Authorization requests, licenses and permits

All required permissions have been obtained. An internal agreement between the Council of Almeria (WWTP owner) and Aqualia has been signed in order to get the official consent to start works and obtain the permits to install the project demo plants in El Bobar WWTP.

A.1.3. Chemical and microbiological characterization and monitoring of El Bobar WWTP secondary effluents

In order to evaluate the impact and assess the viability of the different technologies proposed in the project, chemical and microbiological characterization of different effluents was done. WW after secondary treatment was characterized in terms of physic-chemical parameters, pathogens like E. coli, anions and CECs (CIESOL). Concerning sludge line characterization, three samples of dewatered sludge and centrate stream were collected in late 2019 and sent to CETIM lab in order to determine physic-chemical parameters, cations, E. coli, metals… Biogas from the digester reactors was also analysed with a portable multi-gas analyser COMBIMASS GA-m (Sensotec Instruments) to quantify the main components (Aqualia). No significant results were found regarding CH4, CO2 or O2 levels in the biogas, however H2S presented peaks of increased concentration. Moreover, historical data of WW characterization was compiled in order to study the variability and compare the results obtained in the analysis. High organic load was found in WW, although conditions that treatments will have to confront will not mean any obstacle to the performance of the demo plants. All this data were used to set the basis of the design of the prototypes (Action A2).

A.1.4. Prototypes configuration preliminary assessment of the configuration of all prototypes

The final location of the different plants in El Bobar WWTP was decided during this activity, the layout is next presented. The plants will be located in two main areas, plus the advance aeration control system which will be implemented in one of the full-scale aerobic reactors:

- Area 1 (ABAD Bioenergy + UASB): biogas upgrading and anaerobic pretreatment with PUSH system. It is located in the area between primary decanters, having a good access to the biogas and primary WW. The biofuel refueling station had to be relocated to the entrance of the WWTP by safety and security reasons.

- Area 2 (tertiary treatment, nutrient recovery plants): water tertiary treatment and nutrient recovery plant for fertilizer production are located close to secondary WW and sludge centrifuges. Enough free space with no shadow is available for raceway installation (100 m^2) and crop field tests for reuse water and fertilizer (400 m^2).

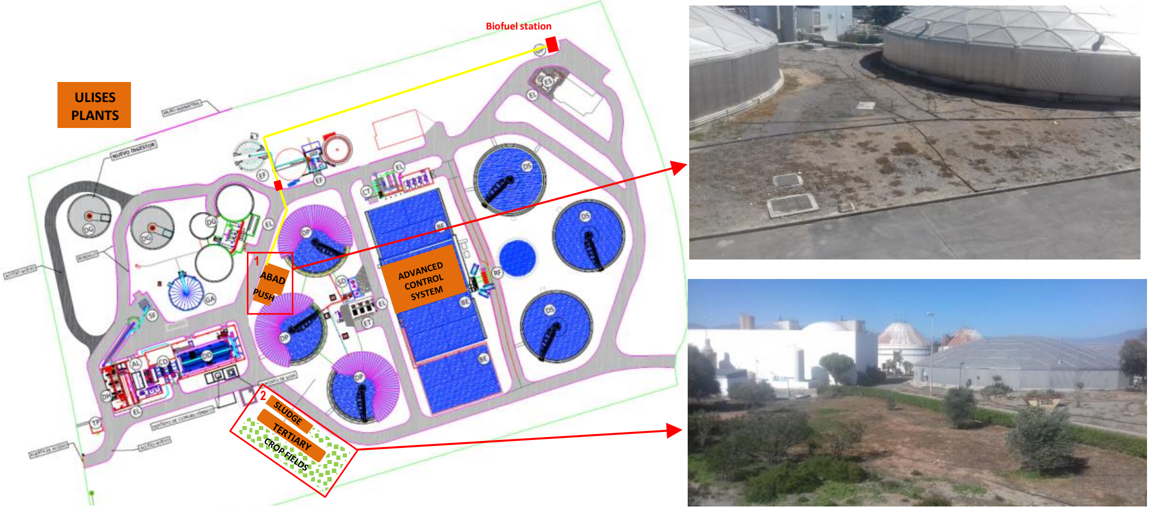

Figure 3: El Bobar WWTP layout. Area 1 and Area 2 location for LIFE ULISES plants

Moreover, in situ measurements by GPS were performed to obtain detailed drawings of the plant. Layouts, maps and drawings were draw with Autocad to design slabs, civil works, pipes and wells. A land prospection of the soil was carried out for the geotechnical study in order to make structure calculations.

Preliminary actions related to "project impact monitoring: C Actions"

During this time period, preliminary studies related to "C Actions" were also carried out. Accordingly, ENERGYLAB conducted a review for LCA methods applied to wastewater treatment plants and wastewater treatment processes. Furthermore, it was performed an initial analysis of data needed for life cycle inventory.

Deviations and problems encountered in the action

The analysis of certain parameters and the consideration of maximizing the sampling period in A.1.3 are the reason of the later end date, which took 5 months more than it was planned.

Complementary actions & perspectives for continuing after the end of the project

None

Deliverables

D.A.1.1 Preliminary analyses and wastewater characterization 12/2019 ✓

Milestones

M.A.1.1 Location of the demonstration prototype plants 10/2019 ✓
M.A.1.2. Obtaining the authorizations to install the prototype 10/2019 ✓
M.A.1.3 Selection of the prototype plant configuration 10/2019 ✓

Attachments

None

A2. Design of prototype plants, technical specifications and preliminary project			
Status	COMPLETED		
Foreseen start date:	01/07/2019	Actual start date:	01/07/2019
Foreseen end date:	31/03/2020	Actual (or anticipated) end date:	31/05/2020

Activities Undertaken and outputs achieved

A 2.1 Up-grading plant

A new concept biogas scrubber (patented technology by Aqualia: ABAD Bioenergy®) was designed to treat 15 Nm3/h of raw biogas and produce about 10 Nm3/h of biomethane, removing CO2, sulphur and other undesirable compounds from biogas and thus producing a vehicle biofuel for CNG cars.

The up-grading plant is installed on a concrete slab next to the UASB plant (Area 1). From here, biomethane is pumped to the dispenser area, close to the parking area of the WWTP. Biogas is taken from the full-scale digesters' pipe and is pumped by three biogas blowers (Mapner CL.12/21.G) into two scrubbing columns, where primary WW is supplied by a submergible pump (FLYGT NF 3069). Biomethane coming out from the columns is then polished by adsorption and drying processes in order to meet the quality requirements for its use as biofuel in transport (European Standard EN 16723-2). Then, biomethane is compressed at 250-300 bar in the refueling station, able to store 375 Nm3 of gas.

All the layouts, designs and equipment specifications were defined, as well as the electric and control system with full automatization of the plant.

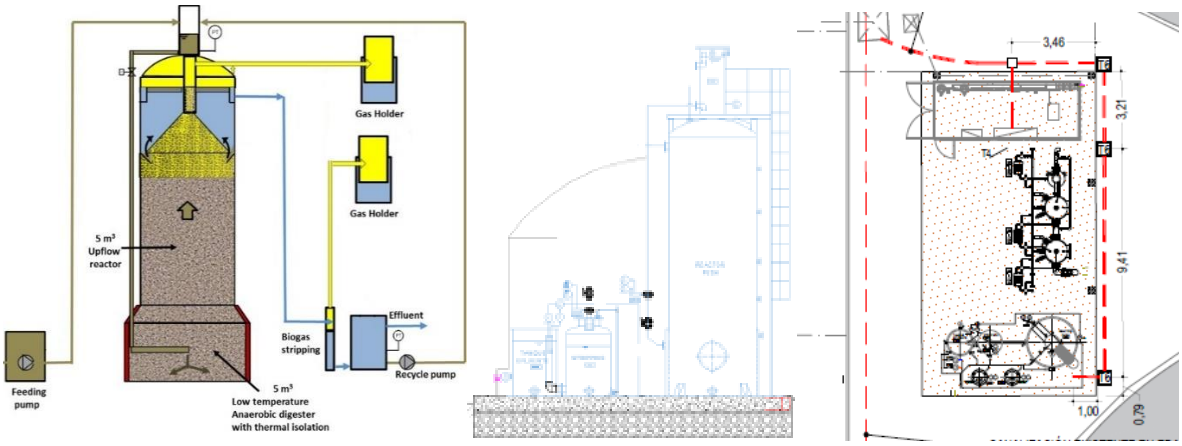

Figure 4. Layout drawings PUSH reactor (left and centre); up-grading and PUSH distribution in Area 1 (right)

A 2.2 Anaerobic pretreatment plant – UASB

This anaerobic pretreatment plant was proposed as an alternative to conventional primary treatments as decantation, in order to remove organic matter from WW and transform it into biogas. This UASB reactor includes an innovative system called PUSH, developed and patented by AQUALIA, which regulates reactor WW inlet by pulses. Pulses are generated by filling a small tank located above the UASB reactor and draining it suddenly with automatic valves. Pretreated WW (after the desanding-degreasing) is used as inflow, which is pumped with a submergible pump. The outflow passes through a stripping reactor, desorbing the dissolved biogas, which is collected in a gas holder. A different gas holder will collect and quantify biogas from the reactor. The treated WW is stored in an effluent tank and is partially recycled back to the reactor.

A 15 m^3 PUSH reactor from another European project (H2020 INCOVER) located in Chiclana de la Frontera (Cádiz) has been reused for LIFE ULISES project. The plant was upgraded with certain modifications in order to improve and optimize its design and operation. The plant had to be transported to Almería, and a new independent electric panel was built, with a fully automatized control system.

A 2.3 Advanced aeration system plant

The outflow tank of the PUSH system can be converted into an aerobic membrane bioreactor system (AeMBR) by adding an ultrafiltration membrane module in the stripped effluent tank. This system up-grades the anaerobic treatment and results in several benefits, converting the whole dual system (PUSH + AeMBR) into a full treatment equivalent to primary and secondary wastewater treatment. This provides an innovative wastewater treatment solution that could directly impact on reaching energy self-sufficiency in WWTP by reducing energy consumption at the biological process by implementing measures at different stages of the water line. It supposes an alternative treatment route compared to conventional energy intensive systems based on activated sludge processes, by the implementation of anaerobic processes in the water line to recover energy from raw wastewater with low energy demand, and membrane systems to provide a high-quality effluent that could be directly reused for irrigation.

UF aerobic MBR drastically increase the quality of the PUSH effluent, removing even bacteria from wastewater, and reaching partial disinfection of the effluent treated wastewater. This effluent could meet certain water quality for reuse purposes according to European Regulation, but a tertiary treatment such as the photo-Fenton solar disinfection process could be considered for further disinfection and removal of emergent pollutants. Also, air injection for membrane cleaning in the effluent tank from the PUSH reactor will promote nitrification, so that ammonia will not be liberated in the effluent. Then, nitrogen would still be present in form of nitrite or nitrate in the MBR effluent which, unlike ammonia, represent two valuable nutrients for plants growth. But another strategy, if internal recycling from the membrane tank is returned to the anaerobic PUSH reactor, denitrification would take place in the last, promoting nitrogen removal from wastewater (if nutrients must be removed by regulation). Nitrogen would be then liberated as N2 in the biogas from the PUSH reactor.

A 2.4 Design of the plant for bioproducts obtained from sludge and nutrients recovery

Under this Action, CETIM and AQUALIA carried out the pre-design of the pilot plants for nutrient recovery and biofertilizer production, defining the configuration of each process.

Prior to the pre-design of the nutrient recovery processes, CETIM carried out lab-scale hydrolysis tests using digested sludge from El Bobar, in order to identify operational conditions and type of enzymes to be used at pilot scale. As result of its incubation temperature, hydrolysis of one of the enzymes led to an increase in the pathogen content in, which might comprise its further use as fertiliser. While no significant differences were found between the other two enzymes, thus both were selected for additional testing at pilot scale.

Based on the conditions identified, Aqualia designed a hydrolysis reactor of up to 300 L capacity, reusing a stirred reactor from a digestion plant not in operation. This reactor was modified and equipped with a heating system, pH and T probes, and other accessories to fulfil the requirements of the hydrolysis process.

Regarding the nutrient recovery plant, CETIM reviewed several FO membranes manufacturers (Aquaporin, CSM, Porifera, Toyobo, Toray, FTS) pre-selecting a FO module from Aquaporin (HFFO.6; 0.6 m2) for lab-scale testing using both synthetic and real centrate. These tests were complemented with struvite precipitation tests identifying the best conditions for struvite concentration from FO stream.

Based on these results, pre-design of the plant was carried out, obtaining the main Process Flow Diagram (PFD) of the system and the expected flows and minimum membrane area required. Based on these flows, the struvite reactor was also designed.

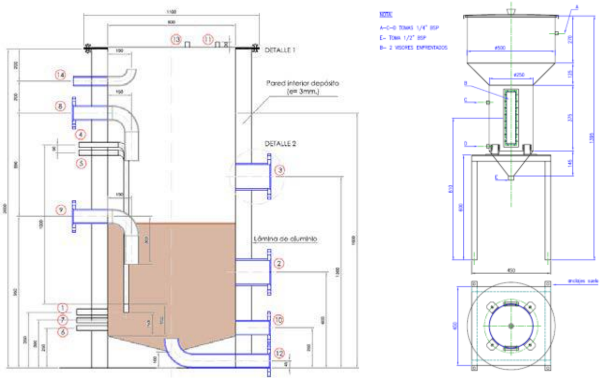

Figure 5. Layout drawings of hydrolysis reactor (left) and struvite reactor (right)

A 2.5 Design of the Solar tertiary treatment plants

The solar tertiary treatment is based on the photo-Fenton process. The feasibility of low-cost reactors such as raceway pond reactors (RPR) operated in continuous flow mode for pathogen inactivation as well as for micropollutant removal has recently been reported by several scientific reports. The design of these photo-reactors for the solar photo-Fenton tertiary treatment allows a simple, versatile, and economical construction and operation of the plant, taking into account the critical parameters at process scale up from a technical point of view. HRT, liquid depth (LD), reagents dosage and the seasonal period are the limiting variables to carry out the process operation in continuous flow mode.

The design was based on economic and operational criteria beginning with the study of the variables involved in the photo-Fenton solar process, such as the annual distribution of the irradiance, the geographical location, the temperature, and the number of solar hours.

The operation of the plant is carried out in continuous flow mode under two different strategies (acidic and neutral pH). In addition, the reactor operation was explored in terms of HRT, LD, iron source and reagent concentrations (iron and hydrogen peroxide). The hydrogen peroxide, pH, water temperature, conductivity, turbidity, and irradiance are monitored online before and after treatment. The tracking of all the variables together with the operating conditions allow to accumulate data that will be applied to develop and calibrate of semi-empirical models enable to predict the behavior of the process. The objective of this action is to design and implement the control strategy that allow the stable and safe operation of the plant maximizing the treatment capacity at different seasons of the year.

Regarding the design of the plant for concentrated solar disinfection study, FRESNEL technology was selected as these systems provide a higher concentration factor (32 suns) compared to other technologies such as CPC (Compound Parabolic Cylinder) reactors. FRESNEL modules are designed to be used as solar boilers for the generation of heat in the form of steam, pressurised hot water and thermal oil for industrial applications.

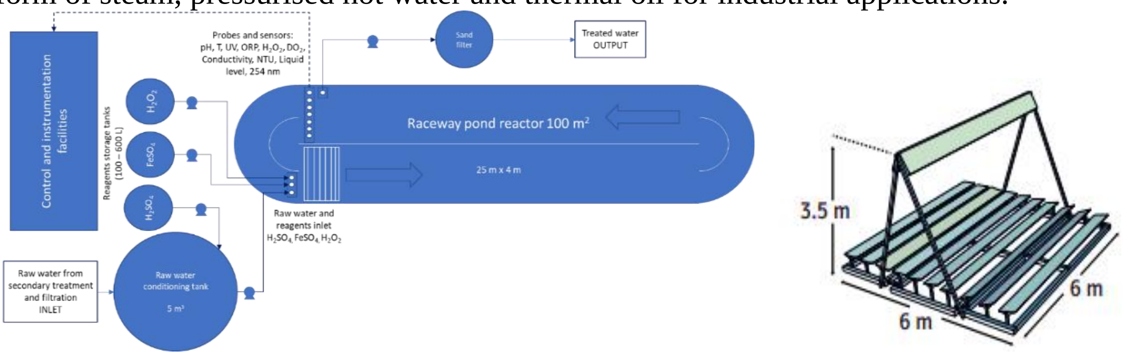

Figure 6. Solar photo-Fenton tertiary treatment (left) and FRESNEL solar collector (right) plants layout.

Deviations and problems encountered in the action

The design of the Fresnel solar collector has been incorporated into this action.
Complementary actions & perspectives for continuing after the end of the project
None
Deliverables
D.A.2.1. Preliminary design of prototypes 03/2020 ✓
Milestones
M.A.2.1. Process flow diagram 03/2020 ✓ M.A.2.2. Prototype plants preliminary design 05/2020 ✓
Attachments
Deliverable D.A.2.1. is attached to this Final report because it has been modified by including the design of the Fresnel solar collector.

B1. Construction and commissioning of the plants			
Status	COMPLETED		
Foreseen start date:	01/01/2020	Actual start date:	01/01/2020
Foreseen end date:	30/06/2020	Actual (or anticipated) end date:	31/01/2021

Activities Undertaken and outputs achieved

Aqualia coordinated and supervised all works of LIFE ULISES project in El Bobar WWTP. All safety and health issues were taken into account, and a continuous communication with WWTP staff was maintained to minimise works impacts on the plant daily operation. As well, legal requirements regarding to occupational safety aspects were considered by Aqualia during the works. A safety and health external coordinator (SGS) was designed, who made periodic visits to the works every week. All civil works were contracted and performed by Aqualia and then, each partner has contracted and supervised its own mechanical and electric installations.

Constructive project was finalized in February 2020 and civil works were going to start on March. However, Covid-19 epidemiologic pandemic lead to a 3 month complete lockdown in Spain, causing a delay on the start of the works. Then, civil works took place from mid-June to August 2020. During this period, certain ex-situ works could be performed (construction of electric panels, absorption columns, refuelling station, polishing unit), so that this delay was minimised. From September to December 2020, in situ mechanical and electric works were accomplished. So, a total delay of 6 months was accumulated.

Anaerobic pretreatment plant

Anaerobic pretreatment and up-grading plant were installed in Area 1 and were integrated within the WWTP taking into account practical aspects such as the minimization of piping, pumping and concrete slabs in order to reduce construction and operating costs of the project. A concrete slab was built of reinforced concrete measuring 13m long and 7m wide. Underground pipes for water supply, drainages and electrical conduits were also installed during civil works.

The UASB plant was uninstalled and upgraded in El Torno WWTP (Chiclana de la Frontera, Cádiz). Several modifications were performed before its transportation in order to improve its design and optimize its performance: a triphasic separator was extended and closed until the top of the reactor; a new biogas outlet line was installed from triphasic separator in order to separate the biogas streams of the PUSH reactor from the stripping; a new access ladder was installed. Then, the plant was transported by truck and installed in El Bobar WWTP in Almeria in September 2020. The electric works started in November 2020, setting a PLC located in a new electric control board equipped with a SCADA system in order to control, automatize the process and register data into a computer. In January 2021, the plant was ready for start-up and operation (B3 Action).

Detailed description of the final design and construction of the anaerobic pretreatment plant can be found in the deliverable D.B.1.2 Executive project of Anaerobic pretreatment plant.

Figure 7. Area 1 view: concrete slab during civil works (left) and ABAD and PUSH plants (right)

Up-grading plant

The same considerations for civil works explained for the anaerobic pretreatment plant affect this plant. ABAD Bioenergy plant makes use of primary WW and biogas: WW is pumped from the inlet channel of the biological treatment and is driven to the Area 1 by aerial and underground PVC pipes. Biogas is pumped in stainless steel pipes from the biogas line of the digesters, before its entrance to the biogas holder or burnt in the torch. A return biogas pipe from the upgrading process, which works when biomethane does not meet the quality requirements, is also connected to this line to avoid biogas emissions to the atmosphere.

The ABAD Bioenergy upgrading plant is composed by: two absorption columns manufactured on plastic materials (Fiberglass); three biogas blowers (MAPNER CL.12/21); H2S removal system; biogas flowmeter; security pressure valves; pressure and temperature sensors; a refining or polishing system (which is containerized) with different equipments, such as a gas analyser to measure the biomethane composition (INCA 3011, UNION Instruments), a moisture sensor to measure the biomethane humidity, a flowmeter to measure the biomethane production, a chiller and heat interchanger, two molecular sieves Pneumatic valves were also installed.

Figure 8. ABAD Bioenergy up-grading columns (left) and polishing container inside view (right)

Biomethane, once purified, flows underground over 200 m distance to reach the refueling station. Biomethane is compressed up to 300 bar with a NARDI compressor and is stored in 10 bottles of 125L each at 300 bar. (maximum storage capacity: 375 Nm3). The compression, storage and refueling station was purchased as one unit to a supplier (AGAS21). This equipment was delivered with more than 3 months delay (due to 04-09-2020, delivered on the 16-12-2020) because of mobility problems linked to pandemic alarm situation. So, this was also cause of delay accumulated in Action B1.

Detailed description of the final design and construction the up-grading plant can be found in the deliverable D.B.1.1 Executive project of Up-grading and refueling plant.

Figure 9. biogas aerial pipes (left), biomethane underground pipe (centre), refuelling station (right)

Aerobic Membrane Bioreactor (AeMBR) plant

An AeMBR reactor of 5.5 m3 plant is used for up-grade of the anaerobic treatment and results in several benefits, converting the whole dual system (PUSH® + AeMBR) into a full treatment equivalent to primary and secondary wastewater treatment. The plant is located next to the anaerobic pretreatment demo plant, in the available area of the concrete slab where the PUSH reactor and ABAD Bioenergy plants are currently placed. A total surface of 15 m^2 is available (6 x 2.5 m), with enough space to place all the equipment (membrane tank, pumps, blowers, permeate tank…). Electric supply is also available, as the plant id connected to the electric control board and PLC of the PUSH reactor. Hydraulic piping for water supply and effluent discharge are also available next.

An ultrafiltration (UF) membrane cassette was installed inside of the AeMBR reactor in order to increase the quality of wastewater, removing even bacteria from wastewater. Air injection for membrane cleaning promote nitrification, so that ammonia will not be liberated in the effluent. Then, nitrogen would still be present in form of nitrite or nitrate in the MBR effluent which, unlike ammonia, represent two valuable nutrients for plants growth.

Detailed description of the final design and construction the up-grading plant can be found in the deliverable D.B.1.3 Executive project of Aerobic membrane bioreactor plant

Nutrient recovery plants

Based on the pre-design carried out in Action A2, final design was done of the two nutrient recovery plants that treat the dewatered biosolids (Hydrolysis plant) and centrate (struvite precipitation). In addition to them, a crop testing area was designed for simultaneous testing of nutrients and reclaimed water obtained in LIFE ULISES.

Nutrient recovery plant obtained struvite and a liquid concentrated stream rich in P and N. This plant is composed by a FO module, a direct contact membrane distillation unit for draw solution recovery, and a struvite precipitation reactor. The plant is designed for treating 100 L/h of centrate, producing up to 13 L/h of concentrated centrate and 87 L/h of recovered water. Membrane modules were installed to ensure plant operation during maintenance or in case of failure of one module. Pilot plant is constructed in a 20 feet container. Construction experienced delays due to stock rupture of the DCMD module.

Figure 10. Struvite plant (left) and hydrolysis plant installed at is final location (right)

AQUALIA carried out the final design of the hydrolysis plant, based on the adaptation of a previous reactor of 600L. After civil works at the pilot area were finished, equipment of the hydrolysis plant was brought form an existing facility. Digester with recirculating pump was located next to the electrical panel, and a reconditioned tank, equipped with a stirring system was placed in a second frame, next to the heating system and the pumps required for filling and discharging the plant. A roof was installed too.

In addition to the pilot plants, a crop surface was designed and constructed next to the pilot area. This surface, divided into 4 plots allowed to tests the different fertilizers produced, as well as the water obtained in the tertiary treatment plant. Crop area has a total surface of approximately 400 m2, and was equipped with a drip irrigation system, a fertirrigation unit to dose fertilizers in liquid form (such hydrolysate or concentrate stream after precipitation) and a control unit for programmed operation. Works in the area were done in January 2021, including land levelling, soil sampling and irrigation installation. On the next weeks, different ornamental plants were planted on the area.

Figure 11. Construction works of the crop testing area

Solar tertiary treatment plants

The solar photo-Fenton plant was located in 'Area 2' at El Bobar WWTP to be close to the secondary effluent output. The works began in October 2020. Given the topographical features of the land, the base of the reactor was paved with a concrete slab. The works were finished in February 2021. Details concerning the construction of the demonstration plant are reported in the deliverable "D.B.1.6 Executive project of Tertiary treatment plant".

Briefly, the solar photo-Fenton demonstration plant has two vertical tanks of 5,000 L, one for pre-treatment (conditioning tank) and another one for effluent storage (reclaimed water). Mixing inside the conditioning tank is carried out by means of a blower (0.2 kW). In this tank, H_2SO_4 is dosed for pH adjustment around 2.8 (operating strategy at acidic pH) or bicarbonates desorption to avoid their undesirable hydroxyl radical-scavenging effect (operating strategy at neutral pH, ~6.5). Probes of pH, conductivity, and turbidity were installed in both tanks to control the water quality before and after treatment. The 100-m^2 RPR was built in high-density polyethylene. Stakes around the reactor support the geomembrane until 25 cm wall height. Water is set in motion by a paddlewheel with 8 blades of 1.9 m wide x 0.92 m diameter. This system is powered by a three-phase 1 hp electric engine (0.75 kW) controlled by a frequency inverter. For reagent supply, the plant includes three dosing pumps and tanks with a capacity between 25 - 125 L. Ø 75 mm PVC was used for the piping network. Auxiliary ball valves have been installed both at the inlet and outlet of the reactor as in drainage system. The RPR level control is done by one ultrasonic level sensors and two pumps for both inlet and output water. Finally, a filter filled with calcium carbonate (to neutralize the treated effluent and retain residual iron, operation at acidic pH) or silica sand (to retain precipitated iron, operation at neutral pH) was installed in the outlet flow. This filter has an automatic selector valve that allows the control of filtration, washing, rinsing and emptying. Incident UVA radiation (W m^{-2}) is measured on-line using a global UVA radiometer with a spectral range from 327 to 384 nm. This radiometer was placed in the same orientation as the photo-reactor. In addition, a SCADA system was programmed in DAQ Factory.

Figure 12: Evolution of the solar photo-Fenton plant

Work on the FRESNEL solar collector took place from December 2022 to February 2023. The module was located close to the solar photo-Fenton plant. Thus, the conditioning tank feeds both demonstration plants based on solar tertiary treatment. The deliverable " D.B.1.6 Executive project of Tertiary treatment plant " has been modified to include more details about the construction of the FRESNEL solar collector plant. The plant has a centrifugal pump and flow meter to control the secondary effluent inlet flow. In addition, a H_2O_2 dosing pump was installed to study the synergistic effect of solar/thermal and chemical in the bacteria inactivation. A heat exchanger was also included at the process outlet. Regarding the instrumentation, the plant has four PT100 temperature probes for on-line measurement of the water temperature at the system, as well as two irradiance sensors: one for the measurement of UV irradiance and one for the total solar radiation. In addition, a SCADA system was programmed in DAQ Factory.

Deviations and problems encountered in the action

Constructive project was finalized in February 2020 and civil works were going to start on March. However, Covid-19 epidemiologic pandemic led to a 3 month complete lockdown in Spain, causing a delay on the start of the works. Moreover, the pandemic situation has led to different delays with equipment supplies, works schedule linked to trips and mobility issues. So, a total delay of 6 months was accumulated in B1 Action.

Concerning tertiary plant construction, initially the reactor was going to be installed on the land, nevertheless, the irregularity of the terrain has obligated to put a concrete platform not included in the preliminary design neither the budget.

Concerning the struvite plant, construction experienced delays due to stock rupture of the DCMD module.

Concerning the advanced aeration control system implementation, an unexpected decision from WWTP staff supposed the impossibility to carry out this activity in El Bobar WWTP biological reactors, causing the necessity of planned activities modification.

Complementary actions & perspectives for continuing after the end of the project

None
Deliverables
D.B.1.1 Executive project of Up-grading and refueling plant 07/2020 ✓ D.B.1.2 Executive project of Anaerobic pretreatment plant 07/2020 ✓ D.B.1.3 Executive project of Advanced aeration system plant 04/2022 ✓ D.B.1.4 Executive project of Enzymatic hydrolysis plant 07/2020 ✓ D.B.1.5 Executive project of Struvite production plant 07/2020 ✓ D.B.1.6 Executive project of Tertiary treatment plant 07/2020 ✓
Milestones
M.B.1.1 Technical specifications required for the construction of the demonstration Plant 01/2020 ✓ M.B.1.2 Construction of demonstration plant 06/2020 ✓ M.B.1.3 Implementation of the instrumentation equipment in the prototype plants 06/2020 ✓
Attachments
Deliverable D.B.1.3 and D.B.1.6. is attached to this Final report

B2. Demonstrate the suitability of biomethane in the automotive sector			
Status	COMPLETED		
Foreseen start date:	01/07/2020	Actual start date:	01/07/2020
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

The installed biogas upgrading plant produces up to 10.8 Nm^3/h of biomethane from about 15 Nm^3/h of raw biogas. The primary water used in the ABAD process is taken from the inlet channel of the biological treatment, while the biogas is taken from the gas line of the digester before its entrance to the gasholder.
Biomethane, once purified from biogas, flows underground over 200 m distance to reach the refuelling station, where the biomethane is compresses up to 250 bars in 10 gas bottles of 125 L each one.
The average of the main composition of the biogas was CH_4=60.8%, CO_2=33.5%, O_2=0.2% and H_2S=3555 ppm, and the main composition of the obtained biomethane during almost two years of operation was CH_4=88.1%, CO_2=8.0%, O_2=0.02%, H_2S=1.8 ppm and Moisture = 21.5 ppm. The ABAD process increases the concentration of methane from 60,8% to 88,1 % and remove the 99.9% and 76.1% of hydrogen sulphide and carbon dioxide respectively. In addition, the moisture is also reducing below 30 ppmv to avoid the problem of blocking the fuel hose during the refuelling due to the ice formation. The biomethane was used in two GNC cars from Aqualia: Volkswagen Up and Fiat Doblo. These cars travelled a total of 6962 and 15008 km respectively using biomethane.
A vehicle monitoring system was installed via an OBD and a tablet connected to the vehicle. The data obtained through the OBD monitoring system installed in the vehicle is evaluated to determine normal vehicle operation during use with biomethane in order to identify types of malfunctions. The parameters recorded by the OBD correspond to normal driving on different routes by several drivers. The vehicle has travelled a total of about 8,000 km using biomethane (approximately). Every vehicle placed on the market is subject to compliance with standards. These set out the measurement procedures, how they are to be carried out, the conditions and the maximum limits for pollutant emissions, depending on the type of vehicle and engine used. For vehicles registered from 2018 the application cycle is the WLTC. For the biomethane test in a bi-fuel vehicle, the Volkswagen Up has been selected, which, by year of manufacture, must comply with the emissions regulations based on the NEDC cycle, as it is a vehicle from 2013. Both cycles have been carried out, the WLTP is the most exhaustive and is the one that current vehicles must comply with and the NEDC cycle that allows comparing the values obtained with those provided by the vehicle manufacturer. The consumption during the cycle has been analyzed on the roller bank to compare it with that declared by the manufacturer in addition to the emissions during the cycle, CO2, CO, THC, NOx, CH4, PN... Emissions are within the parameters allowed by the euro corresponding to the year of manufacture of the vehicle, EURO5. The WLTP test shows higher emissions values as it is a test closer to reality. Regarding the CO2 values declared by the manufacturer of the Volkswagen Up, this variation is mainly due to the increase in the percentage of CO2 in biomethane compared to natural gas (the fuel used in the manufacturer's approvals). The rest of the emissions more than comply with the regulatory limits. A real driving test has also been carried out, analyzing the emissions produced. The Real Driving Emissions (RDE) test verifies that cars maintain low emissions even under real driving conditions on the road. The RDE test does not replace but complements the WLTP laboratory test. During the RDE test, the vehicle is driven on the road, under a wide range of different conditions. Of all the studies and analyzes carried out, there is no relevant effect on the emissions and consumption values, and the characteristics of the engine analyzed, as well as

the conditions in which the vehicle has worked, the results obtained do not differ significantly from what is expected. of a CNG vehicle. Consumption remains within the values approved by the manufacturer, so biomethane does not negatively affect the system. The after-treatment of the vehicle tends to lower emissions (CO, THC, NO_x, CH_4, PN) as the optimal operating temperature of the three-way catalyst is reached. This operation enables compliance with the various regulatory limits set by the regulations.

Analysis of biomethane from the last year has been carried out, making reports for each analysis carried out. This analysis consisted of the basic determination of the characteristics of a gas sample from the El Bobar WWTP (Almería). This analysis has included the determination of: Permanent gases (CH_4, O_2, N_2, H_2, CO_2, H_2S), siloxanes and silicon compounds. A column called: "Values 16723-2" has been included in the tables, where the necessary values for its use in mobility are shown according to the Spanish standard: UNE - EN 16723-2 ("Natural gas and biomethane for use in transport and biomethane for injection into the natural gas network. Part 2: Automotive fuel specifications").

In turn, an additional column "SUITABLE" is included, which indicates:- Suitable for use in mobility/ Not suitable for use in mobility/ Or parameter not referenced in the relevant regulations (-).The studies carried out on biomethane conclude that the biogas samples comply with EN 16723-2 ("Natural gas and biomethane for transport use and biomethane for injection into the natural gas grid - Part 2: Specifications for automotive fuel").

Deviations and problems encountered in the action

No special deviations have been found in this Action.

Complementary actions & perspectives for continuing after the end of the project

The up-grading plant will be operated after the project as it will provide biofuel to Aqualia fleet cars, so the performance of the plant and the quality of biomethane will be then monitored after the end of the project.

Deliverables

D.B.2.1 Biomethane production and biogas cleaning system results 06/2023 ✓
D.B.2.2 Automotive fuel quality testing report 06/2023 ✓

Milestones

M.B.2.1 Performance of the tests in the prototype plant 08/2020 ✓
M.B.2.2 Start-up of the up-grading plant 10/2020 ✓
M.B.2.3 Validation of biomethane quality 12/2020 ✓
M.B.2.4 Start vehicle exhaust emissions test 01/2021 ✓

Attachments

Deliverables D.B.2.1 Biomethane production and biogas cleaning system results and D.B.2.2 Automotive fuel quality testing report are attached to this Final report

B3. Implementation of water line technologies to reduce energy consumption in WWTP			
Status	COMPLETED		
Foreseen start date:	01/07/2020	Actual start date:	01/07/2020
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

B3.1. Anaerobic pretreatment UASB reactor

The UASB reactor was operated continuously since September 2021. The system was fed with raw municipal wastewater during the months of September 2021 to February 2022June 2023 The main parameters analysed for the inflow and outflow wastewater were as follows: COD, sCOD, SO_4^{2-}, TN, NO_3^-, NH_4^+ and TSS. The UASB reactor presents a removal capacity of 78% of the COD, and 79% of SO_4^{2-}. In terms of TSS, the UASB reactor is capable to reduce 93% of TSS present in wastewater. These values remained stable even in the winter season when wastewater temperatures dropped to 14-16 ºC. The average biogas production in the UASB reactor ascends to 803 NL d-1 with a composition of 75% CH_4, 11% CO_2 and 4306 ppm H_2S. In terms of methane yields, the UASB reactor obtained values ranging from 0.13 to 0.29 m^3 CH4 kg^{-1} $COD_{removed}$.

B.3.2. Advanced aeration system

After the modifications of this action were approved by CINEA, an AeMBR reactor of 5.5 m^3 was operated continuously since May 2023 at ambient temperature in order to meet certain water quality for reuse purposes according to the European Regulation. The main parameters analyzed for the inflow and outflow were as follows: COD and sCOD, SO_4^{2-}, TN, NH_4^+ and TSS. The AeMBR reactor presents a removal capacity of 91% of the COD and 95% of TSS present in the inflow. The decrease in the COD concentration outflow is due to aerobic biomass activity. Meanwhile, the high removal capacity of the TSS is caused by membrane rejection. The AeMBR reactor also presents a removal capacity of 80% of TN and 93% of NH_4^+ present in the inflow. The high removal capacity of NH_4^+ present in the inflow is due to nitrification (from toxic ammonia to plant nutrients) with a possible denitrification by internal recycling to anaerobic process which involves a high TN removal capacity.

Deviations and problems encountered in the action

B.3.2. Action concerning the advanced aeration system is delayed because of the reasons discussed previously in Action B1.

Complementary actions & perspectives for continuing after the end of the project

The plants will continue in operation for 3 years after the project ends.

Deliverables

D.B.3.1 Anaerobic pre-treatment performance in UASB reactor long-term continuous operation 06/2023 ✓
D.B.3.2 Advanced aeration effect on activated sludge reactor performance 06/2023 ✓

Milestones

M.B.3.1: Anaerobic pretreatment pilot plant optimized operation 06/2022 ✓
M.B.3.2: Optimization of the advanced aeration control system 06/2023 ✓

Attachments

Deliverables D.B.3.1 Anaerobic pre-treatment performance in UASB reactor long-term continuous operation and D.B.3.2 Advanced aeration effect on activated sludge reactor performance 06/2023 are attached to this Final report

B4. Measure bioproducts quality obtained from sludge and test performance in land application			
Status	COMPLETED		
Foreseen start date:	01/07/2020	Actual start date:	01/07/2020
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

B4.1: Biofertilizer production by enzymatic hydrolysis of sewage sludge

During the present sub-action, dewatered sludge was subjected to an enzymatic hydrolysis in the pilot plant using two types of enzymes to generate peptides and amino acids with phytostimulant properties.

Firstly, preliminary reactions were carried out to scale the process of pathogen reduction and sedimentation from laboratory to pilot scale. The optimized process consists in mixing collected dewatered sludge from sludge line with water in a feeding tank, add the enzymes and transfer the mixture to reactor. The hydrolysis is performed and then the hydrolysed product is subjected to a thermal treatment to inactivate the enzyme and eliminate pathogens. Finally, the liquid fraction which is the BF of interest for the project and the insoluble fraction are separated by gravity and characterized to assess their agronomic potential.

Results showed that all the BFs and insoluble fractions obtained are microbiologically safe according to Re. (UE) 2019/1009 and present very low content of heavy metals (Hg, Cd, Pb, Cr, Ni, Cu and Zn) far from threshold values of this Reglament. Phytotoxicity assays indicate that the BFs obtained must be diluted for its application. The physical and chemical characteristics of the four BFs indicate that one of the enzymes produces the BF with greater agronomic potential since it causes a higher increase in lower molecular weight proteins and amino acids. Dewatered sludge hydrolysed with this enzyme, without separation of the phases (in order to simplify the production process) alone or combined with struvite (B4.2) were used for the validation by crop testing (B.4.3). Complete results of this sub-action are reported in D.B.4.1

B4.2: Nutrient recovery from liquid fraction of digestate dewatering

Nutrient recovery was studied at the membrane-based pilot plant designed and tested in B4.2. Different experiments were carried out using the centrate stream obtained after sludge dewatering, testing different draw solutions and Mg:P ratios to attain the struvite precipitation. One solution was chosen due to the higher yield, and to use the undesired Mg2+ diffusion effect (if occurs) to favour struvite precipitation.

FO module showed a poor concentration performance, due to the nutrient loss in pipelines and pre-filters, and the clogging and precipitation of these nutrients in the plant. This effect also showed that it was unfeasible the use of biofertilizer as feed stream of the plant.

In contrast, the membrane distillation module showed a great performance for DS regeneration and the production of water suitable for irrigation. Recovery factor achieved in the different tests was 1, which indicates the full regeneration of DS with membrane distillation. Additionally, the quality of treated water in all 8 experiments met the reuse criteria for agricultural irrigation: class A according to Regulation (UE) 2020/741 and Quality 2.1 in accordance with Spanish Real Decreto 1620/2007.

Finally, struvite precipitation was successfully achieved at the struvite reactor, with P recovery rates over 90% of the P available in the feed. Analysis of the precipitate showed struvite purity >90% in most of the tests, and the absence of metals or other substances that might comprise its use as fertilizer. Complete results of this sub-action are reported in D.B.4.2.

B.4.3. Demonstration of plot validation by crop testing

Under this action, the performance of the different biofertilizers obtained in the project were assessed in the crop test area (approx. 400 m2) installed at El Bobar WWTP. Prior to this validation, phytotoxicity and plot tests were carried out under controlled conditions to determine the best doses and formulations. Phytotoxicity tests (Zucconi tests) were carried out for both struvite and concentrate liquid fertilizers, using lettuce (Lactuca sativa) and garden cress seeds (Lepidium sativum.) to determine the impact on germination. These tests, and the high salinity observed, suggested that the concentrated fertilizer (supernatant after struvite precipitation) was not a suitable fertilizer. Fertiliser pot essays were carried out under a grow chamber under controlled conditions (photoperiod and temperature) using lettuce and beetroot. Different combinations of struvite and hydrolysed biofertilizer were tested, in order to meet nutrient requirements of the crops. and control fertilizers were tested, measuring the growth of the plant and the evidence of lack of nutrients. Results showed a better performance of combination of struvite and liquid biofertilizer (alcalasa), comparable to conventional fertilisers. Final test of the biofertilizers was carried out in the plot area seed with grass. Irrigation of the field was carried out with water obtained from the solar tertiary system (B5). Plot area was divided into 4 plots, one control and 3 where fertilisers were applied (struvite, biofertilizer, and a combination of both). Results showed an increase in the biomass production of the three plots where fertiliser was applied, compared with the control. Small differences were observed among the fertilised plots. Longer monitoring periods and periodic applications of the fertilisers would be required to see long-term impact of the fertilisers. Complete results of the tests are reported in deliverable D.B.4.3.
Deviations and problems encountered in the action
No special deviations have been found in this Action.
Complementary actions & perspectives for continuing after the end of the project
The plants will continue in operation for 3 years after the project ends.
Deliverables
D.B.4.1. Results from continuous operation of enzymatic hydrolysis plant 06/2023 ✓ D.B.4.2. Results from continuous operation of membrane-based nutrient recovery plant 06/2023 ✓ D.B:4.3. Results from biofertilizer crop testing 06/2023 ✓
Milestones
M.B.4.1. Optimized conditions achieved at sludge hydrolysis demonstration plant 09/2022✓ M.B.4.2. Optimized conditions achieved at membrane-based precipitator for nutrient recovery 09/2029 ✓ M.B.4.3. Formulation of fertilizers to be used at crop testing 10/2022✓ M.B.4.4. Start of field tests with crops 10/2022 ✓
Attachments
Deliverables D.B.4.1, D.B.4.2, and D.B.4.3 are attached to this Final report

B5. Solar tertiary treatment plant operation. Water reuse quality			
Status	COMPLETED		
Foreseen start date:	01/07/2020	Actual start date:	01/02/2021
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

B 5.1 Solar tertiary treatment plant operation. Water reuse quality

Due to the delay in the construction of the solar photo-Fenton tertiary treatment plant, this action started in February 2021. First, a fluid dynamics study was performed to identify the reactor mixing patterns. Second, the 100 m^2 RPR was operated batchwise to check the effect of mixing on the process. Third, the solar photo-Fenton treatment plant was operated in continuous flow mode under two strategies: acidic (2.8) and neutral pH. The reagent concentration used for the continuous flow operation were in the range of 0.1 - 0.2 mM for iron solution and 1.47-2.94 mM of H_2O_2. The HRT was selected as a function of LD based on the fluid dynamics aspects of the 100 m^2 RPR characterization: a) 18 cm (LD) and 45 min (HRT) for summer operating condition and, b) 10 cm (LD) and 60 min (HRT) for winter operating condition. Details concerning the operation of the demonstration plant are reported in the deliverable "D.B.5.1. Solar based tertiary treatment plants operation report."

The initial target of the Ulises tertiary treatment plant was to ensure the production of reclaimed water that meets the Spanish RD 1620/2007 requirements for reuse in irrigation. In this sense, the results have shown that the process is able to achieve the highest quality required by this regulation for agricultural purposes (Quality 2.1). Nevertheless, during the course of the LIFE Ulises project, European Commission approved a new regulation (EU 2020/741) tightening the minimum requirements for water reuse. According to this new EU Regulation, water quality class B, and therefore C and D, can be produced operating the process at acidic pH, achieving more than 75% of CEC removal, and treatment capacities up to 2,000 L m^{-2} d^{-1} for 8 h of operation. Nevertheless, the operation at neutral pH only reached quality class D and 50% of CEC removal by doubling the reagent concentrations (0.2 mM Fe^{3+}-NTA and 2.94 mM H_2O_2). This operating condition gives a treatment capacity of 800 L m^{-2} d^{-1}. It is important to highlight that the treatment capacities meet at Ulises solar photo-Fenton plant are much higher than those reported for solar water treatments.

In addition, the European regulation 2020/741 mentions the need to perform risk assessments to ensure safety water reuse, minimum requirements regarding CEC discharge into the environment have not yet been established. Furthermore, the new EU proposal regarding Urban Wastewater Treatment (Directive COM(2022) 541) sets a minimum removal percentage of 80%, regarding several substances proposed as indicators, for quaternary treatment of CEC removal. In this sense, only acidic pH strategy could meet this target, removing more than 85% of these substances. The reclaimed water qualities obtained in the tertiary treatment plant can be extrapolated to secondary effluents with similar characteristics to those from El Bobar WWTP, it being possible to obtain better results in effluents with lower matrix effect.

Concerning the FRESNEL solar collector, the results of previous laboratory-scale tests showed that disinfection in the device could a priori be attributed to the thermal effect, being 50º the minimum water temperature required for E. coli disinfection and 70º the water temperature value with better results. Based on these results, the photoreactor was designed, selecting FRESNEL technology, which allows a higher concentration factor. Furthermore, the synergistic effect of temperature, UV radiation and the addition of H_2O_2 was studied to set the temperature below 70º for the operating in continuous flow allowing the treatment capacity to be increased. Once the FRESNEL model was installed, the optimal operating conditions were tested to maximize the treatment capacity and ensure the disinfection of the water to be treated up to the levels established by the European Regulation 2020/741 on water reuse. In addition, the equipment is provided with a heat exchanger at the end of the treatment line to pre-heat the inlet water stream using the waste heat from the outlet stream, allowing to reduce the HRT and, consequently, increases the treatment capacity.

B 5.2 Justification for the installation of the FRESNEL solar collector

The FRESNEL solar collector was purchased from the company Solatom, because it was the only supplier specialized in this technology that had the capacity to execute the modifications required by AQUALIA and CIESOL to adapt the plant to achieve the solar disinfection of wastewater for its subsequent reuse. On the other hand, its size allows easy transport of the system (it folds into a size equivalent to a standard 6-meter container) to test the technology in another location of interest or another project. The purchase of this equipment has followed Aqualia's internal purchasing process. The installation of the FRESNEL solar collector prototype is motivated by the search for a new option for tertiary treatment and disinfection of the water coming from the wastewater treatment plant. The results obtained during the operation of the plant show that it is a viable technology for solar water disinfection and that it complies with all the requirements established by European regulations.

B 5.3 Solar tertiary treatment plant operation. Dynamic modelling of the continuous disinfection by solar photo Fenton

In parallel to the operation of the solar photo-Fenton plant, works have been carried out on this action to develop kinetic models able to estimate microcontaminant removal as a function of environmental conditions (temperature and UVA irradiance) and reactor geometry (liquid depth) with the aim of integrating them into the plant's control system. Since the objective was to operate the plant at both acidic and neutral pH, firstly, the previously developed kinetic model of the photo-Fenton process at acidic pH was improved to consider the effect of water temperature on the kinetics of the process. This model does not consider disinfection as bacterial inactivation occurs due to the acidic environment and the contribution of the photo-Fenton process is negligible being decontamination the limiting step. Secondly, a new kinetic model was developed for the operation at neutral pH with Fe^{3+}-NTA. Based on the results obtained during the solar photo-Fenton plant operation which showed that the acidic pH is the best operating strategy for El bobar effluent, efforts were focused on the development of the control system at acidic pH, so the disinfection model at neutral pH was not developed.

In addition, both models have been used to develop two educational simulation tool, ones based on Easy Javascript Simulations (link: https://w3.ual.es/docencia/idiq/LIFE_ULISES/index.html) and, the other one called FentonSims® which was registered as intellectual property (registration number 04/2022/2875) developed in MATLAB® App Designer (R2021.b), (download link: https://ciesol.com/software/) available as a stand-alone application for Microsoft Window and MacOS operation systems. More details about the tools and models can be found in the deliverable "D.B.5.1. Solar based tertiary treatment plants operation report".

B 5.4 Design of the control system and operation strategy

The event-based control system was the control strategy selected for the solar photo-Fenton plant. Control strategies based on events are very useful when control action design is difficult and/or acquiring process information is expensive or not feasible. After an event, the control signal is generated in open loop being applied to the process at a constant value until a new event is addressed.

The event-based control system design was addressed using the dynamic model of the plant that was obtained by imposing molar balances assuming continuous flow operation and perfect mixing. For this aim, the enhanced kinetic model of the photo-Fenton process at acidic pH previously presented was used. Afterwards, a huge simulation study of the large-scale photo-Fenton plant was conducted for different operating scenarios (15625 simulations) using MATLAB® programming software. Following, all the data generated via simulation was used in a statistical analysis software (STATSGRAPHICS18®) to perform a multilevel factor analysis (6 factors and 5 levels). The response variables analysed were CECs removal yield (%), residual concentration of hydrogen peroxide in the outlet water flow (mM) and the total cost of the treatment (€ m^{-3}). Finally, a decision table was generated by solving the optimization scheme for different environmental scenarios (water temperature and UV irradiance values in the range of 10 - 35 ºC and 10 - 35 W/m^2, respectively) for a minimum CEC removal yield of 90%. This decision table is the core of the event-based controller.

For the control of the FRESNEL solar collector, a cascade control system was chosen to monitor the water outlet temperature. For the system design, the primary and secondary loop dynamics were obtained by performing step stimulus to the treatment manipulated variables, to fit the responses to first order linear systems with delay using the reaction curve method. First-order linear systems are simple black-box models that allow tuning of PI controllers by the use of classical tuning methods. Once the dynamic responses of the motorized valve and the solar concentrator were modelled, the control system was simulated with Simulink software (Matlab®), using the Lambda method. This tuning method is widely used in automation engineering for the design of PI controllers. Finally, the developed cascade control was programmed in the DAQFactory environment of the plant's SCADA. In this way, a control system was designed that automatically adapts the water feed flow to the solar concentrator depending on the environmental conditions in order to maintain a stable operating temperature previously set by the user (setpoint).

Deviations and problems encountered in the action

No special deviations have been found in this Action.

Complementary actions & perspectives for continuing after the end of the project

None

Deliverables

D.B.5.1. Solar based tertiary treatment operation report. 06/2023 ✓

Milestones

M.B.5.1. Photo-Fenton based tertiary treatment plant optimized operation 03/2023 ✓
M.B.5.2. Recovery of ULISES water quality according RD 1620/2007 03/2023 ✓

Attachments

D.B.5.1. Solar based tertiary treatment operation report is attached to this Final report
Budget of FRESNEL solar collector

B6. Replicability and transferability			
Status	COMPLETED		
Foreseen start date:	01/01/2021	Actual start date:	01/01/2021
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

Replicability and transferability aspects have been addressed in this task. In particular, results from the operation of the LIFE ULISES demo plant at El Bobar have been used to define in the first place a set of transferability and replicability guidelines, and, in the second place, a Business Strategy Plan for the exploitation of the project results at commercial level. Results from these two actions are presented below.

B6.1 Transferability and replicability

Within this subtask, four scenarios have been considered: replication at WWTTs, replication at other plants with biogas production, transferability for solar disinfection technologies and transferability of the nutrient recovery technologies. In all four cases the work started with the collection from all projects partners of **limiting parameters, optimal conditions, construction requirements and operation guidelines,** as resulting from the lessons learned during the plant operation at El Bobar.

Two different methodologies have been used in the guidelines, one for the replicability guidelines and a separate one for the transferability guidelines. For the replicability guidelines, the methodology consists of 5 phases: 1. Understanding the situation of the sector through qualitative data, 2. Analysis of the characteristics of the site, 3. Study of the characteristics of the facilities wishing to adopt the technology, 4. Evaluation and implementation. This methodology is flexible and can be adapted to the characteristics of each site. On the other hand, the guidelines for technology transfer to other sectors follow a different scheme, first explaining which sectors could be of interest and then giving a series of broader advice and indications for technology transfer.

-Guidelines for replicability of LIFE Ulises technologies in a WWTP and replicability of biogas technology in other sectors

The work done for these guidelines started with a brief market sector analysis to detect the opportunities for replication. Afterwards, the different steps required for replication of the LIFE prototype plant in each WWTP and in biogas installations in other sectors have been developed including:

1st. Local context analysis considering that WWTPs are very sensitive to the geographical conditions, so it is important to understand the specifics of the site, including Geographical conditions and administrative organisation.

2nd. Evaluation of the existing conditions of the WWTP system including flow and technical characteristics of the installation.

3rd. Implementation of the plant including installation of monitoring system; preliminary characterisation of gas and sludge flows; influent and effluent; licenses and permits; construction and validation.

- Guidelines for the transfer of solar treatments and nutrient recovery

Solar technologies are the ones that pose more issues since they require very specific conditions and their application is rather limited to a few sectors. The thermal energy demand of the process, the production profile, the available space, the geographical location, the climatic conditions, the low cost of fossil fuels, the thermal storage systems- which are still in the research phase-, and inefficient or non-existent energy policies are very important conditioning factors when implementing this type of solar technologies.

The transferability study was done both for the Photo-Fenton plant and the Fresnel Collector in relation to the solar technologies, and for the enzymatic hydrolysis and struvite

precipitation technology. In this case the focus was put in studying potential sectors and industrial setting for transfer selecting potential end-users and intermediaries. **B6.2 Business Strategy Plan** A Business Strategy Plan for the commercialisation of LIFE Ulises technologies has been developed and is included in D.B.6.2 attached to this final report. The Plan considers both the technologies and the products generated (biomethane and biofertilisers) outlining a strategy for each. The plan includes an analysis of the motivations, the market and customer segments, the business model (value proposition, operations, marketing), a prospective financial analysis and the planning stage (objectives, actions, promoters and members), and finally risk analysis.
Deviations and problems encountered in the action
No special deviations have been found in this Action.
Complementary actions & perspectives for continuing after the end of the project
After the project partners will come together to implement the Business Strategy Plan
Deliverables
D.B.6.1. Replicability and Transferability Plan of LIFE ULISES project 06/2023 ✓ D.B.6.2. Business Strategy Plan LIFE ULISES project 06/2023 ✓
Milestones
M.B.6.1. Collection of data to develop the Transferability and Replicability Plan 10/2022 ✓ M.B.6.2. Collection of information to develop Business Strategic Plan 10/2022 ✓
Attachments
Deliverables D.B.6.1. Replicability and Transferability Plan of LIFE ULISES project and D.B.6.2. Business Strategy Plan LIFE ULISES project are attached to this Final report

<table>
<tr><th colspan="4">C1. Effectiveness of project actions on WWT process. Monitoring LIFE ULISES Key Performance Indicators</th></tr>
<tr><td>Status</td><td colspan="3">COMPLETED</td></tr>
<tr><td>Foreseen start date:</td><td>01/07/2019</td><td>Actual start date:</td><td>01/07/2019</td></tr>
<tr><td>Foreseen end date:</td><td>30/06/2022</td><td>Actual (or anticipated) end date:</td><td>30/06/2023</td></tr>
<tr><th colspan="4">Activities Undertaken and outputs achieved</th></tr>
<tr><td colspan="4">Considering C1 Action, special effort has been dedicated by Aqualia to update project Key Performance Indicators, which have been reviewed at the beginning of C1 action, adjusting them to the development of the different technologies involved in the project. Most of these indicators were also transferred to the KPI Webtool. Monitoring strategy is based in the continuous review of the performance of ULISES demo plants, and results from the Implementation Actions, ensuring that deviations from the project´s objectives are minimized.

Initial Statement of the progress performance indicators was revised once the project started and preparatory actions took place, providing more information about the state of the WWTP and the performance of the prototypes. Also, the baseline scenario of the LCA analyses the current state of the WWTP (D C.2.1. LCA analysis of current WWTP (baseline scenario)). Furthermore, for certain parameters, a new column referring to the full implementation of LIFE ULISES technologies in the WWTP was added in order to quantify the impact that the project would have when scaling-up the whole WWTP size. All KPIs update are included and explained in D.C.1.2. Progress Performance Indicators: Final Statement.</td></tr>
<tr><th colspan="4">Deviations and problems encountered in the action</th></tr>
<tr><td colspan="4">No special deviations have been found in this Action.</td></tr>
<tr><th colspan="4">Complementary actions & perspectives for continuing after the end of the project</th></tr>
<tr><td colspan="4">Project KPIs will be monitored in a 5 years period after the project ends.</td></tr>
<tr><th colspan="4">Deliverables</th></tr>
<tr><td colspan="4">D.C.1.1. Progress Performance Indicators: Midterm Statement 02/2021 ✓
D.C.1.2. Progress Performance Indicators: Final Statement 06/2023 ✓</td></tr>
<tr><th colspan="4">Milestones</th></tr>
<tr><td colspan="4">M.C.1.1. Evaluation of progress performance indicators: Mid-term Statement 01/2021 ✓
M.C.1.2. Complete data for all progress performance indicators: Final Statement 06/2023 ✓</td></tr>
<tr><th colspan="4">Attachments</th></tr>
<tr><td colspan="4">Deliverable D.C.1.2. is attached to this Final report</td></tr>
</table>

C2. Evaluation of the environmental impact: Life Cycle Assessment			
Status	COMPLETED		
Foreseen start date:	01/07/2019	Actual start date:	01/07/2019
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

In the framework of C2 action, firstly, it has been conducted a comprehensive bibliographic review in the field of LCA applied to WWTPs. Thus, despite the many scientific publications and reviews in the field, many studies have discussed how LCA methodology has been adapted for assessing wastewater systems from a holistic approach in terms nutrients and water recycling. To date, nevertheless, there is no single body of work which provides systematic guidance to LCA practitioners regarding how to conduct LCAs related to wastewater infrastructure, WWTPs, and wastewater management decisions. In this context, the International Water Association (IWA) created the Working Group for Life Cycle Assessment of water and wastewater treatment (LCA-Water WG), aiming at developing consensual methodologies to promote better use of LCA in the urban water systems. The main outcomes of the WG were implemented in the project.

Secondly, it has been evaluated the environmental performance through LCA of the LIFE ULISES baseline scenario. Before the evaluation of project actions implementation, it is necessary to carry out the environmental analysis of current WWT operations. In this regard, the results obtained from current study will serve as basis for the comparative assessment of baseline scenario and project implementation scenario that will be developed at the end of LIFE ULISES project. The goal of the LCA study was the evaluation of the environmental profile of the WWTP located in El Bobar during 2019. The system under study started with the incoming WW and included the different unit processes operation, the background processes related to energy and chemicals consumed, discharge of water treated and dewatered sludge final treatment. The construction phase of the WWTP was excluded from system limits in order to keep coherence with coming reports.

The life cycle environmental impacts obtained showed that the sludge and water lines were the main impact responsible in terms of relative contribution. For water line, the impact was related to electricity consumption. For the sludge line, the sludge management was the main impact responsible. In this sense, landfarming was the main process responsible for impact because of N-based field emissions (e.g., indirect $N2O$ to air) which present a high impact for climate change impact category. Similarly, P-based field emissions are responsible for impact related to eutrophication impact categories.

After prototypes installation, we carry out the environmental assessment of wastewater treatment (WWT) operations in project implementation scenario (ULISES scenario), according to the same scope conditions established in the LCA of baseline scenario. This scenario would be the result derived from the fact that the prototypes developed in the project were used to treat the whole wastewater of the El Bobar during a year and represents the current parameters and unit processes of a resource recovery facility. Direct data about different technologies operation were provided by the partners responsible for each prototype CETIM (Enzymatic Hydrolysis and Nutrients Recovery) UAL – CIESOL (Tertiary Treatment by photoFENTON) and Aqualia (UASB, ABAD and aeMBR). Electricity consumption was determined through direct monitoring in the plant and energy audit to compare different operating regimes and obtain representative data. To include the environmental benefit of valuable products, the principle of expanding the limits of the system has been applied, taking representative processes from the Ecoinvent 3.8 database.

The results obtained shows that, in ULISES scenario, the sludge and water lines were the main negative impact responsible in terms of relative contribution. The tertiary treatment is also important because its negative effects in certain categories, but it suppose an important environmental benefit for water consumption. Gas line has in this scenario an important contribution in the system, because of the biomethane produced, that suppose environmental benefits in almost all impact categories analyzed. This positive impact is capable of significantly offsetting the negative effects derived from the processes of the other subsystems.

The comparison between the baseline scenario and the project implementation scenario was done, to establish the differences between de environmental performance and determine de advantages and disadvantages of each option. The results of this benchmarking show that, the introduction of the technologies developed within the framework of the project, supposes in general fewer negative effects or net benefits, due to the resources and energy recovered and materials transformed into valuable product.

The results obtained allow demonstrating the improvement of the environmental performance of the transformation of a conventional wastewater treatment plant (WWTP) into a highly efficient bio-refinery, with the prototypes developed in the project, because of the reduction of the consumption and transformation of the resources and energy and the environmental benefits derived from the recovery of valuable resources.

A specific environmental assessment of the biomethane produced with ULISES technologies and used as fuel for road transportation was carried out. The approach Well to Wheels (WTW) were considered to evaluate the impact of the whole processes from fuel production up to engine consumption specifically to exhaust emissions. In addition, different fossil fuels commonly used were studied and benchmark under the same approach. The lower relative impact of the WWT and TTW phase, together with the emissions of biogenic origin, make the production and use of ULISES biomethane a promising alternative from the environmental point of view for its application in road transport. The results obtained allow demonstrating that the biomethane produced from WWT with PUSH and ABAD technologies, constitutes an alternative with better environmental performance than other conventional fuels commonly used in road transport, both in its production phase (WTT) and during its use (TTW). Therefore, ULISES biomethane could contribute not only to reducing the impact linked to wastewater treatment systems but also to the harmful effects on the environment, particularly linked to emissions of GHG, from road transport.

Finally, we applicate the Water-Energy-Carbon (WEC) nexus and the ENERWATER methodology in the comparative assessment of baseline scenario and project implementation scenario. Both methods are specifically defined to evaluate WWT system, so we expect that they contribute to demonstrate the potential improvements made with the implementation of the technologies proposed.

The WEC methodology jointly evaluates environmental impact indicators related to the consumption of water, energy, and climate change, considering the intrinsic relationship that exists between these three environmental aspects in wastewater treatment systems. In this sense, he considers that the modification (positive or negative) of one aspect can influence the others. Thus, the methodology proposes obtaining a standardized and weighted indicator to jointly assess the impact on these three categories. Applying this approach to the environmental impacts o baseline and the ULISES scenario in with different weighting factors, we observe that, in all cases, the ULISES scenario shows the best performance.

We also classify and label the baseline and ULISES scenario according to the ENERWATER, a specific system to evaluate, label and continuously improve the general energy performance of WWTPs. The ULISES scenario ranked as class F for Gross energy, indicating higher energy consumption due to the implementation of intensive new technology. However, this is offset by the production of biogas, resulting in an improved ranking of class D for Net energy. Furthermore, the method does not consider the potential

environmental benefits of other energy recovery systems instead of on-site electricity production. Even then, findings underscore the importance of balancing energy demands with sustainable solutions highlight the need to deepen the development of specific methodologies for evaluating the sustainability of production systems based on the principles of the circular economy.
Deviations and problems encountered in the action
No special deviations have been found in this Action.
Complementary actions & perspectives for continuing after the end of the project
None
Deliverables
D.C.2.1. LCA analysis of current WWTP (baseline scenario) 11/2020 ✓ D.C.2.2. LCA analysis of project implementation and benchmarking with baseline scenario 05/2023 ✓ D.C.2.3. LCA report on bio-methane used for road transportation 06/2023 ✓ D.C.2.4. Energy-Water-Carbon Nexus and ENERWATER reports 06/2023 ✓
Milestones
M.C.2.1. Life cycle inventory data for baseline WWTP operation 07/2020 ✓ M.C.2.2. Life cycle inventory data for WWTP operation after project implementation 08/2022 ✓ M.C.2.3. Life cycle inventory data for obtained by products: bio-fertilizer and water reuse 08/2022 ✓ M.C.2.4. Consumption and emissions data for bio-methane vehicle's test 12/2022 ✓
Attachments
Deliverable D.C.2.2., D.C.2.3. and D.C.2.4., are attached to this Final report

C3. Evaluation of the socioeconomic impact			
Status	COMPLETED		
Foreseen start date:	01/07/2019	Actual start date:	01/07/2019
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

C.3.1. Economic evaluation of Life ULISES project

A cost-benefit analysis (CBA) was performed by determining the cost indicators (CAPEX - OPEX) and the potential revenue of the products obtained in each of the project technologies (irrigation water, biomethane, fertilizers), determining from this the net benefit or expense of each (Lee, 2016).

OPEX for each technology has been determined with respect to the functional unit of measurement of the product generated in each technology. The CBA takes into account the operating costs and expected benefits of each technology within one year of operation.

At the same time, the operational data of El Bobar WWTP collected during the project were used to classify and label the baseline and ULISES scenario according to the ENERWATER methodology following the rapid audit approach. In this regard, the methodology required the following data: WWTP size, flow rate, energy consumption, sludge generated, biogas produced, etc. It is worth mentioning that for the ULISES scenario only the chemical NaOH has been considered, as the ENERWATER platform does not take into account other chemical such as H2SO4, H2O2, FeSO47H2O and MgCl among others.

A Levelized Cost of Energy (LCOE) has been performed by adapting the calculation of a normal LCOE towards one focused on the LCOE of biomethane for road transport (Lee, 2016).

All the information of the CBA and LCOE is detailed in the deliverable *D.C.3.1 Socio-economic analysis of LIFE ULISES project* attached to this Final Report

C.3.2. Social evaluation of Life ULISES project

A linear model of resource consumption, goods production and waste generation is an exhausted socio-economic model. Therefore, LIFE ULISES proposes a circular economic model, changing the paradigm of WWTPs. Today's problematic wastewater will be harnessed in the production of a high value-added biofuel in the ULISES project, which will reduce the EU economy's external dependence on fossil fuels, reduce GHG emissions and demonstrate the viability of a new energy model based on local resources and technology.

In addition to the production of biomethane, LIFE ULISES will obtain an improved biofertiliser from sewage sludge that will improve the efficiency of agriculture, reduce emissions associated with this activity and reduce external dependence on mineral fertilisers. Thus, the project clearly aims to achieve an economically, socially, and environmentally sustainable production process.

In this context, the LIFE ULISES project is expected to have a significant impact on employment and growth. The consortium has an ambitious replication plan to be achieved within five years after the end of the project.

To address all this impacts, a social impact assessment has been conducted using the SWOT/DAFO methodology. This methodology has allowed for the identification of:

- **Strength:** this section identifies the internal advantages of Life Ulises technologies to produce positive impacts on the groups identified in Section 4.1.
- **Weakness:** this section includes areas where the Life Ulises technologies present internal deficits or gaps that may hinder the achievement of its full potential to produce positive social impacts.
- **Opportunity:** the third part of the analysis includes external factors than can give an advantage or boost of Life Ulises positive social impacts.

- **Threat:** the last section includes external elements that have the potential to harm the social impact of the Life Ulises project.

The image below presents the finds of the application of the SWOT methodology to the social impact of Life Ulises in the identified potential impact groups.

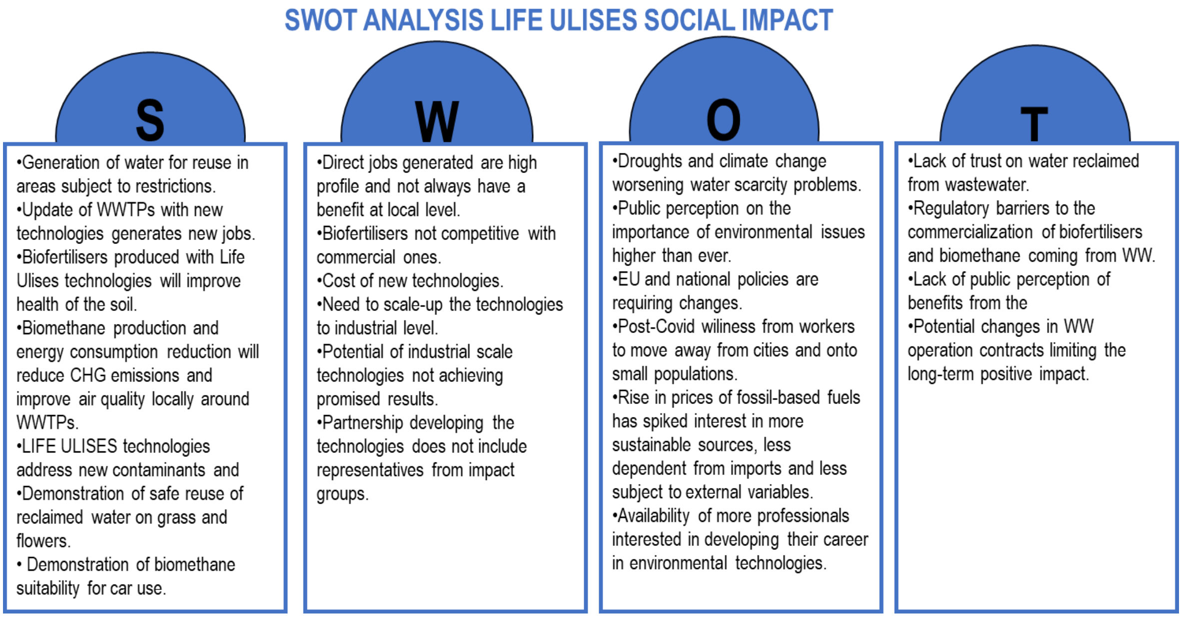

Figure 13: Logotype of LIFE ULISES Project

Deviations and problems encountered in the action

No special deviations have been found in this Action.

Complementary actions & perspectives for continuing after the end of the project

None

Deliverables

D.C.3.1. Socio-economic analysis of LIFE ULISES project 06/2023 ✓

Milestones

M.C.3.1. Performance of economic balances and LCOE analysis of LIFE ULISES project 06/2023 ✓

Attachments

Deliverable D.C.3.1. is attached to this Final report

D1. Communication activities for public awareness: information, technical dissemination			
Status	COMPLETED		
Foreseen start date:	01/07/2019	Actual start date:	01/07/2019
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

Dissemination Plan (DP)

AQUALIA with the support from all partners has prepared a dissemination plan early on the project defining the overall strategy for dissemination, the target groups and the stakeholders with whom communication should be prioritized for their outreach. Project image – logotype, typography and templates for documents have been developed by AQUALIA in collaboration with partners.

Project website

The project website was launched in May 2020 and can be accessed through the link https://life-ulises.eu/. It is available in two languages – English and Spanish. It has been designed including the project description (objectives, work plan with actions, location), the logotype of LIFE ULISES, partners' description and their contribution to the project, a specific section to the demo plants and technology, media contents and news. It features the LIFE Programme logo and its contribution to the project.

Figure 14: Logotype of LIFE ULISES Project

Figure 15: Screenshot of the website of LIFE ULISES Project

Dissemination materials

Communication and printable materials have been produced by AQUALIA with the support of all partners. A project card was elaborated and printed at the start of the project with basic information. As well, a brochure has been elaborated and printed in two languages – English and Spanish, the brochure provides a full description of each technology together with a picture of each demo plant.

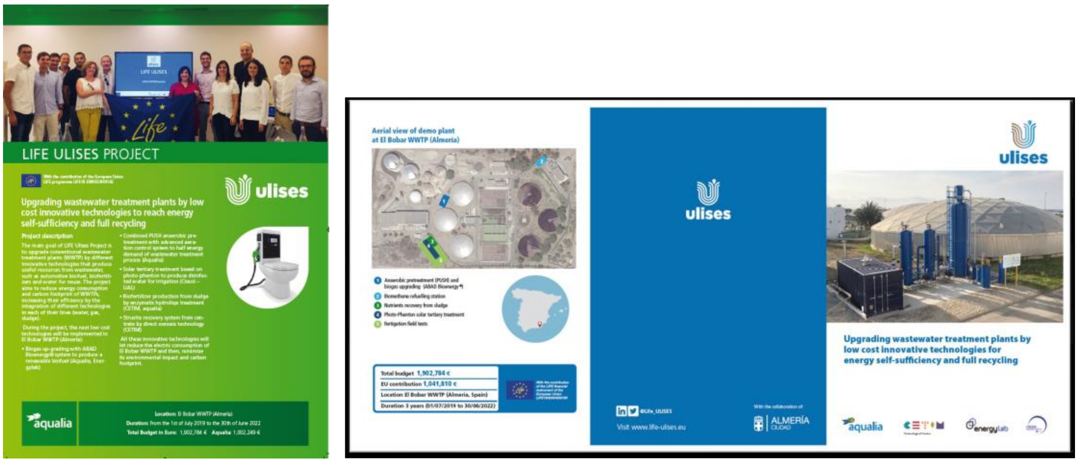

Figure 16: Project card LIFE ULISES Brochure

Moreover, notice boards for their installation in the pilot site have been designed. They are located in accessible and visible places in the WWTP and the pilot plants. Panels for permanent display at the partner's headquarters and panels for events were also developed by AQUALIA.

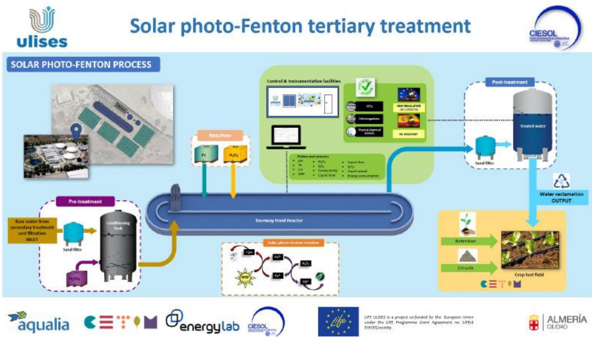

Figure 17: Notice Boards of LIFE ULISES Project

Three different project newsletters were designed by the consortium. These project newsletter has been released and it is publicly accessible in the project website for its download (EN & ES). The first newsletter was published in June 2020, the second one in June 2021 and the third one in October 2022. All the newsletter includes the main progress in the different plants, news about the project meetings and the different dissemination activities in which the project has been involved.

Deviations and problems encountered in the action

No special deviations have been found in this Action.

Complementary actions & perspectives for continuing after the end of the project

The consortium will continue disseminating the project results after it ends. The project website will be maintained during five years period after the end of the project. Furthermore, the consortium members will continue participating in events and forums of interest to the project to disseminate LIFE ULISES results at least three years the end of the project.

Deliverables

D.D.1.1. Dissemination Project Plan 02/2020 ✓
D.D.1.2. Project Logotype 12/2019 ✓
D.D.1.3. Project website launch 11/2019 ✓
D.D.1.4. Project Brochures 01/2020) ✓
D.D.1.5. Newsletters uploaded in project website 06/2023 ✓

D.D.1.6. Project Panels 06/2022 ✓ D.D.1.7. Project Notice Boards Pilots 12/2020 ✓ D.D.1.8. Layman's Report 06/2023 ✓
Milestones
M.D.1.1. Document for website design and content approval 11/2019 ✓ M.D.1.2. Agreement on Dissemination Plan 02/2020 ✓ M.D.1.3. Project website operative 11/2019 ✓
Attachments
Deliverables D.D.1.5., D.D.1.6., and D.D.1.8. are attached to this Final report

D2. Dissemination of results: networking with other projects, technical publications			
Status	COMPLETED		
Foreseen start date:	01/07/2019	Actual start date:	01/07/2019
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

D.2.1. Networking with other projects

Throughout the LIFE ULISES project, the consortium members have attended several activities and events to disseminate the different actions carried out during the project. These activities and events were organized by the network of EU projects related to the objectives of our project. The following LIFE projects were contacted: LIFE BEWARE, Biomethane in transport: Networking of LIFE projects, LIFE GREEN SEWER, LIFE Clean Up - Networking days, LIFE DRAIN RAIN, LIFE Aquacycle.

D.2.2. Project's Seminars and final event

Workshop nº 1 should have been celebrated in June 2020 however it took place in September 2021 in Almería. For this seminar, organised by CIESOL, a session of around 30 participants was planned for each event and it lasted 3 hours as it had been described in the GA. Finally, this workshop had a participation of 107 people who were able to meet the project, and the project's system.

D.2.3. Other activities for Project's outputs diffusion

For increasing the project's diffusion, the consortium members have participated in different general events in order to disseminate the different actions carried out during the project. This section includes several participations in popular dissemination activities, such as the European Researchers' Night, the International Day of Women and Girls in science, the Science Week or several general events which have included talks on the project progresses, as well as visits to the El Bobar facilities. At the same time the consortium has participated with oral and poster presentations in different national and international conferences and seminars, in all of which the project and its results have been presented. A total of 19 oral presentation and 12 poster presentation have been developed have been presented throughout the project. The project has also appeared in several press articles in different media. The links to these articles are included in deliverable D.D.2.2 Finally, with the results obtained in the project 8 scientific papers have been published in different international journals.

Deviations and problems encountered in the action

No significant deviation has been found.

Complementary actions & perspectives for continuing after the end of the project

After the project, partners will continue attend specific events related with the project and also will be extended the activity of collaboration with other R&D projects.

Deliverables

D.D.2.1. Report on the seminars, workshops and the final event organization and results 06/2023 ✓

D.D.2.2. Report on the events attended and results 06/2023 ✓

D.D.2.3. List of networking members 06/2023 ✓

Milestones

M.D.2.1. Identification relevant events for attendance 08/2020 ✓

Attachments

Deliverables D.D.2.1., D.D.2.2. and D.D.2.3. are attached to this Final report

E1. Project Management			
Status	COMPLETED		
Foreseen start date:	01/07/2019	Actual start date:	01/07/2019
Foreseen end date:	30/06/2022	Actual (or anticipated) end date:	30/06/2023

Activities Undertaken and outputs achieved

The project has started on 1st July 2019. The first step taken by the consortium was the elaboration of the partnership agreement, which was signed on September 2019.

AQUALIA has developed a project management guide in collaboration with the partners of the consortium, including all relevant information for the management of the project. A sharepoint system has been implemented for the project information and documentation exchange. Every 3 months, financial and technical documentation is collected and reviewed by AQUALIA, supported by CETIM.

Moreover, a Stakeholder Advisory Panel (SAP) has been constituted in order to provide technical advice and monitoring during the project and assessment for future replication and transferability. At this moment, the SAP is formed by four relevant stakeholders from industry (biogas and water reuse sectors) and policy makers: Naturgy, Herogra, Confederación Hidrográfica del Guadalquivir and the Provincial Council of Almeria (Diputación de Almería).

Furthermore, regular meetings of project consortium have been organised, approximately every 6 months. A total of 9 consortium meetings took place:

- Kick off meeting – organised by AQUALIA, on 30 September 2019, in Almería (Spain)
- 2nd Project Meeting – organised by ENERGYLAB, on 12 March 2020, and finally done virtually due COVID-19 outbreak, even though it was planned and organised face to face.
- 3rd Project Meeting – organised by CIESOL, on 17 September 2020 (virtual meeting).
- 4th Project Meeting – organised by AQUALIA, on 13 January 2021 (virtual meeting).
- 5th Project Meeting – organised by AQUALIA and CIESOL, on 10 September 2022, in Almería (Spain)
- 6th Project Meeting – organised by AQUALIA, on 23 May 2022, in Almería (Spain).
- 7th Project Meeting – organised by CETIM, on 2 March 2023, in A Coruña (Spain).
- 8th Project Meeting – organised by AQUALIA, on 26 June 2023 (virtual meeting).
- Final Meeting – organised by AQUALIA, on 22 August 2023 (virtual meeting).

Figure 18: Consortium Meetings LIFE ULISES

Furthermore, AQUALIA and CETIM have attended the kick-off meeting of LIFE Projects in Brussels on 7-8th November 2019. Regarding Monitor’s Meetings, the first one has taken place on 20 May 2020 (virtual meeting), the second one has been on 23 May 2022 in Almería

(Spain), in this meeting the monitor made a site visit to El Bobar WWTP. Finally, a third meeting has taken place on 22 August 2023 (virtual meeting).
Deviations and problems encountered in the action
No significant deviation has been found.
Complementary actions & perspectives for continuing after the end of the project
Not applicable.
Deliverables
D.E.1.1. Consortium Agreement 09/2019 ✓ D.E.1.2. Project Management Guide 11/2019 ✓ D.E.1.3. LIFE ULISES Green Procurement Plan 11/2019 ✓ D.E.1.4. After LIFE Communication Plan 06/2023 ✓
Milestones
M.E.1.1. Consortium Agreement Approval 09/2019 ✓ M.E.1.2. Defined content of After LIFE Communication Plan 06/2023 ✓
Attachments
Deliverable D.E.1.4 is attached to this Final report

6.2. Main deviations, problems and corrective actions implemented

Constructive project was finalized in February 2020 and civil works were going to start on March 2020. However, Covid-19 epidemiologic pandemic lead to 3 months complete lockdown in Spain, causing a delay on the start of the works. Moreover, the pandemic situation has led to different delays with equipment supplies, works schedule linked to trips and mobility issues. Then, **a total delay of 6 months was accumulated in B1 Action**.

Concerning tertiary plant construction (**Action B1**), initially the reactor was going to be installed on the land, nevertheless, the irregularity of the terrain has obligated to put a concrete platform not included in the preliminary design neither the budget.

Concerning the struvite plant (**B4 Action**), construction has experienced delays due to stock rupture of the DCMD module. The end of the works and the start-up of this plant is expected for February 2021.

Concerning the advanced aeration control system implementation (**Action B3**), an unexpected decision from WWTP staff has supposed the impossibility to carry out this activity in El Bobar WWTP biological reactors, causing the necessity of planned activities modification. After the modifications presented in the Midtem Report a change in this action has been approved by the commission, an AeMBR reactor of 5.5 m^3 was installed and operated continuously since May 2023 at ambient temperature in order to meet certain water quality for reuse purposes according to European Regulation.

As **6 months delay were take place in most of the Implementation Actions** (B2 to B5), the LIFE ULISES project consortium made an amendment and obtain a prorogation of the project for one year. This amendment was approved by the commission.

6.3.Evaluation of Project Implementation

6.3.1. Methodology

	Methodology Involved	Evaluation
A1	Standard Methods (ISO, APHA, etc.) were followed for the characterization of secondary effluents. Prototypes preliminary configuration was assessed according to the Consortium experience.	Technical methods used were adequate to provide the expected results of water samples and to obtain the preliminary configuration of prototype plants.
A2	The design was based on the results obtained in A1 and previous expertise of the Consortium. Sludge characterisation and tests for enzymatic hydrolysis, struvite recovery and centrate concentration by FO were also used as a basis of design. Common design rules employed in WWT equipment were also employed, such as, use of hydraulic loadings, specific transmembrane fluxes, etc.	Technical methods used were adequate to design the demo plants and ultimately reach the expected performances.
B1	The six demonstration plants have been built according to the designs from A2 by initially installing the main equipment of each plant, such as membrane modules, tanks… Later on, pumps and piping were installed as needed and finally, sensors and control system. The last part was the connection to the wastewater, sludge and/or biogas pipes. Hydraulic testing and testing of the monitoring and control systems was finally done to assure the correct operation of the plants.	Methods for construction of the demonstration plants are the common industry standard for such systems.
B2	Biomethane will be analysed according to EN 16723-2:2018. Vehicle testing will follow NEDC or WLTP cycle, and RDE test will be performed to measure the pollutants. The engine mechanics will be assessed for wear. Exhaust gas will be analysed according to EURO 6c and 6d.	Technical methods are deemed adequate to provide the expected results from biomethane samples and automobile performance assessment.
B3	Validation of LIFE ULISES water line technologies has not yet started. Methodology for their operation will be based on previous experience of AQUALIA. Characterization of water samples will follow Standard Methods. Biogas will be analysed by a portable composition analyser with an electrochemical gas sensor.	Technical methods are deemed adequate to provide the expected results from water samples and biogas.
B4	Methodology for operation will be based on previous experience of CETIM and AQUALIA. Characterisation of liquid streams will follow Standard Methods. Agronomic potential of hydrolysed fractions (biofertilizers) will be assessed according to Regulation EC No 2003/2003 and through techniques such as UV-vis spectroscopy, Kjeldahl method, chromatography, Zucconi test and Germination Index. Crops' health and growth will be assessed by foliar analysis, crop yield, etc.. Metagenomic analysis were carried out to evaluate	Technical methods are deemed adequate to provide the expected results from water samples, biofertilizers and crops tests.

	changes in soil's microbiota as result of the biofertilizer application.	
B5	Conventional water parameters will be measured following Standard Methods (ISO, APHA, etc.). Pesticide and other micropollutants will be measured by liquid chromatography coupled by mass spectrometry. Microbiological characterisation will be done by culture and colony enumeration. Modelling and design of the control system will be done based on UAL-CIESOL experience and using a black box model approach.	Technical methods were deemed adequate to provide the expected results of water samples. Modelling and control methodology was appropriate, resulting in a validated and semiempirical kinetic model for the solar photo-Fenton process at neutral pH using Fe3+-NTA as chelating agent. Moreover, a simulation software, a model-based optimizer and a control system based on virtual sensors were developed to enhance the plant performance.
B6	Methods applied in this action are focused on developing the LIFE ULISES Replicability and Transferability guides, as well as a Business Strategy Plan. In order to collect useful data, several surveys are being carried out based on data gathering by templates, bibliography, Consortium experience and contacts, SAP expertise… Nevertheless, key data for guidelines elaboration will come from pilot validation.	Data was gathered from bibliography and operational lessons from the validation of the LIFE ULISES pilot plant. Data was then elaborated into guidelines that were sent to technical partners for final validation.
C1	This action requires monitoring and updating KPIs selected on the beginning of the project. Partners provide to the task leader their corresponding data.	Key parameters were identified and updated into the Webtool. These parameters have been monitored and updated.
C2	LCA is being carried out following the standard LCA procedures (ISO 14040 & 14044) and different wide known impact methodologies (ReCiPe 2016, CED, NEB) In addition, the whole WWTP performance in baseline and ULISES scenarios is being assessed by WEC and Enerwater methods.	Methodology followed is the adequate for LCA study. ENERWATER that is not full adapted to new technologies conditions and possibilities.
C3	Cost efficiency of the project and cost/benefit ratio will be addressed by calculating Energy Feasibility, OPEX/CAPEX, Cost Benefit Analysis and Levelized Cost of Energy, among others. Social impact will use tools such as SWOT analysis, surveys and interviews and evaluation of different relevant indicators.	The efficiency of the methodologies were evaluated on this Action. The methodology proposed is widely used for this type of assessment.
D1	Methods involved in this action include developing a dissemination plan and the dissemination pack, updating the project's website in English and Spanish.	This methodology has been applied successfully
D2	Methods involved in this action include promoting the project networking actions with other projects and relevant stakeholders, the organization of seminars & final event and the actively participation in events of interest	The methodology itself has been applied successfully and the consortium does not expect deviations in the results achieved by the end of the project.
E1	The detailed management organisation set up for the project can be found in the deliverable of Project Management Guide.	Project management has been refined on the basis of the knowledge gained throughout the project and also as a

		direct consequence of the Project Monitor and the European Commission recommendations.

6.3.2. Results

	Foreseen in the revised proposal	Achieved / Evaluation	
A.1	**<u>Objectives</u>:** start project management, preparation and permits. **<u>Expected results</u>:** Select demonstration site, obtain licenses and authorizations, fulfil initial characterizations of streams, preliminary configuration of the plants	Achieved	All expected results were achieved: El Bobar WWTP was selected for implementation of the project. Permits were obtained. Complete characterizations of WW, biogas and sludge were carried out. Plants configurations were assessed and possible locations were analysed.
A.2	**<u>Objectives:</u>** final design of demo plants **<u>Expected results</u>:** Design all demo plants, define all components and equipment, obtain a preliminary project, select final location of each plant	Achieved	Final designs of each plant were described, including materials and equipment specifications, in a Construction Project. Plants were located in two Areas of WWTP.
B.1	**<u>Objectives</u>:** construction and commissioning of the plants **<u>Expected results</u>:** Tender and purchase of materials, contract suppliers and workers, construct all demo plants	Achieved	All demo plants have been constructed and are ready for start-up. The implementation suffered 6 months delay.
B.2	**<u>Objectives</u>:** demonstrate biomethane production and use as transport fuel **<u>Expected results</u>:** Operate and optimize up-grading plant, check biomethane quality, test biomethane in vehicles	Achieved	Two GNC cars from Aqualia used the biomethane obtained in this plant
B.3	**<u>Objectives</u>:** reduce energy consumption in the water line **<u>Expected results</u>:** demonstrate the performance of PUSH, evaluate the effect of the advanced control system in full-scale reactor	Achieved	The UASB reactor was commissioned and operated successfully for almost 2 years, These results demonstrate that this technology can be used as an alternative to the primary treatment of conventional WWTPs. In addition, the UASB reactor is considered a suitable source of energy generation through the use of the biogas produced by it.
B.4	**<u>Objectives</u>:** obtain and test high quality biofetilizers from sludge **<u>Expected results</u>: p**roduce biofertilizer from sludge, produce struvite from centrate, optimize operation of the plants, test their quality in crop field tests	Achieved	Validation of the 2 pilot plants (enzymatic hydrolisys and nutrient recovery) allowed to obtain 2 different fertilisers (Biofertilizer from hydrolized sludge and struvite). Performance of these fertiliers was evaluated at different agronomic essays showing higher yields than control crops.
B.5	**<u>Objectives</u>:** obtain water for reuse by solar photo-fenton tertiary treatment **<u>Expected results</u>:** operate tertiary treatment plant to produce water for reuse, check its quality in crop field tests, modelling of the process	Achieved	Reclaimed water according to RD 1620/2007 and EU 2020/741 has been achieved. The plant has successfully regenerated secondary effluent operating in continuous flow mode.
B.6	**<u>Objectives</u>:** Promote replication and transferability	Achieved	4 Guidelines were prepared based on the validation of the LIFE ULISES plant: replicability of technologies in WWTP,

	<u>Expected results</u>: Prepare replicability and Transferability guidelines		replicability in biogas production sites, transfer of solar technologies and transfer of biofertilizers. The guidelines served as inputs for the Life Ulises Strategic Business Plan.
C.1	**<u>Objectives</u>:** Evaluate project impact and control project actions progress **<u>Expected results</u>:** update KPIs, continuous monitoring of project actions	Achieved	Final Statement progress performance indicators have been updated. KPIs were uploaded in LIFE Webtool. All project Actions were developed correctly.
C.2	**<u>Objectives</u>:** evaluate the environmental impact of the project **<u>Expected results</u>:** perform LCA of the project technologies	Achieved	The baseline and ULISES scenario LCA and benchmarking was completed. The environmental profile of ULISES biomethane used for road transportation from a WWT approach was completed. The WEC and Enerwater methods were applied.
C.3	**<u>Objectives</u>:** evaluate social and economic impacts of the project **<u>Expected results</u>:** assess the social implications of the project, calculate economic feasibility and cost analyses	Achieved	An initial assessment of social and economic impacts was done. Investment costs were recorded. LIFE ULISES impulses employment by the new recruitment of 4 people and the indirect contracts with local suppliers and workers.
D.1	**<u>Objectives</u>:** Maximize visibility and dissemination of LIFE ULISES. **<u>Expected results</u>:** Develop a Dissemination Plan, Website and dissemination materials (brochures, panels, notice boards, press releases etc.) and a Layman’s report	Achieved	Several actions have been carried out in order to raise public awareness and ensure dissemination of the project actions and results. DP, website, brochures design, press release, etc.
D.2	**<u>Objectives:</u>** Increase the outreach of the project and its target audience through networking actions **<u>Expected results:</u>** Organization of seminars and participation in events of interest. Establishment of direct contacts with other LIFE and non-LIFE projects	Achieved	Several networking actions have been carried out in order to increase the outreach of the project and its target audience.
E.1	**<u>Objectives</u>**: Ensure the correct technical and economic progress of the project **<u>Expected results:</u>** Fulfilment of the contractual obligations with the Grant Agreement and according to the Project’s objectives and the work plan. Development of an After-LIFE Communication Plan	Achieved	The Project Management Team has pursued the good advance of the technical and financial parts of the project.

6.3.3. Replication and Dissemination

Replicability and transferability aspects of the results of the operation of the LIFE ULISES demo plant at El Bobar WWTP have been used to define a set of transferability and replicability guidelines. Four scenarios have been considered: replication at WWTTs, replication at other plants with biogas production, transferability for solar disinfection technologies and transferability of the nutrient recovery technologies. In all four cases the work started with the collection from all projects partners of limiting parameters, optimal conditions, construction

requirements and operation guidelines, as resulting from the lessons learned during the plant operation at El Bobar.
Two different methodologies have been used in the guidelines, one for the replicability guidelines and a separate one for the transferability guidelines. For the replicability guidelines, the methodology consists of 5 phases: 1. Understanding the situation of the sector through qualitative data, 2. Analysis of the characteristics of the site, 3. Study of the characteristics of the facilities wishing to adopt the technology, 4. Evaluation and implementation. This methodology is flexible and can be adapted to the characteristics of each site. On the other hand, the guidelines for technology transfer to other sectors follow a different scheme, first explaining which sectors could be of interest and then giving a series of broader advice and indications for technology transfer.

-Guidelines for replicability of LIFE Ulises technologies in a WWTP and replicability of biogas technology in other sectors

The work done for these guidelines started with a brief market sector analysis to detect the opportunities for replication. Afterwards, the different steps required for replication of the LIFE prototype plant in each WWTP and in biogas installations in other sectors have been developed including:

1st. Local context analysis considering that WWTPs are very sensitive to the geographical conditions, so it is important to understand the specifics of the site, including Geographical conditions and administrative organisation.

2nd. Evaluation of the existing conditions of the WWTP system including flow and technical characteristics of the installation.

3rd. Implementation of the plant including installation of monitoring system; preliminary characterisation of gas and sludge flows; influent and effluent; licenses and permits; construction and validation.

- Guidelines for the transfer of solar treatments and nutrient recovery

Solar technologies are the ones that pose more issues since they require very specific conditions and their application is rather limited to a few sectors. The thermal energy demand of the process, the production profile, the available space, the geographical location, the climatic conditions, the low cost of fossil fuels, the thermal storage systems- which are still in the research phase-, and inefficient or non-existent energy policies are very important conditioning factors when implementing this type of solar technologies.
The transferability study was done both for the Photo-Fenton plant and the Fresnel Collector in relation to the solar technologies, and for the enzymatic hydrolysis and struvite precipitation technology. In this case the focus was put in studying potential sectors and industrial setting for transfer selecting potential end-users and intermediaries.

Regarding the dissemination activities, the consortium members have attended several activities and events to disseminate the different actions carried out during the project. These activities are divided into three different categories:

- Networking with other projects

Throughout the LIFE ULISES project, the consortium members have attended several activities and events to disseminate the different actions carried out during the project. These activities and events were organized by the network of EU projects related to the objectives of our project. The following LIFE projects were contacted: LIFE BEWARE, Biomethane in transport: Networking of LIFE projects, LIFE GREEN SEWER, LIFE Clean Up – Networking days, LIFE DRAIN RAIN, LIFE Aquacycle.

- Project's Seminars

Workshop nº 1 should have been celebrated in June 2020 however it took place in September 2021 in Almería. For this seminar, organised by CIESOL, a session of around 30 participants was planned for each event and it lasted 3 hours as it had been described in the GA. Finally, this workshop had a participation of 107 people who were able to me the project, and the project's system.

- Other activities for Project's outputs diffusion

For increasing the project's diffusion, the consortium members have participated in different general events in order to disseminate the different actions carried out during the project. This section includes several participations in popular dissemination activities, such as the European Researchers' Night, the International Day of Women and Girls in science, the Science Week or several general events which have included talks on the project progresses, as well as visits to the El Bobar facilities. At the same time the consortium has participated with oral and poster presentations in different national and international conferences and seminars, in all of which the project and its results have been presented. A total of 19 oral presentation and 12 poster presentation have been developed have been presented throughout the project. The project has also appeared in several press articles in different media. The links to these articles are included in deliverable D.D.2.2 Finally, with the results obtained in the project 8 scientific papers have been published in different international journals.

6.3.4. Policy Impact

LIFE ULISES project contribute mainly to EU Water and Circular Economy Policy Areas. The most relevant policies identified where the project will impact are listed below:

- Water Framework Directive 2000/60/EC,
- Directive 91/271/EEC for Urban Wastewater,
- Directive 86/278/EEC of 12 June 1986 related to Sewerage sludge, currently under review and Open Public Consultation
- EU Fertilizers Regulation: Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019
- EU Regulation 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse, and
- EU Action Plan for the Circular Economy

6.4.Analysis of benefits

The benefits of the results obtained in the project are detailed below:

6.4.1 Environmental benefits

The following are some of the benefits obtained during the project:

- Reduction of 4635 tons per year of the GHG emitted by WWTP (CO_2 eq).
- Reduction of the GHG emissions in transportation:
    - 96% CO_2 eq (well to wheels)
    - 99% CO_2 eq (tank-to-wheels)
    - 94 N_2O (tank-to-wheels)
- Reduction on the emissions for transportation
    - 82% Particulate matter
    - 93% NO_x
    - 100% Sox
- Reduction of 4 log unit of CFU in the water pathogen content of E.coli
- Improve on the water quality of the tertiary treatment (9626729 m37year)

6.4.2 Economic and social benefits

The following are some of the benefits obtained during the project:

- Creation of 7 new job positions
- New business opportunities by the participation in 5 new R&D projects
- Opportunity to use new renewable energy sources which have a positive impact on the local economy
- The total incomes expeted to obtain in 2027 (5 years after project ends) is around 1,675,235 € calculated on the basis of the Financial Projections of LIFE ULISES, considering a price per unit established in 2027 in 585.360€
- It is expecting to reach 5 units of WWTP (whole) above 100.000 p.e. It also consider taxes and the accumulated profit (negative) to the end of the project

6.4.3 Replicability, transferability, cooperation

As explained in section B6, results from the operation of the LIFE ULISES demo plant at El Bobar have been used to define a set of transferability and replicability guidelines, for the exploitation of the project results at commercial level.

Four scenarios have been considered: replication at WWTTs, replication at other plants with biogas production, transferability for solar disinfection technologies and transferability of the nutrient recovery technologies. In all four cases the work started with the collection from all projects partners of limiting parameters, optimal conditions, construction requirements and operation guidelines, as resulting from the lessons learned during the plant operation at El Bobar. The replicability guidelines are the following:

- Guidelines for the replicability of LIFE ULISES technology in a WWTP
- Guidelines for the replicability of biogas technology in other sectors
- Guidelines for the transfer of solar treatments
- Guidelines for nutrient recovery technology transfer

6.4.4 Best practice lessons and Innovation and demonstration value

The innovative nature of the project has been proved at technical level on the design and construction of the different technologies involved in LIFE ULISES. The results obtained in this section are developed in Actions B2, B3, B4 and B5 and are presented in the different deliverables for each action.

6.4.5 Policy implications

LIFE ULISES project contribute mainly to EU Water and Circular Economy Policy Areas. The most relevant policies identified where the project will impact are listed below:

- Water Framework Directive 2000/60/EC,
- Directive 91/271/EEC for Urban Wastewater,
- Directive 86/278/EEC of 12 June 1986 related to Sewerage sludge, currently under review and Open Public Consultation
- EU Fertilizers Regulation: Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019EU Regulation 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse, and
- EU Action Plan for the Circular Economy

7. Key Project-level Indicators

Two different contexts were generated for the incorporation of data into the webtool: the first context, called “Almeria” contains data of the impact of the project in El Bobar WWTP, whereas the context called “Replicability” includes data of the after-LIFE period, which considers the replication of the project in 5 WWTP.

Project area/length

The project area/length is the total spatial extent of the project directly influenced by the project actions that aim at achieving the main project objective. For LIFE ULISES project, the WWTP length was referred here.

Humans to be influenced by the project

This indicator refers to individuals targeted by the project, it is linked to the previous one. In this case, the population to which the WWTP gives service was chosen, around 200.000 persons. A second value under the context of dissemination and transferability was included, extrapolating the value to 5 extra WWTP under the same conditions.

Water: water abstraction/diversion

This indicator considers the water required for agricultural purposes. The project aims to produce tertiary water, of quality enough to be used in agriculture. Therefore, the potential production of tertiary water has been considered as water that will be saved for agriculture. It will also lead to avoid the discharge of secondary effluent of the WWTP.

Waste management

This KPI considers the reduction of non-appropriately managed waste. The project includes technologies for transformation of sludge and centrate (wastes) into biofertilizer and struvite, two different natural-fertilizers. Therefore the reduction of waste management into a recycled product is considered here.

Resource efficiency

- Energy consumption: the reduction of the energy demand of the wastewater treatment process was reflected here.
- Renewables production: production of energy by the transformation of biogas into biomethane by the operation of the ABAD Bioenergy® plant was declared here.

Air: emissions

This indicator reflects the effect of the usage of biomethane as fuel in vehicles. The reduction of emissions of SOx, NOx and particulate matter is indicated herein. This indicator does not include emissions linked to electric consumption, as it is already reflected in the CO2eq emissions.

Climate change mitigation: GHG emissions

- CO_2: CO_2 emissions linked to different processes are contained in this indicator. As in the performance progress indicator table, there is a differentiation between the whole wastewater treatment process (considering all lines and biomethane recovery), CO_2 linked only to the electric consumption and CO_2 related to the transport sector.
- Other GHG: N_2O linked to electric consumption is reflected in this indicator.

Governance

This indicator contains information about the involvement of non-governmental organisations and other stakeholders in project activities. In LIFE ULISES case, two companies and two public bodies were chosen as stakeholders.

Information and awareness raising to the general public

- Website: measured as number of unique visits.
- Other tools for raising awareness: publications, print media, video, events and other displayed information was declared here.

Capacity building: networking

This indicator is based on measuring the number and type of individuals that will be included in any of the different networking activities.

Jobs

Number of created jobs is reflected in this indicator.

Contribution to economic growth

- Running costs during the project and in case of continuation after the project period/Future funding: a definition of a period of 5 years for operating the prototypes was done. A calculation of the costs associated with this operation was performed, including the value in this indicator.
- Revenue expected: value obtained from the progress performance indicator document was reflected here, indicating the expected revenue in case of replicating the project in 5 WWTP.
- Entry into new entities/projects: transferability and replication expected results were introduced in this indicator.

The table below reflects the value of some indicators that have been updated at the end of the project. Further information about the update of progress performance indicators can be found in D.*C.1.2 Progress Performance Indicators: Final Statement*.

Indicator	Specific Context	Begin Value	End Value	Beyond 5 Years Value	Units
Project area/length	Almeria	0	1300	54000	m^2
	Replicability	0	0	270000	m^2
Humans (to be) influenced by the project	Almeria	0	5662	9200	Number of residents within or near the project area
Water abstraction/diversion	Almeria	9719585	9481895.2	0	m3/y
Renewables production	Almeria	3413.32	3512.92	3512.92	MWh/y
CO2	Almeria	1855508	1810131	0	KG of CO2 /year
	Almeria	0.19	0.19	0.18	kg CO2/unit produced
Involvement of non-governmental organisations (NGOs) and other stakeholders in project activities	Almeria	0	5	5	umber of stakeholders involved due to the project
	Almeria	0	2	2	number of individuals
Other tools for reaching/raising awareness of the general public	Almeria	0	27	34	Number of different publications made (Journal/conference)
	Almeria	0	3	3	Other distinct media products created (e.g. different videos/broadcast/leaflets)
	Almeria	0	16	19	Number of events/exhibitions organised
	Almeria	0	12	14	Number of different displayed information created (posters, information boards)