PROJECT FINAL REPORT

Final Publishable Summary Report

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Project acronym: ADAW

Project title: ***Saponification pre-treatment and biosensors based control system for slaughterhouse waste anaerobic digestion improvement***

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Final report: **1st** ☐ **2nd** X☐ **3rd** ☐ **4th** ☐

Period covered: **from** **01/12/2013** **to** **28/02/2015**

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Declaration by the scientific representative of the project coordinator[1]

I, as scientific representative of the coordinator1 of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):

  ☐ has fully achieved its objectives and technical goals for the period;

  ☒ has achieved most of its objectives and technical goals for the period with relatively minor deviations[3];

  ☐ has failed to achieve critical objectives and/or is not at all on schedule[4].

- The public website is up to date, if applicable.
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: Mr Alfredo Martin

Date: 30 / 04 / 2015

Signature of scientific representative of the Coordinator:

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

[3] If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

[4] If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

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1. Executive Summary

EU Slaughtering industry produces large amounts of different solid wastes and wastewaters. Direct disposal of highly polluted wastewater and organic residues into the sewerage system without prior treatment is mostly not acceptable due to resulting environmental problems and the risk of clogging in the wastewater piping systems. Moreover, the Directives 1069/2009 and 142/2011 limit the use of landfill as animal by-products management strategy and suggest treatment alternatives. Non-risk animal by-products (ABP Category II and III) can be treated by Anaerobic Digestion (AD) according to EU Directive, being the allowed technology that has got a positive energy balance (biogas for electricity or heat) with lower investment and operational cost.

Slaughterhouse animal by-products are characterized by rich content of lipids and protein, which has up to 20% more biomethanisation potential than other feedstock (energy crops or municipal wastes) but have some difficulties to be biologically treated. Lipid rich waste produces microorganism inhibition reducing process efficiency and creating operation and maintenance problems in anaerobic digestion.

ADAW project aims to get an improved biogas production technology in to efficiently treat lipid rich wastes like animal by-products from the slaughtering industry, by means of and adequate integration of some key techniques:

- Thermo-chemical pre-treatment to improve biogas yields by hot hydrolysis reaction between a fatty acid from slaughterhouse wastes (non-soluble) and an alkali, resulting in simpler and soluble molecules with better contact between the substrate and micro-organisms, thereby enhancing their anaerobic biodegradability.
- Ultrasonic dispersion after thermal pre-treatment that favours the process by breaking complex organic molecules and easind their digestion by the bacterial consortia culture during the Anaerobic Digestion.
- Better control of the anaerobic digestion condition by development of sensors for on-line detection of alkalinity and Volatile Fatty Acids (VFA) and an advance controller for stable automated biogas process control.

ADAW technology is directed to two main target customers:

- Slaughterhouse operators (small and medium size) who will benefit from an alternative solution for waste by integrating a farm scale biogas plant in their facilities without a large investment.
- Commercial biogas holders who will be able to use also slaughterhouse wastes as a potential energy source, replacing at least in part the use of expensive energy crops as feedstock.

ADAW technology also has an impact in EU society reducing the tons of wastes that need to be incinerated and so the associated emissions, at the same time that produces green energy contributing to achieve the renewable energy target of EU.

2. Summary description of project context and objectives

Every year nearly 360 million pigs, sheep, goats and cattle as well as several billion poultry are killed in EU slaughterhouses. Germany, Spain and France produce almost half (48 %) of the pig meat produced in the EU. France, Germany and Italy produce a similar proportion (47 %) of cattle meat. The United Kingdom and Spain produce more than half (51 %) of the sheep meat while Greece alone produces almost half (48 %) of the goat meat produced in the EU. Five Member States (France, the United Kingdom, Spain, Germany and Poland) account for almost 2/3 of total EU production of poultry meat.

Slaughtering industry produces large amounts of different solid wastes and wastewaters. Direct disposal of highly polluted wastewater and organic residues into the sewerage system without prior treatment is mostly not acceptable due to resulting environmental problems and the risk of clogging in the wastewater piping systems. Moreover, the Directives 1069/2009 and 142/2011 limit the use of landfill as animal by-products management strategy.

Consequently, this sector that often run on tight margins of profit, has limited options for waste managements which increase of total slaughtering industry costs. Incineration is mandatory for high risk animal by-products (Category I) but the investment and maintenance cost and its environmental impact make them not suitable for the treatment of non-risk animal by-products (Category II and III). Composting and Anaerobic Digestion (AD) are more economic solutions suggested by the EU Directive to treat Category II and III animal by-products, being the last one the unique that has got a positive energy balance (biogas for electricity or heat production).

Slaughterhouse animal by-products are characterised by rich content of lipids and protein, which has up to 20% more biomethanisation potential than other feedstock (energy crops or municipal wastes). This high methane potential makes attractive the use of these wastes, but there are some technological barriers that make them difficult to treat. ADAW technology addresses directly these problems and provides an effective solution by:

- Saponification pre-treatment to improve biogas yields. : by hot hydrolysis reaction between a fatty acid from slaughterhouse wastes (non-soluble) and an alkali, resulting in simpler and soluble molecules with better contact between the substrate and micro-organisms, thereby enhancing their anaerobic biodegradability.

- Ultrasonic dispersion after thermal pre-treatment that favours the process by breaking complex organic molecules and eases their digestion by the bacterial consortia culture in during the Anaerobic Digestion.

- Better control of the anaerobic digestion condition by development of sensors for on-line detection of alkalinity and Volatile Fatty Acids (VFA) and an advance controller for stable automated biogas process control.

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Feedstock costs have a large impact on the economic viability of a biogas plant. Depending on the type of feedstock, they could account for up to 50% of production costs. For energy crops (forestry biomass) there are multiple markets and the food and energy industry are competitors, e. g. in the maize market. The price for energy crops such as maize silage and wheat differ by country and region due to national and local supply-demand dynamics and regulations, making the biogas business very volatile. However, the use of waste and manure often have negative or zero costs as they have to be processed in some manner prior to disposal, being and important alternative to energy crops.

In ADAW case, the feedstock is treated as an income. It is considered as a resource with a double benefit. For the waste production facilities, the ADAW technology allows to pay less for its treatment compared to traditional management methods. For the biogas facilities, ADAW technology enables to treat a new kind of organic waste which supposes an extra income and a better profit performance

ADAW project is aiming to get an improved biogas production technology in to treat lipid rich wastes like animal by-products from the slaughtering industry. In order to get this, ADAW project has defined several scientific and technological objectives.

Scientific objectives:

1. To determine the combined conditions for saponification and pressure sterilisation pre-treatment to meet Directive 1069/2009

2. To define sonication conditions and the effect of ultrasounds specific energy on waste solubilisation.

3. To monitor the anaerobic bacteria evolution taking into account: fatty acids inhibition effect at lab and prototype scale.

4. To establish the relationship between VFA, Alkalinity concentration and CH4 production.

5. To determine representative data for VFAs (ethanoic acid, propanionic acid pentanoic acid)

6. To determine the ionophore used for alkalinity detection considering response time, LOD and dynamic range.

Technological objectives:

1. Ultrasound sonotrode customised equipment to work under conditions defined in Scientific Objective Number 2.

2. Coupling of saponification and pressure sterilisation processes in a single tank that meets Directive 1069/2009 conditions.

3. Fuzzy control software embedded in a customised hardware controller.

4. Volatile Fatty Acids on-line sensor array with high accuracy and suitable range of detection.

5. Alkalinity electrochemical potentiometric online sensor with suitable range of detection.

6. Reduction of operation cost in 7% for European Slaughterhouse SMEs and increase in 20% biogas yields.

In order to overcome these problems, the SMEs have selected 3 RTD organisations (IRTA, INRA, INSP) with wide experience in the fields required to improve existing technology. IRTA has been contacted due to their previous work in slaughterhouse anaerobic degradation, including bacteria selection. INRA has been contacted due to their great experience in saponification pre-treatment for the digestion of wastes with high fatty acid content. IRTA and INRA have been previously working together in the degradation of animal waste and have already relevant publications in the field. INSP has been included in their Consortium for their wide knowledge in monitoring sensor and advance control system development, especially in fuzzy logic based algorithms for industrial applications. They have also previous experience in ultrasonic system applications for waste treatment, being involved in another European Project for the development of US technology on pig manure fractions.

3. Description of main S & T results/foregrounds

The actual developments obtained for each result after the execution of the ADAW project have been:

1. Definition of anaerobic digestion design basis for the prototype reactor involving saponified material compared to sterilized and untreated waste. Test with combination of pH, temperature and reaction time of on the saponification process showed that those parameters do not have a significant effect on the CH4 potential, but have an effect on the CH4 production rate. In addition, the type of alkali agent does not play a significant role on the total potential of methane production.

2. Selection of the best mixture of ABP wastes after a study of the methane production of each fraction, and identification of the methane potential of the mixture. The selection of fraction to be saponified has been important at time to save alkali. The saponification pre-treatment of lipidic waste has demonstrated to be a suitable process in combination to AD, since increase in the anaerobic degradation performances in contrast to sterilization.

3. A study of the effect and conditions of sonication on lipid waste solubilisation and biomass activation in AD, defining specific energy, time and application mode with laboratory probes and using continuous laboratory reactors.

4. Design of ultrasound chamber for process scale-up using the results of specific energy at laboratory scale and commercial sonotrodes. The position of transducers in the chamber has been defined by computer simulation attending to maximizing the energy transmission. Sonication chamber was constructed with different power densities in order to be versatile for the pilot plant and tested at lab scale before install it in the prototype.

5. Study and development of a sensor array for VFA and alkalinity determination. Three different types of sensors have been developed with the expected accuracy and detection range a volatile fatty acid sensor, a biosensor for total VFA determination and an alkalinity sensor. Different sensors were selected to be a part of the array based on their sensitivity and signal stability. The winners were encapsulated in a cell for a better handling and sample availability. The array was calibrated using real samples by spiking with VFA and carbonates.

6. A portable on-line sampling system has been designed and built using the encapsulated sensor array as base of detection. The operating and measuring protocol was defined and implemented leading to an automatic device.

7. Develop of the advance control system strategy for the biodigestion plant that led to the definition of the P&IDiagram of the pilot plant that integrates all innovations of ADAW technology, identifying equipment (reactors, agitators, tanks, pumps),

instruments (probes and sensors), devices (valves and actuators) and electrical cabinet.

8. A plant prototype of 100 l digester has been built for Anaerobic Digestion with all necessary equipment and control cabinet based on the defined design. ADAW innovations products were implemented and integrated.

9. Fuzzy logic control software was designed and programmed based on the operator's knowledge. It takes the information from the on-line measuring system and automatically corrects the plant operation. The hardware has been implemented in an industrial PLC, which has been installed inside the control cabinet of the pilot plant.

10. Testing the integration of the ADAW technology at pilot plant for several months. Conversion rates and biogas production were determined in different campaigns on stable conditions and stresses conditions.

11. Finally, ADAW technology consist of:

    Integrated solution process for specific Anaerobic Digestion of lipid rich material that permits a more cost-effective solution to treat slaughterhouses wastes and also allows biogas plants operators to feed a high biomethanisation feedstock to their installations by:

    a) Coupling of saponification and the compulsory pressure sterilization processes (for Category II and III Slaugterhouse waste) in a single step with energy recovery, meeting safety regulation treatment for these wastes at the same time that makes the fatty feedstock more bioavailable for AD by change in the chemical structure.

    b) An ultrasonic dispersing and de-agglomeration system customized for its use as pre and post treatment that:

        - Enhance the solubilization and the biodegradability of organic matter, increasing their biogas transformation in Anaerobic Digestion.

        - Avoid operational problems related to cloggings which are caused by lipids into the anaerobic reactors.

        - Avoid foam formation, which involves an inefficient gas recovery from the digesters, a fouling of gas collection pipes due to entrapped foam solids and problems in settling.

c) Selection of a well-adapted and specific Bacterial population to work on high organic loads of wastes with high-lipid and protein content.

d) A liquid-phase on-line sensing and measuring system for individual estimation of Volatile Fatty Acids (VFA) and Alkalinity in the digester that allows working with higher ORL (≈4 kg COD/m3d). It gives to a close monitoring of a bioprocess that is the key to maximize process efficiency.

e) An advanced and customised control system for real time monitoring to facilitate automatic process control and optimized energy management based on the information provided by the liquid-phase on-line sensing and measuring system. ADAW´s fuzzy logic take decisions, as a reaction of a situation previously programmed based on operators knowledge.

4 Potential impact and main dissemination activities and exploitation results.

POTENTIAL IMPACT ON EU SOCIETY

ADAW project will provide additional benefits at European level as an impact in the environment and in employment.

Slaughterhouse waste incineration is mandatory for Category I animal by-products and an alternative option for the treatment of Category II and III. The incineration process produces ashes that contain hazardous components. Emissions from incinerators can include heavy metals, dioxins and furans, which may be present in the waste gases, water or ash. Plastic and metals are the major source of the calorific value of the waste.

The pollutants which are created, even if trapped, reside in filters and ash, which need special landfills for disposal. In case energy recovery is attempted, it requires heat exchangers which operate at temperatures which maximize dioxin production. If the gases are quenched, it goes against energy recovery. Such projects disperse incinerator ash throughout the environment which subsequently enters our food chain. Incinerator technological intervention in the waste stream distorts waste management. Such systems rely on minimum guaranteed waste flows. It indirectly promotes continued waste generation while hindering waste prevention, reuse, composting, or its energy valorisation.

By optimising the anaerobic digestion for biogas production from slaughterhouse wastes, ADAW project will benefit not only slaughterhouses both in a cost-efficient approach and as an environmental sustainable option for their waste, but EU society reducing the residue to the incinerated (less ash and pollutants). At the same time, ADAW boosts the use of another source of green energy helping to comply with EU renewal energy target.

SMEs continue to be one of the main pillars of the EU´s economy, even though they are operating under an uncertain economic stability in Europe. Despite the current situation, EU´s SMEs started to overcome the recession of 2009, but with a smother employment recovery, causing loss of jobs across Europe. In this context, ADAW project arise from the need to enhance the competitiveness of the SMEs of the sector, to enjoy the market opportunities of the current European economic framework and to gain strong position in national and European markets.

IMPACT ON PARTICIPANTS

The aim of ADAW project is to find an economic solution to treat waste with high lipid and protein content. Using the slaughtering industry waste as substrate for anaerobic digestion plants for biogas production appears as economic-efficient technology for treating animal by-products of Category II and III. The research activities of ADAW project are addressed to offer to the market a competitive solution for slaughterhouse operators and commercial biogas plant holders (include waste processing operators).

The impact that ADAW solution will have for the different end-users of the solution that are divided in 3 main groups:

- Small slaughterhouse operators (TECNO): which do not have enough investment capacity to integrate the waste management technology in their own facilities.
- Medium slaughterhouse operators: with capacity to integrate a waste management plant in their own facilities (farm scale biogas plants).
- Industrial biogas plant holders (BFC): That receive the waste for several industries, including small slaughterhouse operators, under a fee that the operators have to pay so the waste processor handle their waste.

DISSEMINATION ACTIVITIES

ADAW partners continued to dissemination actions in order to fulfil with the objectives established into the Dissemination Plan. These actions were led by the Exploitation Manager (BFC) and the Dissemination Manager (EST) in order to ensure that no confidential information is shared without the approval of the SMEs partners, to safeguard the competitive advantage of the SMEs involved in the ADAW project and to guarantee that efforts are appropriately devoted.

In this sense, different activities have been developed to facilitate the approach to the potential stakeholders in national and European markets:

- ADAW Project Website. It is available since April 2013 and updated, at least every 3 months. It has been developed in English and contains the main news and updates of the project.
- Presence at partner websites. ADAW partners have added notes related to the project development in their own websites. It facilitates the project diffusion on research and business area.
- ADAW logo design and creation.
- Public Access Publications. ADAW partners have published news about the project development on different communication means.
    - Article on the Spanish magazine RETEMA (www.retema.es), leading journal in Spain in the Environmental Sector, published on RETEMA magazine nº169 “Especial Bioenergía”.
    - Article on the Greek magazine “ECOTEC” (www.ecotec.gr) in November 2013 edition.
    - Note on the Greek magazine “MI magazine”.
- Presence at technical events and trade fairs. ADAW partners have attended technical forums related to project topic.
    - INRA attended a technical conference organized by the “Association Technique Energie Environnement”. 16th and 18th October 2013 in Narbonne (France).

    - BFC attended the working day “Financial instruments for the food industry”. 27th November 2013 in Galicia (Spain).

- Identification of stakeholders and potential customers. The Centre of Excellence List has been developed with the help of all partners. It contains all contacts done during the project development by partners in conferences, fairs, events and any dissemination activity and is updated on a 3 month basis.
- Printed dissemination material. Brochures, leaflets and posters have been designed and distributed among partners, stakeholders, clients and general public in attended events.
- Production of audiovisual dissemination tools. Two videos about the ADAW project were developed and spread.
- Production of printed tools. Stickers for the prototype and a roll-up with the main features of the ADAW technology were developed.
- Publication of public and technical articles. Several articles have been published by the ADAW partners:
    - Article on the Greek newspaper “EREVNA”.
    - Article on the French magazine “RIA”.
    - Articles on several technological blogs and websites (detailed on deliverable related to dissemination activities).
- Presence on technical events and trade fairs related to the project topic (detailed on deliverable related to dissemination activities):
    - Participation on several professional events about anaerobic digestion (such as “Anaerobic Digestion” workshop in July 2014), about automation (such as “IFAM” in March 2014) and about pre-treatments (such as “JRI Rennes” in February 2015).
    - Organization of technical workshop about ADAW project.
- Networking. Synergies between other projects (such as LIFE VALPORC and CAPACITY) were evaluated and dissemination scope was also boosted.
- Identification of stakeholders and potential customers. A “Centre of Excellence List” has been updated with the collaboration of all ADAW partners.
- Wikipedia page about the ADAW project was developed.

A project brochure regarding about project aims, needs to fulfil, strategy, and expected benefits to users. This brochure was translated to different languages and distributed among the partners in order to be used in every conference or trade fair they attend.

An intense activity has been done by the RDT performers to show technology developments to SMEs. Many of this activity has carried out in devoted meetings, some of them carried out after or before the consortium meeting (to save project resources), but other took place by teleconference or special visits.

Once technical the objectives have been achieved, the RTDs are in a position to elaborate scientific publications with the outcomes achieved in the ADAW project,

always without disclosing the knowledge considered as confidential by the SMEs and with the approval of them. In this sense, although at that moment the project would be finished, publications will make a specific mention to the ADAW project and to the support provided by the European Commission through the Seventh Framework Programme.

EXPLOITATION OF RESULTS

The ADAW project Foreground exploitation strategy is constructed under following pillars:

- Identification of project results and relevant IP to be derived.
- Distribution and /or ownership of foreground IP between partners
- Updated patent analysis of the market to be penetrated and identification of competing patents.
- Establish a exploitation model

The Exploitation Model has covered the following actions:

1. Protection of ADAW innovations by means of filling the corresponding European/World patent/utility model or register design, if applicable.
2. A commercial agreement will be subscribed at time of the result is exploited, to protect the rights and background of partners that have been participating in the development.
3. A commercial agreement has been subscribed about the share of each partner of the production cost (including profit) of the solution. This share has been applied similarly to the sales volume in order to estimate individual sales volumes.
4. An Assessment of European and worldwide market demand study in order to design the best marketing strategy to allocate efforts initially at the largest demanding regions.
5. An in-depth Product Cost Characterization study to evaluate on quantitative and qualitative potential markets, the associated cost of waste with high lipid and protein content treatment.
6. Public Access to ADAW results by dissemination activities within the industrial sector such as slaughterhouses operators, biogas plant holders, external waste processors and sensors companies. The transfer of the knowledge acquire to general public can be via ADAW website, publications in journals and magazines proposed by SMEs and the video of the project. All dissemination material has been previously approved by the Exploitation Manager and the Management Board in order to prevent any information shared affects the exploitation of non-protected results.
7. Private Access to ADAW results is available via the member’s area of ADAW website. The web based portal has served as a contact point to exchange information between partners.

8. Dissemination and Commercialisation of the technology to End-users has been up to now and will be ensured by exhibition in Fairs. A Centre of Excellence List has been elaborated with the participation of all SME partners, which includes contacts done by them within the project duration for the identification of stakeholders and future clients.

The market search done has identified market needs, target customers, market segment, and competitors. As it has been already mentioned in above paragraphs target customers are divided in 3 main groups:

- Small slaughterhouse operators (TECNO)
- Medium slaughterhouse operators.
- Industrial biogas plant holders (BFC)

A strategic approach for commercial activity and an implementation schedule has been developed. The business plan has estimated sales forecast and preliminary profit scheme. The implementation schedule has identified several phases:

PHASE 1: During the time-to market, Partners start exploitation activity in their countries, looking for market opportunities in national markets. Partners will be in contact with their clients but also with Spanish waste processing industries and slaughterhouses to present ADAW solution, and outline agreements for ADAW solution installation.

PHASE 2: The aim of the second phase is to cross border to enter EU markets (France and Italy). Germany has a large tradition in Anaerobic Digestion treatment for agricultural waste and has got special policies which support a feed-in rate strategy to promote biogas plants. Partners will collaborate with German companies in industrial activities to introduce ADAW solution in German market. A second marketing campaign will be initiated in France.

PHASE 3: The Consortium SMEs will maintain their market opportunity in Spain, Italy, Greece, France and Germany, but also targeting at other EU countries.They will sign agreements with local entities to act as sales representatives

PHASE 4: New market opportunities will be explored during the fourth phase. Spill-over sectors will be studied.

Industrial licensing and private contracts will be foreseen, especially from the end of Phase 2. In order to access international markets, and when production limits are exceeded, SME partners will need support from local companies that can manufacture and install biogas facilities.

5. Address of project public website and relevant contact details

5.1. Consortium Members

Participant Legal name	Beneficiary type	Partner Short name	Country
Biogas Fuel Cell, S.A	SME	BFC	Spain
Electrochemical Chemical Sensor Technology Ltd	SME	EST	UK
SBIA Stamatiou Pan. Evangelos	SME	SBIA	Greece
Sinaptec S.A.	SME	SIN	France
Institut de Recerca i Tecnología Agroalimentaries	RTD PERFORMERS	IRTA	Spain
Institut National de la Recherche Agronomique	RTD PERFORMERS	INRA	France
Tecnologías Avanzadas Inspiralia S.L.	RTD PERFORMERS	INSP	Spain
Tecnocárnico Valle del Ebro S.A.	OTHER ENTERPRISES OR END-USERS	TECNO	Spain

5.2. Project Contact and Logo

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Project website[5] address: www.adawproject.eu

[5] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.