AQUASEF

ECO-EFFICIENT TECHNOLOGIES DEVELOPMENT FOR ENVIRONMENTAL IMPROVEMENT OF AQUACULTURE

PRACTICAL GUIDE ON THE IMPLEMENTATION OF NEW TECHNOLOGIES IN AQUACULTURE FACILITIES

LIFE 13/ENV/ES/00420

ariema

ctaqua CENTRO TECNOLÓGICO DE LA ACUICULTURA

D&B Tech
Generación de burbujas y cultivos biológicos

Inoma renovables,sl

Esteros de Canela

Eco-efficient technologies development for environmental improvement of aquaculture

LIFE-AQUASEF

Deliverable: D 14

Practical guide on the implementation of new technologies in aquaculture facilities

Guía práctica de implementación de nuevas tecnologías en instalaciones acuícolas

LIFE ENVIRONMENT PROGRAMME

LIFE 13 ENV/ES/000420

Action: D

TASK: D 1.9

Report Date: 30/06/2017

http://www.aquasef.com/index.php/es/

Bibliographical Information

Project: Eco-efficient technologies development for environmental improvement of aquaculture- LIFE-AQUASEF

Subject: Demonstration of best practice in by-products valuation.

LIFE ENVIRONMENT PROGRAMME

Contract No. **LIFE 13/ES/000420**

Duration of Contract: 02/06/2014-30/06/2017

ACTION: D. Communication and dissemination

TASK: D. 1.9 Practical guide on the implementation of new technologies in aquaculture facilities

Other Partners: ARIEMA, D&B TECH, INOMA

Report Date:30/06/2017

Pages:41 (including figures, tables, attachments)

Key words: Aquaculture, Employment, GHG emissions, Land aquaculture, electrolyser, renewable energy.

Contact Person Editing Partner

Name: Myriam Retamero

Phone: +34 956 569 363

Fax: +34 956 569 364

E-mail: m.retamero@ctaqua.es

Authors Editing Partner

Name: Mª del Mar Barrios

Phone: +34 956 569 363

Fax: +34 956 569 364

E-mail: mm.barrios@ctaqua.es

Name: Laura Bermudez

Phone: +34 956 569 363

Fax: +34 956 569 364

E-mail : l.bermudez@ctaqua.es

TABLE OF CONTENTS

1. Introduction

Replicability of results in R&D&I or technology development projects, as it is the case of the LIFE ENV/ES/000420 project is a key element to have in mind during the execution of these projects. It is very important that the results obtained within these projects reach an important number of final users in order to guarantee that the resources invested have a direct impact either on production systems or directly on the environment. Thus, the environmental and production sustainability may be increased in all of the implementation sectors of the project.

Particularly, within the AQUASEF project, the results have a direct impact on the renewable energy sector and especially, on the aquaculture sector. Through the implementation of the technologies developed within this project, we intend to minimise the impact the activity has on the environment, by reducing the polluting emissions to the air and taking out the maximum benefit of the resources used.

This is why it is necessary to develop a guide on the implementation of the new technologies developed, in order to help the potential users both the access to the technologies and their later use in facilities they wish them to be installed.

In this sense, this document provides a compilation of the techniques implemented and the technology developed in the framework of the LIFE AQUASEF project so that they might be implemented in areas with similar issues. On this report, we include:

- Regulatory measures
- Potential technology solutions
- Advantages provided
- Links of interest
- Entities supplying equipment
- Recommendations

2. Electrolyser for obtaining oxygen and hydrogen out of water

Developed by ARIEMA, the electrolyser is a 5 kW alkaline equipment specifically developed to use both gases, oxygen and hydrogen and it has a sensoring and automation levels which are not available for the current equipment on the market.

Picture 1. Electrolyser for obtaining oxygen and hydrogen out of water (Source: ARIEMA)

2.1. Regulatory measures

Please find below a review of all the existing regulations concerning this technology.

2.1.1. Binding regulations in Spain

*Pressure equipment

- ✓ Pressure equipment (Royal Decree 769/1999 - European Directive 97/23/EC.) (Royal Decree 2060/2008, Spanish OJ February 5, 2009).
- ✓ ITC MIE-AP7 (Spanish Technical Instruction): Cylinders for compressed, liquefied and dissolved under pressure gases.
- ✓ ITC EP-6 on transportable pressure receptacles.

- ✓ Transportable pressure equipment (Royal Decree 222/2001 - European Directive 1999/36/EC.)

*Storage of chemical products

- ✓ Regulation on the storage of chemical products Royal Decree 379/2001.
- ✓ ITC MIE-APQ-005 Technical Instruction of the Regulation on the storage of chemical products: Storage of cylinders for compressed, liquefied and dissolved under pressure gases.

*ATEX (Explosive atmospheres)

- ✓ Equipment and protective systems intended for use in potentially explosive atmospheres (Royal Decree 400/1996 - European Directive 94/9/EC.)
- ✓ Royal Decree 681/2003 on the protection of health and security of workers exposed to risks arising of explosive atmospheres in the work place.
- ✓ ITC-BT-29 (Particular provisions for electric installations in premises with fire or explosion risks) of the Regulation on radio-electronics for low voltage installations.

*Electromagnetic compatibility

- ✓ European Directive 2004/108/EC Equipment electromagnetic compatibility.
- ✓ European Directive 2006/28/EC Electromagnetic compatibility relating to the type-approval of motor vehicles and their trailers.

*Machines

- ✓ European Directive 2006/42/EC.
- ✓ Directive 97/23/EC on pressure equipment.

*Others

- ✓ RAP: Regulation on pressure devices.
- ✓ RAG: Regulation on devices using gas as a fuel.
- ✓ IPE: Regulation on oil installations.
- ✓ RIG: Regulation on gas installations.
- ✓ RCG: Regulation on networks and connections of gaseous fuels.
- ✓ RGC: Regulation on the public service of fuel gases.

2.1.2. Specific regulations

DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the deployment of alternative fuels infrastructure. Regulating the set up of a deployment of hydrogen as a fuel for transport, among other fuels.

Chart 1. Compilation of Spanish regulations (the most relevant being underlined) (Source: ARIEMA)

AENOR Standard	AENOR Designation	AENOR Status
UNE 181001:2010	Hydrogen technologies. Terminology.	In force
UNE-EN 50465:2015	Gas appliances - Combined heat and power appliance of nominal heat input inferior or equal to 70 kW (Endorsed by AENOR in March of 2015.)	In force
UNE-EN 62282-2:2012	Fuel cell technologies. Part 2: Fuel cell modules	In force
UNE-EN 62282-3-201:2013	Fuel cell technologies. Part 3-201: Stationary fuel cell power systems. Performance test methods for small fuel cell power systems.	In force
UNE-EN 62282-3-300:2013	Fuel cell technologies. Part 3-300: Stationary fuel cell power systems. Installation.	In force
UNE-EN 62282-5-1:2013	Fuel cell technologies. Part 5-1: Portable fuel cell power systems. Safety.	In force
UNE-EN 62282-6-200:2013	Fuel cell technologies. Part 6-200: Micro fuel cell power systems. Performance test methods.	In force
UNE-EN 62282-6-300:2013	Fuel cell technologies. Part 6-300: Micro fuel cell power systems. Fuel cartridge interchangeability.	In force
UNE-IEC/TS 62282-1:2013	Fuel cell technologies. Part 1: Terminology.	In force
UNE-ISO 14687:2006	Hydrogen fuel. Product specifications	In force
UNE-ISO 16110-1:2015	Hydrogen generators using fuel processing technologies. Part 1: Safety.	In force
UNE-ISO 22734-1:2012	Hydrogen generators using water electrolysis process. Part 1:	In force

AENOR Standard	AENOR Designation	AENOR Status
	Industrial and commercial applications.	
UNE-ISO/TR 15916:2007 IN	Basic considerations for the safety of hydrogen systems	In force
UNE-ISO/TS 20100:2013	Gaseous hydrogen. Fuelling stations.	In force

Chart 2. Compilation of international regulations (the most relevant being underlined) (Source: ARIEMA)

International Standard	International designation	International status
IEC 62282-3-100:2012	Fuel cell technologies - Part 3-100: Stationary fuel cell power systems - Safety	Revised
IEC 62282-3-200:2015	Fuel cell technologies - Part 3-200: Stationary fuel cell power systems - Performance test methods	Revised
IEC 62282-3-400:2016	Fuel cell technologies - Part 3-400: Stationary fuel cell power systems - Small stationary fuel cell power system with combined heat and power output	Revised
IEC 62282-4-101:2014	Fuel cell technologies - Part 4-101: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) - Safety of electrically powered industrial trucks	Revised
IEC 62282-4-102:2017 PRV	Fuel cell technologies - Part 4-102: Fuel cell power systems for industrial electric trucks - Performance test methods	Revised
IEC 62282-6-100:2010	Fuel cell technologies - Part 6-100: Micro fuel cell power systems - Safety	Revised
IEC 62282-6-100:2010/AMD1:2012	Amendment 1 - Fuel cell technologies - Part 6-100: Micro fuel cell power systems - Safety	Revised
IEC 62282-6-100:2010/COR1:2011	Corrigendum 1 - Fuel cell technologies - Part 6-100: Micro fuel cell power systems - Safety	Revised
IEC 62282-6-	Fuel cell technologies - Part 6-100: Micro fuel cell power	Revised

International Standard	International designation	International status
100:2010+AMD1:2012 CSV	systems - Safety	
IEC 62282-6-200:2016	Fuel cell technologies - Part 6-200: Micro fuel cell power systems - Performance test methods	Revised
IEC PAS 62282-6-150:2011	Fuel cell technologies - Part 6-150: Micro fuel cell power systems - Safety - Water reactive (UN Devision 4.3) compounds in indirect PEM fuel cells	Revised
IEC TS 62282-7-1:2017	Fuel cell technologies - Part 7-1: Test methods - Single cell performance tests for polymer electrolyte fuel cells (PEFC)	Revised
IEC TS 62282-7-2:2014	Fuel cell technologies - Part 7-2: Test methods - Single cell and stack performance tests for solid oxide fuel cells (SOFC)	Revised
ISO 13984:1999	Liquid hydrogen -- Land vehicle fuelling system interface	Confirmed
ISO 13985:2006	Liquid hydrogen -- Land vehicle fuel tanks	Confirmed
ISO 14687-1:1999	Hydrogen fuel -- Product specification -- Part 1: All applications except proton exchange membrane (PEM) fuel cell for road vehicles	Under review
ISO 14687-1:1999/Cor 2:2008	Hydrogen fuel -- Product specification -- Part 1: All applications except proton exchange membrane (PEM) fuel cell for road vehicles /Cor 1:2008	published
ISO 14687-2:2012	Hydrogen fuel -- Product specification -- Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles	Under review
ISO 14687-3:2014	Hydrogen fuel -- Product specification -- Part 3: Proton exchange membrane (PEM) fuel cell applications for stationary appliances	Under review
ISO 16110-2:2010	Hydrogen generators using fuel processing technologies -- Part 2: Test methods for performance	Confirmed
ISO 16111:2008	Transportable gas storage devices -- Hydrogen absorbed in reversible metal hydride	Under review

International Standard	International designation	International status
ISO 17268:2012	Gaseous hydrogen land vehicle refuelling connection devices	Under review
ISO 22734-2:2011	Hydrogen generators using water electrolysis process -- Part 2: Residential applications	Under review
ISO 26142:2010	Hydrogen detection apparatus -- Stationary applications	Confirmed
ISO/TR 15916:2015	Basic considerations for the safety of hydrogen systems	published
ISO/TS 15869:2009	Gaseous hydrogen and hydrogen blends -- Land vehicle fuel tanks	Confirmed
ISO/TS 19880-1:2016	Gaseous hydrogen -- Fuelling stations -- Part 1: General requirements	Under review

2.2. Technology solutions

The need to provide the cultivation environment with oxygen to maximise production implies the obtaining of an external oxygen supply. The purchase of oxygen is considered as a potential mean of supply, however, a commercial supply nearby the site concerned is not always possible. Therefore, also the possibility for self-generation of the oxygen required has to be analysed.

Water electrolysis is a process of conversion from electric energy to chemical energy which uses an electric current for the decomposition of water into oxygen and hydrogen. This production method is mainly used for the production of hydrogen, however, the on-site production of oxygen may represent an interesting option under certain conditions.

Moreover, there are other methods for oxygen production such as the air purification techniques; cryogenic distillation, polymeric membranes and pressure swing adsorption.

- Air cryogenic distillation gets liquid oxygen at temperatures lower than -150ºC.
- Polymeric membranes separate oxygen from nitrogen when the air goes through a separation membrane splitting up both components.
- Pressure swing adsorption uses a zeolite or activated charcoal molecular sieve with affinity to hydrogen, which retains and separates this from oxygen, obtaining pure oxygen in an independent current.

Finally, the production of oxygen may be carried out by chemical reactions among precursors in which oxygen is obtained as a final product. However, this oxygen production method is the least convenient due to the security and supply issues of the raw material used for the obtaining.

The self-production of oxygen for applications in aquaculture is, therefore, only one of the several technical options from which the aquaculture producers may choose. As a method for oxygen production, in the strict sense, the electrolysis will be hardly competitive concerning costs: according to estimates, the production costs would be around 2.00 €/kg nowadays and around 0.70 €/kg in the long term, when technology and market for this equipment are completely mature. These prices do not benefit profitability, as the current cost for the commercial supply is around 0.35 €/kg. And through air purification methods, costs might reach around 0.10 €/kg. However, the key for this concept is the other product which consistently generates the reaction: hydrogen. The incomes on sales or the savings generated when exploiting the hydrogen might cover the whole of the oxygen costs and result in a potential supplementary net profit for the site, estimated around 1.50 € per kg of oxygen produced in a scenario of a great development of hydrogen technologies as an energy vector.

2.3. Advantages provided by water electrolysis

The self-production of oxygen by means of electrolysis in aquaculture facilities guarantees the set-up of a secure and ongoing supply of oxygen not linked to external issues of the aquaculture site concerned. This element is very important, since not only the cost for self-production of oxygen and the technical and economic viability compared to the external supply shall be taken into account, but also it is essential the location in which the site is placed.

As already mentioned, the significance of the by-product obtained through water electrolysis, the hydrogen, is fundamental. This by-product has the highest energy content of all fuels, therefore, it introduces itself as one of the main energy vectors for the future due to the current changes in strategies in the use of energy resources.

The hydrogen is valorised in the AQUASEF project in a customised motor generator, replacing the electric power from the general supply. Moreover, a part of the gas is stored to supply an Uninterrupted Supply System (USS) with fuel cell, assuring the operation of some critical charges in case of default of the local electric supply.

The exploitation made by the AQUASEF project might be applied in any facility with similar features. However, there are also other applications. Notwithstanding, the only actual alternative would come if the aquaculture facility was nearby a metallurgical, semi-conductors or glass industry, namely, industries in which hydrogen is used as a raw material.

Despite the minor applications of the hydrogen jointly produced nowadays, in the future, hydrogen represents an actual alternative in the energy market. The self-production of oxygen in an aquaculture facility through electrolysis will therefore provide in the future a source of extra incomes due to the sale of the by-product obtained at the facility or to a better exploitation of this.

The hydrogen produced at the aquaculture facility will be stored under high pressure, liquefied or combined with other materials for a later use when efficiently generating electric power through fuel cells. Also for its transformation into synthetic natural gas, for its chemical use or for electricity production by combustion, among other uses.

2.4. Links of interest

- Fuel Cell Today. (2013). *Water electrolysis & renewable energy systems.*
- Carmoa, M., Fritza, D. L., Mergela, J., & Stoltena, D. (2013). *A comprehensive review on PEM water electrolysis.* International Journal of Hydrogen Energy, 4901-4934.
- National Renewable Energy Laboratory. (2004). *Technology Brief: Analysis of Current-Day Commercial Electrolyzers.* Taken out of http://www.nrel.gov/docs/fy04osti/36705.pdf
- Energy.gov. *Hydrogen production: Electrolysis.* Taken out of https://energy.gov/eere/fuelcells/hydrogen-production-electrolysis
- Zoulias, E., Varkaraki, E., Lymberopoulos, N., Christodoulou, C. N., Karagiorgis G. N. (2002). *A review on water electrolysis.*
- Thyssenkrupp. *Water electrolysis: Power to Gas.* Taken out of https://www.thyssenkrupp.com/en/company/innovation/technologies-for-the-energy-transition/water-electrolysis.html
- Greenlysis. (2010-2012). *Hydrogen and Oxygen production via electrolysis powered by renewable energies to reduce the environmental footprint of a WWTP*. Layman's report. Taken out of http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=LIFE08_ENV_E_000118_LAYMAN.pdf

- H2-International. (2017). *Electrolyzer market overview.* Taken out of https://www.h2-international.com/2017/06/06/electrolyzer-market-overview/
- Kato, T., Kubota, M., Kobayashi, N., Suzuoki, Y. (2005). *Effective utilization of by-product oxygen from electrolysis hydrogen production*. Energy 30, 2580-2595.
- Sakurai, M., Terao, T., Sone, Y. (2015). *Development of Water Electrolysis System for Oxygen Production Aimed at Energy Saving and High Safety*. 45th International Conference on Environmental Systems.
- Bertuccioli, L., Chan, A., Hart, D., Lehner, F., Madden, B., Standen, E. (2014). *Development of water electrolysis in the European Union*. Final report. Fuel Cells and Hydrogen Joint Undertaking.

2.5. Entities supplying equipment

Despite the deep knowledge in the technology for water electrolysis, there are no so many manufacturers or suppliers of this production method of oxygen and hydrogen. Moreover, it is important to highlight that the majority of companies focused on this technology have as a main objective the production of hydrogen.

Please find below the main company supplying electrolysers in Spain. This company focuses their objectives not only on the production of hydrogen, but also on that of oxygen like in the AQUASEF project.

Chart 3. Main supplier of electrolysers in Spain (Source: ARIEMA)

ARIEMA Energía y Medioambiente S.L.	Independent company, a leader in Spain in hydrogen and fuel cells, working with Spanish and international manufacturers to supply pressure alkaline electrolysers and polymeric electrolysers in Spain and Spanish-speaking countries. In terms of power, it works with equipment consuming between 200-300 watts up to great installations consuming hundreds of kilowatts in order to have the best technology solutions of hydrogen and oxygen production in Spain.	ariema http://www.ariema.com/

Concerning the manufacturing of electrolysers, in Europe, there are around twelve manufacturers which are normally focused on the manufacture of hydrogen, not oxygen or other gases. Please find below the most relevant manufacturers.

Chart 4. Manufacturers of electrolysers in Europe (Source: ARIEMA)

Accadue	Manufacturer of the AQUASEF machine, a newly created Spanish company with long-experienced staff. Alkaline electrolysis technology settled, nowadays working on EMP technology.	http://www.accadue.es
ITM Power	British manufacturer with experience in big EMP electrolysis sites, also service stations and integration with renewable energies and "power-to-gas".	http://www.itm-power.com/
Hydrogenics	Canadian manufacturer, place of business and manufacturing also in Europe (Germany and Belgium). Pressure alkaline electrolysis as their main asset, but also very active lines in EMP electrolysis and their own fuel cells.	http://www.hydrogenics.com/
NEL	Norwegian manufacturer with experience in big EMP electrolysis sites, also fully settled and transportable service stations.	http://nelhydrogen.com/
McPhy	French manufacturer with a full range of electrolysers, storage, fuelling stations and customised solutions. Also offering small production electrolysers similar or smaller than that of AQUASEF.	http://mcphy.com
ErreDue	Italian manufacturer of gases generation and handling equipment, including both electrolytic hydrogen and oxygen and nitrogen. The electrolysers are low	http://www.erreduegas.com/

	pressure and efficiency, but this also implies a lower cost.	

2.6. Recommendations

The self-production of oxygen in an aquaculture facility through water electrolysis also generates hydrogen as a by-product. Hydrogen is combustible gas which may imply risks when handling it. Moreover, it is also remarkable the danger when handling pure oxygen, due to its properties as a combustion accelerator. The set-up of this oxygen production system will require, therefore, to take the following measures in order to assure the security within the facility:

- Training of operators on the elements which might be dangerous, their identification and the measures to be taken.
- Signalling of risks, codes of colours, exclusion areas and existence of fire-extinguishing equipment.
- Monitoring variables of early detection of incidents and the contribution to improve the decision-making process when allocating the site resources.
    - Installation of **electric power sensors** to monitor the consumption of the facility as a whole and the partial data for different sections.
    - Installation of **temperature sensors** to monitor the air temperature, that of the flow and that of the tank/pond.
    - Installation of **dissolved oxygen concentration sensors** in the tank or pond to monitor and adjust the content of oxygen in water.
    - Installation of **CO_2 concentration sensors** in the water to assess and adjust the injection of O_2 or CO_2 depending on the cultivation environment.
    - Monitoring and **sensoring** to record the **changes in the weather** which may affect the installation, such as rain, wind or irradiation measurement.
    - **Control of** incoming and outgoing water and gases **flows** of different equipment set up in the facilities.
    - Installation of **nitrogen sensors** to control and detect potential hydrogen leakage in closed environments.
    - Smoke detectors, temperature ramps, CO and flames detectors, among others.

- Evaluation of the quality of the available supply and the suitability of the equipment and their mode of connexion.
- Set-up of equipment in the outside of the facilities and high areas to minimise risks.
- Use of certified materials concerning the contact with pressure hydrogen, always built in austenitic stainless steel such as the 316 L or similar ones.
- Forced ventilation in indoors areas likely to the existence of hydrogen leakage, if possible in an overhead position.

In the facilities designed within the AQUASEF project, the pure oxygen generated by electrolysis is not stored, which reduces the probability for this to be in contact with other fuels. In this case, the major risk factor is the hydrogen produced, its storage and later consumption.

Most of these recommendations may be also applied to all the methods for the production of oxygen.

Based on the information stated in this document, the producer may carry out a diagnosis to assess which is the best way to produce oxygen in his/her facilities both at technical and economic levels. This document is mainly focused on the self-production of oxygen through electrolysis and the advantages the implementation of this production method may provide in the future, but other methods for oxygen production are also indicated which are more demanded nowadays. It should be noted that the producer will have to analyse the advantages and disadvantages provided or to be provided by each method depending on the needs, the location and the directives and regulatory measures in force and those to be implemented.

3. Thermal solar installation for heating aquaculture cultivation tanks

Developed by INOMA Renovables S.L., this thermal solar installation is based on the use of low cost and high performance thermal solar collectors for a range of temperatures. The design has been specifically devised to supply thermal energy to the aquaculture cultivation tanks. The installation is devised by modules and it can be sized up depending on the specific needs of the aquaculture facilities.

Picture 2. Thermal solar installation (Source: INOMA Renovables S.L.)

3.1. Regulatory measures

Please find below the referral regulations concerning this technology.

- ✓ Royal Decree 1027/2007, July 20 approving the Regulation on Thermal Installations in Buildings hereinafter RITE.
- ✓ Royal Decree 865/2003, July 4 setting forth the hygiene and health criteria for the prevention and control of legionella.
- ✓ Ministry Decision FOM/1635/2013, September 10 updating the Basic Document DB-HE "Energy Savings" of the Building Technical Code approved by the Royal Decree 314/2006 March 17.

3.2. Technology solutions provided by the thermal solar installation

One of the major energy consumption in aquaculture facilities is for the heating of process water used in these. The optimal temperature varies depending on the species of cultivation, although the this is around 20º C.

The installations of thermal solar energy normally use flat plate collectors suitable for the production of domestic hot water, which is normally stored in storage devices at a temperature between 45º C and 60º C. In order to produce water at such a temperature, the primary circuits of the installation usually work at temperatures around 90ºC. The flat plate collectors use the green-house effect to reach these working temperatures.

However, given that the temperature needed for aquaculture cultivations is much lower than that of domestic hot water, for the installation PEHD Polyethylene High Density collectors have been used These collectors are normally used for the partial heating of water in swimming-pools, although an innovative application has been achieved, which allows to be adapted for heating water in aquaculture cultivations.

3.3. Advantages provided by the thermal solar installation

The thermal solar installation reduces the thermal energy to be produced out of hydrocarbons or electric resistances. Thus, for heating, renewable energy sources are used helping to reduce emissions to the air. Thus, the production costs of the site are reduced.

Some of the advantages provided by this type of installations are:

- ✓ Lower cost than flat plate collectors.
- ✓ Heat exchangers are not used so the process water is directly heated in the installation.
- ✓ The already existing pumping systems are used.
- ✓ The collectors boast a high performance for the working temperatures.
- ✓ Heating problems may be prevented, which is very common in thermal solar energy installations in the latitudes they are located in (areas with high sun radiation).

3.4. Links of interest

- Duffie, J., Beckman, W (2013). *Solar Engineering of Thermal processes.* John Wiley & Sons.
- Peuser, F., Remmers, K., Schnauss, M. (2010). *Solar Thermal Systems. Successful Planning and Construction.* Solarpraxis.

3.5. Entities supplying equipment

Please find below the main companies supplying this equipment and manufacturing this technology.

Chart 5. Main supplier of this technology (Source: INOMA Renovables S.L.)

INOMA Renovables S.L.	INOMA Renovables is an advance energy engineering company providing a wide range of specialised energy services and products with a quality to compete in international markets. It offers solutions for energy savings and efficiency in businesses, companies and public institutions.	http://www.grupoigfoton.es/

Chart 6. Main manufacturer of the thermal solar technology (Source: INOMA Renovables S.L.)

Roth	Global Plastic S.A, the main company of the Roth group is on the market for more than 10 years now manufacturing polyethylene tanks for diesel oil. For the last years, new business lines have been developed based on the protection of the environment, including the manufacturing of thermal solar energy systems for domestic hot water (PEHD collectors).	http://www.roth-spain.com/

3.6. Recommendations

As far as the thermal solar installation is concerned, this does not require complex maintenance efforts. However, it is convenient to follow a suitable plan for monitoring and maintenance allowing to verify the good operation of the installation, as well as to maintain its properties, protection and durability within the acceptable margins. On the following charts, you may find these actions.

Chart 7. Monitoring actions for thermal solar installation (Source: INOMA Renovables S.L.)

Element of the installation	Operation	Frequency (months)	Description
COLLECTOR	Cleaning	To be determined	Using demineralised water and suitable products.
	Connections	3	VI Cracks and deformations
	Absorber	3	VI Corrosion, deformation, leakage, etc.
	Connexions	3	VI Leakages
	Structure	3	VI Degradation, hints of corrosion
PRIMARY CIRCUIT	Pipe, isolation	6	VI Absence of dampness and leakage
SECONDARY CIRCUIT	Thermometer	Daily	VI Temperature
	Pipe, isolation	6	VI Absence of dampness and leakage

*VI: Visual inspection

As it is an installation bigger than 20 sqm of collection surface, it is recommended to carry out two revisions every year of the installation, in which the following items must be checked:

Chart 8. Check points of the installation (Source: INOMA Renovables S.L.)

Collection system

Equipment	Frequency (months)	Description
Collectors	6	VI Differences with the original VI Differences among collectors
Connections	6	VI Cracks, deformations
Absorber	6	VI Corrosion, deformations
Body	6	VI Deformation, oscillations, ventilation windows
Connexions	6	VI Detection of leakages
Structure	6	VI Degradation, hints of corrosion and tightening screws

*VI: Visual inspection

Hydraulic circuit

Equipment	Frequency (months)	Description
Water tightness	24	Carry out pressure test
External isolation	6	VI Degradation protection of connections and lack of dampness
Internal isolation	12	VI Connections and lack of dampness
Automatic drainage	12	OC and cleaning
Manual drainage	6	Drain the air out of the bottle
Pump	12	Water tightness
Cut-off valve	12	OC actions (open and close) to prevent tightening
Security valve	12	OC actions

*VI: Visual inspection; OC: Operation control

Electric and control system		
Equipment	**Frequency (months)**	**Description**
Electrical panel	12	Always check it is firmly closed and dust does not come in.
Differential control	12	OC actions
Thermostat	12	OC actions
Verification of the measuring system	12	OC actions

*OC: Operation control

4. Renewable energy systems for self-consumption in aquaculture sites

Installation devised by INOMA Renovables S.L., the installation is made up by photovoltaic sun modules and a mini wind power air generator. These systems can be easily sized up depending on the needs of the aquaculture site. Moreover, it includes a small weather station allowing to monitor different environmental patterns having an impact on the energy production.

Picture 3. Photovoltaic sun systems and mini air generator (Source: INOMA Renovables S.L.)

4.1. Regulatory measures

- ✓ Royal Decree 1699/2011, November 18 regulating the network supply from production installations of low power electric energy.
- ✓ Royal Decree 413/2014, June 6 regulating the activity of electric energy production out of renewable energy, co-generation and wastes sources.
- ✓ Royal Decree 842/2002, August 2 approving the Electro-Technical Regulation for Low Voltage and applicable Spanish standards UNE in force at the time of certifying the project.
- ✓ Decision on February 25, 2005 of the Direction General of Industry, Energy, and Mines setting forth supplementary regulations for the connexion of certain installations generating electric energy under special frameworks and their groupings to the low

voltage distribution networks. Regional Ministry of Innovation, Science, and Enterprise of the Government of Andalusia.

- ✓ Royal Decree 900/2015, October 9 regulating the administrative, technical and economic requirements for the electric energy supply methods with self-consumption and production with self-consumption.

4.2. Technology solutions provided by the renewable energy systems

The use of energy generation installations through the exploitation of renewable resources helps to reduce the consumption of fossil fuels required for energy generation, and so reducing the carbon footprint. The photovoltaic and wind installations are built in such a way that the electric energy they produce may be directly used in the aquaculture facility. They are fully compatible, since they allow to use either wind or sun radiation, which diversifies the potential sources of renewable generation.

The photovoltaic and wind installations can be scaled up and sized up depending on the energy demands, as well as the power contracted. In the case of the photovoltaic installation, the modules are distributed on the existing covers in the aquaculture facility. Therefore, very little additional surface is required for the installation. Moreover, it is devised so that the photovoltaic generator is placed on the same level of the waters of the cover. Thus, it is fully integrated in the building on which it is set up, reducing the visual impact.

Definitely, through self-consumption of clean energy produced by photovoltaic and mini-wind energy, two renewable resources may be exploited, the sun and the wind in order to reduce the electric energy consumption in ponds, while reducing pollutant emissions. Moreover, the economic savings achieved allow the amortisation of the installation.

4.3. Advantages provided by the renewable energy systems

Some of the advantages provided by the photovoltaic and wind installations connected to the network include the production of electric energy out of renewable resources. This electric energy will be used directly in the aquaculture facility, reducing the amount of electric energy to be bought by the premises. The economic savings achieved allow the amortisation of the installation in a few years.

Moreover, since they are installations made up by modules, they can be easily sized up depending on the energy needs of the aquaculture site, as well as the power contracted and the particular features of the production process.

4.4. Links of interest

- Antony, F., Dürschner, C., Remmers, K. (2010). *Photovoltaics for Proffesionals.* Solarpraxis.
- Jain, P. (2013). *Wind energy Engineering.* McGraw-Hill.
- Rivkin, D., Silk, L. (2012). *Wind Turbine Operations, Maintenance, Diagnosis, and Repair.* Jones & Bartlett Learning books.

4.5. Entities supplying equipment

Please find below the main companies supplying this equipment and manufacturing this technology.

Chart 9. Main supplier of this technology (Source: INOMA Renovables S.L.)

INOMA Renovables S.L.	INOMA Renovables is an advance energy engineering company providing a wide range of specialised energy services and products with a quality to compete in international markets. It offers solutions for energy savings and efficiency in businesses, companies and public institutions.	http://www.grupoigfoton.es/

Concerning the manufacturers of photovoltaic and wind installations for self-consumption, it should be noted those indicated in the following chart.

Chart 10. Main manufacturers of photovoltaic installations (Source: INOMA Renovables S.L.)

833 Solar	Company supplying photovoltaic modules, produced under high quality standards, which may be adapted to any type of projects (home, industrial or isolated systems projects).	http://www.833solar.com

Fronius	Manufacturer of electric current inverters, the Solar Energy department at Fronius is focused on photovoltaic energy since 1992 and distributes their products through a worldwide network of wholesalers. Through their 141 Solar Energy subsidiaries, Fronius works all over the world at maximum performance.	http://www.fronius.com/
Enair	Spanish manufacturer of low power air generators between 3 and 30 kW, complying with the Standard IEC 61400-2, standard regulating the mini-wind power generation at world level.	http://www.enair.es/
Solar-log	Solare Datensysteme GmbH (SDS) is one of the leader companies in the field of sun monitoring, smart energy and management of supplies into the network. From 2007, they have developed and distributed their Solar-Log™ devices and the portal Solar-Log WEB Enerest™. Also, they distribute compatible weather measuring equipment.	http://www.solar-log.com

4.6. Recommendations

In this section, a number of recommendations are set out in relation to the use and maintenance of the above-mentioned equipment.

- The equipment must be set up and operated by qualified staff.
- Never leave a module unleashed or properly fixed to prevent falling and glass breaking. Never use a glass broken module.
- Never let the module fall or throw objects on it. Do not stand or walk on it.

- Do not disassemble the module or take down any part, label or piece set up by the manufacturer, including protection diodes, without express authorisation.
- In case of using protection fuses in the installation, follow the instructions of the technical specification card of the module attached.
- Do not concentrate sun light on the module.
- A photovoltaic module generates electricity when exposed to the sun light or other light sources. Fully cover the surface of the module with an opaque material during installation, dismantling or handling.
- Use duly coated tools in isolating materials during the works on the module.
- Always work under dry conditions, both for the module and the tools.
- Do not place the module if there are flammable gases or vapours, as they may generate sparks.
- Prevent electric shocks when installing, wiring, starting or maintaining the module.
- Do not touch the terminals while exposed to light. Fit the installation with suitable protection devices to prevent 30 V or higher shocks in CC to any person. When the modules are serially connected, the voltages are added and when connected in parallel, the intensity is added in its turn. Therefore, a system made up by photovoltaic modules may generate high voltages and intensities which represent an additional risk.
- Under normal conditions, a photovoltaic module is likely to go through conditions producing a major current and/or voltage than those indicated under standard conditions. Therefore, the Isc and Voc values shown on the label with the features of the module should be multiplied by a 1.25 factor to determine the maximum acceptable values of the components of the installation concerning, voltage, current, conductors' sections, fuses and size of the controls connected to the output of the photovoltaic generator.
- Fix the ground connection to the corresponding drill hole of the frame though a mechanical fixation system such as screws and nuts.

Among the maintenance actions to be carried out, they are included:

- Regular cleaning of the module.
- Visual inspection of potential internal degradations of the tightness of the module.
- Control of the conditions of electrical connexions and wiring.
- From time to time, control of the electrical features of the module.

- Verify the inverter support to avoid the equipment making much noise.
- Verify that the location of the inverters is not exposed to direct sun light.
- Verify that the surrounding area of the equipment is free to allow free circulation of fresh air and avoid high temperatures.
- Verify all connexions and contact points to avoid errors in frequency, voltage, impedance and isolation.
- Verify the ventilation pipes of the equipment are not plugged, to avoid an energy performance lower than usual.
- The recommended preventive maintenance tasks shall be carried out YEARLY.
- Check the conditions of the cover of the inverters, verifying the conditions of the locks, doors and handles, as well as the fixation of the equipment to their slings both on the upper and lower side if applicable. Moreover, the good conditions of the cover must be checked and the absence of hits, scrapes or rust which may damage the cabinet or make it lose its protection rate. In case any of these defaults are detected, all the affected parts should be replaced.
- Verify the conditions of wires and terminals, the right placement of the wires so that they are not in contact with active parts, defaults in isolation or hot spots, verifying the colour of isolation and terminals.
- Verify the tightness of the plate screws and power cables.
- Proceed to check the tightness.
- Visually check that the connexion plates of the AC supply keep the security distance, as well as their initial electrical features.
- Verify the absence of humidity inside the cabinet.
- Verify the right fixation to their corresponding fixation points of the components of the cabinet.
- Verify the right ventilation of the equipment, that is: verify the conditions of the air-extracting fans, proceed to the cleaning and replacement if necessary, clean radiator's flaps, clean ventilation grids.
- Verify the conditions of the environment so that no buzz is amplified or transferred.
- Tighten again screws, shaft, rotating axle and head of the air-generator.
- Tighten again screws of the air-generator stem.
- Grease the bearings of the air-generator.

- Verify the conditions of the blades of the air-generator.
- Verify the right functioning of the air-generator.
- Verify the cover (painting, defaults, rusty spots, etc.) of the air-generator.
- Inspection of brushes, rings and connexion cables of the air-generator.
- Replacement of brushes of the air-generator.

5. Plug&Play equipment

Independent system operated by photovoltaic sun energy, devised by INOMA Renovables S.L. In the framework of the AQUASEF project. Based on the photovoltaic energy, the Plug&Play equipment allows to supply the necessary electric power in aquaculture facilities located in places where the sources of supply are far away or they are little reliable.

Picture 4. Plug&Play equipment (Source: INOMA Renovables S.L.)

5.1. Regulatory measures

- ✓ Royal Decree 842/2002, August 2 approving the Electro-Technical Regulation for Low Voltage and applicable Spanish standards UNE in force at the time of certifying the project.
- ✓ Order March 26, 2007 approving the technical specifications of the photovoltaic installations in Andalusia. Regional Ministry of Innovation, Science, and Enterprise of the Government of Andalusia.

5.2. Technical solutions provided by the Plug&Play equipment

The Plug&Play compact photovoltaic systems have been devised to cover the electric supply in distant areas through photovoltaic technology. These systems devised for different powers

and autonomies are useful to match one-time demands of energy (pumps, lighting...) in distant sites.

Moreover, this equipment has been specifically devised for areas in which the aquaculture sites are set up, areas with high corrosion due to the extreme temperature, humidity and salinity conditions existing in these locations. In fact, these extreme environmental conditions are those making that most of the standard equipment existing in the market has a very limited durability. Therefore, with the Plug&Play photovoltaic systems the reliability in supply has been improved.

5.3. Advantages provided by the Plug&Play equipment

The Plug&Play compact photovoltaic systems allow to supply electricity on one-time basis in locations to which the electric supply is not normally available. This is quite common at aquaculture facilities. Thus, the issue of the electric supply is solved for moderate consumptions in distant areas. Moreover, since it is an equipment specifically designed for high humidity and salinity conditions, they are much more durable than that existing nowadays on the market.

5.4. Links of interest

- Ferry, D, Bird, J. (2001). *Electronics Materials and Devices.* Academic Press.
- Mohan, N, Undeland, T, Robbins, W. (2003). *Power Electronics: Converters, Applications and Design.* McGraw Hill.

5.5. Entities supplying equipment

The company designing the Plug&Play compact photovoltaic systems is INOMA Renovables S.L. Further information is provided below.

Chart 11. Main supplier of this technology (Source: INOMA Renovables S.L.)

INOMA Renovables S.L.	INOMA Renovables is an advance energy engineering company providing a wide range of specialised energy services and products with a quality to compete in international markets. It offers solutions for energy savings and efficiency in businesses, companies and public	Inoma renovables,sl http://www.grupoigfoton.es/

	institutions.	

5.6. Recommendations

Please find below a number of recommendations are set out in relation to the use and maintenance of the above-mentioned equipment.

- In case of repair, fully unplug the equipment to avoid any kind of lingering current which might cause a short circuit when handling the CPU or any other integrated circuit.
- Pay attention to use of magnetised objects or tools which may affect the behaviour of the circuit, as well as damage certain electronic components.
- Wear anti-static gloves during the repairing in order to prevent electrostatic shocks on the circuit.
- Use suitable screwdrivers when unpacking the product, as otherwise the screw might be damaged.
- Use the appropriate tools, as well as the necessary instrument for an adequate repairing.
- Be especially careful when welding, do not put components under high temperatures.
- It is recommended to use a power supply with commutator and protected against short circuits when repairing instead of a battery.

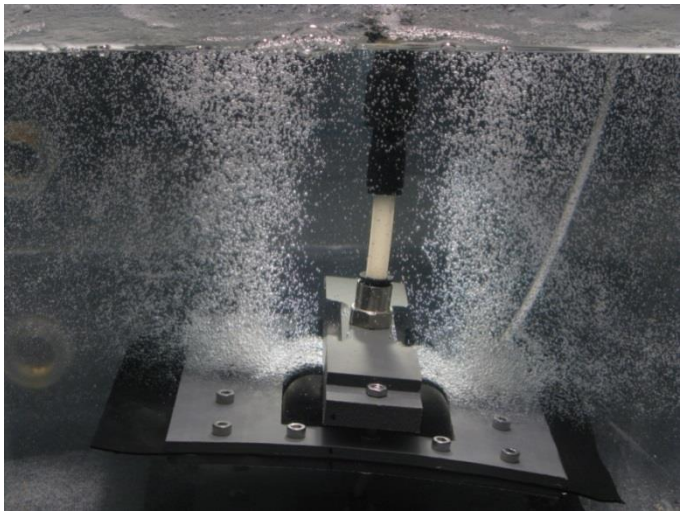
*Safety for Electrostatically Sensitive Devices (ESD)

Many of the electronic components, mainly semi-conductors (integrated circuits (IC), BGA chip, etc.) may be easily damaged by electrostatic shocks. These components are also known as ESD (Electrostatically Sensitive Devices). Please find below a number of instructions to prevent damages on the ESD caused by static electricity.

- Remove the potential static electricity in your body by touching some metallic material in advance (metal body or plate) before manipulating any electronic component.
- Wear anti-static gloves during repairing, as well as anti-static wristbands connected to a metallic body if necessary.

6. MicroBTech diffuser for fries' tanks

Developed by D&BTech, this diffuser for fries' tanks consists in a device generating micro bubbles of air to supply oxygen.



Picture 5. Diffuser for fries' tanks (Source: D&BTech)

6.1. Regulatory measures

The transfer tests carried out on these devices comply with the ASCE-1992 regulations.

6.2. Technology solutions provided by the MicroBTech diffuser

Cross-flow air device with the ability to generate bubbles within a size range of [100-2000] micrometres. As smaller sizes of bubbles are obtained compared to other diffusers in the market, an improved efficiency in the transfer from gas to liquid is achieved.

6.3. Advantages provided by the MicroBTech diffuser

Savings in the consumption of oxygen up to 50% have been achieved in fries' tanks.

6.4. Links of interest

- http://www.dbtech.es/productos-generacion-burbujas/difusores-precision-generacion-controlada-microburbujas

6.5. Entities supplying equipment

The MicroBTech devices are devised by the company D&BTech. They are assembled and adapted to a high fidelity calibration by D&B Tecnología S.L. itself. This company has been manufacturing air devices for aquaculture for more than 15 years.

Chart 12. Company supplying this technology (Source: D&BTech)

Drops & Bubbles Tecnología S.L.	D&BTech is a company developing and trading innovative technology for gases and liquids mixes in different industrial sectors. The devices they develop are easily installed and besides, they generate energy and consumption savings compared to the best ventilation equipment on the market, higher than 50%.	http://www.dbtech.es/

Some of the components of these diffusers are manufactured by the company Ibercool Water Blocks in their accurate CNC machinery.

Chart 13. Company supplying components for diffusers (Source: D&BTech)

Ibercool Water Blocks	Ibercool Water Blocks is a company designing and manufacturing high efficient and quality liquid cooling blocks at very competitive prices. From the Research and Development processes, including raw materials and manufacturing management, and ending with the packaging and customer support, the company assures the highest quality standards through the ISO 9001 quality management systems, as well as their full respect to the environment through the ISO 14001 environmental management standards, both of them certified by external audits.	http://www.ibercool.com/es/

6.6. Recommendations

This air device due to its physical rationale is highly recommendable for salty waters and specifically for sea water. It suits environments requiring little stirring such as bio-reactors, micro-algae tanks or some products of the food industry. The device works by means of a cross flow of water and oxygen.

- The oxygen flow to be added ranges from 0.5 l/min to 10 l/min.
- The water flow depends on the oxygen flow based on the relation between water flow and oxygen flow (r=Ql/Qg). The highest efficiency values for the equipment range between r=1 and r=10.
- The pressure on the oxygen line necessary to achieve the said flows ranges from 100 mbar to 1 bar compared to the diffuser discharge pressure.

The pressure for oxygen supply shall not exceed in any case, the addition of the output pressure of the diffuser plus 1.2 bar, which constitutes the maximum operational limit for gas pressure.

7. O_2BTech air device for ponds

Developed by D&BTech, this O_2BTech air device for fish fattening ponds allows to achieve the optimal oxygen concentration only by supplying air micro bubbles, even in periods with maximum oxygen demand. Thus, the provision of additional oxygen is nearly eliminated. Moreover, it allows a better nutrients mix, which results in an improved quality in the cultivation environment.

Picture 6. Air Device O_2BTech (Source: D&BTech)

7.1. Regulatory measures

The transfer tests carried out on these devices comply with the ASCE-1992 regulations.

7.2. Technology solutions provided by the O_2BTech air device

Cross-flow air device with the ability to generate bubbles at a size around 1 mm of diameter. As smaller sizes of bubbles are obtained compared to other diffusers in the market, an improved efficiency in the transfer from gas to liquid is achieved.

7.3. Advantages provided by the O_2BTech air device

Savings in the consumption of oxygen up to 100% have been achieved in fattening tanks.

7.4. Links of interest

- http://www.dbtech.es/productos-generacion-burbujas/dispositivos-aireacion-aireadores

7.5. Entities supplying equipment

The O_2BTech devices are fully designed and assembled by the company D&B Tecnología S.L. itself.

Chart 14. Company supplying this technology (Source: D&BTech)

Drops & Bubbles Tecnología S.L.	D&BTech is a company developing and trading innovative technology for gases and liquids mixes in different industrial sectors. The devices they develop are easily installed and besides, they generate energy and consumption savings compared to the best ventilation equipment on the market, higher than 50%.	http://www.dbtech.es/

7.6. Recommendations

This air device due to its physical rationale is highly recommendable for salty waters and specifically for sea water.

This device uses two flows, one flow from water out of the tank and another air flow taken from the environment.

- It is recommended the water flow to be the lowest possible in order to save pumping energy. It has been proved that under the conditions existing in fish fattening ponds, a

relation by 1 Q_{liquid} /Q_{gas} is enough to achieve the adequate bubble size and maximise the energy efficiency of the equipment.

Always in line with a low energy consumption rate, the operating pressures are low: The pressure on the gas line is around 100 mbar to 1 bar compared to the diffuser discharge pressure. Concerning the water pressure, it is only required that of + 10 mbar water column. These very low pressures imply that the energy consumption is very little compared to the amount of bubbles which are being generated.

8. Open tank for micro-algae cultivation

Developed by D&BTech, it is a hydro-dynamic tank excavated in the ground for mass cultivation of micro-algae. It has been designed through CFD fluid-dynamics simulation techniques for an efficient energy use and the reduction of the efforts when doing the maintenance.

Picture 7. Open tank for micro-algae cultivation (Source: D&BTech)

8.1. Regulatory measures

The tanks developed comply with the EC Regulation No 258/97 on micro-algae cultivation.

8.2. Technology solutions provided by the cultivation tank

An open tank for micro-algae cultivation has been designed aided by numerical simulation techniques in order to improve circulation and mixing. Also, this design helps the settlement of solids in suspension in specific areas for later removal. The propulsion system is also developed ad hoc for the project and it is different from the traditional paddle-wheel system.

The provision of CO2 coming from the combustion of the propane boiler is achieved through cross flow diffusers which are also developed for the project.

8.3. Advantages provided by the cultivation tank

Some of the advantages achieved are given below:

- ✓ Energy savings in propulsion (50%) compared to the traditional paddle-wheels systems.

- ✓ Substantial improvement of the exposure time of the algae to sun radiation, affecting productivity.
- ✓ Improved cleaning operations due to the settlement of solids in specific areas, which are defined in two small areas (at the ends of the central panel).

8.4. Links of interest

- http://www.dbtech.es/productos-generacion-burbujas/tanques-cultivo-microalgas-acuicultura

8.5. Entities supplying equipment

The micro-algae cultivation tanks are fully devised, optimised and built by the company D&B Tecnologia S.L.

Chart 15. Company supplying this technology (Source: D&BTech)

Drops & Bubbles Tecnología S.L.	D&BTech is a company developing and trading innovative technology for gases and liquids mixes in different industrial sectors. The devices they develop are easily installed and besides, they generate energy and consumption savings compared to the best ventilation equipment on the market, higher than 50%.	http://www.dbtech.es/

Some of the components of these tanks have been purchased from other companies; canvas (Toldos La Sombra), propulsion equipment (Innovaqua S.A.).

Chart 16. Some companies supplying components (Source: D&BTech)

Toldos la Sombra de Sevilla	Toldos la Sombra de Sevilla is a company with more than 30 years of experience specialising in every kind of awnings.	http://www.lasombradesevilla.com/

Innovaqua S.A.	Innovaqua S.A. is a company group focused on the provision of comprehensive services specialising in the field of aquaculture and water technology. They are specialists in the design and installation of recirculating and close-circuit systems.	INNOVAQUA http://www.innovaqua.com/

8.6. Recommendations

There are some recommendations to be taken into consideration:

- Size up the tank depending on the needs, as a production surplus may be generated which may be difficult to manage. In any case, a project by D&BTech or specialised company should be required.
- Although the extra supply of CO_2 (in the project coming from the combustion out of the boiler) helps to increase production, this operation might not be needed in case of non-availability of a propane boiler at the facility. The propulsion and mixing systems would also make productivity to attain the right levels.

9. CONCLUSIONS

The viability for the setting up and implementation of each of the technologies developed within the LIFE 13 ENV/ES/00420 AQUASEF project proves the replicability of results of this project.

Once the technical experience with each of those has come to an end, we have verified the degree of implementation achieved or that to be achieved in the near future for each type of technology. For example, for the hydrogen technologies their implementation in a sector in which they had never been implemented has been proved, that is, in the aquaculture sector. Although the viability has been proved, the hydrogen technologies market is still a starting market so the economies of scale does not allow yet an economic viability for their implementation, due to the huge production costs of the equipment. With regards to the technologies used for the exploitation of renewable energies such as the thermal solar, photovoltaic and wind energies, we have proved their economic and technical viability. This a very good option that producers should take into consideration for carrying out actions aiming to improve the sustainability of the activity, both at environmental level (emissions reduction) and economic level (electric costs cut-off). Finally, as far as the ventilation techniques for aquaculture facilities are concerned, we have proved their technical viability. Increases in the efficiency for oxygen diffusion into water have been proved. Therefore, the improved performance of this equipment compared to that existing in the market at around 30%. This is why this constitutes an interesting option for the oxygenation processes in cultivation tanks. Moreover, the combination of these ventilation systems with the new design of tanks for cultivation of micro-algae may imply a significant advantage in the cultivation of micro-algae due to the increase in productivity of the systems.

On this implementation guide, the most relevant information has been included so that final users may purchase and begin to sue any of the technologies developed in the framework of the AQUASEF project. However, as already mentioned on the technical description of each technology, the implementation of each technology in new facilities should be assessed in advance, since depending on the features of each facility, it would be required to determine the correct size and design to optimise their implementation. For this purpose, we recommend

to contact the expert technical staff in charge of developing, setting up and validating each of the technologies stated in this methodology guide.

Please find below the details of all of them:

ENTITY	TECHNOLOGY	CONTACT PERSON
ariema http://www.ariema.com/	Electrolyser for obtaining oxygen and hydrogen out of water	**Rafael Luque Berruezo** General Director / CEO Mob. (+34) 91 804 53 72 | 91 241 95 31 rafael.luque@ariema.com
Inma renovables,sl http://www.grupoigfoton.es/	Thermal solar installation for heating aquaculture cultivation tanks	**Francisco Javier Leal Juárez** Technical Director Ph: +34 956 264 612 j.leal@grupoigfoton.es
Inma renovables,sl http://www.grupoigfoton.es/	Renewable energy systems for self-consumption in aquaculture sites	**Francisco Javier Leal Juárez** Technical Director Ph: +34 956 264 612 j.leal@grupoigfoton.es
Inma renovables,sl http://www.grupoigfoton.es/	Plug&Play equipment	**Francisco Javier Leal Juárez** Technical Director Ph: +34 956 264 612 j.leal@grupoigfoton.es
D&B Tech http://www.dbtech.es/	MicroBTech diffuser for fries' tanks	**Álvaro Lobo** Business Development Manager Ph: (+34) 691 60 19 29 alobo@dbtech.es
D&B Tech http://www.dbtech.es/	O2BTech air device for ponds	**Álvaro Lobo** Business Development Manager Ph: (+34) 691 60 19 29 alobo@dbtech.es
D&B Tech http://www.dbtech.es/	Open tank for micro-algae cultivation	**Álvaro Lobo** Business Development Manager Ph: (+34) 691 60 19 29 alobo@dbtech.es