LIFE Project Number

LIFE13 ENV/ES/000420

FINAL Report Summary

Covering the project activities from 02/06/2014 to 30/06/2017

Reporting Date

23/10/2017

LIFE+ PROJECT NAME or Acronym

AQUASEF. Eco-efficient technologies development for environmental improvement of aquaculture

Project Data

Project location	Ayamonte, Huelva. South-western Spain.
Project start date:	02/06/2014
Project end date:	30/06/2017 Extension date: NOT APLICABLE
Total Project duration (in months)	37 months
Total budget	1.899.318 €
Total eligible budget	1.840.593 €
EU contribution:	919.744 €
(%) of total costs	48.42 %
(%) of eligible costs	49.97%

Beneficiary Data

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1. List of contents

List of abbreviations

AC	Alternative Current
CB	Coordinating Beneficiary
CFD	Computational Fluid Dynamics
CNA	National Aquaculture Congress
CONAMA	Spanish Congress for the Environment
EATIP	European Aquaculture Technology and Innovation Platform
EC	European Commission
EEP	External Experts Panel
EMT	External Monitoring Team
EPDM	ethylene propylene diene terpolymer
EU	European Union
FC	Fuel Cell
ICE	Internal Combustion Engine
IDEA	Spanish Institute for Energy Diversification and Saving
IR	Inception Report
KOH	Potassium Hydroxide
LC	LC filter
LPG	Liquefied Petroleum Gas
MR	Mid Term Report
MUREE	Modernizing Undergraduate Educational Experiences
OCA	Independent Certification Agency
PCB	Printed Circuit Board
PEM	Proton Exchange Membrane
PMH	Project Management Handbook
PTEPA	Spanish Technology Platform for Fisheries and Aquaculture
PV	Photovoltaic
PVC	Polyvinyl Chloride
PWM	Pulse Width Modulation
RD	Royal Ordinance
RMS	Rout Mean Square
RPM	Revolution Per Minute
SC	Steering Committee
SMD	Surface-Mount Devices
SMT	Surface- Mount Technology
THD	Total Harmonic Distortion

TMG	Technical Management Group
TMY	Typical Meteorological Year
UHU	Huelva University
UPS	Uninterrupted Power System
VAC	Voltage in Alternative Current

2. Executive Summary

Objectives and main activities:

The main objective of this project is to demonstrate, promote and disseminate among European Union some efficient and low-emission innovative technologies and the best practices to implement them in the aquaculture sector. AQUASEF Project outlines measures to reduce external energy and oxygen dependency, and to minimize environmental impacts by effluent treatment techniques and CO_2 fixation by microalgae cultivation. These actions result in an increased value added to the production by means of:

A. **Reducing the carbon footprint** (energy savings, renewable energy sources and CO_2 fixation by microalgae);
B. **Self-producing complements** for fish and mollusc diet (minimizing or even avoiding the use of chemical additives);
C. **Improving the quality of effluents**, thus reducing its impact over the aquatic ecosystems downstream.

The consortium translated these objectives into 7 main activities to implement:

1- Contributing to the **sustainability of onshore aquaculture** by applying best management practices in facilities, pursuant to EU commitments under the UNFCCC Kyoto Protocol aiming at reducing 20% of greenhouse gases emissions by 2020 in the EU.

2- Demonstrating the environmental advantages of integrated **energy generation** in onshore aquaculture facilities by replacing traditional fossil-based systems with others based on renewable energy sources.

3- Reducing or eliminating liquid oxygen external supply while maintaining production levels: combination of **locally produced electrolytic oxygen** with **efficient aeration** systems.

4. Demonstrate the useful application of electrolytic hydrogen and **fuel cell technologies** for aquaculture sector.

5. Integration of new techniques for **microalgae cultivation** with fish and molluscs production, for resource optimization and effluent treatment.

6. Validation and **quantification** of the usefulness and efficiency of the implemented technologies.

7. Dissemination and **technology transfer** activities throughout the European sector.

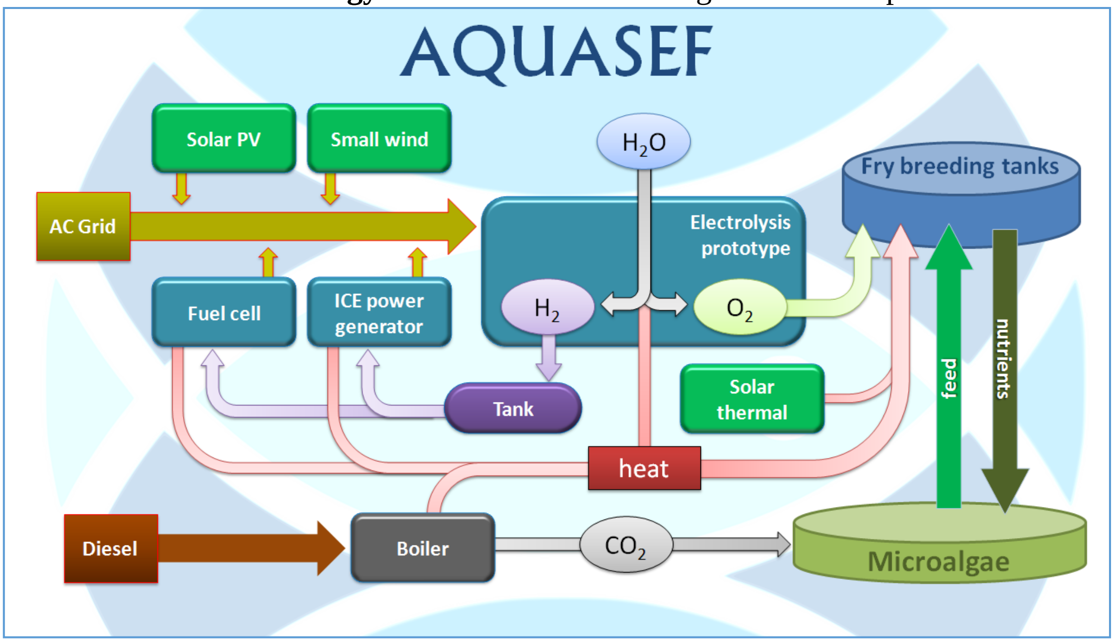


Figure 0. AQUASEF activities scheme

Summary of the main activities developed:

Renewable sources and energy efficiency

Figure 1. AQUASEF PV panels installed

In the initial phase, prior to introduction of any modification, all mayor energy flows within the plant were accurately quantified and compared with the electricity tariff chosen in order to identify any deviation from optimal. Measurements were conducted using professional equipment and following systematic protocols, registering and then calculating a wide set of parameters: active energy, power factor, electric incidences, flickers, total harmonic distortion (THD), voltage and current, etc. When comparing these actual measured needs with the electricity contract, some important points were found to be non-optimal: the improvements recommended in this assessment would imply some low-cost implementations but a very significant saving in electricity bills. Some operative problems appeared during the measurement period and some data sets had to be repeated, generating a slight delay which had no incidence over the project's time schedule. The conclusions reached by this full analysis were collected and summarized in the "Best Practices Manual for energy efficiency in aquaculture facilities".

Three different renewable energy technologies were selected to be integrated in the facility's energy system: solar thermal panels (33m^2), solar photovoltaic panels (30kW), and small wind power (5,5kW). Specific software, certified by international scientific community and widely accepted, was employed for computing simulation of the local conditions in order to estimate the most expectable power output of several combinations and configurations of components; the best option among those considered to be possible was selected. Some unexpected civil works were necessary to be executed in order to guarantee safety and optimal operability of the final layout. As well, due to some changes in the Spanish regulation, additional administrative process was required. For these reasons, this task also suffered some delay, but finally a wide real data period could be recollected, and then a detailed analysis was done, including a comparison between measured data and long-term data.

For the supply of electric energy in areas without electric grid, but located in the aquaculture installation, photovoltaic compact units were installed. These devices were specifically designed for aggressive conditions of humidity and salinity, with different power and autonomy, and, during the project, a comparison between this plug&play units and standard, commercial devices was done. The devices are used for standing independent applications, such as pumping, lighting, etc.

Oxygen self-production

The equipment needed for this purpose must be both reliable and cost-effective, as stand-alone operation and good cost-efficiency will be features strictly demanded by aquaculture farmers.
Throughout the project, ARIEMA developed the first electrolyzer unit to produce electrolytic oxygen for an aquaculture plant; at the same time, this device produces pressurized hydrogen, which is stored and then consumed for power generation in Esteros de Canela plant. ARIEMA's personnel conducted several preliminary tests on the electrolyzer located at the University of Huelva laboratories, mainly in order to set the initial performance parameters of a hydrogen-focused alkaline electrolyzer. Once reached the final design, efforts were focused in the

manufacturing, transport and installation works, initiating the final stage of field-testing. Self-produced oxygen was consumed as usual in the aquaculture plant, with no unexpected effects at all.

<u>*Hydrogen and fuel cell*</u>

The electrolytic oxygen generator prototype uses electricity for extracting O_2 from water: the necessary by-product of this process is pure hydrogen. Hydrogen is a highly valuable resource for chemical industry, but its transport is problematic and only the onsite application is being tested here. The gas is being stored and then recycled for power generation, by the adaptation of two kinds of devices: internal combustion engine (ICE) and fuel cell (FC) technology. A conventional gasoline ICE system was modified to be fed in hydrogen only, and field-tested for energy recovery from hydrogen by produced. The more efficient, but less proven technology of fuel cells was also tested in the final application of emergency power generation: the main difference between these two technologies is the achievable electric efficiency: 15-20% for ICE generator and 35-50% or even more for fuel cell. Storage of the produced hydrogen was also an important point in the development, and two different storage technologies were deployed: the more usual pressurized storage, keeping the 15bar of the electrolyzer's output, and also the metal hydride technology, a "solid state" storage, which allows smaller volumes of the tanks. The safety analysis and preventive interventions carried out by ARIEMA in the facility were very significant tasks itself, as there is no tradition of combustible gases handed in this kind of industry. The complete system was tested onsite for six months; despite some minor repairing and improvements were needed, the overall experience points to a positive feasibility of the concept, only lacking from a longer testing period for ensuring long-term endurance.

Figure 2. AQUASEF electrolysis prototype

<u>*Advanced aeration*</u>

In the development of this task, apart from the normal setbacks of a project of this type, the biggest drawback was to adapt the equipment to the harsh conditions of the environment in which the equipment would operate. The culture media in which the diffusers are located are very different from those in the laboratory, especially regarding the high concentration of organic matter and its effect of deposition and alteration of the systems. Once the disadvantages were solved, the installed equipment has worked correctly and the marked objective of reducing the consumption of pure O_2 has been achieved and therefore, indirectly, contributing to making the production plant more sustainable while reducing its operating costs.

Figure 3. AQUASEF D&Btech diffusors

The company D&BTech is already working on the commercial aspect of these diffusers that have been welcomed with interest by the technicians of the sector in the networking events. The company is preparing a commercial plan to be implemented before the end of the year, which will have demonstration equipment that will be left in the aquaculture plants that request it in order to verify its effectiveness and efficiency.

Microalgae cultivation

Once we have overcome the initial problems in order to work fully in this activity, we believe that the final result obtained is very satisfactory. The plant will be able to stop buying the microalgae needed to grow fry in hatcheries and nurseries and will be able to enrich the culture medium of the fattening tanks with the algae produced in the open tanks specifically designed and built for the project. It is also noteworthy that a water heating system has been incorporated whose CO_2 emissions are used for the growth of microalgae. This last aspect also contributes to the sustainability of the facility.


Figure 4. Photobioreactors

Validation and quantification

AQUASEF was conceived as a mainly demonstrative project, so quantification and field-testing of all technologies and procedures were the central objective to fulfil. This chapter began with the systematic description of the initial state of the plant, measuring all involved magnitudes like energy sources, energy consumption, heating needs, oxygen intakes and other. These reference data have now been compared to those recorded after the interventions, providing reasonable estimations of the improvement made, and how extensible are they to other plants or geographic areas. The main indicators to quantify were: CO_2 emission, renewable energy generation, savings in electricity and fuel costs, and savings in oxygen purchase.

Dissemination

The performed AQUASEF's dissemination plan contributed to build up and increase networks capacities and raise awareness on the best use of innovative technologies which promote best environmental practices in the aquaculture sector. It was focused on researchers, on the aquaculture professional sector and also in general public, in order to raise awareness on the necessity of reducing the environmental impact related to productive activities and increasing mitigation strategies on climate change impact. The main website has been operative throughout almost the whole period, LIFE+ signalling and project graphic materials and news are shown in visible points in the aquaculture facility, and several paper materials were printed. Some of those materials were shown in those events where the AQUASEF Project was presented, including several of the most important summits for innovation, environment and aquaculture at national scope. When remarkable milestones were reached, press releases were generated for publication at AQUASEF's website and for broadcasting to specialized media.

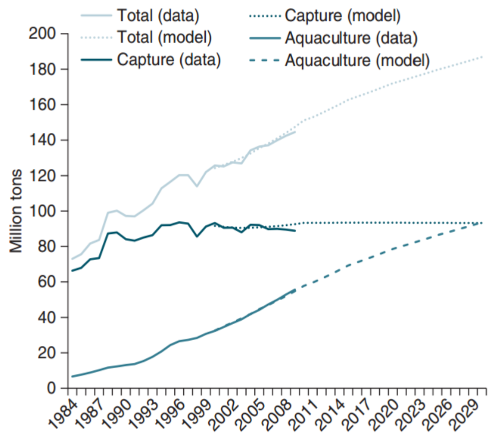
Financial status

The total costs incurred and declared by the end of the project by all project's partners are 1.899.318 €. This amount represents the 99,57% of the approved budget for the whole project, thus being well aligned with the project's overall level of implementation and duration. During the whole project implementation, the compliance of the costs incurred with those in the project's approved budget has been checked periodically.

ARIEMA, as project coordinator, has ensured that all partners have a clear understanding of the financial needs of the project, transmitting all the necessary information in the coordination meetings and keeping in touch with them by phone or email to clarify all the doubts that have arisen regarding the financial justification of the project. For the approval of the costs incurred, ARIEMA has developed the financial control of the activities by means of quarterly evaluating the expenses incurred by each partner and certifying their accuracy though the review of invoices and other supporting documents of all expenditures.

3. Introduction

Aquaculture has been the agro-industrial activity with the highest growth rate worldwide in the last four decades. From 1970 to 2008, the production of aquaculture organisms grew at a rate of 8.3% per year, compared to less than 2% of fisheries, and 2.9% of livestock. Despite the undeniable benefits of aquaculture, the activity is one of the most criticized worldwide, mainly because of the environmental impacts related: destruction of natural ecosystems; consumption of energy, water and raw materials; and eutrophication.



Sources: FishStat and IMPACT model projections.

Figure 5. Data and projections for different fish productions.

The essential role played nowadays by the aquatic products in the EU population's diet leads to a short-term need to increase the number of aquaculture facilities in Europe, which requires a strategic planning based on sustainability and minimization of the environmental impact. The project AQUASEF has aimed to be a leader in modern sustainable aquaculture, facing the growth expectations for this sector in the European Union and in the international scenario. The project intended to demonstrate, promote and disseminate low-carbon technologies and best practices for European aquaculture, including:

I. Energy production through renewable energy systems (solar photovoltaic and wind power turbine).
II. Oxygen production *in situ* through water electrolysis.
III. Achievement of efficient and low-cost aeration through micro-bubble technology.
IV. Use of self-produced hydrogen from the electrolysis process, to generate additional power.
V. Microalgae cultivation: valorisation of minerals in effluent waters and fixation of CO_2 from fuel combustion.

The actions developed within this project have been intended as a pilot phase, since oxygen, electricity and heat just partially cover the total needs of the plant. AQUASEF project achieved the following results: reduction of CO_2 emissions (about 35ton/year equivalent), direct and indirect energy savings (about 110MWh/year equivalent), renewable energy generation (about 65MWh/year), oxygen self-production (6.7 ton/year), demonstration of aeration techniques (80% reduction in oxygen consumption) and hydrogen and fuel cells technologies in aquaculture (validated 1500W UPS), improvement of the nutritional quality of fish and molluscs' diet with the contribution of microalgae, also used to improve the quality of the water effluent, and elaborating a communication plan, guides and explanatory panels, exchanging the information with other agents so the taken measures can be used in other aquaculture plants.

Often the obstacles for the implementation of new technologies are not related to the sector itself but to the lack of a regulation governing the use of these emerging technologies. This project has aimed to work hand by hand with public administration, to validate and regulate the use of technological innovations in the aquaculture sector. To manage this point, active collaborations have been engaged with the Spanish Technology Platform of Fisheries and Aquaculture (PTEPA) and the European Aquaculture Technology and Innovation Platform (EATIP), in which sectorial industry-science representatives and public administration at the national and the European level take part. Likewise, the transfer of the results, by the collaboration with the technology platforms, to other industries of the sector with similar characteristics will contribute to the replicability of the results obtained and the inclusion of the best technologies in low emissions used on this project in the European aquaculture plans.

4. Administrative part

4.1.Description of the management system

In order to ensure the proper execution of the tasks proposed in the project, both representatives of the aquaculture sector and experts on each of the technologies to be validated have participated as associated beneficiaries in AQUASEF. The project has been coordinated by ARIEMA Energía y Medioambiente S.L. The consortium has been composed by representatives from the energy sector ARIEMA, HELIOTRONICA and INOMA, representatives with Hydrodynamics background (Drops& Bubbles Tech) and Aquaculture sector (CTAQUA Technology centre with strong aquaculture R&D background) and Esteros de Canela, representative of aquaculture production and final user of the technologies. The management structure of the AQUASEF project has been the following:

a. Lead partner (coordinating beneficiary, CB)

Head of the overall project management. Interlocutor between the project partners and the managing authorities LIFE +, as well as with the European Commission. It has been also in charge of reporting the project status in a timely and appropriate manner to the European Commission. Leader: Maribel Rodríguez Olmo (ARIEMA)

b. Steering Committee (SC)

It has included a representative from each partner organization in the project. The strategic decisions of the project have been presented to the Steering Committee and have been approved by a majority when consensus was not possible. The Steering Committee was systematically and regularly abreast of the progress of the project and has decided on any unforeseen deviation. Members: Maribel Rodríguez and Rafael Luque (ARIEMA), Álvaro Lobo (Drops & Bubbles), Ángel Carro (Esteros de Canela), María del Mar Barrios and Juan Manuel García de Lomas Mier (CTAQUA) and Fco. Javier Leal Juárez and Manuel Domínguez (Heliotrónica Sistemas) and (INOMA).

c. Technical Management Group (TMG)

It has been formed by the leaders of the actions or work packages scheduled within the project. This group has been responsible for the daily monitoring of the progress of the actions proposed within each work package. It has been responsible for preparing the necessary progress reports to be presented at the meetings of the steering committee and coordinating the collection of the necessary information for drafting the official reports of the project.
Members: In this project, the Steering Committee and Technical Management Group have consisted in the same members that, consequently, have developed the functions corresponding to the two agents. The project coordinator also has taken part of the SC and the TMG to facilitate communication.

d. External Experts Panel (EEP)

The main function of this body has been to guarantee the transfer of the project results to the Member States comprising over 90% of total aquaculture production of the European Union (so preferably Spain, France, UK, Italy, Greece, Netherlands, Ireland, Germany or Denmark). They have enabled the adaptation and implementation of the proposed measures in other similar aquaculture facilities at a European level, and also have ensured that the project results have been provided in a friendly way for industrial use. AQUASEF EEP members have been: Mr. Pier Antonio Salvador (Associazione Piscicoltori Italiani, Italy), Mr. Pedro Pousão (Aquaculture Research Station, Portuguese Institute for the Ocean and Atmosphere, Portugal), Ms. Luz Arregui (National Association of continental aquaculture, Spain), Dr. Johan Verreth (Aquaculture and Fisheries group, Wageningen University, The Netherlands), Ms. Marina Argyrou (Ministry of Agriculture, Rural Development and Environment, Cyprus), Ms. Aurora de Blas (Ministry of Agriculture, Food and Environment, Spain) and Dr. Jason Cleaversmith (Scottish Aquaculture Innovation Centre, United Kingdom). These members have received quarterly updated information of the project and the have sent by mail comments about the evolution of the project and how to make more understandable the results. Besides, some of them have participated in the dissemination events organized by the project. For example, Mr. Pedro Pousão attended to the AQUASEF International seminar, as well as Mr. Gabriel Ocaña, representing the Spanish Ministry of Agriculture and Environment, and Mrs Aurora de Blas opened and made a speech at the first networking event held in the General Secretary of the Sea.

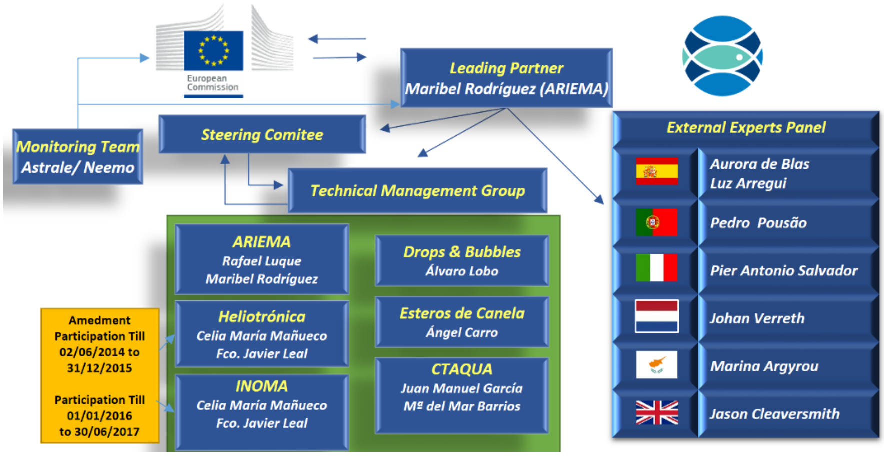


Figure 6. AQUASEF project Organigramme

4.1.1 Project management and developed coordination activities

Task E.1. Project management and coordination

This task, under the responsibility of the project coordinator: ARIEMA Energía y Medioambiente S.L., was started with no delays at the beginning of the project involving the following subtasks:

E.1.1. Decision on the management system for the proper project execution

Foreseen start date: June2014 Foreseen end date: June 2017
Actual start date: June 2014 Status: Finished

The choice of the project coordinator was ratified at the beginning of the project. The coordinator has performed its functions for AQUASEF full time, acting as the contact person of the European Commission and as an interlocutor between the project partners and the LIFE + authorities. The Steering Committee and the Technical Management Group were also appointed on time, which in this LIFE project consist of the same members, as specified previously. As members of both management bodies they have been responsible for being aware of the project progress and to make decisions about unexpected deviations, as well as of the preparation of the official progress reports.

It was decided to delay the external expert's panel appointment in order to reach the start-up of the equipment and prototypes installed, being able to show to this group of experts the procedures followed during the installation and system operation in a good working order. The first members of the External Experts Panel showed their interest and started participating informally from April 2015, after the initial consultation made in collaboration with EATIP and PTEPA. After that, several inquiries have been made in order to find new EEP participants, so the Memorandum of Understanding has not been formally signed until March 2016, when a significant number of representatives (6) has been reached. The EEP of the project has been regularly updated with AQUASEF progress for it to provide new inputs to the consortium about possible improvements, recommendations and also disseminate the project results within their respective countries.

E.1.2. Supervision on the technical coherence and project progress monitoring

Foreseen start date: June2014 Foreseen end date: June 2017
Actual start date: June 2014 Status: Finished

Since the beginning of LIFE AQUASEF, the project progress has been revised through a series of meetings between all project partners, two of these meetings with the attendance of a representative of the external monitor team in Spain. Since that date the partnership has met 11 times to revise the project progress.

All these meetings have facilitated the project development and the integration of the different technologies implemented by each consortium member.

Apart from the partnership meetings convened by the coordinating beneficiary, several visits to the installation have taken place in order to develop project tasks and monitor the project progress respecting the foreseen schedule.

Besides AQUASEF webpage have been an effective mechanism for a fluid work and rapid knowledge sharing between beneficiaries. Apart from AQUASEF website, as a communication tool, there has been a day-to-day contact between AQUASEF partners via telephone, e-mail or Skype. All administrative issues were solved by the CB taking into account the Common Provisions and the LIFE+ regulations. In case of doubt, enquiries were sent to the EMT before taking any decision. All communications to Neemo or the Commission were made through the CB.

E.1.3. Financial coordination and management

Foreseen start date: June 2014 Foreseen end date: June 2017
Actual start date: June 2014 Status: Finished

Action E.1.3 has been developed with no delays since the beginning of the project. ARIEMA has ensured that all partners had a clear understanding of the financial needs of the project, and has developed the financial control of the activities evaluating quarterly the expenses incurred by each partner and certifying their accuracy though the review of invoices and other supporting documents of expenditures. In terms of internal report, at the beginning of the project, it was decided that each partner should report every three months to the CB all the expenses and the required documents to justify the project expenses.

Description of changes due to amendments to the Grant Agreement: On February 2016, an amendment request was submitted to the European Commission with the purpose of incorporating a new partner in the project: INOMA RENOVABLES S.L., from IGFOTON Group, who, upon approval of the EC, has developed the technical tasks initially assigned to HELIOTRÓNICA SISTEMAS S.L.

4.2. Evaluation of the management system

Overall, the project partnership has communicated fluently. The managing work developed by the coordinating beneficiary has consisted in supervising the state of expenditures, monitoring the technical progress and reporting, and compiling information to justify project activities as done in the project Inception report (handed to the European Commission in March 2015), in the Midterm Report (handed to EC in March 2016) or in this Final report.

The technical delays (further specified), caused two management delays: The activity of the External Experts Panel and the organization of the Networking events. The remaining administrative issues have been developed as foreseen in the project proposal.

The communication with the European Commission and the External Monitoring team has been fluent and regular, especially with the External Monitoring team. Two previous reports were sent to the Commission (the IR and the MR) and three visits of the EMT to the project have taken place. The report and the visits obtained positive feedback from both the Commission and the Monitoring team as demonstrated by the assessment letters from the LIFE+ programme.

5. Technical part

5.1.Technical progress, per task

5.1.1 B.1. Demonstration of the energetic optimization possibilities and the use of renewable energy

Task B.1.1. Energy use optimization at the aquaculture plant by implementing best practices of energy use

Foreseen start date: June 2014 Foreseen end date: September 2014
Actual start date: June 2014 Actual end date: January 2015
Status: Finished

This task was developed according to the initial planning. The main objective of this task was doing the complete energy consumption analysis in the fish plant and elaborate a report with the proposal to get energy saving.

The works in this task B1.1, were developed during two months for measurements in EsterosCanela Plant, and after this data adquisition period, one month more was required for data storage analysis. The storaged information, gave us very good information about the energy consumption profile of the user in the plant, non-effiency uses of the energy and what were the main load and uses.

The measurements were done with a professional equipment situated in the main electrical box, inside the nursery and hatchery plant. These measurements were done in the correct point because there, all energy variables required to do the study could be recorded. These places are the points for the electric energy supply to the main loads in the nursery and hatchery aquaculture plant. The next pictures show the measurement points with the electric sensors installed to measure all variable required.

Figure 7. AQUASEF measurements B1

The instantaneous measurements taken during a global period, in two measurement points (nursery and hatchery) was:

- Phasor diagram of voltage, current and impedance
- Waveform voltage in all 3 phases
- Waveform intensity on the 3 phases
- Waveform of active power in 3 phases
- Voltage for the 3 phases expressed in% of rated voltage
- Current harmonics for 3 phases RMS expressed
- Impedance components per phase

From this basic data, we could calculate all energy values required to get results and conclusions included in the different documents developed and provided in the AQUASEF project. The main variables studied are active energy, power factor, electric incidences, flickers, total harmonic distortion (THD), for voltage and current, etc. This task of the project has given a very important information in order to analyse the quality of the electric signal and a complex detail of when the electric consumption is done. As example, the next figures give some obtained information:

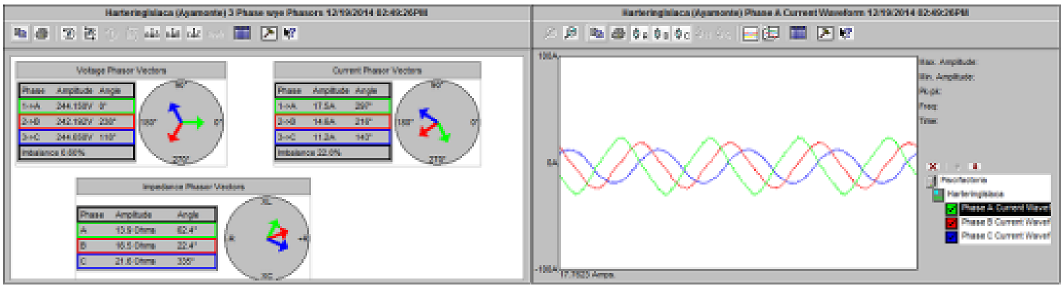


Figure 8. AQUASEF measurements.

The climatic condition of year 2014 was very exceptional, in the initial period planning in the project, because in a normal year the weather is colder, this means in a normal condition the energy consumption must be higher. The solution adopted was to wait a colder weather, as the expected in this period of the year, for measure the real maximum energy requirement in the aquaculture plant. While the cold weather came, the time was spent on preparing the definitive measurement protocol. This little delay didn’t cause any delay in the project because the study of energy consumption and good practice manual were done. This delay was not significant, and the task was developed according the project objectives.

In parallel with this work, and energy audit was required, to detect the correct use of the energy in the plant, the different load and its loses and uses, the inefficient loads, and the energy uses good practice by the plant staff. This last point was very important because different interviews with them were done for the redaction of the Good Practice Manual.

One important task was the energy invoice analysis to detect the energy consumption profile. We could detect a bad energy management in reference to the energy purchase and the energy consumption planning, really the maximum consumption was in the maximum energy price period, according Spanish electric tariff. The consumption that can be seen in the next pictures was done mainly in expensive period, and one of the recommendations was to adapt the pumping period every day to a cheaper period, if it is possible according with the tide.

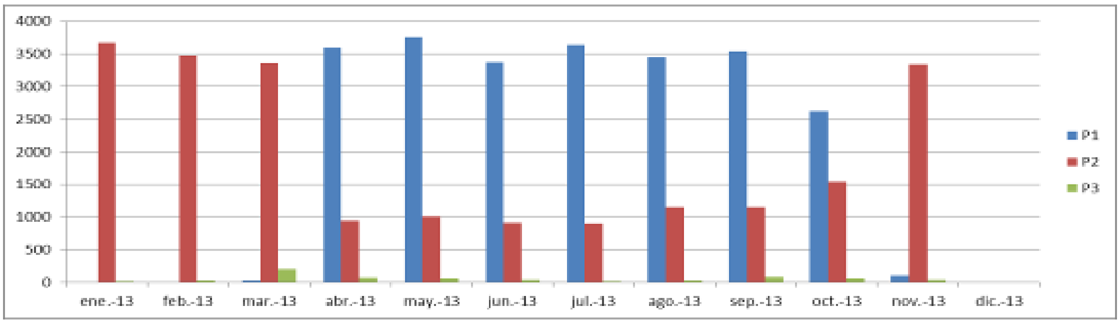


Table 1. Initial energy consumption profile among energy tariffs

In this final report we can show a summary of the conclusions:

1. It is recommended to change the power consumption daily profile. Thus, the maximum consume in the more expensive tariff period would be avoided.
2. The proper operation of equipment reactive power compensation must be checked, and the suitability for installation of the equipment installed should be assessed, especially in periods of low consumption.
3. It is recommended to adjust the energy peak demand to reduce the contracted power. It is noted that readings maximeter are well below 85% of the contracted power, accordingly to registered 50% or rather less power, thus 85% of the contracted are invoiced, when the real power registered is much less.
4. It is necessary to improve the general electrical maintenance significantly in high and low voltage.

5. It is highly recommended to look for a more efficient alternative solution, such as the contribution of solar thermal heat or heat pumps, to produce thermal energy for the different uses required in the plant, with no electricity.
6. It should be assessed the modification of the electrical system to have planned the use of generators with some of the great main pumps, to reduce possible points of power demand during peak periods, when the pump cannot be programmed in plain hours or valley.
7. It is highly recommended to install renewable energy to reduce the consumption from the grid. According to the natural resources available, photovoltaic and small wind electric can be installed for direct generation of electricity, such as solar energy for heat generation and reduce the intensive use of inefficient electrical resistances for heating the ponds.

Conclusions of Good Practice Manual.

1. In general a lack of maintenance on the equipment and facilities is denoted. It should be improved.
2. There are two known energy consumers highly relevant; on the one hand, the electrical resistors for regulating the water temperature in the tanks. This is an inefficient use of energy and should be changed.
3. Implementation of renewable energies will increase the sustainability of the plant.

These conclusions can be applied to all aquaculture sector; thus, this study and work will be a sure application to other companies and will give a good answer to improve the sustainability and reduction of gases emission in all aquaculture plants. The results of AQUASEF can be easily translated to other plants, letting the generalization of results of the project., and after the dissemination action, and the workshop done, other aquaculture plants of Spain and Portugal, have asked for the tested technology, and the apply on their own plants are under study. This is a demonstration of the benefits of the project AQUASEF and the high interest in the sector for the results.

Only we had a minor problem: we had to repeat some measurements, because the network analyser instrument was accidentally disconnected and for one week the data were lost. The solution was very simple: to repeat the measurements one more time in the same measurement point during the same period of time in order to sample the variable for study.

Task B1.2 Demonstration of renewable energy systems for consumption in aquaculture plants

In this task several technical works were developed, including design, calculation and computer simulation. For computing simulation, specific software for this kind of installations were used. All software simulator used are validated in the sector and in the international scientific community, because the results given for them have high accuracy, with very precise results.

During the process of installation of systems some problems appeared. These problems were solved with some delay respecting the initial schedule. The problems were related with civil works because some repairs were necessary in the building in order to install all parts of the renewable energy systems.

During this process, and in parallel, we were working on the protocol for getting the legalization of the installations, and adapting the electrical connections and administrative process to the new Spanish regulation published in the execution period of the AQUASEF project.

The main delay in the start of the installation was led by the long process to get the different licenses from administration, electric company, quality certifications after testing of all requirements of Spanish law (administrative, industrial and safety). The project started in 2014, and, after this kick-off, the main Spanish regulations about renewable energies changed totally, and the new administrative requirements were different. Here we show the main regulation and its changes. Of course, these changes produced other changes in all legal frame, but for us the most important legal changes were in the law referred below:

RD 900/2015, this law has changed different aspects, critical aspects, for our installations in AQUASEF. The first and main: the typology of grid connected self-consumption changed. This law is mandatory for new installations, installations under construction and all installations constructed and in operation, thus our installations needed to adapt the process and the measure point of energy production.

In our case the first point was to select the typology of self-consumption, so we had to wait to the decision of the owner of the plant. He needed the advising of his legal responsible, to know what consequences this new regulation could have. Of course, he needed some time for this. Once the option was selected, we begun a new protocol to adapt the administrative steps that had been already done, and to change the measurement point according to new mandatory regulations, because now two counters were required.

The administrative processes done according to new rules are:

- Industrial project of the installations. We had to do some changes in the project that were done before the new regulations, changing the counters, now two counters in different places were required, this change needed to adapt the project and to get a new conformity of the professional engineer college (more time to the administrative process).
- It was necessary to confirm the connection point to the grid, given by the electric company. The electric company needed to review the initial document required and validate the connection point, the new counter situation according the new regulation. This process required time before to get the permission for continuing with the process.
- All technical documents required a new low voltage certificate given by the official installer, to verify the correct execution of the installations according to the engineering project with the new modification required by the new regulation. This certificate was obtained after a period of time required to do the modification and the safety of the installations.
- When we could have this document, before connecting the installations, the Spanish industrial administration required the quality, safety and technical certificate by an Independent Certification Agency, called in Spain OCA. For obtaining this certificate, we needed different visits and inspections until verifying the quality of the installations. In our project, the Quality certification was obtained, but more time was necessary for this.
- When these certifications (Professional College of engineers, Low Voltage Certificate, Final Engineer Certificate, Quality Certificate by OCA) were obtained, we sent an official communication to the Spanish Regional Government asking for permission to connect the installation. After the period of official delivery, more time, this document was obtained. This document, called “Comunicación de Puesta en Funcionamiento” is required by the electrical company to sign the contract.
- According to the new regulation and the administrative rules approved in the RD 900/2015, chapter II, article 14, and next, we needed to sign a new contract among the owner of the aquaculture plant and the electric company. This step spent a great time to get the contract signed by both parts. This contract is called “Contrato para la entrega de la energía eléctrica producida a partir de fuentes de energía renovables”
- With the contract signed the Company installed the energy counter, according to the actual regulation. And finally a modification of the commercial contract with the dealer of electric energy was required, according: RD 1955/2000, Ley 24/2013 Sector Eléctrico, RD 1110/2007 Puntos de Medida, RD 1699/2011, RD 413/2014 Producción de electricidad con energías Renovables and RD 900/2015, condiciones administrativas,

Técnicas y económicas de las modalidades de suministro de energía eléctrica con autoconsumo y de producción con autoconsumo.

In conclusion, the changes of the basic regulations for renewable energy installations were the cause of the delay for a significant period. This delay was around 20 months, because we needed to finish the legal process and have a measurement period long enough for getting significant data for adequate conclusions and analysis.

This problem was solved by the extension of total period of measurement until the end of the project, thus we could get enough data, because this new measurement period extended did not affect any other task and partner of the project. We thought it was an opportunity for testing more time the different installations while we could do different tests in different real conditions. Our experience confirms that this decision was correct, because the period of data acquisition is more representative and was observed different performance of the installations with different point of exploitation of the plant with a high variability of the weather.

Now all systems are in full operation with very good results. Excepting little stops of wind power systems due to problems with the salinity in the generator, solved by the manufacturer. In the end, we can consider that these stops were irrelevant and the systems work properly.

In the pictures below, the systems installed can be seen:

1. Installation process



2. Installation, measurement and sensors, finalized.






After the end of the project we have verified the good results estimated with the Typical Meteorological Year (TMY), because the comparison between measured data (real data) and long-term data (TMY) give only small differences of energy production (around 5%).

Month	Solar Thermal [kWh]	Wind power [kWh]	Photovoltaic [kWh]	TOTAL [kWh]
January	*1.723*	*177*	*2.324*	*4.224*
February	*1.925*	*141*	*2.487*	*4.553*
March	*2.413*	*276*	*3.608*	*6.297*
April	*2.621*	*132*	*4.178*	*6.931*
May	*2.883*	*270*	*4.814*	*7.967*
June	*850*	*167*	*5.113*	*6.130*
July	*0*	*433*	*5.179*	*5.613*
August	*0*	*260*	*4.873*	*5.133*
September	*609*	*149*	*3.417*	*4.174*
October	*2.296*	*122*	*3.387*	*5.805*
November	*1.846*	*134*	*2.147*	*4.127*
December	*1.700*	*80*	*2.088*	*3.868*
TOTAL	***18.866***	***2.341***	***43.615***	***64.822***

Table 2. Renewable energy production obtained per month

INSTALLATION	Yearly Energy [kWh]	Power [kW]	Specific Energy [kWh/kW]
SOLAR THERMAL	*18.866*	*25,4*	***742,7***
WIND POWER	*2.341*	*5,5*	***425,7***
PHOTOVOLTAIC	*43.615*	*30,0*	***1.453,8***

Table 3. Yearly energy and power obtained

For results analysis in renewable energy is very important the seasonal energy production, in the next table the final obtained results can be seen:

Season	Solar Thermal [kWh]	Wind power [kWh]	Photovoltaic [kWh]	TOTAL [kWh]
Spring	*6.354*	*569*	*14.104*	*21.028*
Summer	*609*	*842*	*13.469*	*14.919*
Autumn	*5.841*	*336*	*7.622*	*13.799*
Winter	*6.062*	*594*	*8.419*	*15.075*
TOTAL	***18.866***	***2.341***	***43.615***	***64.822***

Table 4. Seasonal energy production

Finally, the difference between the real obtained data and theoretical simulations are very close, so we can consider the installations have a good performance, according to the design. In the next table the differences obtained can be seen:

Month	Solar Thermal difference [%]	WindPower difference [%]	Photovoltaic difference [%]	Global Difference [%]

Spring	*-21,02%*	*-40,07%*	*6,38%*	*-5,51%*
Summer	*-82,05% (*)*	*-5,99%*	*2,57%*	*-14,35%*
Autum	*42,62%*	*-58,00%*	*9,42%*	*16,33%*
Winter	*34,24%*	*-43,62%*	*5,09%*	*11,00%*
TOTAL	***-5,90%***	***-36,72%***	***5,43%***	***-0,45%***

Table 5. Difference between real production and theoretical simulations

(* in summer the very high temperatures produced the stop of the installation to prevent a very high temperature in the water fish tank)

Task B1.3 Demonstration of compact photovoltaic systems, "plug & play" for stand-alone application

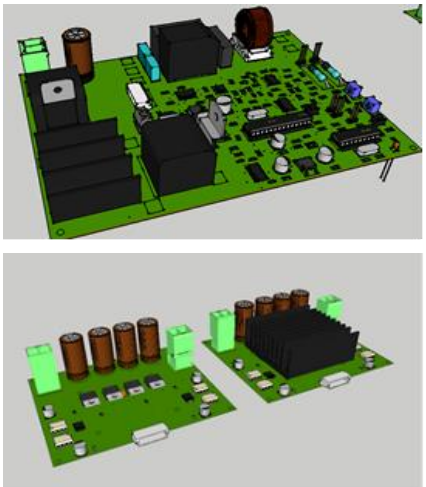


Figure 9: Mother board (top) and power board (bottom) computer simulation

The initial design began according to the schedule, last quarter of 2014, to continue with the design of the different versions along 2015, until getting the final design proposed, to build the definitive prototype to be tested in Esteros de Canela. During 2015, the design process let improve the performance and solve some technical problems. The laboratory test done have been included in the documents generated during the project execution. Three versions were developed. The strategy was to construct first by Protoboard technology the main electronic control of the system (Prototype 1) and the remaining parts were constructed in a simple PCB to test each one of them, and to solve the potential problems. After this, the Protoboard assembly was constructed in Through-hole technology as (Prototype 2, described below). In this process several technical problems were detected and it was required to spend more time than expected, but the delay was not a problem to the project because this task was independent from the others. The project could continue without major problems and the objectives were achieved according the project memory. The works in this task were developed and finished along 2016 and first semester of 2017. Finally, the computer design showed in figure 9, was constructed by subcontracting company. This initial design, called Plug&Play PV Compact prototype, Prototype 3, described below, let to get 150W with 12V battery.

After this prototype, we decided to increase the power, because we thought that it was more interesting for commercial success offering more power with a small increase of the costs. This decision required important changes in the design, for example, with this power it was necessary increase the voltage of the system until 24V. With this voltage, the current in the circuit would be smaller and, of course, less loses of energy will be produced.

The last version, called Prototype 4, described below, let to get 400W with 24V battery. As resume, the block diagram of the Plug&Play PV Compact System can be seen. This block diagram shows the battery charger, which include a microprocessor that works as described in Figure 10:

- If the battery voltage goes below a "battery low level" set point, the regulator plug the photovoltaic generator to the battery. When the battery voltage goes over a "battery charged level" set point, the regulator unplugs the photovoltaic generator.
- If the battery voltage goes below a "battery discharge level" set point, the regulator unplugs the output load from the battery to hold his life as long as possible.

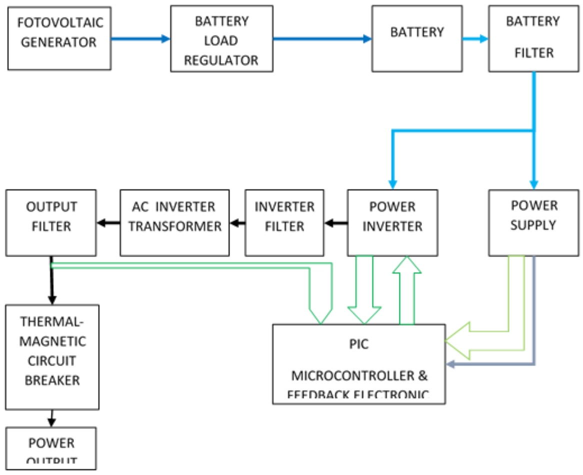


Figure 10: General scheme of the designed electronics.

This multifunction concept includes the inverter to use AC loads, the inverter works at 230 VAC and is integrated in the system, like the other functions. The inverter has power transistors, L filter, AC power transformer, LC output filter and a thermal-magnetic circuit breaker. The power supply has 5V for the microcontroller and 10 V for the operational amplifiers used for feedback signal and their multiplexer. More details were included in the midterm report.

The evolutions in the design and prototype can be resumed as follows:

Prototype 1. Protoboard (breadboard) technology. 12 V battery.
The first development has been mainly implemented by using Protoboard technology for creating a temporary prototype and experimenting with the designed circuit.

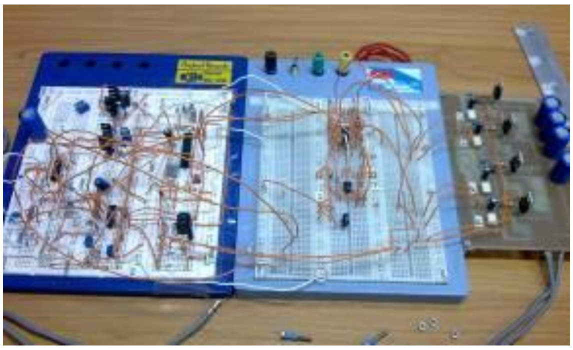


Figure 11. Protoboards fitted with components and inverter power transistors PCB.

Figure 12. Inverter Power Transistors PCB.

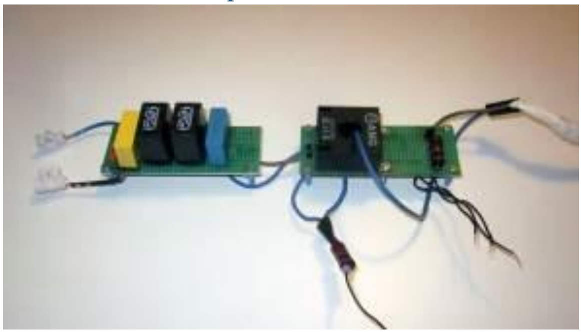


Figure 13. Output LC filter (left) and output feedback current transformer (right).

Figure 14. Battery charger PCB.

Prototype 2. Through-hole technology. 12 V battery.

For prevention of wiring connection failures, the second development was implemented by using the through-hole technology construction method.

Components with wire leads were fitted into holes on a designed printed circuit board (PCB) instead of use a stripboard or a perf board.

Figure 15. Full Inverter PCB. All components were integrated

Prototype 3. Surface-Mount Technology (SMT). 12 V battery.

To reduce dimensions and components cost, the third development has been implemented by using the Surface-Mount Technology (SMT). Components are Surface-Mount Devices (SMD) placed directly onto the surface of a new designed printed circuit board (PCB). Only components not suitable for surface mounting such as large transformers and heat-sinked power semiconductors have been placed with through whole technology or separately.

Actually, this development 3 was our first Plug & Play PV compact.

Figure 16. Inverter without Power transistors and Battery load regulator PCB.

Figure 17. Inverter Power Transistors PCB (SMT technology).

Figure 18. General vision of the first Plug & Play PV compact.

To grow the output power to 400 W, Prototype 4 has been carried out based on a 24 V battery, as told in previous paragraph.
Once tested in labs and field period, the first prototype based in 12V voltage level was finished. Different technical problems, especially about 400W of power, would be solved in the definitive prototype with 24 V voltage level.

Prototype 4. Surface-mount technology (SMT). 24 V battery.
To increase power output to 400 W, the fourth development has been carried out. Some components have been replaced to reach 24 V power supply and new ones have been added to allow a better control of power transistor gates. This development needed to design a new printed circuit board (PCB). So two printed circuit boards have been designed: The Motherboard and the Inverter Power board. The first one included the inverter control (microcontroller and all electronic circuits to feedback purpose) and the battery charger control (microcontroller, battery feedback voltage, relay). The second one is the power inverter itself. The next picture shows the final PCB:

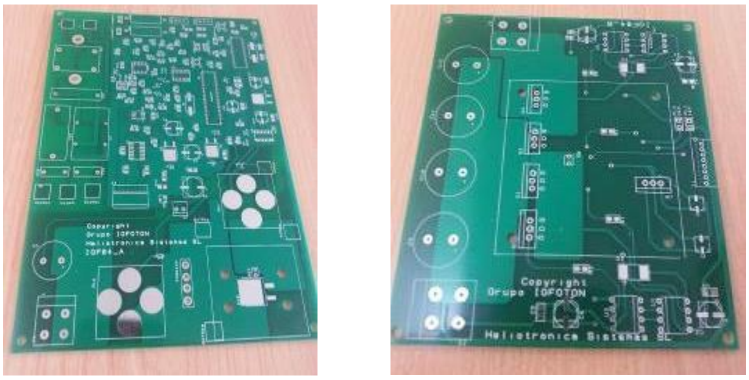


Figure 19. Prototype 4 Final PCB

Finally, during the period of field test, along 2016 and first semester of 2017, all units of plug & play were monitored, by the comparison between our designed system and other compact systems built with different commercial equipment, for testing the performance and the behaviour in aggressive conditions of salinity and humidity. We continue implementing changes in the compact from the experience in the LIFE project, one of the new goals is to develop and hybrid compact PV-Wind, after the workshop sessions was a new idea from potential user.

The behaviour of the systems has been good during the period of testing, during each visit the state of charge of the batteries, and the influence of salinity and humidity in the danger of corrosion was checked. Actually, the behaviour of compacts that were built with commercial devices (no compact) was good but they had some problems with high temperature. In comparison with our systems, these problems were less important. Our system can be built with special protection for very strong conditions of salinity and humidity; this is a good advantage in comparison with commercial equipment, with standard protection and with more high requirements to refrigeration of the electronic components.

Pictures bellow show some effects of the corrosion, no critical, because they only affect to battery connection, but the electronic circuit in our compact, with the second box and the quality of the PCB, appear after the period of testing, without corrosion damage.

Figure 20. Corrosion effect in batteries connection

The comparison was done with different commercial manufacturers, in the pictures we show some of them:

Figure 21. Comparison of the corrosion effect

During the test, the energy was used for lighting the outdoor installations of the aquaculture plant in Esteros Canela.

Task B1.4 Demonstration of the use of solar thermal systems to supply hot water for aquaculture

This task has finished according to schedule. The solar thermal system was designed, calculated and computer simulated. The solar thermal collectors were installed on the roof of Esteros de Canela, and the connection between solar thermal array and fish-tanks was finished. All administrative processes were successfully finished, and, during 2016 and 2017, real data were acquired, and analysed according to project planning.

The results have been better than expected. During the whole year, the solar thermal installation has been working properly without problems, avoiding the use of low efficiency electric resistances for heating water.

Figure 22. AQUASEF solar thermal installation

The main difference according to initial forecast was that, during the summer, the supply of thermal energy was not necessary, because the temperature of water in fish tank was higher than 20º C (set point). Then, the solar thermal installation was used for other function, which was energy dissipation during the night.

In our opinion, heating water for fish tanks is an excellent new application of solar thermal installation developed during this LIFE project, because the installation is quite simple, the costs are not very high and the amortization period shows that the solar thermal installation is a good investment.

B1 Action resume

		2014				2015				2016				2017			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Action B.1.	Proposed																
	Actual																
Task B.1.1	Proposed																
	Actual																
Task B.1.2.	Proposed																
	Actual																
Task B.1.3.	Proposed																
	Actual																
Task B.1.4	Proposed																
	Actual																

Table 6. Action B1 Progress summary

Tasks B.1.2, B.1.3. and B.1.4 have been extended till 2nd semester 2017 with the aim of analysing as much real data as possible in the AQUASEF project framework. This information, previously submitted to the EC at midterm report, was resubmitted again with further real data acquired, since with the initial planning the prototypes and equipment installed at Esteros de Canela did not have enough real data to proceed to statistical analysis. This analysis improve and precise the conclusions about how and when incorporate renewable energies into an aquaculture facility. The extension of this activity did not negatively affect to any other activity but it offers further useful information to adapt the prototypes/equipment set to Esteros de Canela weather conditions, to finally issuing accurate recommendations for suitable operation of renewables into an aquaculture plant.

Major problems

B1.1 No important problems and the task was finished totally

B1.2 The major problem was civil works in the buildings to install the renewable energy plants, and the new regulation that has been explained in detail, that required the adaptation of the system to the new laws, so new administrative works are required, but all these problems are solved, the installation is producing energy properly, and accurate data can be obtained.

B1.3 The major problems were technical difficulties to solve optimal design. These problems were solved in 2015 and the first prototype was built and tested. The final prototype has been tested according the updated schedule.

B1.4 No important problems, administrative process finished and installation is working properly. Accurate data have been obtained.

Perspectives

-Dissemination of results to apply to other aquaculture plants.

-The energy audit is an effective tool to get energy saving and incorporate good practice in the energy uses for all aquaculture sector.
-The Plug&Play PV compacts have a good future to be used in high salinity and humidity places, like marine aquaculture plants, with much more results than commercial inverters and regulator device. These can be a good commercial opportunity to sell these new systems.
-In general, AQUASEF has shown a new strategy to improve the competitiveness and sustainability in the aquaculture sector, by energy saving and CO_2 emission reduction.

5.1.2. B.2. Demonstration of the environmental benefits due to the use of fuel cells and hydrogen technologies in the aquaculture sector.

Foreseen start date: July 2014 Foreseen end date: June 2017
Actual start date: July 2014 Actual end date: June 2017

B.2.1 Demonstration of oxygen self-production systems

Foreseen start date: July 2014 Foreseen end date: October 2016
Actual start date: July 2014 Actual end date: December 2016
Status: Finished

In order to contribute to the sustainability of aquaculture activity, the AQUASEF project introduced the idea of self-generation of oxygen from renewable energy, saving operation costs in the gas itself, the delivery service and the renting of the needed equipment, while reducing associated emissions of transport. Oxygen can be produced by several ways, also analysed within the project, but water electrolysis was chosen because it generates an important by-product: hydrogen gas. This gas is considered the energy carrier for the future, and a break-even point is expected in the next decade, with hydrogen-powered vehicles becoming popular and renewable energy being massively stored in the form of hydrogen gas or compounds. Production, storage and use of hydrogen technologies will probably influence many commercial activities, and the experience acquired here may be crucial for the European aquaculture to start ahead.

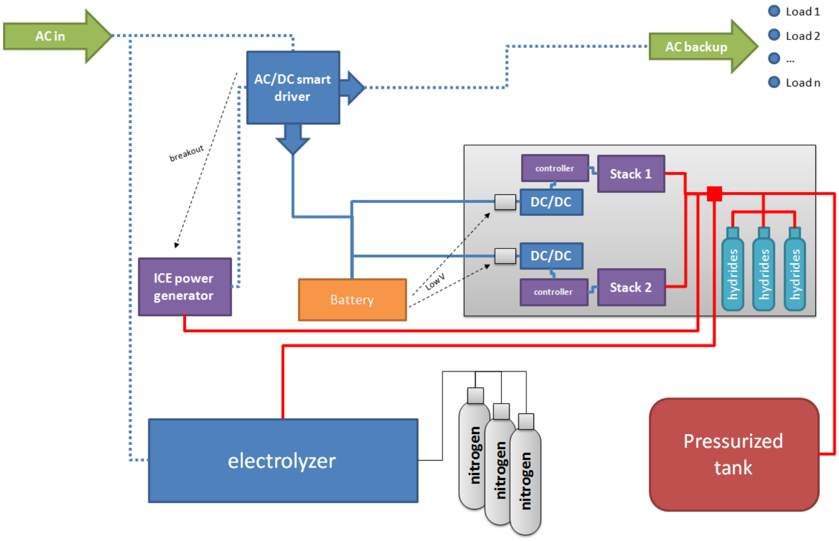


Figure 23. Conceptual scheme of the hydrogen/electric system in AQUASEF.
Several electric loads will be selected for being fed by the system in uninterruptible mode: from AC in regular condition (total: 3000W) and from hydrogen technology when selected or when AC supply fails (total: 1000W).

The main advantage of hydrogen technologies in aquaculture is the use of the self-generated oxygen for achieving enhanced aeration in some key areas of the breeding process. The equipment needed for this purpose must be both reliable and cost-effective, as stand-alone operation and good cost-efficiency will be features strictly demanded by aquaculture farmers.
Throughout the project, ARIEMA has developed the first electrolyzer unit to produce electrolytic oxygen for an aquaculture plant; at the same time, this device produces pressurized hydrogen, which is stored and then consumed for power generation in Esteros de Canela plant.

The manufacturing of the electrolysis prototype was problematic, with an unexpected change in the provider of some of the key components including the electrochemical reactor itself (stack); this was forced because the cease of activity of this company. However, the result was only some delay in the schedule and all activities have been undertaken successfully.

Testing procedures with Huelva University's Laboratory.

Before the final design of the electrolysis prototype was ready, ARIEMA's personnel conducted several tests on the electrolyzer located at the University of Huelva laboratories, mainly in order to set the initial performance parameters of a hydrogen-focused alkaline electrolyzer. The conducted tests comprised KOH traces assessment and control, settings' influence on quality, achievable efficiency and effect of overpressure in oxygen outlet.

Electrolysis prototype design, manufacturing, installation and testing.

The alkaline electrolysis fundamentals are well known and widely demonstrated over decades; however, the specific designing details over stack configuration, catalyst selection and preparation and control strategy, among others, are decisive points in which only experienced manufacturers have a full view and demonstrated criteria.
Design efforts were aimed at developing all the auxiliary components and methodology for the unit to be adapted to the aquaculture oxygen uses, and to comply with CE certification, and in particular with Pressure Equipment Directive 2014/68/EU, compulsory to comply for all the components inside the prototype. ARIEMA clearly defined specifications in the purification of each gas' (hydrogen and oxygen) stream production, and the prototype includes a special control block and a suited device to eliminate KOH traces both in hydrogen and oxygen streams.
Most of the design of piping were performed during the early stages of the project, but part of these tasks had to wait until the electrolyzer was completely assembled and installed in Ayamonte. When all equipment was ready in place, ARIEMA worked with a local engineering company (Logmax) to adapt the design and install the final layout of the piping system. Pressure tests and leak tests were conducted both in hydrogen and oxygen side in order to guarantee safety and performance of conductions.

Figure 24. Steps for the electrolysis prototype's activity: design and 3D drawing (top left), transport and installation (bottom left), final placement and testing (right).

After several months of testing and improvements, the main specifications of the electrolysis prototype are:

Oxygen production (nominal)	0,8574	kg/h
	0,6	Nm^3/h
Hydrogen production (nominal)	0,10788	kg/h
	1,2	Nm^3/h
Outlet pressure (max)	15	bar
Nominal power consumption (stack)	5,42	kW

Nominal power consumption (auxiliary)	1,6	kW
Nominal temperature (range)	60 (55-63)	ºC
Stack efficiency	81	%
Total efficiency	52	%

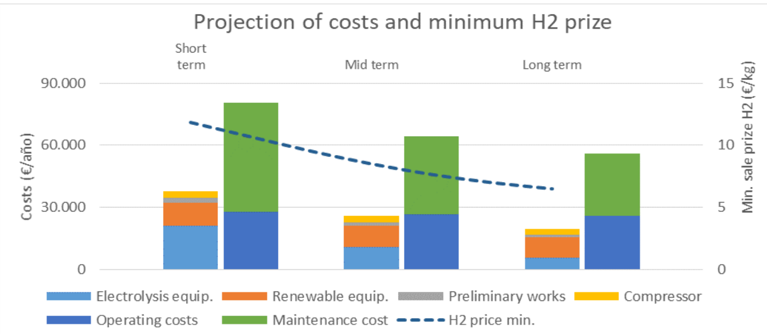
Table 7 Main specifications of the electrolysis prototype

Self-produced oxygen was consumed as usual in the aquaculture plant, with no unexpected effects at all. The pH influence of the oxygen stream was controlled periodically, and no significant changes were detected, most probably, because the natural pH buffer capacity of marine water prevents significant changes even in the small volume's samples tested. The final data about oxygen self-production were:

• Total oxygen production time: 1226 h (approx. 7 weeks). This generation did not occur continuously, but represents the combined amount of several periods. In any case, and given the high investment required in equipment, the field tests should be extended several years to ensure durability in a purely commercial deployment of these systems. Although this is impossible within the time frame of the AQUASEF Project, ARIEMA will continue to operate and collect data on this system.

• Total oxygen produced: 809 kg = 566 Nm^3. This amount of gas would be worth about 200€ at the final cost of the oxygen that Esteros de Canela paid before the intervention. Savings are expected to be significantly higher in the commercial phase, as these systems will have a much higher availability than that observed during the project, and in remote locations the price of the external supply may be much higher (production capacity would be above 6 ton/year in the commercial phase).

Technical alternatives for oxygen self-production, their synergies with other tested technologies and the cost analysis and future perspectives were studied. Importance of advanced aeration is analysed, other technical options of oxygen production are described and quantified in costs, and several scenarios of oxygen/hydrogen systems are analysed for the short, medium and long terms.



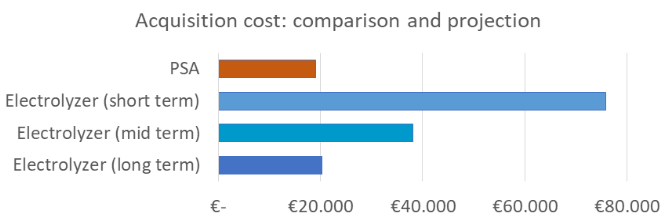


Figure 25. Costs' analysis of the improvements in AQUASEF

Cost breakdown analysis and projection for one of the analysed scenarios (top); investment cost and projections for electrolysis technology and PSA technology (bottom).

B.2.2 Hydrogen storage and use.

Foreseen start date: December 2014 Foreseen end date: June 2017
Actual start date: December 2014 Status: Finished

Apart from the electrolysis device, all other components have been installed and tested in Esteros de Canela's facilities, providing some valuable data for future improvements. A conventional ICE power generator was modified to be feed on hydrogen and tested, two fuel cell stacks were installed and tested for UPS purposes, and two types of hydrogen storage technology were used (pressurized tank and metal hydride tanks). In order to support in the selection and adaptation of all these components, some preliminary testing was performed using Huelva University's laboratories and equipment,

Testing procedures with Huelva University's Laboratories

After several months of works in the test bench of the University of Huelva (UHU), ARIEMA defined the scale of all prototypes for hydrogen storage as an energy carrier with the power and the limitations of the installation. These tests were a complete diagnosis in the University's test bench laboratory for energy storage. ARIEMA studied how to adapt every prototype for the specific field of the aquaculture and the specific salt corrosion conditions.

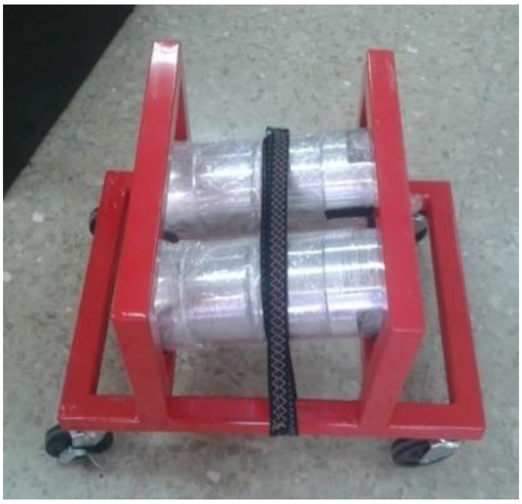


Figure 26. Hydrogen storage metal hydride cylinders for testing in UHU.

- **Hydrogen Storage in metal hydride**; ARIEMA studied and tested the correct absorption/desorption flow of hydrogen and heat/cool demands in different conditions, charging and discharging different metal hydrides mixtures and volumes.
- **Hydrogen Storage in low-pressure tanks**; ARIEMA's personnel assessed Huelva University facilities to help define some variables for the Project's equipment: pressure, dimensions, materials, protections against special conditions, etc.
- **Fuel cell test**; ARIEMA conducted or assessed different tests and studies to quantify the efficiency of different PEM stacks, life test, and the different balance of plant for a complete fuel cell system.
- **Combustion engine test**; ARIEMA tested the safety of the hydrogen modifications in a combustion engine. Moreover, ARIEMA made testing to analyse the different types of uses, consumptions and possibility of heat recovery from the exhaust gases.

Hydrogen storage

Hydrogen storage in AQUASEF Project includes two different technologies: medium pressure storage tank and metal hydride storage systems.

- **Medium pressure gas storage.** These technologies are the most commonly used for the storage of hydrogen. The main problem of this technology is its dependency on tailored-design tanks depending on the pressure (range between 10-50 bars); ARIEMA defined the correct size, volume and material of this tank. ARIEMA has worked with a manufacturer of LPG tanks, modifying with the provider a standard steel tank of LPG to use with hydrogen. The tank was manufactured and passed certification processes in order to comply with the Pressure and Equipment Directive, and was installed in the selected site in Esteros de Canela: on the roof of the breeding buildings, the best place for hydrogen safety concerns but close enough to all other prototypes to be operative.

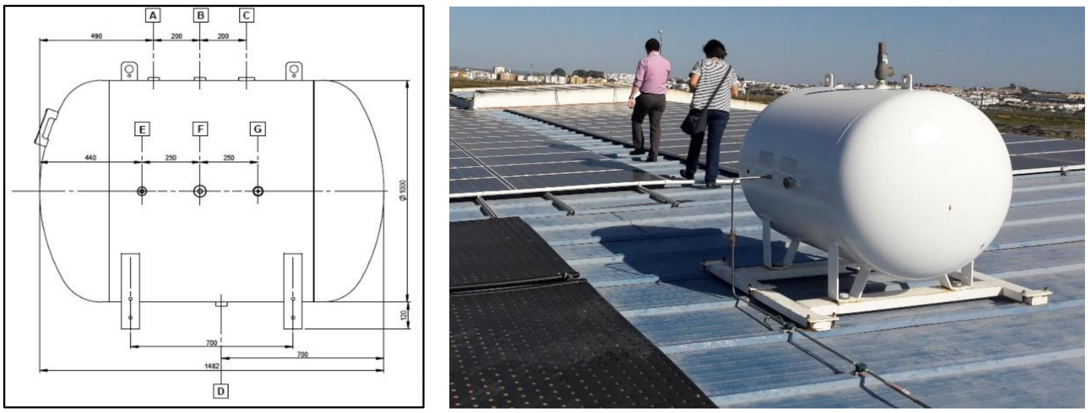


Figure 27. Hydrogen pressurized tank

The tank manufactured is a 1m^3 and 15bar-rated cylindrical design, thus able to store about 14h of production from the electrolysis system. Image extracted from the approved detailed drawings (left) and picture of final location and piping (right).

- **<u>Metal hydride</u>**. For this prototype, ARIEMA worked with Huelva University to calculate the different flow of hydrogen of each tank at different temperatures to adjust the number of units to our requirements of power to use in fuel cell. After preliminary tests and assessment performed, ARIEMA purchased three tanks of 500 litres' hydrogen capacity (1.500 litres in total). A fuel cell varies consumption of hydrogen at different power, and it is necessary to fit these requirements from the hydrogen storage. The rate of desorption in a metal hydride tank depends on the total exposed surface, and this is the reason why ARIEMA will use 3 different tanks to increase the total surface and reduce the requirements in heat/cold and can be used directly in the air.

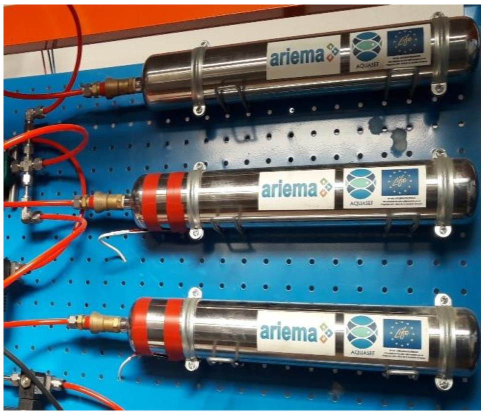


Figure 28. Metal hydride tanks

Three independent tanks were used to maximize exposed surface and facilitate heat exchanges with ambient air. They included Swagelok HLCQ03 female connectors, ideal for easy and quick connection/disconnection. Two of them were equipped with temperature probes to monitor its condition.

Metal hydride tanks degrade quicker than steel cylinders with cycling, so they are recommended to occasional use; in our case, they were intended to use only for UPS service.

Hydrogen fuelled power generator

Internal Combustion Engine (ICE) is a mature technology; in this point ARIEMA made modifications from commercial products of gasoline technology to burn only with hydrogen. Within AQUASEF, it was feed with the hydrogen locally produced by the water electrolysis prototype.

In this area ARIEMA's personnel has worked in the laboratory of the University to test the same model of engine in pure hydrogen mode, measuring the electrical power to measure the direct electrical efficiency and the response of start/stop, to calculate the feasibility and the alternatives of recovering heat from the exhaust gases.

With all data acquired from the university facility, ARIEMA developed full detail specifications for modifying a commercially available motor (Honda GX390) to work with hydrogen. Following ARIEMA's instructions, a company with expertise in modification of engines to LGP (Motorgas) adapted the engine to use hydrogen, and both entities conducted some testing in their factory with hydrogen bottles.

After these modifications, ARIEMA needed to develop all the necessary electronic devices to transform and/or manage the power from the hydrogen fuelled power generator and integrate it properly in the facilities of Esteros de Canela. Moreover, it was necessary to adapt and control hydrogen flow to the engine with some specific materials (pressure regulator, flow control device, etc.). When fully operative, the final testing was performed.

Figure 29. ICE Power generator during transformation works and in AQUASEF facility
The chosen engine is a very accessible Honda model (GX390). Preliminary works took place throughout 2015 and early 2016 (left), and then installation and field-testing (right).

Fuel cell system

Fuel cell technologies are the best option in efficiency and performance: these systems double the energy efficiency of a standard engine. However, these solutions still have limitations in lifespan, price and availability of products.

The first months of the project, ARIEMA worked in the main definition of the fuel cell and studied the possible integration of all required systems. ARIEMA's personnel made some analysis with the support of the Huelva University focused in the development of one unit of energy backup for AQUASEF project.

ARIEMA's personnel worked to define and design correctly all the stack sizes (number of cells and total active area), working in the logic program and development all the balance of plant of each unit. In particular, ARIEMA concluded to use 2 units of 1000 watts of rated power. This option complied our specifications requirements of 1500 watts and allows the possibility of developing a prototype of backup system with 2 units instead of one, one more step to ensure power supply.

The fuel cells were adapted to be used as backup system (UPS) to ensure critical needs in the plant. Our prototype developed all sub-systems from scratch, deciding a specific number of cells and active area of a stack to the development of all auxiliaries, logic program unit, electronic, batteries for start up the unit and power electronics to integrate in a common system.

ARIEMA decided to postpone this purchase because stack's internal components, mainly polymeric electrolyte and electro-catalysts, are highly sensible and are degraded even with no use. When all other components were almost ready, the stacks were ordered and integrated into the fully operative backup system.

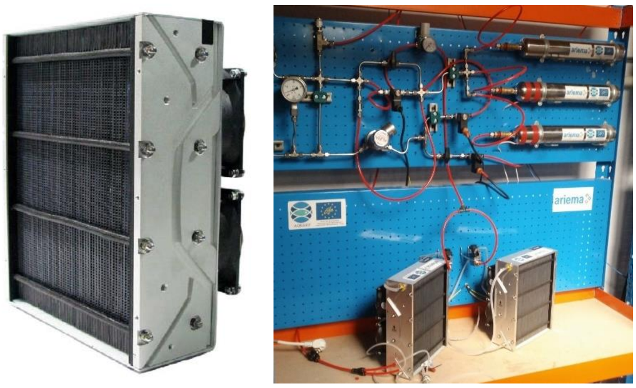


Figure 30. Fuel cell stacks in AQUASEF's system
Left: view of the selected fuel cell stack. Right: picture of the two stacks integrated in the final system.

Testing and results

Field-tests of oxygen production and equipment for generation, storage and use of hydrogen took place in the final phase of the project, between January and June 2017. Although the main equipment had already been individually tested at the factory, their interconnection and usage in the final location generated new uncertainties that made necessary some on-site testing. Tests included both normal operation and incidental events, such as power failure or emergency stop. Longer periods of testing are still needed in order to clarify systems' endurance in these ambient conditions, so testing is intended to continue beyond AQUASEF's timeframe. Still, data and experience derived from this demonstration project supports the technical viability of the oxygen/hydrogen implementation for these purposes.

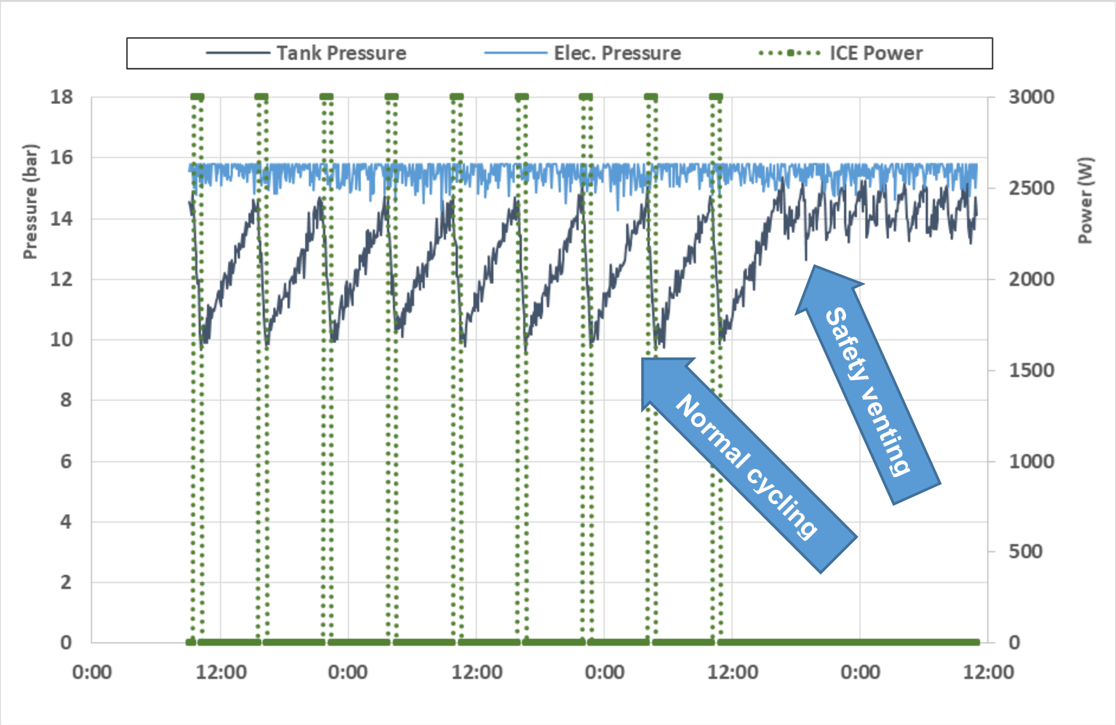


Figure 31. Field-testing of the hydrogen valorisation system

Data series of a three days' test between April 24th and 27th, simulating continuous and unattended operation. Two behaviours can be clearly distinguished in the chart: on the left, ICE generator starts every 5.5 hours, generating electric power and bringing down tank's pressure. In the third day, ICE generator was manually disconnected simulating its malfunction, and automatic venting of hydrogen prevents the system to trigger an emergency stop, thus allowing oxygen production to continue. The red line represents energy re-generated from hydrogen surplus, improving general energy efficiency.

Complementing on-site equipment development and testing, ARIEMA's personnel performed extensive efforts in order to help fish farmers to benefit from the findings and improvements proposed in AQUASEF Project.

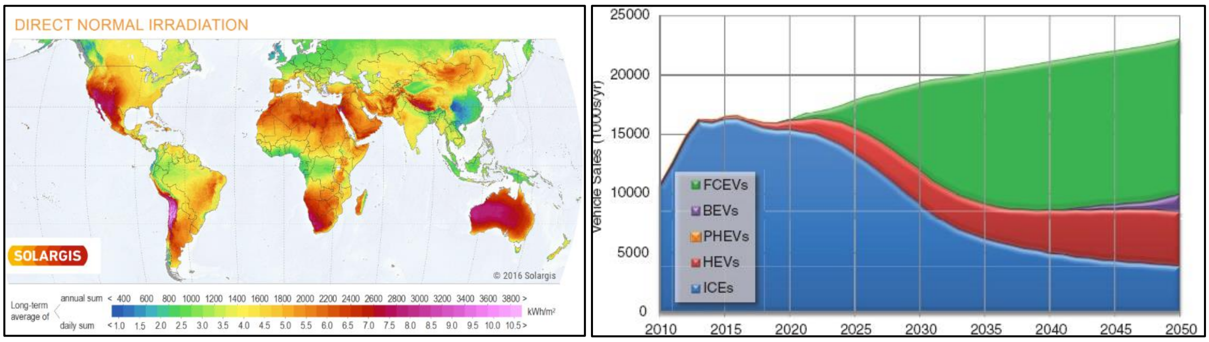


Figure 32. Technologies and perspectives' analysis
Solar irradiation World map (left) and projections about fuel cell electric vehicles (FCEV in green) (right).

B2 Action resume

		2014				2015				2016				2017			
		I	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**
Action B.2.	Proposed																
	Actual																
Task B.2.1	Proposed																
	Actual																
Task B.2.2.	Proposed																
	Actual																

Table 8. Action B2 Progress Summary

The electrolyzer prototype construction was the most difficult action of this Action, supposed the necessity of intensify ARIEMA´S effort to finish the activity on time. The electrolyzer was built and firstly tested before installed. The data acquisition in this period was not under the real conditions, (not into an aquaculture facility with the salinity and the humidity real conditions.

5.1.3. B.3. Demonstration of the best oxygenation techniques in culture tanks in salty water

Foreseen start date: July 2014 Foreseen end date: September 2016
Actual start date: July 2014 Status: Finished

The main objective of this activity was to check the functioning of two devices developed by Drops & Bubbles Technology (D&BTech) in order to save electric energy required for aearation in both the open ponds and the hatcheries/nurseries of the aquaculture facility.

During the first months of the project, the technical team of the company was mainly dedicated to design and build the first prototypes and later test them in the laboratory. Once the results were satisfactory, four devices were built with solid materials in order to install them in the Esteros de Canela factory: two were placed in an open pond raceway and the other two, for an inner smaller tank in the hatchery.

The final versions of the two aerators were named *O2BTech* for the open ponds and *MicroBTech* for the hatcheries/nurseries tanks. A short description of the two elements follows:

<u>O2Btech</u>

Using the principles of cross flow, air and water are pumped through special conducts and holes performed in a membrane with the final result of obtaining small bubbles with a remarkable reduction in energy consumption. The two aerators built for the project have 6 diffusers each. Two floats maintain the structure at the desired depth once put inside the pond.

<u>MicroBTech</u>

The technology applied to these devices is the same than that of the O2BTech. The only difference is that in this case there are no water and gas pumping. The gas is pure oxygen which flows in pressure from the storage tank. On the other hand, water flow comes taking advantage of a hydraulic jump from the pipeline layout.

Figure 33. Left: O2BTech with its 12 diffusers and two floats. Right: the MicroBTech being tested in the laboratory

Some technical problems had to be solved during the process until the aerators were successfully finished and ready for beginning the process of collecting data: sedimentation inside the pipes, clogging in the MicroBTech membrane (this issue was solved by introducing a valve with timer to expel periodically the solids out of the membrane holes) and floating balance.

The instruments required for studying the behaviour of the O2BTech and MicroBTech diffusers were flowmeters. Workers in the aquaculture company were asked to take note of the following data in order to compare our aeration instruments with those already operating in the facility: operating time every day, pure oxygen consumption for the existing aerators in similar ponds. Oxygen concentration in the ponds is obtained several times in the day because it is a critical point for the fish.

As a conclusion of the work carried out concerning this task:

The devices developed produce significant energy savings in terms of the generation of industrial oxygen to be supplied to the aquaculture facility. In the studied case of Esteros de Canela, we would go from 190.000 kg O_2/year to 9.000 kg/year, which means a saving of more than 75% (after including the fish-load changes observed in the same period). This reduction has a significant impact on the reduction of CO_2 emissions since a significant amount of energy is required to produce industrial O_2. About 0,65 kWh is required to produce 1 kg of O_2. Therefore, in the installation of Esteros de Canela, with the maximum fish load observed during the period considered, the indirect energy saving in the manufacture of oxygen would be above 90.000 kWh.

If we take an average figure of 20 ton of fish/year, the use of the devices would mean a decrease from 9,5 kg of O_2 per kg of fish to 2,35 kg of pure industrial O_2 per kg of fish. As for the energy consumption per kg of fish, we would pass from 6,1 kwh/kg of fish produced to 1,5 kwh/kg of fish.

B.3.1. Oxygen consumption study: volumes and seasonality

Foreseen start date: July 2014 Foreseen end date: July 2015
Actual start date: July 2014 Actual end date: September 2015
Status: Finished

The data to fulfil this task have been obtained using estimations of the oxygen consumption in the facility and the measures from the installed flowmeters and functioning hours, which were everyday written down by the personnel. Also measures of oxygen content of the water were collected in order to prepare the final report. All the measures had to be taken in the pond where the devices designed and built by D&BTech were placed: two of them in the open ponds and the other two in the hatcheries/nurseries facilities.

At this point it is worth mentioning the fact that Esteros de Canela is located in an especially warm area, with average temperatures during the day higher than 30º in the summer months. These conditions result in high oxygen consumption needed to maintain the necessary dissolution rates for growth of the fish in the fattening tanks.

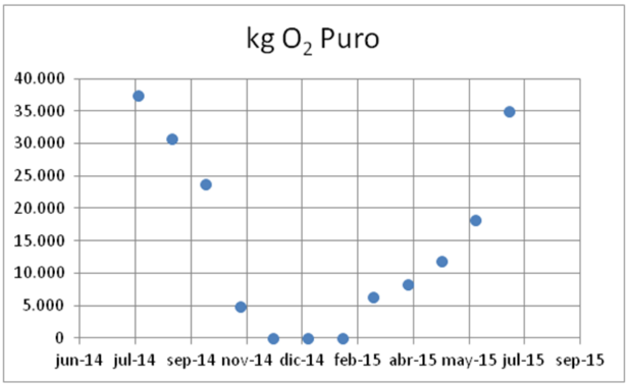


Figure 34. Oxygen consumption in Esteros de Canela

The seasonality of oxygen consumption is therefore verified: in the period of 6 months May-October, consumption represents 89% of the total consumption of the year, with special incidence in the 3 months of July/August/September: 58% of the annual total.

Since the completion of this task, the collection of oxygen concentration data, which it is a daily task performed several times in the plant, has continued by the operators as a work of their daily activities. This information has been shared with the technicians of D&BTech in order to corroborate the good behaviour of the diffusers installed in the project in relation to the load of fish that were in the fattening tanks and hatcheries/nurseries.

B.3.2. Installation of devices for oxygenation in tanks for fry cultivation

Foreseen start date: October 2014	Foreseen end date: September 2016
Actual start date: October 2014	Status: Finished

In the first months of work, the technical team assigned to the project worked on preparing the prototypes in the laboratory making computer designs (CAD) and then they were manufactured in numerical control machines to pass later to standardized transfer tests (SAE and SOTE). These test-error cycles were repeated until valid values were achieved in order to go to field testing.

The main objective was to achieve a small bubble size so that in the course of about 1 m up to the surface, it would completely dissolve and not be lost in the atmosphere upon reaching the surface. As mentioned, the device is based on a cross flow of gas and liquid. After testing the option of installing a pump to achieve water flow, it was considered best to take advantage of the inlet tap that is used for the renewal of the water of the tanks. By making a bypass, a portion of the flow was directed to the MicroBTech devices.

Figure 35. The MicroBtech in operation in one of the tanks inside the hatcheries

During the project, we had some problems with clogging inside de diffusers. These problems were solved installing a solenoid valve which periodically cuts oxygen supply and so allows the water flow to clean the solids or dirtiness accumulated in the holes zone of the membrane. The diffusers were operated by technical personnel of the plant, who also took daily readings of oxygen flow and operation time. When technicians from D&BTech visited the plant, the devices were temporarily disconnected and carefully examined in order to check possible damages in the structure; also, some tests were made with the EPDM (ethylene propylene diene terpolymer) membrane to ensure it maintained its main proprieties: flexibility, durability and the holes through which the oxygen flows were not clogged or had widen their size.

B.3.3. Installation of aerators for tanks used in fish growing ponds

Foreseen start date: July 2014	Foreseen end date: June 2016
Actual start date: July 2014	Status: Finished

The aeration devices developed for the open tanks devoted to fish fattening have the same technical principles as the MicroBTech for the hatcheries/nurseries: cross flow of air and liquid that passes through a membrane inflated by the gas under pressure. The difference is in the size, as a considerable amount of oxygen needs to be transferred into these tanks where the fish have high rates of respiration.

After exhaustive work and laboratory tests, a first prototype was installed in field. Once flotation problems and other technical issues with the required water and air pumps were corrected, it was put into continuous operation and began the gathering of information with the collaboration of the plant staff. When this first prototype was finally approved, another diffuser with the same characteristics was built to locate them both in the same fattening tank in order to achieve the objective of supplying the needs of oxygenation without the contribution of pure industrial oxygen or the aerators that were previously used in the aquaculture plant.

Later, there was a problem that had to be solved. In one of the routine checking, it was detected that the grid weighed too much and the floats were a bit more sunk. It was decided to put the grid out of the water and open it. Along the pipes were the pumped water circulates there was some 1 to 2 cm height of solids sedimentation. This caused a decrease in the efficiency of the aeration system. New calculations and CFD (Computational Fluid Dynamics) simulations had to be performed and when the best solution was achieved (some modifications in the structure), the aerators were repaired in situ. We expect no more solids deposition inside the pipes. In any case, this issue will be carefully checked in next inspections.

Figure 36. The second diffuser (definitive prototype) being placed in an open pond. Right: The same diffuser just before sinking to its final position. Bubbles already being generated

Another point that had to be modified was the rubber pipe that carries water from the pump to the diffuser. It was detected that the material was not able to resist the action of organic and inorganic materials in the pond. Now, a PVC yellow pipe has been purchased and installed.

The following image shows part of the tests of new materials under the conditions in which the aerators are installed: water with high organic load (fish waste) and living beings. The materials tested are PVC, ABS and high-density polyethylene. This is the device designed specifically for the test. It consists of an axial pump that supplies water with the same speed as the one that circulates in the aerator. The flow of water is passed through tubes of the different materials being tested.

When the two diffusers are in operation, the generation of bubbles allows an efficient transfer of oxygen, not being necessary the addition of pure oxygen except in the moments of maximum solar intensity.

Figure 37. Materials tested in the study for avoiding deposition and fouling on the pipes and pumps

B3 Action resume

		2014				2015				2016				2017			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Action 3	Proposed																
Task B.3.1.	Proposed																
Task B.3.2.	Proposed																
Task B.3.3.	Proposed																

Table 9. Action B3 Progress Summary

In the development of this action, apart from the normal setbacks of a project of this type, the biggest drawback was to adapt the equipment to the harsh conditions of the environment in which the equipment would operate. The culture media in which the diffusers are located are very different from those in the laboratory, especially regarding the high concentration of organic matter and its effect of deposition and alteration of the systems.

Once the disadvantages were solved, the installed equipment has worked correctly and the marked objective of reducing the consumption of pure O_2 has been achieved and therefore, indirectly, contributing to making the production plant more sustainable while reducing its operating costs.

Consumption of supplied pure O_2 has been 100 % in the fattening tanks (Esteros) and 50 % in the hatcheries and nurseries. The new developed diffusers have longer operational life and less maintenance costs.

In the company D&BTech we are already working on the commercial aspect of these diffusers that have been welcomed with interest by the technicians of the sector in the networking events.

The company is preparing a commercial plan to be implemented before the end of the year, which will have demonstration equipment that will be left in the aquaculture plants that request it in order to verify its effectiveness and efficiency.

5.1.4. B.4. Demonstration of the best techniques for the valorization of subproducts

Foreseen start date: June 2014	Foreseen end date: June 2017
Actual start date: January 2015	Status: Finished

The implementation in the field of this action was delayed in relation to the planning initially thought for two reasons:

- The need to do some unanticipated previous work on the CFD (Computational Fluid Dynamics) simulation of the tanks to be built in the aquaculture plant; the construction of a scale model to obtain data and correct the final geometry.
- A certain delay in the complete availability of personnel of the plant to collaborate in the important work of construction of the tanks as well as in the location of the equipment and starting to operate.

This delay was met with an intense and greater dedication to what was initially planned from the part of D&BTech personnel in the work of this action 4, especially in the last two quarters of 2016 and the first quarter of 2017.

The acquired experience in the mentioned previous activities before in-field works facilitated the quicker commission of both the open tank for algae cultivation and the photobiorreactors for closed algae cultivation.

We will now describe the main points of these previous activities:

- CFD (Computational Fluid Dynamics) simulation of the raceway in order to analyze flows, current lines, head losses, sedimentation zones. This study produced the best geometry to minimize head losses and consequently, energy requirements to maintain the desired speed of the water in its necessary movement for algae growing. The following image is an example of the outcomes that the simulation provides.
- Once the simulation was finished and the best configuration established, the next step was to choose the best impulsion system, able to move the water at the required speed but on the other hand with the minimum energy requirement as it is one of the objectives of the AQUASEF project. The two main options were a propeller and a modified and improved design of the traditional paddle-wheels system. The electrical motor for the first option had to rotate at low revolutions and it was difficult to find a standard machine with this characteristic and also the power given in the CFD simulation. After some hard work trying to find this motor with special characteristics, it was found in a supplier and two electrical motors modified for our purpose where bought.
- Finally, a scaled open tank was built. The main objective was to test the special canvas that would be used in the tank and also to check different ways of building the curved zone and the central wall which forms the two channels inside the raceway. Below, there is a picture of this "small" raceway, specially built for this project.

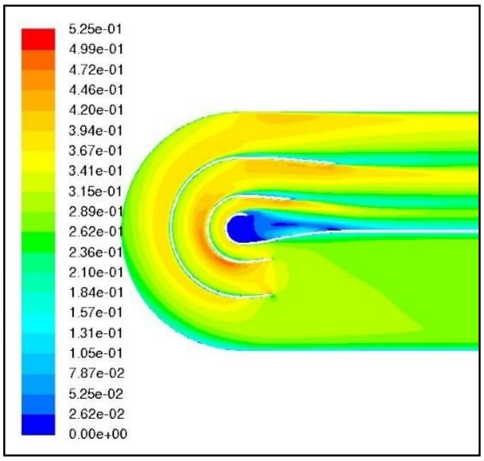


Figure 38. Detailed image of the flow in one of the curves at 20 cm depth. Colours represent variation in speed.

Once it has been explained the reasons for the delay and the work done previous to the "in situ" installation of equipment and building of the open tanks, we will describe in the next sections the Tasks associated to this A4 activity.

Figure 39. (top) One of the two electrical motors (Model AG 10 1,0M). (bottom) Open tanks for microalgae cultivation. Beginning of works. (right) Scaled pond built before the definitive one was ready in the plant.

B.4.1. Fixation of C02 emitted through the cultivation of microalgae

Foreseen start date: June 2014 Foreseen end date: III/2016
Actual start date: III/2015 Actual end date: II/2017
Status: Finished

The implementation in the field of this action was delayed in relation to the planning due to the reasons explained above in the introduction to this Action 4. In this report, we will focus on the description of field operations.

In the aquaculture plant the CO_2 emitted to the atmosphere comes from a propane gas boiler that is used to heat -by means of an exchanger- the water that supplies the hatcheries and nurseries.

- One of the objectives of the project is to prevent this CO_2 from entering the atmosphere. To achieve this objective, a system has been designed and installed with the purpose of conducting the CO_2 produced in the boiler to an open tank of microalgae culture where it will dissolve to contribute to improve productivity in the generation of microalgae in the tank. These microalgae will later be fed to the fattening tanks for the indirect enrichment of the environment in which are grown the fish in the farm: golden fish and sea bass. With the help of an engineering company specialized in energy issues, the most suitable equipment for water heating was chosen as well as the heat exchanger that best performed the required functions
- Subsequently, it had to be designed and calculated the collection system for the exhaust gas in order to address it to the external microalgae tank. The main handicap to overcome was the high temperature at which the gases emerge. The calculations had to be accurate so that the gas cooled sufficiently in its path until dissolved in the tank.
- Finally, the CO_2 had to be dissolved in the most efficient way in the tank. For this purpose, we worked on the design of diffusers that generated a bubble small enough to make it dissolve rapidly in its upward movement and thus avoid it going into the atmosphere. These diffusers employ a system similar to those of the MicroBTech and O2BTech devices but adapted to CO_2 instead of O_2 or air.
- CO_2 dissolved into the microalgae raceway depended on the necessities of heating water for hatcheries and nurseries and the limit of suitable pH in the tank in order not to damage microalgae.

Figure 40. Top: Gas boiler for heating water (CO_2 generator). Bottom: Part of the outer conduction of CO_2 in its path to the tank (cooling). Right: System of four diffusers in series for the dissolution of CO_2 in the open tank of microalgae

B.4.2. Optimization of microalgae complementary culture

Foreseen start date: III/ 2014 — Foreseen end date: III/2016
Actual start date: I/2016 — Actual end date: II/2017
Status: Finished

In addition to the cultivation of microalgae in open tank, the project includes a controlled culture under laboratory conditions in photobioreactors. The algae grown in this way are intended to feed the zooplankton necessary to feed the fish in the early stages of their development before moving on to open tanks for fattening.

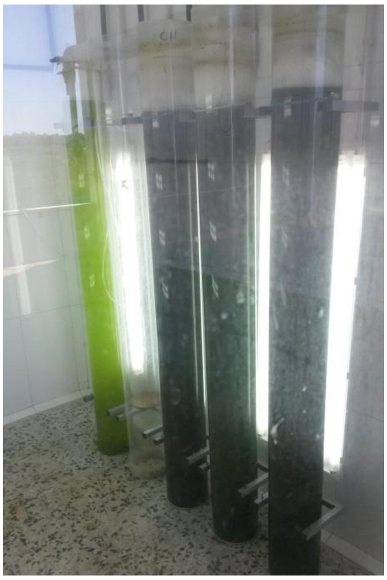


Figure 41. Set of photobioreactors used for the cultivation of Nannochloropsis gaditana.

The work carried out in this task consisted firstly in the advice of IBFV (Institute of Biochemistry and Plant Photosynthesis) of La Cartuja (Seville). The needs of the plant were first estimated and the way of starting the crops was determined. The initial inoculum selected was from *Nannochloropsis gaditana*, native algae from the area. The initial growth was done in the laboratory of the mentioned Institute. Once a content of 100 ml of culture was prepared, it was passed to the room of culture specially prepared under conditions of maximum cleaning in the aquaculture facilities.

With the instructions provided, the crop was expanded to an operative level that allowed to supply algae culture to the fish tanks for zooplankton feed.

In addition, D&BTech developed a device for the dissolution of CO_2/air by generating bubbles with the size of 100 microns. Comparing a bubbling with normal devices to the one used in the project, improvements in the growth rate of 20% were observed.

B.4.3. Evaluation of the improvements introduced by the integrated culture of microalgae

Foreseen start date: IV/ 2014	Foreseen end date: II/2017
Actual start date: IV/2015	Actual end date: II/2017
Status: Finished	

As previously mentioned in the introduction to this Action B4, prior to the in-situ construction of the two open raceway tanks, numerical simulations (CFD) were done as well as a scale model to determine the best geometry of the design to be developed. The goal was to minimize head losses and thus minimize the energy consumption of the agitators needed to make circulate the water around the central partition. Another aspect to highlight in the operation of the tanks is that related to the concentration of solids at two determined points (inside the curves with the form of a "?". This gathering of solids in a small area facilitates the maintenance work.

The tanks were completely covered with a waterproof canvas.

- The tanks also incorporate two agitators, specifically designed and ordered for this application. The previous simulations determined that it was more convenient in terms of energy saving the use of this system instead of the traditional "paddle-wheels".
- Finally, in order to improve tank productivity and achieve the objectives set out in the AQUASEF project, three new elements were added to the tank:
    - pH control system to activate the CO_2 input when the level exceeds a marked threshold level. The purpose of CO_2 is twofold: to maintain the appropriate pH level in the culture medium and to provide carbon for the growth of microalgae.

- System of CO2 diffusers described in the previous section. The objective is to achieve a very small bubble that does not damage microalgae while favouring the complete dissolution of the gas.
- New system developed specifically for the AQUASEF project with the help of numerical CFD simulation. It consists of elements with specific geometry that are introduced into the tank in certain positions to favour a light turbulence so that all algae are exposed to the same amount of solar radiation and therefore increase productivity (measured around 20%).

Figure 42. Installation of special plates to promote productivity in tanks

B4 Action resume

		2014				2015				2016				2017			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Action B.4	Proposed																
	Actual																
Task B.4.1	Proposed																
	Actual																
Task B.4.2	Proposed																
	Actual																
Task B.4.3	Proposed																
	Actual																

Table 10. Action B4 Progress Summary

Once we have overcome the initial problems in order to work fully in this activity, we believe that the final result obtained is very satisfactory. The plant will be able to stop buying the microalgae needed to grow fry in hatcheries and nurseries and will be able to enrich the culture medium of the fattening tanks with the algae produced in the open tanks specifically designed and built for the project.

It is also noteworthy that a water heating system has been incorporated whose CO_2 emissions are used for the growth of microalgae. This last aspect also contributes to the sustainability of the facility.

First, it must be explained that this B4 activity was delayed in terms of its field work (Esteros de Canela, Ayamonte-Huelva). The start was scheduled for March/14 and work began in situ in July/15. During these months, however, it is important to mention that we worked on a more in-depth knowledge of the processes as well as everything related to the construction of a pilot plant on a reduced scale to facilitate and improve the efficiency of the subsequent work in the facilities.

The delay was mainly due to two reasons: technical difficulties and availability of time on the part of the technical team that had to face the construction of the two open tanks (raceways), as well as the delay in the authorization by the administrative authorities for such construction.

Finally, all constructions and equipment were operational in June/16, which provided enough time for testing, modification and data collection.

- Between 400 and 500 liters per day of effluent from mollusk cultivation were poured for 2 months in the open tank of microalgae
- This effluent was an extra addition of N (6.2 mg / l) and P (0.2 mg / l) as a nutritive contribution to the microalgae, avoiding the spillage of the plant to the open sea
- During these two months and within the operation for the microalgae culture tank, 5.000 liters of microalgae culture were daily transferred to a fattening tank ("Estero")
- The effect of this microalgae spill was analyzed in this fattening tank compared to a control tank of the same size and stage of fish development for comparative purposes.

The most significant effect was the reduction of the N and P content in the water discharged to the sea (for refreshment with new water in the fattening tanks) by 40% and 55% respectively. No variation in the rate of development of the fish was detected

The main difficulties encountered were the need for maximum cleaning conditions for culture in the photobioreactors to avoid contamination, the design of the cooling circuit of the gases from the combustion of the boiler and the construction of the outdoor tanks by the difficulty in implementing the optimized design from Numerical Simulation (CFD) in the field (curves and blades).

The main conclusion is the verification that, as it was presented in the project proposal, it is viable for an aquaculture facility to generate its own microalgae, taking advantage of part of the flue gases and thus improving the quality of the cultivation medium of the fish that are being raised.

5.1.5. C.1. Project monitoring and evaluation

Foreseen start date: June 2014	Foreseen end date: June 2017
Actual start date: June 2014	Actual end date: June 2017
Status: Finished	

Action C.1., focused on monitoring and evaluation of the project LIFE AQUASEF started on time at the beginning of the project and has been developed appropriately along the whole project implementation period, until its end, in June 2017. This activity has consisted on establishing an adequate procedure to control and monitor the project execution, in which all the partners have taken part, under the coordination of ARIEMA that has supervised the whole project implementation as the project coordinator.

To ensure the compliance of the project objectives, and the timeline commitment, several visits to the project installation have been done by the project coordinator as well as by the technical actions responsible. This meetings and visits are much related with the activity E.1.2 “Supervision of technical coherence and control of project progress”, detailed later in this report, where partners and coordinator supervision meetings and visits are enlisted.

Additionally, according to the project proposal, apart from the project installation advances and timeline commitment, it has been crucial to check out the improvement of the environmental values related with the techniques developed. To this end, as a starting point, ARIEMA, with the support of the Spanish Technology Platform for Fisheries and Aquaculture (PTEPA), developed literature research regarding carbon footprint of other similar aquaculture plants, so comparisons between Esteros de Canela pre AQUASEF and post AQUASEF environmental impact could be made with other traditional aquaculture facilities. It is important to note that very few articles specifically related with carbon footprint calculation of land-aquaculture facilities were found, and none of them were applied explicitly to aquaculture in estuaries. Nevertheless, two interesting studies were useful to compare the Esteros de Canela carbon footprint that would be calculated later on:

- *Salmon aquaculture GHG Emissions. A preliminary comparison of land-based closed containment and open ocean net-pen aquaculture. Conservation Foundation's Save our Salmon Initiative* (Wright, 2011).
- *Huella de Carbono en la cadena de valor de la trucha de piscifactoría* (CTME, 2012)

Afterwards, a preliminary analysis of the energy balance of the plant was made, taking into account both the direct energy consumptions and the actions that indirectly consumed energy, such as the need and dependence on gas companies, measuring the total CO_2 emissions emitted by the aquaculture plant. Thus, for the calculation of Esteros de Canela facility emissions per volume of species production/year, the official methodology of the European Emissions Inventory was used, calculating the CO_2 balance basing on energy consumption, lighting, electricity, processes and transportation as far as possible.

The following facts were used for the calculation of the initial carbon footprint of Esteros de Canela (before AQUASEF technologies implementation, year 2014), and were used as annual monitoring indicators to check out the effectiveness of the project technologies:

- Electricity consumption costs/ fish production (€/kg/year)
- Gas consumption costs / fish production (€/kg/year)
- Diesel oil costs / fish production (€/kg/year)
- Fish feed costs/ fish production (€/kg/year)
- Oxygen consumption costs/ fish production (€/kg/year)

For every indicator, the emission fact could be calculated, basing on previous studies and using official CO_2 emissions calculators from the Spanish Government. It should be noted that the data obtained are not completely accurate due to two facts: the first is that there emissions linked to the treatment of waste, the facility suppliers trucks, or the transport of fish produced are not included, because it was impossible to access to this type of information; the second is because some of the data obtained were based on similar studies (such as the Skretting study for the feed factor emission factor), or in calculations of market prices that do not have to the exact value applicable to Esteros de Canela, but that have utility to make an approximation.

The Spanish Technological Platform for Fisheries and Aquaculture (PTEPA), after helping the project coordinator with the bibliographic research and to define the starting indicators system, has been informed about the monitoring measurements and evolution. Additionally, PTEPA has disseminated the results and promoted the involvement of the agents of the industry and public administrations, in order to favour the integration of the results generated in future action plans related to sustainable aquaculture.

This report was considered crucial as a starting point of AQUASEF project since the calculation of CO_2 emissions from different indicators in Esteros de Canela for year 2014 permitted to establish annual comparisons throughout the project implementation. Thus, according to the project proposal, the measurements made for year 2014 have been repeated annually throughout the project implementation period for the evaluation of the effectiveness of the new facilities in Esteros de Canela and, thereof, the project objectives compliance.

As a remarkable conclusion, it has been observed how direct and indirect CO_2 emissions have been reduced by around 35 t CO_2 equivalent / year when implementing the different techniques and technologies that were initially considered. Among the results obtained, it should be noted that the generation of renewable energy has resulted in a saving of 25 t CO_2 equivalent / year and the saving in commercial oxygen has been 20 t CO_2 equivalent / year.

As a complementary work related to this project monitoring and evaluation activity, in March 2016, ARIEMA was requested to summit data regarding the main focus of the project actions, as well as completing relevant awareness raisin, networking and economic indicators through an online interface created by the European Commission. This system was created to illustrate the performance of the LIFE Programme in the framework of the MidTerm evaluation of the LIFE Regulation 2014-2020, however, since all LIFE+ projects under this programme had started recently, all LIFE+ projects were requested to participate.

The obtained results have been used for the awareness, diffusion and implication of the productive sector and of the citizenship. In addition, the results have been published in a summary and modified version to a daily language, in order to involve citizens in the valuation of food products placed on the market that have been cultivated taking into account environmental values and respect for the environment.

C1 Action resume

		2014				2015				2016				2017			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Action C.1	Proposed																
	Actual																

Table 11. Action C1 Progress Summary

5.1.6. C.2. Evaluation of the socioeconomic impact of the project on the local economy

Foreseen start date: June 2014 Foreseen end date: June 2017
Actual start date: June 2014 Status: Finished

The C2 activity consisted of two specific tasks, the C2.1 activity concerning the actions of getting in touch and meetings with local administrations and the C2.2 activity for the drafting of a database and assessment surveys. All of this, aiming at writing socio-economic compilation report of all the information collected in this action.

For the implementation of this action, it was necessary to carry out an assessment of the strategic sectors involved, as well as of the entities involved within the social economy of the Autonomous Community of Andalusia. Previously, the State context and its link to the European policies was analysed.

The work was done focusing the efforts on two key points, on the one hand, the socio-economic impact of the sectors involved and, on the other hand, the impact of the project's actions. For both issues, the direct impact (concerning the aquaculture sector) and the indirect impact (associated to the renewable energies sector) have been differentiated.)

The methodology used to assess both types of different impacts are shown below:

A – Socio-economic impact of the sectors involved:

For the assessment of the socio-economic impact of the sectors involved, it has been differentiated between the direct impact, concerning the aquaculture sector, and the indirect impact associated to the renewable energies impact.

- ✓ **The direct impact**, being understood like that related to production (Gross Value Added – GVA) and the generated employment in that sector directly related to the project's actions.
- ✓ **The indirect impact**, which will be that associated to the production and employment created in the sectors supplying goods and services in the framework of the project.

B -Impact of the project's actions

✓ ***Direct impact: aquaculture sector***

For the assessment of the impact resulting from the actions set out by the project among the sectors involved (aquaculture and energies), the public administrations, the scientific community and the society in general, a direct contact has been established with all of these. Additionally, a follow-up has been carried out through throughout the project on the points of view of these population groups through several surveys and assessment surveys.

1. Direct contact with entities and facilities

As from the start, a database was drafted in which, the competent local administrations in the field of aquaculture production, energies, environment and employment were included, on the one hand. This database was used at the beginning, to launch a first contact campaign with public entities in order to introduce the project and its objectives to them. They were also informed that during the implementation of this project, their help would be required for processing permits, data collection or their participation in different workshops scheduled within the project.

The direct contact with different entities was supported by the reports collected during the implementation of the project, e.g. summaries, technical report or a methodological guide.

On the other hand, on the preliminary database, also information on the aquaculture facilities which were at the moment carrying out the aquaculture activity in Andalusia were included, those sharing features with the partner Esteros de Canela, in the installations of which the developments are being tested. A total 102 facilities were identified, representing the potential direct beneficiaries of the results of this project. The purpose of this database was to keep them informed on the progress of the project, as well as to invite them to participate in the different workshops.

The database drafted includes:
- Name of the establishment
- Details of the person in charge (name and surname, phone, fax and e-mail)
- Location (address, town and province)

2. Surveys carried out within the project

As already mentioned, other action taken to assess the impact of the project was the design of a socio-economic survey targeting the project's target public (aquaculture farmers, businessmen within the sector of low carbon and eco-efficient technologies), which was distributed during the first two years of the project in different trade shows, workshops and meetings in order to identify the degree of existing knowledge on the eco-efficient technologies in the aquaculture sector.

For the last year of the project, this survey was updated and distributed in different dissemination actions, mostly in different workshops, seminars and meetings.

At the final stage of the project, the last action carried out aimed at getting to know the consumers' opinion. For this purpose, a survey was designed and distributed on line through the social media profiles of the project (Facebook and Twitter), to reach a varied group of the population.

During the project implementation, a follow-up was carried out on the consumptions made in the aquaculture facility and the evolution these electric consumptions have recorded before, and during the project, and an estimate has been calculated for the three years after the project completion.

Issues encountered when developing this action:

The main disadvantage found for this action was, in principle, the collection of answers for the surveys, as they were sent via e-mail to the entities identified on the database. Having this into consideration, it was decided to distribute the surveys on the socio-economic impact assessment during the workshops carried out together with the satisfaction surveys. Being both of them collected at the end of the actions.

Another issue when implementing the tasks was to find employment data being directly related to the renewable energies sector. This issue could not be solved and no data of employment for this sector could be included.

Indicators of results:

- A total 90 surveys on the socio-economic impact were collected during the 5 events held (4 workshops and an international seminar), out of the 128 attendees to these events. This implies that 70 % of the attendees completed the survey on the socio-economic impact.
- The employment associated to the aquaculture sector has kept a rising trend for years 2013-2015, a reduction by -1,2 % being recorded for 2016.
- We have been informed that at least 3 companies have implemented or programmed to implement the renewable energies of the thermal solar type in their facilities, located in the province of Cadiz and Seville. Concerning the rest of the technologies, as they are in a lower maturity stage, some companies were interested in these, but provided that the production costs are reduced and they have a competitive price in the market.
- A total of 86 consumers' surveys were collected.

C2 Action resume

		2014				2015				2016				2017			
		I	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**
Action C.2	Proposed																
	Actual																
Task C.2.1.	Proposed																
	Actual																
Task C2.2.	Proposed																
	Actual																

Table 12. Action C2 Progress Summary

5.2. Dissemination actions

5.2.1 Objectives

The key aim of this activity was to disseminate the project where access to project outputs will be guaranteed by reaching the maximum beneficiaries as possible. The possibility of reproducing the measures performed within the project will be highlighted through the identification of stakeholders at a European level. For this purpose, communication, dissemination activities have been established throughout the project's operation with a special focus on transfer of results. The dissemination plan will contribute to build up and increase networks capacities and raise awareness on the best use for innovative technologies which promote best environmental practices in the aquaculture sector.

5.2.2 Dissemination: overview per activity

Foreseen start date: June 2014 Foreseen end date: June 2017
Actual start date: June 2014 Status: Finished

D.1.1. Creation of a Communication Plan

The subtask started at the beginning of the project (June 2014) involving the creation of a Communication Plan especially oriented to researchers, aquaculture professional sector and general public in order to raise awareness on the necessity of reducing the environmental impact related to productive activities and increasing mitigation strategies on climate change impact. LIFE Programme Manual was distributed among the consortium beneficiaries to ensure the compliance with LIFE Programme requirements regarding the use of LIFE logo on documents and durable goods.

D.1.2. Collaboration Platform. Website

The task started as planned with the release of the AQUASEF website: www.aquasef.com.

The web page has been periodically updated as it was set out since the beginning, including information on the progress of the project, with the most relevant news of the events to which we have attended and with updated pictures of the equipment developed. The website will be operating at least for 5 years after the termination of the project.

Figure 43. AQUAEF website: English version

The total number of visitors into the AQUASEF website during the project has been 30,334 visits being distributed by continents as shown in Figure 44.

Additionally, and in order to increase the dissemination impact, a Facebook profile for the project was created as a way to extend target groups and further develop the dissemination tasks of the project. The profile has been updated on a monthly basis. Also, the project had impact in other social networks such as twitter.

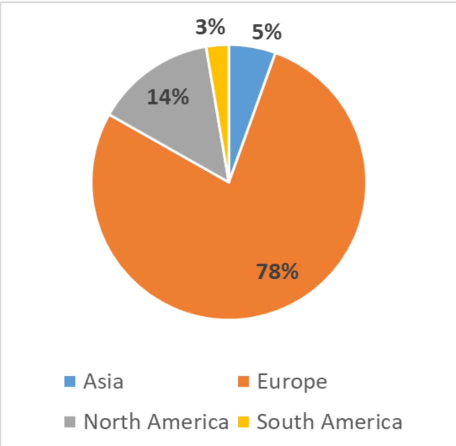


Figure 44. Visitors to the AQUASEF's website before Jun 30th, 2017.

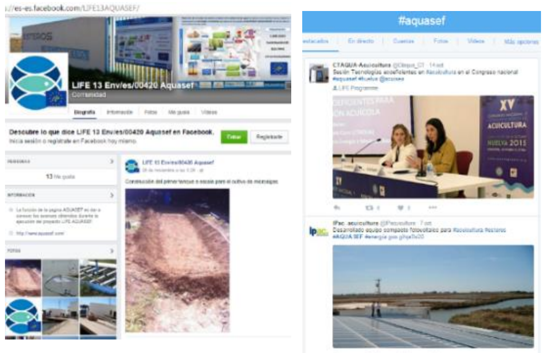


Figure 45. AQUASEF in Facebook and twitter

No delays have been encountered in this task according to the initial timeline.

D.1.3 Monitoring Plan

During the first months of the project, different dissemination actions were carried out:

a) Placement of notice board in Esteros de Canela's Site Front access
b) Erection of notice board inside the site to inform employees and visitors in the progresses of the project. All project partners are sending contributions to maintain updated this information point.

Fig. 46. External Notice Board (left) and Internal Notice Board (right)

In the project proposal, it was stated the update of information on a quarterly basis. Nonetheless, as the project progressed it was decided to change the periodicity twice a year in order to ensure enough useful information is disseminated.

In addition, an initial briefing on the project was sent to seven Local and National Authorities, of which one did reply with the intention of internally disseminate the goals of the project as an innovative pilot demonstration of eco-efficiency (cf. below, IDAE). The remaining six submissions were read but not replied. Nonetheless, Ctaqua has kept informing these authorities on the progress of AQUASEF on a quarterly basis. The aim of this exchange is to disseminate the main goals and achievements tackled by AQUASEF project and its website. The Authorities mailing list comprises: Huelva's provincial deputy for Agriculture and Fisheries; Cadiz's provincial deputy for Agriculture and Fisheries; Almeria's provincial deputy for Agriculture and Fisheries; Malaga's provincial deputy for Agriculture and Fisheries; Regional Ministry of Agriculture and Fisheries (central services); Andalusian Agency of Energy; Spanish Institute for Energy Diversification and Saving (IDAE).

No delays have been encountered in this task according to the initial timeline.

D.1.4 Design and edition of informative materials.

Observing LIFE Programme publicity criteria, the design of a project identity was carried out in the first months with an AQUASEF overview poster and informative leaflets in Spanish and English. During the second project's annuity, a variety of designs for additional dissemination materials have been undertaken, such us folders, project dossiers, USB memories, recycled-sourced notebooks, pens, and also a corporate video. Everything is available in the project website in the following link.

No delays have been encountered in this task according to the initial timeline.

D.1.5 Workshops.

This is the only dissemination task presenting a start delay of six months after the date indicated in the reviewed project as commented in the inception report. However, as foreseen in the project proposal 4 workshops have been organised by AQUASEF project: the first one was held in Madrid (May 2015), in collaboration with aquaculture working group of PTEPA; the second took place in Huelva (October 2015) at the XV National Congress and I Iberian Congress of Aquaculture and the third and fourth workshops (November 2016 and June 2017 respectively) were both organised in a very innovative way: A DEMO-LAB was held in the premises of Esteros de Canela, so that the attendees could personally see the equipment working and ask the technical staff in charge of its development any necessary question.

Figure 47. Visitors during AQUASEF III Workshop

D.1.6 Publication of press notes. Presentation of results in Scientific Publications and specialized media.

During the implementation of the project, a total of 5 press releases have been published obtaining great repercussion at national and international levels and three short notes reaching a great number of visits to the website. The publishing of all these press releases resulted in the participation of some of the project's partners in TV and radio shows.
According to the communication plan, four breakfasts with the press have been organised. These working breakfasts were planned since the beginning of the project; however, they were delayed in time as the most appealing information for the media was generated from the second half of the project (2016-2017). The four working breakfasts were held during this second.

D.1.7 Participation in Regional Fairs, Congress and Seminars.

The activity included the participation in a range of specialized events, to disseminate the outputs of the project. Apart from the events organised by the project partners, AQUASEF LIFE Project was presented in 14 relevant events to date, both national and international.

Figure 48. AQUASEF presentation in WHEC 2016

D.1.8 Layman Report

As it was scheduled for the project, within the final implementation stage, once the technical activities are completed, a Layman report has been completed in which the objectives, the methodology, the results obtained and the conclusions were included, showing the lessons learnt through the implementation of the project.

This task was started at the beginning of 2017, making an exhaustive study of the previous and similar reports from other LIFE projects. After evaluating more than 50 documents, a structure was decided including an introduction to the project; a brief explanation about how to implement AQUASEF efficient technologies and which circumstances should be taken into account in order to select the best combination of them. During second and third trimesters, it was completed with contributions from all partners. The Layman's report is available in two languages: Spanish and English. In this way, we allow a worldwide distribution of it enforcing the local distribution to the general public. The Layman's is available in the web of the project http://www.aquasef.com/index.php/es/documentos.

D.1.9 Practical Implementation Guide of New Technologies

A practical implementation guide on the new technologies developed and validated in the framework of the project has been drafted. Its goal was to compile in a document all the relevant implementation information on the technologies, so that the potential users of these technologies in the future may carry out this implementation in an easy way. Also for them to know the sufficient information in order to take the first steps for the implementation of these technologies.

The implementation guide is available in the following link.

D.1.10 International Seminar

Figure 49. AQUASEF International Seminar

This event took place on May 10th at the premises of CTAQUA. The goal of the seminar was to set up a forum for exchanging knowledge on energy efficiency in aquaculture installations, informing on the results of the most relevant R&D&I projects on this matter carried out all over the world. During this event, the most relevant results of the LIFE AQUASEF project were disseminated by the project's partners. These presented their conclusions during a round table: a debate originated on the actual usefulness of the developed devices in the framework of the project for aquaculture companies. The real interest was focused on the real costs to be assumed by companies for implementing these new technologies and whether this investment could be paid off in a short period of time.

Fig. 50. LIFE+ 25th anniversary logo

Since the last year of AQUASEF project coincided with the 25th anniversary of the LIFE+ Programme, the project events celebrated during the month of May and June (II Networking, IV Workshop and International Seminar) disseminated the anniversary, as requested by the EC, to communicate to stakeholders, local community and media about their work and to raise awareness of the considerable achievements of the EU nature legislation and the LIFE Programme in protecting our nature. All these events were published in the website http://life-25.eu/25th-anniversary/ and the materials given to disseminate the events were included in the programmes, events images and presentations.

D1 Action resume

		2014				2015				2016				2017			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Action D.1.	Proposed																
	Actual																
Task D.1.1.	Proposed																
	Actual																
Task D.1.2.	Proposed																
	Actual																
Task D.1.3.	Proposed																
	Actual																
Task D.1.4.	Proposed																
	Actual																
Task D.1.5.	Proposed																
	Actual																
Task D.1.6.	Proposed																
	Actual																
Task D.1.7.	Proposed																
	Actual																

Task D.1.8.	Proposed																
	Actual																
Task D.1.9.	Proposed																
	Actual																
Task D.1.10.	Proposed																
	Actual																

Table 13. Action D1 Progress Summary

Task E.2. Networking

Foreseen start date: June 2015 Foreseen end date: June 2017
Actual start date: March 2015 Status: Finished

Two networking events have been held as planned in the initial AQUASEF activities description. The Networking activity is framed within Action E2. It is important to note that the first networking event was postponed in order to include in the presentation of the project information about the prototypes and the equipment installed at Esteros de Canela. Thus, the first event took place at the facilities of General Secretary of the sea, at 18 May 2016 and the second one at 25 April 2017 at the facilities of the Economy and competitiveness Ministry.

The present action is based on networking with other projects through information exchange activities with its responsible technicians.

To this end, the AQUASEF consortium has been in contact with more than100 similar projects. The most relevant projects, which have cooperated with AQUASEF are 46 and their names have been linked to the website to "other projects". Some of them are **CO_2ALGAEFIX**

INDUFOOD, RHM Pilot Plant, ROEM-plus, INDEMARES , ALGAE-GHG, LIFE+ TL-BIOFER -

LIFE SEACAN, LIFE ENVIPHAGE, LIFE Saramugo- LIFE LimnoPirineus , LIFE CIPRÍBER - LIFE MIGRATOEBRE -

In addition, in order to carry out all the networking tasks, a distribution list of the project managers with the contact data has been developed and the possible synergies with them have been identified.

Once the existing synergies and the contact list of these projects have been identified, these representatives have been invited to two networking meetings held by the AQUASEF project, one focused on technologies applicable to the aquaculture sector and another focused on clean energies.

The Ministry of Economy, Industry and Competitiveness and the Ministry of Agriculture, Food Fisheries and the Environment, a member of the Panel of External Experts of the project, have hosted these conferences, facilitating the dissemination. In addition, we have had the collaboration of Spanish Technology Platforms linked to the themes of the participating projects, with the aim of achieving maximum reach. Among them, the collaboration of the Spanish Technology Platform for Fisheries and Aquaculture, active collaborator of the AQUASEF consortium, and key element for the dissemination of project events, as well as their progress, to potential stakeholders and end users of the fishing and aquaculture sector.

Both days of Networking promoted by AQUASEF have followed the following scheme:

- Presentation of the LIFE AQUASEF project.
- Presentation of related projects
- Space to enhance the collaboration between the projects presented and those attending those conferences
- Round table and round of questions
- Presentation of the main conclusions and results of the project.

As in all the events promoted by the consortium, and in compliance with the common provisions of the LIFE program, information material has been prepared and distributed with the corresponding information of the call, the support of the European Commission, as well as of the own draft. These materials include programs, notebooks, brochures and brochures, pens and USB flash drives designed specifically for the AQUASEF project, as well as materials for event rooms such as posters, posters, and roll ups.

Task E.3. After LIFE communication Plan

Foreseen start date: April 2017	Foreseen end date: June 2017
Actual start date: April 2017	Status: Finished

The implemented and foreseen dissemination activities after the project have been defined during this action. This action started on April 2017 and has finished on June 2017. During this period of time a dissemination strategy was designed to facilitate the replicability of the AQUASEF initiative and to enhance the use of more efficient technologies among aquaculture sector.

This document is generated in English and Spanish, in order to facilitate the dissemination of the information and to boost the possible replication of the AQUASEF initiative. The document can be found in the following link of AQUASEF website.

Five main activities are included in this communication plan:

- The strong commitment of the AQUASEF consortium to maintain the AQUASEF web site
- The current domain www.aquasef.com will continue available until 2022.
- The technical document development with the description of the technology characterization the prices, and the manual of implementation.
- The maximization of project results knowledge that will facilitate replication through the organization and participation into some sectoral events. Like Genera 2015, WHEC 2016, or EHEC 2018 (after the project deadline)
- The international dissemination of the AQUASEF initiative and the project results.

And not only to aquaculture sector stakeholders but also to general public by using videos like the Final AQUASEF project Video link.

5.3. Evaluation of Project Implementation

AQUASEF project has aimed to be a leader in modern sustainable aquaculture, facing the growth expectations for this sector in the European Union and in the international scenario. The project intended to demonstrate, promote and disseminate low-carbon technologies and best practices for European aquaculture, including:

VI. Energy production through renewable energy systems (solar photovoltaic and wind power turbine).
VII. Oxygen production *in situ* through water electrolysis.
VIII. Achievement of efficient and low-cost aeration through micro-bubble technology.
IX. Use of self-produced hydrogen from the electrolysis process, to generate additional power.
X. Microalgae cultivation: valorisation of minerals in effluent waters and fixation of CO_2 from fuel combustion.

The actions developed within this project have been intended as a pilot phase, since oxygen, electricity and heat just partially cover the total needs of the plant. The general strategy followed to guarantee a correct implementation of the project can be divided into four stages: initial assessment, design and installation of new systems, testing and improvement, and results and conclusions processing. No major impediments have been found in this methodology, but it is worth to say that longer testing periods would be needed for a proper assessment, as the lifespan of many of the improvements made are 10 years or even longer.

In this section, outstanding issues in the implementation of the project actions such as the unforeseen events occurred are exposed. The project implementation assessment has been done per project action, and for each, the results obtained are compared to the ones foreseen in the project proposal.

Additionally, the general project results, as well as the steps followed for their calculation and the annual estimations made based on the data obtained during the project, are shown.

As an introduction to this implementation analysis, the following points are exposed (detailed later on):

Visible results: most actions in the Project have immediate effects or results, as they are related to assessments, design, deployment or improvement of systems:

- renewable energy systems installed,
- aeration systems dramatically improved,
- oxygen production equipment installed,
- hydrogen storage and valorisation equipment installed,
- microalgae cultivation devices ready and in production state,
- CO_2 capture systems operative

Some other results are not physically present, but have provided measurable effects:

- reduction of CO_2 emissions (about 35ton/year equivalent),
- direct and indirect energy savings (about 110MWh/year equivalent),
- renewable energy generation (about 65MWh/year),
- oxygen self-production (above 6ton/year),
- demonstration of aeration techniques (80% reduction in oxygen consumption)
- hydrogen and fuel cells technologies in aquaculture (validated 1500W UPS),
- improvement of fish and molluscs' diet with the contribution of microalgae, also used to improve the quality of the water effluent

There are also some long-term results expected:

- improvements in eutrophication levels downstream the facility (influencing ecological balance, water turbidity, biodiversity)
- gradual increase in qualification level of the staff,
- spreading of the improvements to other companies in the area, multiplying the effect.

Amendments vs results: During the project implementation, an administrative amendment was requested on February 2016, with the purpose of incorporating a new partner in the project: INOMA RENOVABLES S.L., from IGFOTON Group, who, upon approval of the EC, has developed the technical tasks initially assigned to HELIOTRÓNICA SISTEMAS S.L. The partner change has guaranteed a proper finalization of the project, neither affecting its implementation not its results.

An evaluation per each project action implementation can be found below:

Activity B1: Demonstration of the possibility of energy optimization and renewable energy use

This activity consisted on the following tasks:

- **Task B.1.1. Facility's energetic optimization through Best Practices implementation**

Foreseen in the revised proposal: This activity foresaw the development of an energy audit in detail to know the main loads and consumption. Also, a Best Practice Manual for energy saving and improve the energy efficiency was proposed.
Achievements: All the objectives were achieved. The energy audit was done, as well as the first measurement period, analysis of installation, analysis of energy invoices, interviews to plant staff, and the elaboration of Best Practice Manual.
Evaluation: This task was developed according to the initial planning. The works were developed during two months for measurements in Esteros Canela Plant, and after this data adquisition period, one month more was required for data storage analysis. The stored information, gave very good information about the energy consumption profile of the user in the plant, non-effiency uses of the energy and what were the main load and uses.

- **Task B.1.2 Demonstration of renewable Energy systems in servicing aquaculture plants**

Foreseen in the revised proposal: This activity aimed at designing all renewable energy devices, installing all systems, and doing all legal requirements for these installations.
Achievements: In this task several technical works were developed, including design, calculation and computer simulation. For computing simulation, specific software for this kind of installations were used. At the end of the project all systems were in full operation with very good results. Excepting little stops of wind power systems due to problems with the salinity in the generator, solved by the manufacturer. In the end, we can consider that these stops were irrelevant, and the systems worked properly.

Evaluation: During the process of installation of systems some problems appeared. These problems were solved but they caused some delay respecting the initial schedule. The problems were related with civil works because some repairs were necessary in the building in order to install all parts of the renewable energy systems. However, the main delay in the start of the installation was led by the long process to get the different licenses from administration, electric company, quality certifications after testing of all requirements of Spanish law (administrative, industrial and safety).

- **Task B.1.3. Demonstration of plug&play PV compact systems for isolated operation**

Foreseen in the revised proposal: The objective was to design Plug&Play PV compact to be used in coast areas, aquaculture plants, with more reliability than commercial devices for general use, no for specific use in high salinity conditions. After the design, different prototypes would be built and after lab test they would be installed in the aquaculture plant for test in real conditions.

Achievements: The design of the electronic circuits and the computer simulations were finished properly. The temporal prototype, (Protoboard) was built and lab tests were done. Once the lab test period had finished, the prototype was redesigned to build the compact unit. Finally, 4 prototypes were designed and tested in Esteros de Canela along 2016. During the test, the energy was used for lighting the outdoor installations of the aquaculture plant in Esteros Canela.

Evaluation: The major problems were technical difficulties to solve optimal design: It was necessary to reorganize this task in more design steps to solve the technical problems in the circuit design in order to get the maximum quality in the performance of the new device. The solution adopted was to separate the test period in different steps, to solve potential technical problems. The final field test with the final design was done along 2016, the original schedule was extended so the test period was enough to get all the objectives expected.

- **Task B.1.4. Demonstration of solar thermal systems applied to water heating in aquaculture**

Foreseen in the revised proposal: This task aimed at designing and installing a solar thermal installation to prove the technical and economic feasibility of preheating the cultivation water of fries with solar contribution.

Achievements: The solar thermal system was designed, calculated and computer simulated. The solar thermal collectors were installed on the roof of Esteros de Canela, and the connection between solar thermal array and fish-tanks was finished. All administrative processes were successfully finished, and, during 2016 and 2017, real data were acquired, and analyzed according to project planning.

Evaluation: The results have been better than expected. During the whole year, the solar thermal installation has been working properly without problems, avoiding the use of low efficiency electric resistances for heating water.

Action B.1. Results foreseen and obtained:

The results obtained through activity B1 have been:

Expected	Achieved*
Reduce CO2 emissions by **46.6 tCO2/ year and 139 tCO2 in the life of the project** (3 years) using renewable energy systems (30 kW photovoltaic, 30 m^2 thermal and 5 kW small wind).	Up to **63,56 tCO2 eq emissions per year and 190 tCO2 eq in 3 years could be avoided** (depending on the fossil fuel replaced), by using renewable energy systems (30 kW photovoltaic, 33 m^2 thermal (25,4 kW) and 5,5 kW small wind).

*These data have been calculated as follows:

- Total renewable energy produced has been **64.822 kWh/year,** distributed as follows (measured data):

Month	Solar Thermal [kWh]	Wind power [kWh]	Photovoltaic [kWh]	TOTAL [kWh]
January	*1.723*	*177*	*2.324*	*4.224*
February	*1.925*	*141*	*2.487*	*4.553*
March	*2.413*	*276*	*3.608*	*6.297*
April	*2.621*	*132*	*4.178*	*6.931*
May	*2.883*	*270*	*4.814*	*7.967*
June	*850*	*167*	*5.113*	*6.130*
July	*0*	*433*	*5.179*	*5.613*
August	*0*	*260*	*4.873*	*5.133*
September	*609*	*149*	*3.417*	*4.174*
October	*2.296*	*122*	*3.387*	*5.805*
November	*1.846*	*134*	*2.147*	*4.127*
December	*1.700*	*80*	*2.088*	*3.868*
TOTAL	***18.866***	***2.341***	***43.615***	***64.822***

- **Up to 63,56 tCO_2 eq emissions avoided** through the substitution of fossil fuels, calculated as follows:

Replaced fuel	Energy savings	Emission factor	Annual emissions avoided	Emissions avoided (3 years)
	(MWh)	(tCO_2/MWh)	(tCO_2)	(tCO_2)

Coal	64,822	0,976	63,56	190,67
Natural gas	64,822	0,395	25,72	77,17
Propane gas	64,822	0,330	21,49	64,47
Grid energy mix	64,822	0,31	20,19	60,56

Expected	Achieved*
Through the application of good practices and rigorous control of energy processes, it is estimated to achieve a **saving of at least 20% of the total energy consumption** of the facility after the new scale of expected production, **which means a reduction of 56.6 tCO_2 / year.**	With the data obtained, it is observed that the **savings caused by the activities of action B.1. It has meant saving 50.47%.** This figure has far exceeded the expected results, although it must be taken into account that this figure includes not only the saving of the application of good practices (which would be the expected 20%), but also more than 30% of the result of the use of renewable energy systems.

- ***50,47% of energy savings**, respecting the previous year measurements, as follows (measured data):

	PREVIOUS CONSUMPTION (kWh)	FINAL CONSUMPTION (kWh)	ENERGY SAVED (kWh)	PERCENTAGE OF SAVINGS (%)
January	3.690	2.408	1.282	**-34,74%**
February	3.503	3.288	215	**-6,14%**
March	3.593	2.150	1.443	**-40,16%**
April	4.612	2.193	2.419	**-52,45%**
May	4.831	3.068	1.763	**-36,49%**
June	4.323	1.407	2.916	**-67,45%**
July	4.554	2.303	2.251	**-49,43%**
August	4.621	1.358	3.263	**-70,61%**
September	4.766	1.266	3.500	**-73,44%**
October	4.220	1.683	2.537	**-60,12%**
November	3.475	1.551	1.924	**-55,37%**
December	3.708	2.040	1.668	**-44,98%**
TOTAL	**49.896**	**24.715**	**25.181**	**-50,47%**

Expected	Achieved*
To demonstrate the technical viability of the use of compact photovoltaic systems, to work in saline environments, offering an alternative to the use of small generators to provide electricity at points away from the conventional electricity grid and in protected	With regard to the evolution of compact "plug & play" equipment, for isolated use, it can be said that the equipment have worked satisfactorily. During the life of the project, an **analysis of the corrosion state of the equipment has been carried out, obtaining as a conclusion that these have even been better than expected.** The installation has been used without major incidence when a moderate energy supply has been necessary (operation of pumps, small equipment ...). It is

areas from the environmental point of view.	worth mentioning the use of this equipment as an electrical supply to power night lighting devices.

- *The energy produced by the **plug & play systems was 2447,9 kWh/year** (measured data):

	ENERGIA PRODUCIDA (kWh)		
	3xPV150	2xPV400	TOTAL
Ene	58,5	101,0	159,5
Feb	53,7	93,2	146,9
Mar	76,5	132,2	208,7
Abr	78,3	135,8	214,1
May	86,4	149,8	236,2
Jun	88,5	153,2	241,7
Jul	95,7	165,6	261,3
Ago	93,6	162,2	255,8
Sep	80,7	139,8	220,5
Oct	69,6	120,6	190,2
Nov	61,5	106,4	167,9
Dic	53,1	92,0	145,1
TOTAL	896,1	1.551,8	2.447,9

Expected	Achieved
Demonstrate the economic viability of facilities with renewable energies when they are used in regime of self-consumption.	Data reflect a significant reduction in the electrical energy consumed by conventional production. In addition, the production of energy through the renewable energy installations executed (wind, photovoltaic, thermal) has been self-consumed in the aquaculture plant itself. Therefore, it can be considered that **the energy saving produced has been even greater than that shown**, since the power consumption of the plant at present would be greater than that of three years ago.
Demonstrate the improvement in sustainability and in the exploitation account of the use of renewable energies in the different processes to fully or partially cover the energy needs of these aquaculture plants, as ESTEROS DE CANELA.	
Making a report of recommendations on the proper use and efficient operation of aquaculture facilities in order to achieve a reduction in the emissions generated.	Done with success
Realization of a report of the energetic contribution of the plants and their seasonal behavior.	Done with success
Realization of a report of recommendations on when and how to incorporate renewables in aquaculture facilities in land together with a technical and financial feasibility report of the incorporation of energy equipment renewable in these facilities.	Done with success

Activity B2: Demonstration of environmental advantages in the use of hydrogen technologies and fuel cells within the aquaculture sector.

This activity consisted on the following tasks:

- **Task B.2.1. Demonstrating the use of oxygen self-production systems.**

Foreseen in the revised proposal: It was foreseen to design and manufacture all the prototypes to produce electrolytic oxygen in the Esteros Plant, including the design and development all the piping devices.
Achievements: A Design for the electrolysis prototype focused at high purity oxygen production was made. Prototype was manufactured, installed and successfully field-tested. All auxiliary equipment were deployed in time for the testing.
Evaluation: Problems with the main supplier of the prototype; this inconvenient resulted in several changes in the electrolyzer prototype and some delay of this activity, but main deadlines and objectives were accomplished. Technical Demonstration of water electrolysis for oxygen self-production was successfully achieved.

- **Task B.2.2.Demonstrating the utility of electrolytic hydrogen use systems.**

Foreseen in the revised proposal: The proposal foresaw the design and development of the hydrogen prototypes to store hydrogen and produce energy with hydrogen and their installation in the facility.
Achievements: Design, adaptation, installation and testing was finished for all the prototypes, piping and connections:

- Hydrogen combustion engine
- Complete fuel cell system
- Hydrogen storage (pressure system)
- Hydrogen storage (metal hydride)

Field testing was performed for all components, including common integration of the system.
Evaluation: Delay with hydrogen production affected this task's schedule, but main deadlines and objectives were accomplished. Hydrogen by-produced was valorized only for energy generation within the plant, but its commercialization is expected to be plausible in the midterm. Along with reduction of capital costs, this would imply a significant improvement of cost-benefit analysis for systems based on AQUASEF's concepts.

Action B.2. Results foreseen and obtained:

The results obtained through activity B.2. have been:

Expected	Achieved*
Validate the use of electrolytic oxygen in aquaculture as a novel oxygen supply technology, and demonstrate its viability and effectiveness depending on location criteria, amount of use and type of installation. **The oxygen savings are estimated by using 5kW electrolyser at 6,307.2 kg / year.**	- The use of electrolyte oxygen in aquaculture has been validated up to the point that (combined with the vest aeration techniques) no oxygen was purchased by the company at the end of the project. - The prototype developed produces **6,7t O_2/year approximately.** - To maintain the productivity the facility had in 2014, the owner would still have to buy approximately 9 t O2/year.

*These data have calculated as follows:

• Total oxygen production time: **1226 h (approx. 7 weeks).**

This generation did not occur continuously, but it represents the combined amount of several periods.

• Total oxygen produced: **809 kg = 566 Nm³.**
The results obtained during the project implementation have been translated into annual terms

so the can be compared with the expected results.

Oxygen self- production	0,8574 kg O_2/h	6,7 t O_2/ year

Taking into account the oxygen flow rate production of the electrolysis prototype, the **current oxygen self-production is estimated at 6.7 tO_2 / year.** It is estimated that the level of oxygen consumption necessary to maintain the initial productivity of the facility would be about 16 tO2 / year, which would imply the purchase of about 9 tO_2 / year from industrial suppliers.

Expected	Achieved*
Validate the use of hydrogen as an energy vector generated from renewable energies in onshore aquaculture facilities. **Through 5kW of electrolysis and the introduction of H_2 in a fuel cell we would obtain 15,878 kWh substituted by clean technologies, this means avoiding 4.72 tCO_2 / year.**	- Hydrogen has been validated as a energy vector and tested as a back up system for aquaculture facilities. - An **electrolyser of 5,4 kW (+ 1,6 kW Auxiliaries)** has been developed and tested. - Through the 5 kW electrolysis prototype developed, **12.923 kWh** would be obtained from the Fuel Cell system, **what may ascend to 4,01 t CO_2/year** in ideal conditions of functioning of the FC during a whole year, if we consider the emission factor for the energy mix (0,31 kg CO_2/kWh).

*These data have been calculated as follows:
The electrolyser prototype has produced a total amount of 102 kg of H_2 during 7 weeks of functioning, from which 93 kg have been reused, to produce 527 kWh of energy (mainly through the internal combustion engine). This can be translated into annual terms, taking into consideration a 90% of annual availability of the electrolyser, but different scenarios can be considered depending on the method of H_2 use:

SCENARIO 1: All the H_2 is used through the ICE

	7 weeks observed	**Annual data (90% availability)**
H_2 production	102 kg	850,52 kg H_2
H_2 reuse	93 kg	775,48 kg H_2
Energy produced (savings)	527 kWh	4.135 kWh

	Annual energy saving	**Emission factor**	**CO_2**
Emissions savings*	4.135 kWh	0,31 kg eq CO_2/ kWh	1.282 kg CO_2 eq/ year

*In the case the electrolyser was working with 100% renewable sources, no emissions would be linked to the Hydrogen production and energy reutilization. The amount of energy produced through the ICE with no emissions (4.135 kWh/year) would lead to 1.282 kg eqCO_2/ year if it came from the grid's energy mix.

SCENARIO 2: All the H_2 is used through the Fuel Cell

While the efficiency of the ICE has reach a percentage of a 16%, the efficiency of the Fuel Cell reaches a 50%. This means that, in the case in which the hydrogen was used one whole year to generate energy through the FC working properly the results would be:

	7 weeks observed	Annual data (90% availability)
H_2 production	102 kg	850,52 kg H_2
H_2 reuse	93 kg	775,48 kg H_2
Energy produced (savings)	1.646,88 kWh	12.923 kWh

	Annual energy saving	Emission factor	CO_2
Emissions savings*	12.923 kWh	0,31 Kg eq CO_2/ kWh	4.006 Kg CO_2 eq/ year

*In the case the electrolyser was working with 100% renewable sources, no emissions would be linked to the Hydrogen production and energy reutilization. The amount of energy produced through the FC with no emissions (12.923 kWh/year) would lead to 4.006 kg eqCO_2/ year if it came from the grid's energy mix.

Expected	Achieved*
Decrease in electricity consumption from the conventional electricity grid for the production of oxygen as this will be generated by renewable energy.	- An amount of **117.650 kWh/year of reduction of the energy need to produce industrial O_2** not needed by the facility after the project end has been estimated. - Savings in oxygen purchase **are above 30.000 €/ year.**

*These data have been calculated as follows:

Oxygen consumption is the most influenced parameter in AQUASEF project, especially due to the fact that it was excessively high initially. After the application of advanced aeration techniques (activity B3) and the self-production of oxygen by electrolysis (activity B2), the consumption has been drastically reduced to the point that the commercial oxygen supply has been dispensed at the end of 2016, stopping the purchase of almost 190 tO_2 / year that were consumed in 2014.

	Total consumption O_2 €	Annual O_2 consumption (kg O_2/year)	Energy consumption (kWh/kgO_2)	Annual Energy consumption (kWh/year)	Indirect CO_2 emissions (kg CO_2 eq/ kWh)	Total emissions (kg CO_2 eq)
2014	33.616,31 €	187.354	0,65	121.780,10	0,31	37.751,83
2015	15.094,86 €	50.316	0,65	32.705,53	0,31	10.138,71
2016	9.918,16 €	33.060	0,65	21.489,35	0,31	6.661,70
2017	0 €	--	--	--	--	--

The data in € have been obtained from Esteros de Canela Oxygen Supply invoices, and, taking into account that the energy consumption needed to produce 1 kg of O_2 is estimated in 0,65 kWh and the emission factor is 0,31 kg CO_2 eq/kWh consumed (emission factor of the electrical mix of the Spanish commercializers, MAPAMA 2017) the reductions on energy consumption to produce O_2 as well as the consequent reduction in CO_2 emissions has been calculated as shown in the table.

In terms of energy consumption, savings related to the production of the industrial oxygen that has stopped being purchased, are estimated in 121.780,10 kW/h. However, if we take into consideration that 9 t O_2 should still be purchased to maintain the initial production of the facility (together with the 6,7 t of self-produced oxygen), the amount of energy linked to its production would be:

<u>Reduction of emissions linked to the reduction of commercial O_2 purchase:</u>

190t-9t= 181 tO_2 that are not purchased annually.

181.000 kg de O_2/year * 0,65 kWh/kg O_2 * 117.650 kWh/year

Savings in O2 annual consumption

Energetic consumption linked to industrial O2 production

Since the owner would pass from 190 t to 9 t of O_2 bought, this savings, according to the table, are above 30.000 € per year.

Expected	Achieved
This amount is included in the total amount of emissions avoided by the use of renewable energy, which was estimated at ***46.6 tCO_2 / year in total, including all the renewable energy sources used.***	- Total avoided emissions through the production of renewable energies **have been estimated in 24,16 t CO_2/year** (adding the emissions avoided by 65.000 kWh of renewable energy produced annually and the amount that can be reused from the fuel cells). - However, this result has been calculated by considering the emission factor of the energy mix, which is 0,31 kg CO_2/kWh, and this quantity depends on the fuel substituted. We suppose that the expected result was considering other sources of energy such as coal (emission factor of 0,95 kg CO_2/kWh). In this case, **the total emissions avoided by the renewable energy uses in this project may ascend to 63,56 t CO_2/year from renewable energies + 12,3 t CO_2/year from the amount of renewable energy produced by the Fuel Cell .**
· As a result of the work done in B.2., a report will be prepared on how and when to opt for auto oxygen produced by electrolysis taking into account location criteria, technical feasibility as well as cost efficiency of these systems.	Done with success
· It should be noted that the main expected result of this task is to make known as a demonstrative pilot installation, but with documentary support that reports on how and when this kind of technologies in the aquaculture sector.	Done with success

· *Report on the possibilities of using new technologies available for the increase of energy efficiency of onshore aquaculture facilities.*	Done with success

Activity B3: Demonstration of the best oxygenation techniques in salt water cultivating tanks

This activity consisted on the following tasks:

- **Task B.3.1. Oxygen consumption study: volumes and seasonality**

Foreseen in the revised proposal: The main objective of this activity was to analyse the partial consumption of each one of the culture tanks of of ESTEROS DE CANELA.
Achievements: The data to fulfil this task have been obtained using estimations of the oxygen consumption in the facility and the measures from the installed flowmeters and functioning hours, which were everyday written down by the personnel. Also measures of oxygen content of the water were collected. All the measures had to be taken in the pond where the devices designed and built by D&BTech were placed: two of them in the open ponds and the other two in the hatcheries/nurseries facilities.

Evaluation: No unforeseen events happened. This activity was done according to the planning.

- **Task B.3.2. Installation of devices for oxygenation in tanks for fry cultivation**

Foreseen in the revised proposal: The main objective was to achieve a small bubble size so that in the course of about 1 m up to the surface, it would completely dissolve and not be lost in the atmosphere upon reaching the surface of the tanks.

Achievements: the technical team worked on preparing the prototypes in the laboratory making computer designs (CAD) and then they were manufactured in numerical control machines to pass later to standardized transfer tests (SAE and SOTE). These test-error cycles were repeated until valid values were achieved in order to go to field testing. Once in the facility, the diffusers were operated by technical personnel of the plant, who also took daily readings of oxygen flow and operation time.
Evaluation: During the project, we had some problems with clogging inside de diffusers. These problems were solved by installing a solenoid valve which periodically cuts oxygen supply and so allows the water flow to clean the solids or dirtiness accumulated in the holes zone of the membrane.

- **Task B.3.3. Installation of aerators for tanks used in fish growing ponds**

Foreseen in the revised proposal: It was foreseen to design and install two aerators for tanks used in fish growing ponds that allowed to maintain the oxygen concentration needed by a healthy growth of the fish with no liquid oxygen inputs.
Achievements: The two diffusers were developed and tested in lab before their installation in the facility. Once in operation, the generation of bubbles allowed an efficient transfer of oxygen, not being necessary the addition of pure oxygen except in the moments of maximum solar intensity.

Evaluation: In one of the routine checking, it was detected that the grid weighed too much and the floats were a bit more sunk. The reason was that along the pipes where the pumped water circulates there was some 1 to 2 cm height of solids sedimentation. This was causing a decrease in the efficiency of the aeration system, so modifications in the structure were made. Another point that had to be modified was the rubber pipe that carries water from the pump to the diffuser. It was detected that the material was not able to resist the action of organic and inorganic materials in the pond, so a PVC yellow pipe was purchased and installed.

Action B.3. Results foreseen and obtained:

Expected	Achieved*
Increased efficiency and decreased environmental impact due to the total elimination of liquid oxygen consumption of external production. Once the previous oxygenation equipment has been replaced, work will be done with atmospheric air in the fattening tanks and fry culture tanks will use the oxygen produced by electrolysis. ***The reduction in liquid oxygen consumption is estimated around half a ton per year****, which will mean in turn a significant reduction of GHG emissions.*	**181 t of industrial O_2 were estimated to be reduced** in comparison with the starting situation. This means a 95% of reduction respecting the starting point. The indirect energy saving in the manufacture of oxygen would be **117.650 kWh.** The savings in CO2 emissions for not purchasing industrial oxygen ascend **to 36.471 t eq CO_2/year.** Liquid oxygen consumption has been reduced up to 16t/year. **6,7 t O_2 to be used in in the fry culture tanks annually comes from the electrolysis process.** **Fattening tanks devices have been demonstrated to work with atmospheric air**, the generation of bubbles allows an efficient transfer of oxygen, not being necessary the addition of pure oxygen except in the moments of maximum solar intensity.

*These data have been calculated as follows:
As specified previously, 9 t O_2 should still be purchased to maintain the initial production of the facility (together with the 6,7 t of self-produced oxygen), to reach 16 t O_2 needed to maintain the production. This means a **reduction of 181 t of industrial O_2** respecting starting situation (190t of O_2 were bought by the facility in 2014).

This reduction has a significant impact on the reduction of CO_2 emissions since a significant amount of energy is required to produce industrial O_2.

About 0,65 kWh is required to produce 1 kg of O_2. Therefore, in the installation of Esteros de Canela, with the maximum fish load observed during the period considered, the **indirect energy saving in the manufacture of oxygen would be 117.650 kWh.** Considering that the Oxygen produces came from the Spanish energy mix, which emission factor is established in 0,31 kg CO_2 eq/kWh, **the avoided emissions would ascend to 36.471 kg CO_2 eq/year.**

Expected	Achieved
A report will be prepared incorporating all the data collected over the months of the year, in order to determine the typical demands of oxygen and seasonality in the techniques of Saltwater culture common in coastal aquaculture.	The most remarkable achievement has been the reduction of pure industrial O_2 consumption which has economic and environmental benefits.
The main expected result of this task is to publicize a pilot installation, completely documented, to report on how and when viable technologies for efficient aeration in tanks are viable for saltwater fattening and oxygen dissolution technology for fingerling culture (D.8).	Two types of efficient diffusers developed and tested. Next steps will be total implantation in the aquaculture plant and later, marketing actions in the sector.
Another result of great interest for the sector will be the report with training material regarding when and how to incorporate efficient aeration systems	Done with success

and efficient tank designs for fish farming and microalgae.	

Activity B4: Demonstration of the best techniques for by-products valorization

This activity consisted on the following tasks:

- **Task B.4.1. CO2 fixation through microalgae cultivation**

Foreseen in the revised proposal: It was foreseen to study the sources of CO_2 available in the aquaculture facility, as well as the CO_2 fixation process of the microalgae.
Achievements: A system has been designed and installed with the purpose of conducting the CO_2 produced in the boiler to an open tank of microalgae culture where it dissolves to contribute to improve productivity in the generation of microalgae in the tank. These microalgae are later fed to the fattening tanks for the indirect enrichment of the diet of the species that are grown in the fish farm: golden fish and sea bass.

Evaluation: The implementation in the field of this action was delayed mainly in relation to the planning initially thought for two reasons: the need to do some unanticipated previous work on the CFD (Computational Fluid Dynamics) simulation of the tanks to be built in the aquaculture plant. This delay was met with an intense and greater dedication to what was initially planned from the part of D&BTech personnel to meet the project objectives.

- **Task B.4.2. Optimization of the microalgae complementary cultivation**

Foreseen in the revised proposal: It was foreseen to analyze the systems of CO_2 dissolution more appropriate in each case, including its automatic control. Two microalgae cultivation systems were foreseen to be installed, one based on photobioreactors (as a nutrient supply for the larval culture) and another based on the tanks open to the atmosphere designed by D & BTech (as a contribution of nutrients for organisms that provide a high quality nutritional supplement for the fattening of fish).
Achievements: The needs of the plant were first estimated and the way of starting the crops was determined. The initial inoculum selected was from *Nannochloropsis gaditana*, native algae from the area. The crop was expanded to an operative level that allowed to supply algae culture to the fish tanks for zooplankton feed. In addition, D&BTech developed a device for the dissolution of CO_2/air by generating bubbles with the size of 100 microns. Comparing a bubbling with normal devices to the one used in the project, improvements in the growth rate of 20% were observed.
Evaluation: The microalgae cultivation has been satisfactory and the use of them has represented both savings for the plant and better conditions in the fattening tanks. CO_2 from the heater of water has been used for microalgae cultivation and the open tank designed operates with minimum energy costs.

- **Task B.4.3. Assessment of the improvements implemented for microalgae integrated cultivation**

Foreseen in the revised proposal: In function of the results observed in the microalgae cultivation facilities to be carried out at ESTEROS DE CANELA with was foreseen to develop a detailed report regarding the improvement of the quality of the effluents and the nutritional advantages due to the incorporation of autochthonous microalgae to the diet of the fattening tanks.

Achievements: The plant will be able to stop buying the microalgae needed to grow fry in hatcheries and nurseries and will be able to enrich the culture medium of the fattening tanks with the algae produced in the open tanks specifically designed and built for the project.

Evaluation: The main difficulties encountered were the need for maximum cleaning conditions for culture in the photobioreactors to avoid contamination, the design of the cooling circuit of the gases from the combustion of the boiler and the construction of the outdoor tanks by the difficulty in implementing the optimized design from Numerical Simulation (CFD) in the field (curves and blades).

- **Action B.4. Results foreseen and obtained:**

Expected	Achieved
Use of boiler and combustion gases for the dissolution of CO2 in crops of microalgae. GHG emissions associated with the water heating process will be reduced in this way from the hatchery of ESTEROS DE CANELA to less than half.	Installation designed and finished.
The disclosure of this activity may be that the demonstration of this technology can be introduced in other companies in the aquaculture sector.	Leaving apart administrative obstacles for the construction of big open tanks, the result shows that at affordable costs, the plant can have microalgae to feed zooplankton and improve environmental conditions in the fattening tanks.
Enrichment of fish diet by minimizing the contribution of necessary chemical substances to guarantee the healthiness of the fish. On the other hand they allow to improve the feeding diet of the fish, which translates into an improvement of animal welfare and the quality of the final product.	Microalgae from the photobiorreactors have save money to the plant as they have been used to feed zooplankton. Microalgae from the open tanks (apart from being a destination of part of the CO_2 produced by the heater) have been used to improve environmental conditions in the fattening tanks.
The cultivation of microalgae will mean an improvement in the quality of effluents in aquaculture facilities due to the reduction of the organic load, which would otherwise be discharged into the natural environment with the consequent problems of chemical and biological oxygen demand (COD and BOD) and eutrophication, acting therefore microalgae as a natural purification system. The reports made after this activity may make known in a quantitative way the reduction of organic matter in the effluents of the fish farms for the incorporation of microalgae crops.	Spillage water from the cultivation of mollusk has been poured into the open microalgae cultivation tanks. This has supposed savings related to collection from external companies and also supposed some reduction in fertilizer bought to be use for microalgae feed. The water spilled to the sea in the process of renewing the content of the fattening tanks has fewer levels of N (-40%) and P (-55%) when microalgae culture has been transferred from the microalgae cultivation tanks.
The main expected result of this task is to make known as a pilot installation, but with support documentary that reports on how and when the optimized polyculture of microalgae in the aquaculture sector to complement	In our opinion, the main achievement has been how the project has shown the plant owner and other people from the industry that he cultivation of microalgae (taken advantage of the CO2 produced in the plant and the spill from mollusk cultivation) is beneficial for the

the usual activities of fish farming. These results will be included in the report (D.10), which will also include information about the potential for technological improvement and of the use of microalgae culture technologies by the aquaculture sector to improve efficiency and reduce the environmental impact of this activity.	plant from the point of view of operative costs and improvement of overall environmental conditions.

Activity C1: Project monitoring and evaluation

This activity consisted on one unique task.
Foreseen in the revised proposal: Elaborating a first monitoring report at the beginning of the project and updating it annually to study how the energetic consumption and the CO_2 emissions are varying since the project implementation.
Achievements: The first report was done in time and handed to the EC attached to AQUASEF inception report. Annual reports have been attached to the document, that has been updated and resubmitted together with AQUASEF final report.
Evaluation: No delays ocurred.

Note: Reference data of the proposal was energy consumption of 933 Mwh/year, while for the facility consumption data for 2014 was 63 Mwh/year. Hence, he total emissions before the project was implemented were much less than foreseen. We suppose that the data was based on previous years, in which the production was much higher, or came from the whole company emissions, not only the facility. Therefore, it is very difficult to compare the results obtained with the foreseen ones, although some of them are very positive even in this situation:

- **Action C.1. Results foreseen and obtained:**

Expected	Achieved
46.6 tCO2 / year avoided by the use of renewable energy sources to cover at least 10% of the energy supply of the installation.	Up to **63,56 tCO_2 eq emissions per year could be avoided** (depending on the fossil fuel replaced), by using renewable energy systems (30 kW photovoltaic, 33 m2 thermal (25,4 kW) and 5,5 kW small wind). If the data was estimated based on energy mix, **20,15 tCO_2 eq emissions per year could be avoided. The renewable energy systems generate 65.000 kWh/ year, which would cover a 100% of the energy supply of the installation at the beginning of the project.** However, with the technologies developed during the project implementation, new consumptions have appeared linked to the oxygen production, **so a 40% of energy supply of the facility is estimated**.
56.6 tCO2/year avoided by the implementation of control systems and good operating practices; 20% saving of energy consumption.	The savings caused by the activities of action B.1. has led to a **50,47% reduction of consumptions, from which a 20% is expected to come from good operating practices.** In terms of t CO_2 eq, 4,03 t CO_2 per year have been avoided (considering energy mix sources), and up to

	12,71 t CO_2 per year if other fossil fuels were substituted.
17.4 tCO2 / year avoided by the decrease in the consumption of fossil fuels by replacing the power generators 25% of the time.	**Power generators have been replaced a 100%** of the time, since they have not been needed after the project end. This means that avoided emissions would be 4 times the expected result.
4.32 tCO2 / year avoided by the recovery and fixation of the CO2 emitted in the combustion of gases in the plant aquaculture by channeling and supplying the microalgae culture tanks.	**3,2 t CO2/ year fixed** by the CO_2 emitted by the gas boiler annually.
In addition to demonstrating the in situ autoproducción of oxygen by renewable route, the increase of the efficiency of the equipment used, the use of hydrogen technologies and fuel cells, the demonstration of the best techniques of aeration of culture tanks and improve the nutritional diet of fish and cultured molluscs and the quality of the effluents of the culture tanks, through microalgae.	Techniques successfully demonstrated.

Activity C2: Evaluation of the socioeconomic impact

The C2 activity consisted of two specific tasks, the C2.1 activity concerning the actions of getting in touch and meetings with local administrations and the C2.2 activity for the drafting of a database and assessment surveys.

Foreseen in the revised proposal: The proposal foresaw the design of a survey as a tool to gather specific information and the contact to local administrations in charge of local employment plans to set a baseline.

Achievements: The survey was been created and distributed in the project events, the information collected was been analyzed and future actions settled. With regard to the data collection, general data was been gathered and a more specific database designed to redirect efforts.

Evaluation: The main disadvantage found for this action was, in principle, the collection of answers for the surveys, as they were sent via e-mail to the entities identified on the database. Having this into consideration, it was decided to distribute the surveys on the socio-economic impact assessment during the workshops carried out together with the satisfaction surveys. Being both of them collected at the end of the actions.

Another issue when implementing the tasks was to find employment data being directly related to the renewable energies sector. This issue could not be solved and no data of employment for this sector could be included.

- **Action C.2. Results foreseen and obtained:**

Expected	Achieved
Obtaining surveys of interest and usefulness of companies attending dissemination activities.	A total **90 surveys on the socio-economic impact were collected** during the 5 events held (4 workshops and an international seminar), out of the 128 attendees to these events. This implies that 70 % of the attendees completed the survey on the socio-economic impact.
Development of a database with the companies and representative entities.	A database including the competent local administrations in the field of aquaculture production, energies, environment and employment was drafted. Also, information on the aquaculture facilities which were at the moment carrying out the aquaculture activity in Andalusia were included. **A total 102 facilities were identified, representing the potential direct beneficiaries of the results of this project.** The purpose of this database was to keep them informed on the progress of the project, as well as to invite them to participate in the different workshops.
Increase in the number of jobs generated in the area related to the theme of the project.	The employment associated to the aquaculture sector has kept a rising trend for years 2013-2015, **a reduction by -1,2 % being recorded for 2016.**
Detection of facilities that have adopted the new technology developed.	We have been informed that **at least 3 companies have implemented or programmed to implement the renewable energies of the thermal solar type in their facilities, located in the province of Cadiz and Seville**. Concerning the rest of the technologies, as they are in a lower maturity stage, some companies were interested in these, but provided that the production costs are reduced and they have a competitive price in the market.
Obtaining the consumer perception questionnaires and determining the degree of improvement.	A **total of 86 consumers' surveys were collected**.

Activity D.1.: Project Communication

This activity consisted on the following tasks:

- **Task D.1.1. Creation of a Communication Plan**

Foreseen in the revised proposal: The proposal foresaw the creation of a Communication Plan especially oriented to researchers, aquaculture professional sector and general public.
Achievements: The Communication Plan for AQUASEF LIFE Project was created and updated according to specifications and recommendations from experts and stakeholders. The objectives were achieved.

Evaluation: The procedure followed when creating the Communication Plan involved a primary consultation to experts and stakeholders whose validation help to further guide and validate the communication strategy achieving its target groups.

- **Task D.1.2. Collaboration Platform. Website**

Foreseen in the revised proposal: It was foreseen to develop a website in both English and Spanish with an estimated ratio of approximately 2000 visits on a quarterly basis.

Achievements: AQUASEF LIFE Project website released with Spanish and English versions is working and will be until 5 years after the project end. Average monthly visits to the website exceeded the estimations with more than 2500 visits in the last term. In order to increase the dissemination impact, a Facebook and a Twitter profile were created.

Evaluation: The deployment of this task was highly successful in terms of cost-efficiency and impact thought further strategy needs to be developed to increase the impact on target groups such as general public and society.

- **Task D.1.3. Monitoring Plan**

Foreseen in the revised proposal: A quarterly monitoring report was envisaged with successive updating in the notice board. Updating on the project progress to local and national authorities.
Achievements: Quarterly monitoring reports were developed as well as the erection of external and internal notice board in the site and the communication on the project progress to 7 local/national authorities.

Evaluation: In order to ensure enough useful information within dissemination tasks, the updating periodicity to be posted in the notice board and the authorities was modified from quarterly to twice a year. The monitoring report were published in the project website as well.

- **Task D.1.4 Design and edition of informative materials**

Foreseen in the revised proposal: This activity aimed at designing project identity and informative materials.
Achievements: Project materials were designed and printed including posters, informative leaflets, brochures, tryptics, folders, USB and notebooks.
Evaluation: The task was positively developed in terms of time, resources and cost-efficiency.

- **Task D.1.5 Workshops**

Foreseen in the revised proposal: This activity aimed at developing 4 project workshops in 3 regions with attendance from national and international aquaculture companies
Achievements: 4 workshops were developed in 2 regions (Madrid and Andalusia).
Evaluation: This was the only communication task involving a delay of 6 months in accordance with the initial schedule. This delay was justified by the necessity to wait until initial measurement data on renewable energy equipment were obtained. Once the initial schedule of this task was adjusted to the technical developments timeline, no further delays were encountered.

- **Task D.1.6 Publications of Press notes. Presentation of results in Scientific Publications and specialized media**

Foreseen in the revised proposal: This activity foresaw to release press notes and scientific articles: 10 publications on journals, 10 publications/interviews in radios of local/regional/national scope, 25 publications on sectoral journals, 30 releases in websites, 2 reports in local/regional TVs, 2 scientific articles.
Achievements: 5 press notes released due to major goals in the project development, as well as different articles: 42 publications on journals, 3 publications/interviews in radios of local/regional/national scope, 25 publications on sectoral journals, 135 releases in websites, 6 reports in local/regional TVs, 5 technical publications, among others.
Evaluation: This task helped to achieve results immediately visible. The dissemination activities grew substantially in the last semester of the project. It is considered that the impact of the project has been adequately achieved and the dissemination has reached global level.

- **<u>Task D.1.7 Participation in Regional Fairs, Congress and Seminars</u>**

<u>Foreseen in the revised proposal:</u> Participation in regional fairs, congress and seminars, at least 4.
<u>Achievements:</u> AQUASEF LIFE Project was presented in 14 national and international exhibitions through oral presentations or posters. In other 3 events the partners attended for newtworking activities and material distribution: Transfiere 2015 y 2016, CNA, Aquaculture Europe, WHEC 2016, Eureka Innovation week, Workshop on maritime applications, JAMILA,Foro economia verde Cordoba, CONAMA 2015, GENERA 2015, GENERA 2017, SIMBIOCAT III, SIGA 2017, International Conference on Materials & Energy" ICOME' 15, WORK SHOP ABOUT RENEVABLE ENERGY.
<u>Evaluation:</u> This task was achieved with success.

- **<u>Task D.1.8. Layman Report</u>**

<u>Foreseen in the revised proposal:</u> A Layman report, containing an overview of the progress and results of the project: objectives, methodology and techniques used, results, environmental impact assessment, environmental benefits, cost / benefit balance of the results and the replicability of the results.
<u>Achievements:</u> The Layman report is done and upload to the AQUASEF web site. link
<u>Evaluation:</u> This task was achieved with success.

- **<u>Task D.1.9. Guide on the implementation of new technologies in aquaculture</u>**

<u>Foreseen in the revised proposal:</u> The preparation of the guide once obtained the results of technologies and prototypes implementation
<u>Achievements:</u> The guide has been successfully developed during the final phase of the project, including data on legislative measures, technological solutions, benefits, suppliers and contact details of the experts who have developed or tested the technologies and have been distributed among beneficiaries interested in it. It is available in the link
<u>Evaluation:</u> This task was achieved with success.

- **<u>Task D.1.10 International Seminar</u>**

<u>Foreseen in the revised proposal:</u> the celebration of the international seminar with an attendance of 40 people and 10 publications.
<u>Achievements:</u> The seminar was successfully held on May 10, 2017, presenting the results of the AQUASEF project and other interesting projects of similar themes developed at an international level. The event was attended by 53 people and a note was published with repercussion in 9 media and on the web of AQUASEF Y CTAQUA.
<u>Evaluation:</u> The event served as a complement to the two networking events held in the project, as we had the opportunity to exchange views with experts who have developed similar projects, in addition to exposing the results of the project to the company of the sectors involved in the project.

- **<u>Action D.1. Results foreseen and obtained:</u>**

Expected	Achieved
Awareness of the implementation of more sustainable and environmentally friendly facilities ambient. The aim is to reach an impact equal to or	The **impact has exceeded 350.000 people** thanks to: - 14 talks and conferences given - 4 press breakfasts organized - 17 exhibitions attended - 1 film produced - 3 radios reportages

greater than 350,000 people, through the completion of 15 talks and conferences, 10 publications in different newspapers, 10 publications and / or interviews on regional radio, local and national radio, 25 magazines appearances sectors, 30 news on internet portals and 2 reports on local television and autonomic TV	- 6 TV reportages - 5 Press notes published - 16 articles in national press - 18 articles in international press - 24 specialized press articles - 135 internet articles
Website with an estimated traffic of 2,000 quarterly visits.	Website traffic of **2.500 visits per quarter** achieved.
Form a network of communication and exchange of information with groups of interest groups of interest identified.	The network of communication has been developed, by including **more that 130 entities (Public Administration, companies, researchers etc),** that have been updated with the project advances and invited to the project events.
Editing materials in two languages (Spanish and English). Triptychs (5,000 units, size A5, in color), stickers (1000 units) and poster (10 units, 120x90 cm, color) and corporate folders (1000 units), displays (4 units), pens (1000 units), ecological notebooks (300 units, A4 size), USB memories (550 units), printed programs (300 units, A4, color)	Materials edited and printed: - 400 Leaflets - 6 Posters - 550 USB memories - 1300 stickers - 300 Notebooks - 300 Technical dossiers - 5 Displays - 1235 Triptychs - 850 folders - 200 printed programs
Publication of results and their dissemination in at least three events, one of them international).	- Results published through press notes, website, social networks and internet publications. - Results presented in the events at the project end: AQUASEF International Seminar AQUASEF II Networking event AQUASEF IV Workshop
Layman report	Layman report, containing an overview of the progress and results of the project: objectives, methodology and techniques used, results, environmental impact assessment, environmental benefits, cost / benefit balance of the results and the replicability of the results.
Practical guide for the implementation of renewable energies and other innovative technologies	Guideline: including data on legislative measures, technological solutions, benefits, suppliers and contact details of the experts who have developed or tested the technologies.

Publication of the exposed papers and conclusions of the seminar as well as communications in sector magazines. It is estimated an attendance of 40 people and a publication of 10 communications in various means.	The event was attended by 53 people and a note was published with repercussion in 9 media and on the web of AQUASEF Y CTAQUA.

Action E.1. Project management

- **Task E.1.1. Decision on the management organisms**

Foreseen in the revised proposal: Decision on the project management system that would supervise the technical coherence and the project progress.
Achievements: The management system was defined at the beginning of the project, including the project coordinator, the direction committee, the technical management group and the external experts panel.
Evaluation: The management structured was successfully chosen, although it was difficult to get a strong implication of the external expert's panel in the absence of budget.

- **Task E.1.2. Supervision of the technical coherence of the project**

Foreseen in the revised proposal: The detection of deviations from planned activities and resources and the application of the measures of contingency was foreseen to be treated within this action, with internal reports, follow-up meetings, and examination of the economic progress.
Achievements: The project was supervised under the coordination of ARIEMA, that was in constant contact with the partners to check the project implementation and coordination meetings occurred minimum every six months.
Evaluation: All the objectives of this action were achieved, and the project progress supervision and financial monitoring took place until the end of the project.

- **Task E.1.3. Coordination and financial management**

Foreseen in the revised proposal: The project coordinator would take special care to obtain evidence that all partners of the project had a clear vision of the financial needs of the project.
Achievements: ARIEMA was available to solve all the partners doubts and acted as an intermediate with the external monitoring team to ensure that the project financial implementation was going well. The coordinator checked the partners state of expenditures and justifying documents quarterly to distribute the corresponding grant.
Evaluation: All the objectives of this action were achieved.

- **Task E.1.4. Project Audit**

Foreseen in the revised proposal: It was purposed to perform the audit and financial supervision of the project, its payments and the legality of its actions, including its adaptation to both the proposed project and the one approved in each case.
Achievements: The project audit was developed appropriately at the end of the project.
Evaluation: All the objectives of this action were achieved.

- **Action E.1. Results foreseen and obtained:**

Expected	Achieved
Coordination of all the work activities within the framework of the project	Coordination of the work activities was done through the whole project.
Coordination with partners and elaboration of work methodology agreed among the partners.	Coordination with partners and elaboration of work methodology agreed among the partners were done through the whole project.
Development of the project according to the approved budget and agenda, with an accounting transparent according to the standards required by the Life program.	The project was developed according to the schedule and budget, and it followed the transparency rules of the Life Program.
Preparation of progress reports, intermediate, final and as much documentation and contacts are required by the European Commission.	Progress reports were made and handed within the deadlines, including an amendment request respecting a partner change.
Monitoring of the technical and economic progress of the project work and documentation of the same semiannually.	Project progress was monitored permanently, and economic justifications documents were compiled quarterly.
Execution of periodic meetings of the consortium and control of compliance and effectiveness of the same.	Consortium meetings took place minimum every six months.

Action E.2. Networking

This activity consisted on one unique task.
Foreseen in the revised proposal: It was proposed to carry out 2 Networking meetings of LIFE projects and other related ones in the field European Union for the exchange of views and experiences in order to improve the execution of projects and mutually enrich the participants in the face of the narrowing of R & D & I relations and promotion of joint actions.
Achievements: Two networking events: one after the finalization of the first year 18May 2016 of activity and the second after the second year 25 April 2017. Both events were celebrated with great satisfaction of the attendants with an average score of 4,4/5
Evaluation: The first networking event has been postponed to May 2016 in other to be able to show the first project results, due to the delays in the technical activities. This delay also affected to the second event that took place in April 2017.

- **Action E.2. Results foreseen and obtained:**

Expected	Achieved
Establishment of technical contacts with at least 10 projects, especially with *CO2ALGAEFIX - CO_2 capture and bio-fixation through microalgal culture (LIFE10 ENV / ES / 000496)*	Technical contacts were made with the responsibles of the following 10 projects: **LIFE REWIND** - Profitable small scale renewable energy systems in agrifood industry and rural areas: demonstration in the wine sector

and with *INDUFOOD - REDUCING GHG EMISSIONS IN THE FOOD INDUSTRY THROUGH ALTERNATIVE THERMAL SYSTEMS BASED ON INDUCTION TECHNOLOGY (LIFE11 ENV / ES / 000530 for the proximity geography and the thematic convergence of the project.*	**LifeHyGENet -** Hydraulic co-generation system in water abduction and distribution network **LIFE ENVIPHAGE-** Evaluate the effect of phages use in environmental bacterial ecology **LIFE CO2 ALGAEFIX CO_2** capture and bio-fixation through microalgal culture. **LIFE SEACAN-** Reducing the pressure of fish canneries on the marine environment with novel effluent treatment and ecosystem monitoring. **LIFE ECOELECTRICITY.** Valorization of alcoholic wastes to produce H_2 to be used in the sustainable generation of electricity. **LIFE COOP 2020.** Pilot for rural smart grids through optimization of energy use and innovative renewable biomass sources. **LIFE Smart Fertirrigation** - Integrated pig manure digestate processing for direct injection of organic liquid fertiliser into irrigation systems. **LIFE CO_2 FORMARE.** Use of CO_2 as a substitute of chlorine-based chemicals used in o&m industrial processes for macrofouling remedation. **LIFE+Integral Carbon.** Development and global enfrocement of GHG capture photobioreactors in agroindustrial activities. Additionally, more than 60 projects were identified as synergic and were informed about AQUASEF.
Participation of a minimum of 50 people in each meeting, being responsible for the projects identified and the current proposal invited participants. It is expected to held the events in Madrid to facilitate the assistance. Media and online communication tools will be used in the event they occur inconveniences for the attendance of some members.	Both events held in Madrid I Event 43 attendees II Event 25 attendees
Improvement of project management. Exchange of experiences and knowledge to reduce impacts caused by climate change and encourage the development of other initiatives that have the same objective.	Lot of lessons learned through the knowledge interchange with other project responsibles in the events.

- **Action E.3. After life communication Plan**

This activity consisted on one unique task.
Foreseen in the revised proposal: Report in both Spanish and English about how the project results will keeps being disseminating after the project ending.
Achievements: This activity started in April 2017 and concluded at June 2017.
Evaluation: Is important to remark that the aim of the AQUASEF team is to maximize the possibility of implementation of AQUASEF results, promoting the use of efficient technologies so the communication of AQUASEF will continue after the project finalization

Expected	Achieved
Development of an after-life communication Plan.	Done with success. Available in the following link

Table 14. AQUASEF Project Implementation Comments

5.4. Analysis of the long term benefits

As a result of the Project, the beneficiary companies have developed and tested valuable products and services, included in their portfolios from now on:

- INOMA developed and field-tested their plug-and-play modular solar systems, including electronic controllers competitive in this market. The experience gained with the aquaculture plant and the solar photovoltaic and thermal arrays installed in maritime conditions will allow broadening their market scope.
- ARIEMA developed and field-tested an oxygen-aimed electrolysis process in real conditions, thus complementing their previous expertise regarding “only hydrogen” devices. These works will allow diversification to some other oxygen consuming activities in less aggressive environments, like chemical industry or medical care. Besides AQUASEF have suppose a great opportunity to tests and optimize the integration of electrolysis devices with renewable energy supply. Furthermore, the use of fuel cells has been tested as a backup system, opening the market for use this technology for especially important points where the energy supply should be warranted.
- DROPS & BUBBLES TECH developed and field-tested their advanced aeration systems and a semi-extensive procedure for microalgae cultivation with effluent recirculation. Advance aeration has resulted a technological breakthrough, with more than 90% savings observed in oxygen consumption; although this figure may be significantly lower in more technic applications, its commercial perspectives are promising.

Every use of renewable energy implies CO_2 emission abatement, being the importance of this reduction variable depending on the nature of the final sources to replace. In predominantly rural and remote environments like usual for aquaculture plants, main electric grids are frequently interrupted, absent, or weak, and efficiency loses in transport are about the maximum levels observed. These problems result in a high penetration of portable ICE power generators in these facilities, enhancing even more the greenhouse footprint and releasing pollution in areas which tend to be especially sensitive or even protected. Thus, every clean watt generated onsite has a multiplier effect when analyzing carbon and pollution footprint. On the other hand, the aquaculture is exponentially growing all over the world, and renewable and self-oxygen production technologies tested on the project will open the possibility of aquaculture on remote areas where there is not grid connection possible and no distribution of oxygen is performed.

The same reasons can be adduced when considering feeding resources: every kilogram of sustainable self-generated feed is saving emissions derived from agro-machinery, fertilizer manufacturing, feed processing and ship/road transport to the plant. Moreover, self-production of microalgae contributes to recycle mineral nutrients which are commonly released and may generate eutrophic undesired effects in the surrounding ecosystems.

AQUASEF has been carried out a field demonstration of complementary and innovative technologies which are urgently needed in a traditionalist and diffuse sector, with a great amount of remote facilities as is Spanish aquaculture, and for sure the biggest of the long-term benefits is that these technologies will also be highly useful for European partners in their different frameworks, not just aquaculture, but also other industries with remote facilities. At the end, all industries are always open to new ways of lowering costs, and AQUASEF Project demonstrated and quantified some of them. Regulatory organisms will be able to study these interventions and their effects, helping them to adapt strictness threshold in environmental policies. External benefits derived from the Project have been synthesized below:

1. Environmental benefits achieved: carbon emissions abatement (about 35ton/year equivalent), energy savings (about 110MWh/year equivalent), renewable energy generation (about 65MWh/year), improved quality of effluents avoiding eutrophication and suppletory self-produced feed (microalgae) for the fishes and mollusks.

All these improvements gain importance when considering they contribute to the protection of an especially valuable ecosystem with regional protection. The "*Paraje Natural Marismas de Isla Cristina*" is a complex of marshes associated to the mouths of the rivers Guadiana and Carreras, which are very influenced by the Atlantic tides. It is an important breeding area for humid areas species of birds, as well as for the migration and wintering of many other species. The formation of these marshes has required a long and complex process that has been accelerated by the human action. Thus, the deposition of sediments contributed by the Guadiana River, together with the force of the tides, has originated an extensive complex of tidal structures that includes pipes, arms, marshes, channels and muddy plains. Its proximity and similarity to the ecosystem in National Park of Doñana allows this area to act as an extension of this Park, enhancing the attractive effect of the region over wildlife. Considering that just in the surroundings of the Doñana Park 1.142 ton of fishes are produced, just implementing measures of renewable energy, and efficient oxygenation 114.200 kg CO_2 could be saved.

Because this environmentally significant localization of Esteros de Canela, the fact of the implementation of eco-efficient technologies also based on circular economy principles, such as the use of all resources produced in the system, recovery waste or emission reduction (e.g. oxygen use, always vented to the atmosphere until now; use of CO_2 contained in combustion gases to be transferred to open tanks of microalgae cultures; or microalgae cultivation with effluent recirculation) which contributes with the European Circular Economy Strategy, has made AQUASEF go further than simply to reduce the environmental impact of aquaculture industry.

Policies and legislation with which LIFE-AQUASEF has been aligned since its conception:

• Reform of the **Common Fisheries Policy,** it was especially highlighted the implementation of a sustainable aquaculture as an alternative to the overfishing .

• **Strategy for the sustainable development of European aquaculture (COM (2002) 0511),** to assure a sustainable development of the aquaculture activity. Especially, the *Integrated pollution prevention and control* (IPPC) objective was set out, which sets out an efficient use of energy.

• Circular Economy Package (2015) to boost competitiveness, create jobs and generate sustainable growth, which seeks to extract the maximum value and use of all raw materials, products and waste, promoting energy savings and reducing emissions of greenhouse gases.

2. Long-term benefits:

a. Long-term / qualitative **environmental** benefits: environmental sustainability improvements described above are expected to continue. As the demonstrated environmental improvements are implemented by more aquaculture plants and other activities, the ecological pressure along the whole area would be mitigated, contributing to the conservation and spread of biodiversity. If this tendency is maintained in the long term, environmental enrichment could even lead to this area being included under the protection of National Parks, maybe by extension to the West of the Doñana National Park.
b. Long-term / qualitative **economic** benefits: cost reduction in terms of oxygen gas (about 30k€/year), electricity, fuel and feeding inputs; increased income from hydrogen commercialization (10-25k€/year), product diversification, increased competitiveness. As mentioned before, the technification process unchained in Esteros de Canela is gradually allowing higher levels of control along the productive process. New and more exigent commercial species are now exploitable, and survival rates in the most sensitive phases of production (hatchery and nursery) have been improved, generating a surplus of juveniles to be sold alive if needed. These are examples of product diversification and flexibility derived from technology improvement, and many other will probably appear when these AQUASEF eco-efficient technologies spreads (each of them separately or combined systems of them), increasing the competitiveness and differentiation of the most innovative plants.
c. Long-term / qualitative **social** benefits: technification of aquaculture activity may initially refocus the direct employment (with reduction of some manual tasks) to other important tasks of the value chain (as commercialization, product transformation) but indirect and medium-term employment data are expected to improve clearly, along with plant productivity and the technification of professionals in the aquaculture industry. This fundamental change would lead to specialized qualification of personnel, rural population stabilization, public awareness of environmental protection and new possibilities of nature-related tourism activities. In Spain, aquaculture activity employs about 20.000 workers, most of them in a part-time or seasonal scheme. Increased competitiveness and technification should result in higher levels of full-time and year-round employment, thus improving wellness and stability for population in their influence area.

3. Sustainability and continuation of the project actions: most of the equipment installed in Esteros de Canela is intended to continue working beyond the Project's execution period, as lifespan of many of them is considerably longer than 5 years and its economic benefits are clear; diffusion materials and scientific publications will remain accessible for all interested agents. Renewable energy production, advanced aeration and microalgae cultivation show clear advantages today, being applicable to other facilities with only minor adaptations. The economic performance of oxygen self-production from water electrolysis, however, is not so positive in the present day: limitations including high initial costs and hydrogen commercialization will probably difficult their entrance into the market if we only consider the value of oxygen into the electrolysis process in the medium term that's why probably , in the meanwhile, other oxygen self-production methods will be preferable choices for fish farmers. On the other hand, as the hydrogen corridors are expected on the next years (at Spanish, European and worldwide levels), this project is pioneer in the use of oxygen -a waste gas in electrolysis, until now- when hydrogen is produced by electrolysis, demonstrating that this oxygen could be also valorized in many industries, aquaculture.

4. Replicability, demonstration, transferability, cooperation: many AQUASEF's actions are directly applicable to other aquaculture plants and even to other industrial or residential applications. There is not much public data about photovoltaics and thermal systems' performance in marine environment, and this point could affect any deployment in the seashore. Oxygen production through water electrolysis will be applicable to any other oxygen-demanding applications and during the project execution, any damage produced by the saline environment have been detected. Chemical industry, wastewater treatment or ozonisation may take advantage of many of the improvements described here; even medical application could be also possible if all administrative and safety requirements are fulfilled. Many and highly diverse uses are expected to arise in the mid and long term for the by-produced hydrogen, particularly when fuel cell technology reduce its price, which will allow to compete also in price to similar energy solutions. Microalgae cultivation methods developed will be also exploitable as an independent technology and will accept effluents different from those generated in aquaculture. Efficient micro-bubble aeration systems are applicable to many industrial or agrarian processes, such as wastewater aerobic treatments or CO_2 dilution. For a more specific identification of transferability and cooperation opportunities, a brief description of partners' commercialization or implementation plans:

The advance aeration devices developed by D&Btech within AQUASEF have resulted in a significant reduction in oxygen consumption (90%), which derives to important energy savings to the aquaculture facility. This saving has driven D&Btech to the presentation and commercialization these devices to companies in the aquaculture sector: O2Btech for open fattening tanks and MicroBtech for nursery breeding tanks in hatcheries and nurseries. In addition, D&Btech are testing these gas diffusers for the diffusion of CO_2 in the agri-food sector (e.g. beer industry or pickling of black olives) with the application for lowering pH using CO_2 instead of the acids.

Concerning microalgae cultivation, D&Btech with the IBVF (Institute of Plant Biochemistry and Photosynthesis) is already studying the possibility of presenting new R&D projects in the field of cultivation of microalgae in open tanks. The knowledge acquired in AQUASEF project has served as a basis for the presentation of the patent and commercial development of the blade system implanted in the culture tank to improve the mixture of microalgae in open tanks, optimizing the reception of solar radiation, and to approach and present the improvement devices in the project to companies that work in the application of the cultivation of microalgae in tanks open to the purification of wastewater of urban origin (Aqualia - All-gas Project).

INOMA has based its replicability and transferability plan in the development of products designed in AQUASEF project for energy supply in standing remote applications (plug&play PV systems). The results obtained within AQUASEF can be easily extrapolated to other aquaculture facilities, given its high replicability in other companies of the sector, as well as its modulability (the facilities can be easily dimensioned according to the needs of each aquaculture plant, adapting to the available space and the needs of each company in the sector). The replication of the results is not only viable in other companies of aquaculture industry, but also in other sectors as agriculture, ranching, foodstuff industry…

With regard to the technical feasibility of the renewable facilities installed, highlight that the fact of using different resources (solar for thermal and photovoltaic installations, and wind for the wind turbine), provides greater stability to the energy supply through renewable energy sources. It has been proved during the project that the set of facilities has a repayment period of seven years, which is considered interesting for many facilities with an estimated life span of at least 25 years, especially taking into account the foreseeable increase in energy costs in the coming years.

ARIEMA has improved and expanded its knowledge in the field of manufacturing and testing hydrogen production and storage prototypes, as well as demonstrating its applicability in the aquaculture sector, which is considered as a new niche business for the company. Moreover, the knowledge acquired within AQUASEF is considered by ARIEMA as an investment and allow the company for the continuation of research and demonstration in hydrogen technologies and the improvement of their products to different niche markets, in view of their near future commercialization in Spain. The application and commercialization perspectives of hydrogen produced in the near future have different ways to evolution. For example, among the applications in the transport sector, the use of hydrogen in fuel cell vehicles will have a crucial role. The use of hydrogen would allow the electrification of one of the least efficient sectors in terms of energy: road transport. In addition, the location of aquaculture facilities near roads would allow the self-production of oxygen for aquaculture purposes to be synchronized with the sale of hydrogen in service stations that supply the necessary fuel to the vehicles; it could be an alternative oxygen supply of electrolyze on site.

In addition, the development of hydrogen technologies, will be driven due to the change of energy model strategy that many European countries are carrying out and European Commission is demanding from the whole Union. This model will be based on a change in the use of energy resources, introducing renewable energy sources and vectors that contribute to sustainability, such as hydrogen. Therefore, in the medium-long term, electrolysis should be taken into account as an economically viable technology, for the production of hydrogen but also for the oxygen in situ production, as a valuable gas for many other applications as have been mentioned before: aquaculture, chemical industry, wastewater treatment, ozonisation,…

Furthermore, the After Life Communication Plan that will follow AQUASEF partners, includes additional communication activities designed to publicize the benefits of the project and to raise awareness about the importance of the environment protection through the use of eco-efficient technologies.

5. Best Practice lessons: up to date, no relevant conclusions have been reached which support significant changes in established Best Practices performed in the project framework, for any of the general areas involved: electric parameters assessment, solar energy, micro-wind power, hydrogen systems and pressurized systems. Some other aspects of the Project, such as aeration, microalgae cultivation, fish feeding, and water treatment have experienced important problems related to clogging, more severe than expected. This phenomenon was kept in mind from the beginning, but its intensity resulted to be significantly higher than those considered for seawaters in general bibliography. The explanation is most probably related with the high productivity of these ponds, where the natural ecosystem of the marsh is complemented with extra nutrients derived from the fish farming: higher amounts of organic matter and epibionts should be estimated for future implementations.

6. Innovation and demonstration value: AQUASEF is mainly a demonstration project, yet it involves some truly innovative aspects. Energy efficiency principles, renewable energy exploitation and hydrogen technology are areas widely demonstrated in other contexts, which need to be tested in this environment and application. For instance, no guarantee is provided by most solar panel manufacturers for installations closer than 200m or more to the seashore, thus discouraging investments from this kind of facilities. The EU funding granted to the Project will contribute to wipe out any doubt about their performance in these conditions, facilitating future deployments. Oxygen self-production, resource-efficient microalgae cultivation and advanced aeration with novel design nozzles are the most innovative aspects, as they represent a technological break-through not only for aquaculture, but also for its application to other processes alike.

7. Long term indicators of the project success:

- CO_2 emission / kg (fish and molluscs)
- Renewable energy generation / year
- Savings in electricity and fuel costs / year

- Savings in oxygen purchase / year
- Improvement in eutrophication indicators downstream the facility

A jointly funded initiative like this ensures a significant effect in the company directly involved but also a wider and durable effect in the European sector as a whole, thanks to the dissemination of results and procedures. This gradual sectorial shift is expected to generate some by-effects in the European level:

- Decreased ecologic and carbon footprint of aquaculture plants.
- Increased competitiveness of European fish farming companies.
- Decreased pressure over wild fish populations, as increased competitiveness and quality of aquaculture products will modify equilibrium between these substitutive products.
- Renewable hydrogen diffuse generation. Hydrogen is only applicable nowadays for its use within the plant, but in a not so distant future it may be commercialized for fuel cell vehicles or other widespread devices; in that scenario, cost-efficiency could be highly improved depending on location and fuel demand/offer in the surroundings.
- Established cooperation network and self-awareness throughout aquaculture sector. Diffusion activities of the project already gained interest from decision makers in different companies; in a second phase, these demonstrated developments will gradually spread in the community, initiating a durable consciousness about the decisive advantages that new technology and procedures can bring to aquaculture.
- Specific qualification of personnel in best practices and new renewable technologies applied to aquaculture. Initiatives like AQUASEF Project contribute to increase the average qualification level in a traditionally low-specialized activity, as optimization and hybridization of technologies will demand highly qualified personnel.

6. Comments on the financial report

The financial report contains the details of the project's statement of expenditures per each beneficiary, as well as the individual transactions made by the coordinating beneficiary, and the costs broken down per action and per beneficiary.

The financial management of the project has been carried out following the Common Provisions of the LIFE+ Programme and the Grant Agreement signed with the Commission. Additionally, the CB declares that the bank account used to receive the EC funds makes it possible to identify those funds and that it yields neither interests nor equivalent benefits under the law of Spain.

This report includes a financial report and an audit report.

For the review of the costs incurred along the project, ARIEMA has developed the financial control of the activities evaluating quarterly the expenses incurred by each partner and certifying their accuracy though the review of invoices and other supporting documents of expenditures.

Respecting any other costs justified through invoices and proofs of payment, ARIEMA has revised that all the invoices contain a clear reference to the project code, LIFE 13/ENV/ES/000420, either sealed or specified in the invoice content.

Beneficiaries assume that in no case the contribution from the European Union will have the purpose or effect of producing a profit.

6.1. Summary of Costs Incurred

PROJECT COSTS INCURRED			
Cost category	Budget according to the grant agreement*	Costs incurred within the project duration	%**
1. Personnel	1.066.138 €	1.097.394,78 €	102,93%
2. Travel	37.380 €	30.493,46 €	81,58%
3. External assistance	220.425 €	205.587,08 €	93,27%
4. Durables: total non-depreciated cost	361.420 €	350.224,35 €	96,90%
- Infrastructure sub-tot.	*Not applicable*	*Not applicable*	*Not applicable*
- Equipment sub-tot.	117.450 €	112.115,69 €	95,46%
- Prototypes sub-tot.	243.970 €	238.108,66 €	97,60%
5. Consumables	85.145 €	78.065,65 €	91,69%
6. Other costs	8.400 €	9.385,49 €	111,73%
7. Overheads	120.410 €	120.056,51 €	99,71%
TOTAL	1.899.318 €	1.891.207,32€	99,57%

Table 15. AQUASEF Project total costs incurred

The total costs incurred and declared at the project end (30th June 2017) by all project's partners is 1.891.207,32 €. This amount represents the 99,57 % of the approved budget for the whole project, thus being well aligned with the project's overall level of implementation and duration.

6.2. Summary of costs per action

The summary of costs per action is specified in the next page.

Action no.	Short name of action	FORESEEN COSTS	PROJECTED FINAL COST	% OF USE
B1	**Demostración sobre la posibilidad de optimización energética y uso de energías renovables**	336.104 €	299.674,06 €	89,16%
B2	**Demostración de las ventajas medioambientales del uso de las tecnologías del hidrógeno y las pilas de combustible para el sector de la acuicultura**	398.664 €	415.694,77 €	104,27%
B3	**Demostración de las mejores técnicas de oxigenación en tanques de cultivo de agua salada**	144.025 €	153.478,52 €	106,56%
B4	**Demostración de las mejores técnicas de valorización de subproductos.**	175.120 €	201.742,14 €	115,20%
C1	**Seguimiento y Evaluación**	95.992 €	96.334,46 €	100,36%
C2	**Evaluación del impacto socioeconómico de las acciones del proyecto en la economía local**	52.070 €	46.837,67 €	89,95%
D1	**Comunicación y difusión**	365.229 €	349.406,26 €	95,67%
E1	**Coordinación y gestión**	194.944 €	186.239,14 €	97,07%
E2	**Networking**	16.760 €	17.678,69 €	105,48%
E3	**AfterLIFE Communication Plan**	0,00 €	1.065,11 €	-
	Indirect costs	120.410 €	120.056,51 €	99,71%
	TOTAL	**1.899.318 €**	**1.891.207,33 €**	**99,57%**

In addition, in order to better reflect the costs during the lifetime of the project, the following table is included:

Action no.	Short name of action	1. Personnel	2. Travel and subsistence	3. External assistance	4.a Infrastructure	4.b. Equipment	4.c Prototype	5. Purchase or lease of land	6. Consumables	7. Other costs	TOTAL
B1	**Demostración sobre la posibilidad de optimización energética y uso de energías renovables**	127.127,05 €	4.942,15 €	68.350,00 €	0,00 €	82.400,00 €	14.700,00 €	0,00 €	2.154,86 €	0,00 €	**299.674,06 €**
B2	**Demostración de las ventajas medioambientales del uso de las tecnologías del hidrógeno y las pilas de combustible para el sector de la acuicultura**	164.808,92 €	3.560,64 €	73.985,00 €	0,00 €	0,00 €	156.320,94 €	0,00 €	17.019,27 €	0,00 €	**415.694,77 €**
B3	**Demostración de las mejores técnicas de oxigenación en tanques de cultivo de agua salada**	99.407,11 €	1.669,32 €	5.500,00 €	0,00 €	0,00 €	31.531,23 €	0,00 €	15.370,86 €	0,00 €	**153.478,52 €**
B4	**Demostración de las mejores técnicas de valorización de subproductos.**	120.443,16 €	2.346,24 €	13.680,56 €	0,00 €	29.715,69 €	35.556,49 €	0,00 €	0,00 €	0,00 €	**201.742,14 €**
C1	**Seguimiento y Evaluación**	82.334,46 €	0,00 €	14.000,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	**96.334,46 €**
C2	**Evaluación del impacto socioeconómico de las acciones del proyecto en la economía local**	46.455,75 €	65,10 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	316,82 €	**46.837,67 €**
D1	**Comunicación y difusión**	278.637,24 €	8.679,08 €	10.031,52 €	0,00 €	0,00 €	0,00 €	0,00 €	43.427,16 €	8.631,26 €	**349.406,26 €**
E1	**Coordinación y gestión**	161.121,20 €	7.674,78 €	20.040,00 €	0,00 €	0,00 €	0,00 €	0,00 €	93,50 €	309,66 €	**186.239,14 €**
E2	**Networking**	15.994,79 €	1.556,15 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	127,75 €	**17.678,69 €**
E3	**AfterLIFE Communitation Plan**	1.065,11 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	**1.065,11 €**
Over-heads											**120.056,51 €**
	TOTAL	1.097.394,79 €	30.493,46 €	202.387,08 €	0,00 €	112.115,69 €	238.108,66 €	0,00 €	78.065,65 €	9.385,49 €	**1.891.207,33 €**

8. Financial report

AQUASEF financial report, covering costs incurred from June 2014 to June 2017, was detailed among six excel documents, one per each project partner were, following the EC template, the next costs incurred were detailed:

- Personnel costs
- Travel costs
- External assistance
- Equipment
- Prototype
- Consumable material
- Other direct costs
- Overheads
- Funding from other sources, divided in "Contribution of the associated beneficiary", "Other sources of funding" and "Direct income".

As mentioned before, the total costs incurred and declared to date by all project's partners is 1.891.207,32 €. This amount represents the 99,57% of the approved budget for the whole project, thus being well aligned with the project's overall level of implementation and duration.