LIFE Project Number

LIFE15 ENV/ES/000284

Final Report

Covering the project activities from 01/10/2016[1] to 30/09/2020

Reporting Date[2]

<30/12/2020>

LIFE PROJECT NAME or Acronym

LIFE AMMONIA TRAPPING

Data Project	
Project location:	Valladolid, Spain
Project start date:	01/10/2016
Project end date:	<30/09/2019> **Extension date:** <30/09/2020>
Total budget:	1.724.165 €
EU contribution:	1.032.413 €
(%) of eligible costs:	60%
Data Beneficiary	
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[1] Project start date

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

This table comprises an essential part of the report and should be filled in before submission
Please note that the evaluation of your report may only commence if the package complies with all the elements in this receivability check. The evaluation will be stopped if any obligatory elements are missing.

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

Certificate on financial statements (if required, i.e. for beneficiaries with EU contribution ≥750,000 € in the budget) *On paper (signed original) and in electronic version (pdf)*	N/A
Other checks	
Additional information / clarifications and supporting documents requested in previous EASME letters (unless already submitted or not yet due) *In electronic version only*	✔
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**original signature by a legal or statutory representative of the beneficiary / affiliate concerned*

1. Table of contents

2. List of key-words and abbreviations

FGUVA – Fundación General de la Universidad de Valladolid

ITACYL – Instituto Tecnológico Agrario de Castilla y León

UVA – Universidad de Valladolid

DEPORCYL – Desarrollos Porcinos de Castilla y León S.L.

ENUSA – Enusa, Industrias Avanzadas, S.A. SME

INDEREN – Ingeniería y Desarrollos Renovables, S.L.

LA CAÑADA – Avícola Ciria, S.L.

EC– European Commission

EU- European Union

GPMT- Gas permeable membranes technology

TAN- Total Ammoniacal Nitrogen

PM- Particulate Matter

UNECE- United Nations Economic Commission for Europe

BAT- Best Available Technique

SCM - Steering Committee Meeting

3. Executive Summary (maximum 2 pages)

3.1 Project objectives

The general objective of this project was to reduce ammonia emissions from livestock wastes (poultry litter and pig slurry) and from waste treatment processes such as anaerobic digestion and composting, by using the gas-permeable membrane technology (GPMT). This solution is expected to be both environmentally and economically feasible and sustainable, as it will recover the captured ammonia in the form of a nitrogen salt fertilizer.

The first action aimed to confirm the experiences previously carried out by UVA and ITACYL through laboratory tests with the objective of obtaining reliable parameters to design two prototypes, one for the reduction of ammonia from liquid wastes and another one for the reduction of ammonia from the atmosphere. Some problems with the supply of the membranes required to perform the lab tests caused a delay in the beginning of this action. Thus, the initial durability period of the project (September 2016 - September 2019) set out in the project report was modified by acceptance of the one-year extension. Nevertheless, the results obtained in the preliminary lab tests allowed the operational parameters for the design and construction of two mobile prototypes to capture ammonia from liquid wastes and from the atmosphere. These prototypes were designed and constructed within the expected time.

After that, the specific objective was to demonstrate the proper operation of both prototypes for ammonia capture in different locations along the Castilla y León region. On one hand, the performance of the mobile prototype for ammonia capture from atmosphere was evaluated in two livestock facilities (a pig farm located in Guardo (Palencia) and a laying hen farm located in Aldealafuente (Soria)) as well as in a portable composter treating hen manure also located in Aldealafuente (Soria). On the other hand, the performance of the prototype for ammonia capture from liquid wastes was demonstrated in the pig farm in Guardo and in an anaerobic digestion plant in Juzbado (Salamanca). The specific objective was to determine the environmental, technical, economic and social viability of the prototypes. To achieve this objective, periodic samples were taken from the nitrogen salt produced as well as from the air in the case of the prototype for atmosphere and the waste stream treated in the case of the prototype for liquids. A delay in the expected time was registered due to technical issues together with the longer time of the prototype for atmosphere in each scenario. The project demonstrated that gas-permeable technology is an efficient and cost-effective technology to capture and recover ammonia from liquid media and from the atmosphere. Two life cycle assessments were also performed that demonstrated the good environmental performance of both prototypes. In

addition, another specific objective was to evaluate the final product (i.e. ammonium sulphate solution) obtained as a high added value fertilizer. The final product was successfully evaluated in a horticultural crop and in a cereal crop.

An intensive dissemination activity was carried out along the whole project with 34 publications in written press, 64 in digital press, 6 scientific articles, another accepted for publication and 4 more in preparation, 7 posters accepted in congresses, 32 oral communications, 3 extended abstracts and 6 broadcasts on radio and TV. COVID-19 pandemic situation affected this activity during the last months of the project, so the final event and other events had to be done on-line. The project involved also the analysis of the extrapolation of the prototype to industrial scale and the development of an action plan to transfer the results to other European Countries with high ammonia emissions. This objective was, unfortunately, not completely achieved during the project. Although the project has demonstrated that GPMT is environmentally effective and economically viable, a scale-up is required to achieve a commercial model due to some constraints regarding handling and maintenance. These constraints are the base for the development of a new project aimed at transferring and scaling up the technology.

3.2 Key deliverables and outputs

Expected outputs can be summarized as follows:

- Protocols for installation and handling of the performance of the prototypes in order to facilitate assembly.
- It was expected a reduction of TAN concentration in the manure of more than 80%, capturing more than 150 mg TAN per litre and day, for a TAN concentration in manure ranging between 1000 and 2300 mg TAN/L.
- For the anaerobic digestate, it was expected to reduce TAN concentration in more than 70%, capturing up to 400 mg TAN per litre and day for a TAN concentration in the substrate up to 5500 mg TAN/L.
- Regarding the performance of the prototype for the capture of ammonia in the atmosphere (pig farm, laying hen farm and composting), the reduction was estimated at 70% with an ammonia capture rate of 1.3 g per m2 of membrane surface per day.
- It was estimated the production of 785 L of nitrogen fertilizer from liquid wastes and 62 L from the prototype of capture of ammonia from the atmosphere.

Two protocols were elaborated with instructions for the installation and handling of both prototypes. In the case of the prototype for the capture of ammonia in liquid media, it was operated in batch mode with batches lasting for 7 to 20 days. TAN removals were in the range of 15-51% of the initial TAN in the liquid (swine manure and anaerobic digestate). These TAN removals were lower than the expected ones. Possible solutions for increasing TAN removals could be to install a higher membrane surface inside the prototype or to cover the tanks. TAN recovery rates were in the range of 8 to 38 g per m2 of surface membrane per day (equivalent to 104 and 494 mg TAN/L), thus achieving the expected target value. It was evidenced that TAN recovery rate is highly influenced by the temperature in the treated liquid. The obtained ammonium sulphate solution achieved a TAN concentration of up to 32 g/L in approx. 7 days of operation.

In the case of the prototype for recovering ammonia from the atmosphere, it was operated in continuous mode and lasted for 8 months each in the farm scenarios. In composting, the operating cycle lasted 44 days. TAN recovery rates were estimated in the range of 0.4 to 2.3 g per m2 of membrane and day, which are in the range of those expected. TAN recovery rates are highly influenced by the ammonia concentration in the air in contact with the membrane. The

acidic solution reached an ammonium concentration of up to 28 g of TAN/L in 8 months of operation.

Main project deliverables include:

- Preparation: Reports on dimensioning and operating parameters of liquid media and atmosphere prototypes.
- Implementation: Reports on the design and construction of the two prototypes as well as their corresponding manufacturing tests, reports on the evaluation and technique of the equipment and protocols for use, report and evaluation of the fertilizer obtained as a by-product, synergies of the project with the EU strategies, marketing, commercialization and internationalization plan and recommendations to the EC regarding possibilities of incorporating the solution into European regulations.
- Monitoring: analysis of the life cycle of the equipment, its profitability and economic viability and environmental, social and technical evaluation reports.
- Dissemination: Project's website in 2 languages, Notice boards, Layman's report, general project leaflets, newspaper articles and online publications, after-LIFE implementation and communication plan.

4. Introduction (maximum 2 pages)

4.1 Background, problems and objectives

Agriculture is the largest source of ammonia emissions, which are related to diverse environmental problems and health risks in humans. More specifically, more than 91% of the total ammonia emissions in Spain in 2016 were related to agriculture. The reduction of ammonia emissions has become both an environmental and an economic challenge for livestock farmers throughout Europe. Gas-permeable membrane technology (GPMT) presents several advantages for recovering nitrogen from livestock environments, since it is carried out at low-pressure, they present a large contact area between the wastewater and the nitrogen trapping solution and the addition of alkali is avoided. Ammonia passes through a microporous hydrophobic membrane by diffusion and an acidic trapping solution is used to recover it as a valuable ammonium sulphate solution.

The main objective of the LIFE Ammonia Trapping project was to offer an environmental and economically feasible solution to reduce ammonia emissions from excretions in animal husbandry, anaerobic digestion processes and composting through the use of devices that capture ammonia, obtaining as a final product a nitrogen fertilizer. The project has developed the GPMT from the lab-scale level to an on-farm pilot-scale level, to capture ammonia, from livestock wastewaters and from the atmosphere, and to produce a concentrated ammonium fertilizer. At the end of the project is expected to obtain protocols for the installation and handling of the prototypes. With regards to environmental benefits it is expected to reduce TAN concentration in manure more than 80% (TAN concentration in manure ranging between 1000 and 2300 mg TAN/L) and more than 70% in anaerobic digestate (TAN concentration in digestate of 5500 mg TAN/L). Regarding the performance of the prototype for the capture of ammonia in the atmosphere (pig farm, laying hen farm and composting), the reduction was estimated at 70% with an ammonia capture rate of 1.3 g per m2 of membrane surface per day. Moreover, an annual production of 785 L of nitrogen fertilizer from liquid wastes and 62 L from the prototype of capture of ammonia from the atmosphere was estimated.

4.2 Expected longer term results

The project is aimed at demonstrating, at on-farm pilot plant scale, the technical viability of the GPMT to capture ammonia from livestock wastewaters, anaerobic digestion effluents and from the air in animal buildings and composting processes. The socio-economic effects of the project are related to the reduction of ammonia losses to the environment and the recovery of nitrogen in the form of mineral fertilizer. As a consequence, the project influences environmental and human health protection, animal and workers health, livestock and agriculture sustainability, local employment and rural development.

The contribution of the LIFE Ammonia Trapping project to the implementation and development of the EU environmental legislation comprises the use of the end fertilizer product obtained and the potential implementation of GPMT as a Best Available Technology for intensive rearing of pigs and poultry (BAT). First, EU legislation contributes to boost fertilizers obtained from organic waste materials. The ammonium sulphate solution obtained in this project is an example of these fertilizers, since it is obtained from livestock wastes or from livestock-related environments. Second, the project contributes to the reduction of ammonia emissions from livestock sectors and from other industrial sectors. Moreover, the project has synergies with the Common Agricultural Policy (CAP), the European Green Deal and the Research and Innovation Smart Specialisation Strategy (RIS3).

The potential market for the GPMT is mainly focused on the livestock sector, including agricultural anaerobic digestion and composting plants. Other potential applications are the treatment of leachates from municipal sanitary landfills and the ammonia emissions in urban waste management processes. The targeted countries for the future implementation of the GPMT are Germany, France, Italy and Denmark, due to their high livestock density. The marketing and commercialization plan has estimated that 5% of the manure produced in those countries could be treated each year.

The technical, socio-economic and environmental feasibility of the GMPT has been proved within the LIFE Ammonia Trapping project. However, additional efforts are required to design, scale and achieve commercial models adapted to all sizes and complete needs of farms and reach a TRL 9 technology level (complete commercial application available to consumers).

5. Administrative part (maximum 1 page)

5.1Description of the management system:

The management structure as well as the responsibilities and duties of the partners were laid down in detail in a Partnership Agreement, in conformity with the CP of the LIFE Regulation.

General project management was carried out by the project director for FGUVA Mrs. Yolanda Calvo, assisted by 3 project managers of FGUVA who worked in close collaboration with the technical teams of UVA (leaded by Dr. Mercedes Sánchez) and of ITACYL (leaded by Dr. María Cruz García). The project director and the technical coordinators of UVA and ITACYL were responsible for monitoring physical progress, while FGUVA project managers, especially Mrs. Rocío Blanco were in charge of monitoring financial progress, chairing project's meetings, keeping contact with the European Commission and supervising in the most general sense project implementation.

In the daily coordination of the project, main responsibilities were distributed following the structure of:

1. Technical coordination of the project was assigned to the Technical Project Managers of UVA and ITACYL, who supervised the correct technical execution of project actions and assured coherence between these actions and collaboration between involved partners.
2. Technical development of the prototypes was developed by the engineers of INDEREN, who carefully followed the recommendations of technical coordinators and were in touch with the farms and the biogas plant of ENUSA while prototypes were located in their facilities.
3. Awareness raising, dissemination and networking with other projects were coordinated by FGUVA who initially hired a Communication Manager to launch and initiate the communication plan, the website and the social networks strategy. FGUVA internal staff count on experience in communication activities and gave support to project partners in general dissemination activities, the organization of dissemination and networking events, the workshops addressed to farmers with the corresponding visits to the prototypes, etc.
4. Compliance and administrative-financial project management was carried out by FGUVA who initially counted on the support of *APC Economía e Innovación SL*, a firm hired by partners as external experts to ensure compliance management and financial accomplishment. After several internal changes in APC that ran the risk of jeopardizing the good collaboration with FGUVA, the coordinator decided to replace APC in the compliance manager position with the company *Espacios Castellanos de Innovación SLU*, who would support UVA and FGUVA in the economic-financial monitoring of the project during the last months of it. Although FGUVA has extensive experience in LIFE projects, during the proposal phase all partners agreed that for a project of the magnitude of LIFE Ammonia Trapping it was convenient to have an external specialist in charge of monitoring the financial part, in order to guarantee a smooth project execution and financial compliance. The project director and her administrative-financial staff kept day-to-day contact with the compliance manager by regular meetings, emailS, Skype, Teams meetings and telephone.

All partners set up an analytical accounting system in compliance with the programme's requirements, studied the programme rules and kept regularly their books, presenting copies of contracts, invoices, payslips, timesheets, payment proofs etc. to the coordinator and the compliance manager. The financial administration is entirely held on electronic support, making it possible to easily update archives and share them between the financial responsible at FGUVA, the compliance consultant and partners themselves.

All partners were responsible for their own internal organisation and had the obligation to perform all the tasks as assigned to them in the project, to provide the documentation required by the coordinating beneficiary in its monitoring functions and in relation to the reporting obligations as laid down in the Grant Agreement.

Communication with EASME and monitoring team

From the beginning of the project, FGUVA has been in continuous contact with the monitoring team assigned by the European Commission, specifically with Mrs. Cristina Vicente (IDOM-NEEMO LIFE Team). Monitoring visits held:

07/03/2017 In the premises of FGUVA in Valladolid.

23/05/2018 In the premises of Deporcyl in Guardo with visits to the two prototypes installed in the farm of San Pedro de Cansoles.

23/05/2019 In the premises of UVA in Palencia.

15/05/2020 Monitoring visit with the Project Officer. This meeting was initially planned as a two-days meeting in Valladolid with visits to the prototypes installed in Aldealafuente-Soria (the prototype for the capture of ammonia in the atmosphere) and in Juzbado-Salamanca (the prototype for the capture of ammonia in liquids). However, the situation of sanitary alarm obliged to cancel face-to-face meetings and it was only possible to hold a one-day online meeting.

09/12/2020 Online final monitoring meeting.

The project monitor supervised the overall project progress, making valuable suggestions to the consortium in order to advise the partners about the way to complete the different deliverables and reports.

The changes due to amendments of the Grant Agreement

1. The company ENUSA incorporated at the end of its corporate name the acronyms S.M.E, the amendment does not affect the objectives and expected results of the project nor does it imply any change in the total budget of the project.
2. Extension of project duration: The initial durability period of the project (October 2016 - September 2019) set out in the Grant Agreement was modified by acceptance of a one-year extension that had to be requested due to a problem with the membrane used in the A1 action tests. The membrane was not suitable for the purpose of the project because it had fluid permeation problems. Tests had to be carried out on e-PTFE membranes of different characteristics and there were also delays in the reception of the material. All this delayed the subsequent work referred to in actions B1, B2, B3, B4, B5 and C1. The project ended in accordance with the amended planning, considering the extension, in September 2020.

6. Technical part (maximum 25 pages)

6.1. Technical progress, per Action

TECHNICAL ACTIONS

A. Preparatory actions

A.1 Previous Tests

Foreseen start date: 01/10/2016 Actual start date: 01/10/2016
Foreseen end date: 31/03/2017 Actual end date: 30/09/2017

Linked to the specific objective 2.1; *Preliminary tests*.

ITACYL was responsible to establish the operational parameters for the membrane's performance to design the prototype for liquid wastes. For this purpose, several laboratory experiments, that are extensively explained in *Deliverable A1.1,* were performed.

The following conclusions were obtained from these studies:

- An average recovery rate of 27 g/m^2d was achieved when recovering Total Ammonia Nitrogen (TAN) from swine manure at semi-continuous mode, regardless of the TAN loading rate. The increase of aeration rate above 0.24 L_{air}/L_{manure} min did not cause an increment of TAN recovery. This data was used for designing the prototype for liquid wastes.

- Due to osmotic distillation, the membrane recovered water vapour contained in manure. This water condensed in the acidic solution increasing the volume of it. This phenomenon was considered for the design of the acidic tank of the prototype.
- Membranes become partially permeable to organic matter, K^+ and Na^+ after 77 days of operation treating manure. This permeation results in a decrease in TAN recovery rates.
- Membranes with higher density (0.95 g/cm^3) were preferable for the farm prototype, due to its lower water capture and its higher-pressure resistance.
- The higher the flow rate of the acidic solution, the higher the TAN recovery rate. Since the increase in TAN recovery rate was slight for flow rates higher than 40 L/d, this rate was chosen for the prototype. The percentage of TAN recovered over TAN removed increased when increasing the flow rate of acidic solution. Thus, at higher flow rates, the losses of ammonia to the atmosphere decreased.
- Electrical conductivity (EC) was demonstrated as an easy approach for predicting TAN concentration in manure. It could be useful for remote monitoring of the prototype. Linear regression coefficients between EC and TAN concentration in manure were higher than 0.91. For the acidic solutions, coefficients between EC and TAN concentration higher than 0.95 were achieved.
- Water could not be used as a stripping solution replacing sulphuric acid when recovering ammonia from liquid swine manure.
- Combining gas-permeable membrane technology and anaerobic digestion (AD) resulted in nutrient removal efficiencies of 65% and 32% for total N and total P, respectively. Coupling those technologies for the treatment of swine manure, contributed to ammonia emissions mitigation and sustainable livestock waste treatment. Moreover, a variety of valuable products is obtained, namely sustainable energy in the form of methane and fertilizers (i.e. ammonium sulphate and anaerobic digestate).

UVA was responsible to establish some operational parameters of the membranes to design the prototype for ammonia absorption in the atmosphere. For this purpose, several laboratory experiments, that are extensively explained in *Deliverable A1.2,* were performed.

The following conclusions were obtained from these studies:

- At high ammonia emissions, an addition of acid was needed to correct pH of the acidic solution whenever its pH increased >2, as a high pH significantly reduced its capture power. From these tests, the solution of H_2SO_4 1 N was selected as an ammonia capture solution for future trials, as it did not require corrections on a periodic basis and did not have to be renewed frequently.
- Different types of membranes made of expanded polytetrafluoroethylene (ePTFE) with different characteristics and prices were evaluated in order to determine the differences in the recovery efficiency of TAN. Recovery yields were higher with the use of membranes of larger diameter and surface area, but were not affected by differences in material density, porosity, air permeability, and wall thickness. The continuous configuration was selected for the design of the farm prototype, as it presented fewer leakage problems.
- The trials indicated that the chemical modification of g-C_3N_4 can be promising as an efficient pathway to doping Matrimid and other membranes to improve the permeability and selectivity of gas separation membranes. However, research about membranes of this type involved the investment of a lot of time and money, so it was decided to finish this stage and continue rigorously with the development of the actions of the Project.
- The flow rate circulating inside the membrane affected both the TAN mass recovered in the acid N entrapment solution and flow N. Therefore, we note that the fluid speed inside the

membrane should be a parameter to consider to optimize the effectiveness of the GPM system for capturing gaseous ammonia in farms. In this regard, further tests were conducted to assess the influence of acid solution flow (0.8-2.1 L/h) on the efficiency of ammonia capture (Publication in process). Results showed that an increase in acid capture solution flow from 0.8 to 2.1 L/h in GPM systems improves the amount of TAN recovered in acid solution by 60%. From this test, the 2.1 L/h acid solution flow was selected for field-scale prototype design.

- The ammonia mass recovered in acid solution was significantly higher at higher concentrations in the emitting sources regardless of the membrane surface used. This indicates that a higher concentration of TAN in the emitting focus will lead to a greater recovery of ammonia by the GPM system (Publication in process).

These results became visible at conferences during 2019 and 2020 (*Annex 15_Posters-Oral Communications*).

The planned output compared to the final performance is shown in Table 1.

Table 1. Planned output compared to final performance for action A1.

Action A1	Planned output	Performance
Foreseen Action description	Laboratory assays to determine operational parameters for the design of the prototypes.	Deviation in the actual end date due to a delay in the membranes supply.
Expected results (Progress indicators)	● Ratio of manure treated to membrane surface (LP) ● Rate of ammonium removal (LP) ● Ratio ammonia recovery to membrane surface (LP) ● Rate of ammonium removal (AP) ● Ratio ammonia recovery to membrane surface (AP)	78 L/m 387 mg/Ld 27.1 g/m^2 d 185 – 294 mg/d 13.5 - 21.4 g/m^2 d

LP liquid prototype; AP atmosphere prototype

Major problems / drawbacks encountered, delays

The major problem was the supply of membranes, which caused delays in the beginning of this action, as the company Phillips Scientific Inc. to which it was planned to buy the membranes was closed. In September 2016, membranes from Cpisefa (CPI Company) were received and a set of assays was performed at lab scale. Unfortunately, those membranes allowed the pass of water through them, not being suitable for the purpose of this LIFE project. In February 2017, a new batch of membranes from the Irish company ZEUS was received, which worked properly and let us start the experimental work. Those ZEUS membranes were very expensive (about 200$ m^{-1}), making the process economically unfeasible. Therefore, it was decided to test other membranes with different characteristics: i) In May 2017, two batches of membranes with lower outer diameter (4mm) and two different densities (0.95 and 0.45 g/cm^3) from the ZEUS company were received and tested. ii) In July 2017, cheaper membranes from the company PRODYSOL were received. In a first assay, the membranes worked properly, although in next assays we observed transfer of water through them, which could reflect a deterioration of the membranes. iii) Finally, the consortium decided to purchase the membranes of Zeus Company.

In order to find the most feasible solution, the following activities will be carried out by **ITACyL** even after the project ends:

- ✓ Since the cost of the membranes is a bottleneck for the economic feasibility of the GPM technology, an evaluation of different membranes of different materials will be done.

- ✓ Another solution contributing to reducing operational costs could be the use of organic acids to prepare the acidic solution. In this way, lactic and other acids obtained from sustainable biorefinery processes will be evaluated.
- ✓ The performance of GPMT to recover N from other N-rich wastewaters, as landfill leachate or slaughterhouse wastewater, will be studied.

In order to find the most feasible solution, the following activities will be carried out by **UVA** even after the project ends:

- ✓ The operation and capture efficiency of a joint laboratory-scale prototype will be studied, including a membrane for liquid and a membrane for gas. Thus, the use of this type of system could be studied to reduce NH_3 emissions in storage (pits).
- ✓ Another solution that could contribute to reducing operating costs could be the use of other acids and / or the substitution of acids for other more sustainable alternatives such as carbonated water.
- ✓ The performance of GPM technology to recover N from waste treatment processes will be studied, such as urban solid waste treatment plants (MSW).

B. Implementation actions

B1. Design and development of mobile prototypes for ammonia absorption in liquid media and in the atmosphere.

Foreseen start date: 01/01/2017 Actual start date: 01/07/2017
Foreseen end date: 30/06/2017 Actual end date: 31/12/2017

This action is linked to the specific objective 2.2; The results and conclusions obtained in the laboratory tests performed in Action A.1 were communicated to INDEREN for the design and the development of the prototypes.

Specifically, ITACYL, UVA and INDEREN met twice in Palencia (on 15th of February 2017 and on 4th October 2017) to discuss the advances of the project. Continuous exchange of information was also made at this time by mail with INDEREN.

Once UVA and ITACYL finished preliminary tests and after setting up the limiting criteria at lab scale, the scalability of prototypes was carried out jointly with INDEREN and ENUSA.

The procedure for the design of the prototype of absorption of ammonia in atmosphere was the following:

1. Collection of bibliographic data. State of art.
2. Review of balance sheets of matter and energy.
3. Development of drawings of pipes and instruments (P & ID).
4. Development of lists of equipment, instruments, valves and pipes.
5. Plans for the implantation of equipment to establish the assembly of the treatment skid.
6. Data sharing in order to validate P & ID plans and implementation previous to detail design.
7. Development of detail plans for manufacturing.
8. Development of the control and programming philosophy (control screens, etc).
9. Specifications for equipment purchase.

10. Specifications for prefabrication and assembly.
11. Specifications of loading, transport, unloading and positioning of the prototype.
12. Specifications of connection of the prototype with auxiliary installations.
13. Specifications of start-up and resolution of problems.

Weekly revisions of design and problem solving were carried out in order to advance with the detailed design of the prototypes. Additionally, a study was carried out by ITACYL to simulate ammonia recovery for different membrane surfaces according to experimental data, thus providing more information to design the liquid prototype.

Afterwards, it was possible to scale from laboratory tests to prototype size.

Specification preparations: In the second stage, the design of prototypes and development specifications were performed. Afterwards, it was possible to begin purchasing equipment and auxiliary elements. Special regard was taken to comply with current regulations and fit with the approved project proposal.

Development and manufacturing: In this phase the background and manufacturing facilities of INDEREN were required. After receiving the purchased equipment at their installations, as shown in the following images (Figure 1), the materials were assembled and the empty prototypes were tested.

Finally, results and conclusions of this action were summarized in *Deliverable B1.1 and B1.2*.

Figure 1. Prototype for the capture of ammonia in atmosphere

Figure 2. Prototype for the capture of ammonia in liquid media

Major problems / drawbacks encountered, delays

Atmosphere prototype: As explained in the previous action, the main difficulty was to identify a membrane according to the stipulated parameters. The procedure for finding the adequate membranes has been extensively explained in previous action.

On the other hand, another problem was the impossibility of introducing a required number of meters of the selected membrane inside an enclousing designed with limited dimensions. The introduction of this membrane in the enclousing was the next challenge: to design an adequate system for placing the mentioned membrane, since it requires some pressure but always respecting the limits of exudation.

To solve it, frames were designed and introduced into the enclousing, in a way that the membrane was going up and down over each one of those frames and it allowed the introduction of more meters of membrane. The atmospheres from inside the farm rich in ammonia are passed into the exchange enclosure of the membrane in order to eliminate the ammonia

Liquids prototype: One of the biggest difficulties was to place a large tank inside a 20-foot, 5000-liter container to obtain the largest possible surface of the membrane's winding inside it. In addition, it was necessary to find a solution for the acid to have the optimum temperature according to the stipulated parameters.

B2. Installation, start-up and evaluation of the operation of the mobile ammonia capture prototype for atmosphere.

Foreseen start date: 01/07/2017 Actual start date: 15/02/2018
Foreseen end date: 31/12/2018 Actual end date: 30/09/2020

Action B2 is linked to the specific objective 2.3; *Installation, launch and evaluation of the operation of the mobile prototype focused on capturing ammonia from the atmosphere.*

UVA was responsible for evaluating the data obtained during the monitoring and analysis of the samples. The main objective of this task was the start-up and optimization of the monitoring parameters of the mobile ammonia capture prototype for atmosphere in two livestock facilities (pig farm and poultry farm) as well as in a portable composter. Action B2 started in February 2018 with the installation of the pilot plant in the first location (pig farm). However, it was from August 8, 2018 when it began to operate continuously and normally until March 28, 2019. Later, it moved to the second location (poultry farm) where it began to operate cleaning the air of the venue on May 13, 2019 and ended on January 24, 2020. Finally, the pilot plant was connected to a portable composter where it began cleaning ammonia from the atmosphere by completing two cycles, which lasted from June 23, 2020 to September 18, 2020. Cycle 2 data is not used because it is unreliable due to a major technical problem that occurred during its operating period.

During this action, a monitoring protocol was developed for the control parameters: pH, electrical conductivity, flow of acid solution within the membranes, ammonia concentration in the prototype atmosphere, volume of liquid in the acid solution reactor. Specifically, the pH control of the acidic solution was kept below 2 since, at a higher pH, there were not enough H + ions available to continuously react with NH_3 and the capture rate was reduced. Flow of the acidic solution was periodically controlled to establish a flow rate within the membranes at 50 L/d (flow rate with which the best capture results were obtained in action A.2). The volume of acidic solution was monitored daily, since we observed that part of the liquid was lost by evaporation and it was necessary to compensate for the decrease in the liquid level, since it meant a higher concentration of the acid, with the consequences that this would have on the membranes. To try to solve this problem, a water humidifier device was installed inside the structure of the pilot plant. This element would allow to increase the relative humidity in the atmosphere of the plant and, in this way, to try to reduce the vapor pressure of the liquid inside the membrane. The problem could not be completely solved, because liquid was still being lost.

The monitoring of electrical conductivity shows an inverse relationship with the concentration of total ammonia nitrogen (TAN), in such a way that the lower the electrical conductivity, the higher the concentration of TAN in the acid solution. Therefore, by measuring the electrical conductivity of the acid capture solution through an electrode, the concentration of TAN present in the solution could be known without resorting to laboratory analysis.

The pilot plant was installed in different locations (inside or outside the houses) in order to check if there were differences in the capture of ammonia from ammonia between locations. In the first location, the pilot plant was installed inside of a pig farm in Guardo (Palencia). In the second location, the plant was installed outside a free-range laying hen building of a poultry farm in Aldealafuente (Soria). In both facilities it remained in continuous operation for approximately 8 months. In addition, in the poultry farm, the pilot plant was also installed with a portable composter using flexible pipes. A pipe connected the atmosphere of the composter with the inlet of the prototype, so that the loaded air reached the pilot plant and the ammonia passed through the membranes until it reached the outlet pipe, through which the cleaner air became to redirect towards the composter, constituting a closed circuit. Connected to the portable composter, the plant continued to operate continuously, completing 1 cycle with the same duration (44 days), to be comparable. In this action, data on ammonia recovery rates and efficiencies reached by the pilot plant in each location were obtained. In the pig farm (Guardo) the highest recovery values per membrane area surface were reached, followed by the values derived from the composter and those obtained in the poultry farm, being: 2.28 versus 1.35 and 0.45 $g \cdot m^{-2} \cdot d^{-1}$. An ammonia recovery of 74.8% TAN in the pig farm and 39% TAN in the poultry farm was estimated at the end of the operating period. On the other hand, the composting system managed to recover 54% of the TAN emitted in just 44 days. The operating time in each system was very different, 8 months in the case of the farms and 44 days in the composting cycle. This indicates that the GPM system is more efficient in closed atmospheres compared to open systems. In the poultry farm, as it is a free-range laying hen house, ventilation was practically continuous through the opening of gates, which implied lower concentrations of ammonia in the atmosphere of the house, which translated into lower ammonia recovery yield (39%) compared to the rest of locations. Likewise, we observed that the plant could work alternating time periods and seasonal periods, that is, it could be activated at night and in the winter months. In these time bands, ventilation is less, which tends to increase the concentration of harmful gases inside the buildings. For this reason, it could be of special interest to activate its operation in an automated way when the ventilation in the buildings decreases. In addition, Deliverable B2.1 presents a report on the technical and environmental performance of the prototype and a guide for handling the prototype using GPM technology in deliverable B2.2., respectively. These results became visible at conferences during 2019 and 2020 (*Annex 15_Posters-Oral Communications*).

Table 2. Planned result compared to the final performance of action B2.

Action B2	Planned output	Performance
Foreseen Action description	Installation, commissioning and performance evaluation of the atmosphere prototype.	Deviation from the expected end date due to the delay of Action A1 and due to the delay due to the increase in the time the prototype stays at each location.
Expected results (Progress indicators)	**Pig farm** ● Ammonia removal (%) ● Ammonium recovered in the concentrator solution (g)	(-)* 4108.0

	• Treated average air flow (m^3/h) • Ammonia concentration in the atmosphere (mg/L) **Hen farm** • Ammonia removal (%) • Ammonium recovered in the concentrator solution (g) • Treated average air flow (m^3/h) • Ammonia concentration in the atmosphere (mg/L) **Composter** • Ammonia removal (%) • Ammonium recovered in the concentrator solution (g) • Treated average air flow (m^3/h) • Ammonia concentration in the atmosphere (mg/L)	(-)** 20 (-)* 794.6 52.6 6 13.3 458.6 52.6 93.6

(-)* The design of the atmosphere prototype didn't allow a real mass balance to provide data of ammonia removal.
(-)** At the Guardo emplacement, the atmosphere prototype didn't have an air speed regulator installed. Installation of the flow meter was carried out during the transfer to Soria.

The following activities will be carried out by **UVA** to continue this action after the end of the project: The prototype for capturing ammonia in the atmosphere was transferred to the *Santa María* pig farm, located in the province of Segovia. The farm has a capacity of 840 fattening pigs distributed in two rooms with slat flooring and a straw bed, it will allow us to check the effectiveness of the prototype in situations different from those carried out during the Ammonia Trapping development. In addition, the farm has a 500 m3 capacity slurry basin for which a cover is being designed that has a ventilation system that can be connected to the prototype to collect the emitted gases and evaluate their capture.

Major problems / drawbacks encountered, delays

Main problems encountered during the operation of the pilot plant in the different locations were minor technical failures (leaks, broken joints), which were solved without the need to stop the operation of the plant. At the end of the prototype's stay at the first location, the acid drive breakdown occurred. The operation of the plant had to be stopped but, a few days later, it was going to move to the second location, so this problem did not hinder the project development.

B.3. Installation, start-up and evaluation of performance of the prototype for ammonia capture in liquids.

Foreseen start date: 01/07/2017 Actual start date: 15/02/2018
Foreseen end date: 31/12/2018 Actual end date: 19/12/2019

Action B3 is linked to the specific objective 2.3. **ITACYL** was responsible for the evaluation of the data obtained during the monitoring and the sample analysis. The objective was to optimize the operation parameters with two substrates, namely swine manure and anaerobic digestate.

The evaluation of the pilot plant for swine manure treatment was started in Guardo (Palencia, Spain) on May 10, 2018 (the prototype had been installed in February). A set up period of 56 days was carried out to solve technical issues and optimize the TAN recovery rate. Then, the pilot plant was operated in batch mode. Five batch experiments were run, lasting for 72 days. In

addition, two batches were used for cleaning and maintenance. A TAN recovery rate by the membranes (up to 32 g/m^{2}d), similar to that obtained during the laboratory experiments was achieved (Action A.1.1). The batch experiments were carried out to further optimize the pilot plant operation. The batch experiments (B1-B5) lasted for 7 to 20 days, each. In all the experiments, the manure reactor volume decreased with time, probably due to water evaporation. pH in the manure remained stable in the range of 8.2-8.9. On the contrary, pH in the acidic solution increased at some points due to the saturation of the sulphuric acid solution. As soon as an increase in the pH was observed, concentrated sulphuric acid was added to reduce it. Alkalinity was reduced during experimental time. TAN removals were in the range of 30-52% of the initial TAN in the manure, exception made for batch 4. The gas-permeable membranes recovered between 54 to up to 80% of that removed ammonia, as an ammonium sulphate solution. This solution achieved an ammonium concentration of up to 32 g TAN/L. TAN recovery rates were in the range of 8-38 g TAN/m^{2}d. Temperature could highly influence TAN recovery rates.

The evaluation of the pilot plant for anaerobic digestate treatment was carried out in Juzbado (Salamanca, Spain) from January 22 to December 19, 2019. The pilot plant was operated in batch mode. Five periods were identified (Period I to Period V). The objective of Period I was to check the correct performance of the pilot plant with the new substrate. TAN recovery rates were up to 20 g TAN/m^{2}d. A Fed-Batch strategy was evaluated during Periods II and III. Periods II and III lasted for 50 d and 40 d, respectively. The concentration of TAN in the digestate was removed in the range of 5 to 38%. Up to 57% percent of the removed TAN was recovered as a $(NH_4)_2SO_4$ solution. The recovery followed a polynomial curve of second order, which indicates that the majority of the TAN recovered in each batch was recovered during the first days of experimentation in the corresponding batch. The TAN concentration in the trapping solution accounted for up to 32 g TAN/L. The objective of Period IV was to investigate the maximum percentage of TAN that can be removed by the GPM system. For this purpose, three batches were run with the same digestate and, in each of them, a new trapping solution was used. 56% of the initial TAN concentration was removed in 15 days. Period V was carried out to investigate the influence of the digestate pH on TAN recovery. Increasing pH values were tested and, as an average, 52% of the removed TAN was recovered in the trapping solution. A report about the technical and environmental performance of the prototype and a guide for swine manure and digestate management using GPM technology are presented in *Deliverable B3.1.* and *Deliverable B3.2*, respectively.

Table 3. Planned output compared to final performance for action B3.

Action B3	**Planned output**	**Performance**
Foreseen Action description	Installation, start-up and evaluation of the performance of the liquids prototype.	Deviation in the foreseen end date due to the delay in Action A1.
	Swine manure Ratio of ammonium reduction in liquid wastes Ammonia reduction from manure Ratio of saturation of the stripping solution Flow of wastewater treated	8.4-38.2 g/m^{2}d 15-51% 8.5-32.1 g /L 250-714 L/d
Expected results (Progress indicators)	**Digestate** Ratio of ammonium reduction in liquid wastes Ammonia reduction from digestate Ratio of saturation of the stripping solution Flow of wastewater treated	 15-37 g/m^{2}d 27-48 % 12-32 g/L 230-833 L/d

Future activities related to this action, which will be carried out by **ITACyL** and **UVa**, are presented in *Deliverable E3.1 After-LIFE Plan.*

The following activities are being carried out by **INDEREN** to continue this action after the end of the project (see *Deliverable E3.1 After-LIFE Plan)*:

- The prototype is installed in a biogas plant in Vall D´Uixo (Castellón, Spain). The actions planned for the prototype are aimed at improving the recovery of TAN in anaerobic digestates with low suspended solids (Obtained after a solid-liquid separation process). A comparison with the results obtained in the Juzbado biogas plant will be performed.

Major problems / drawbacks encountered, delays

For the operation with manure, the main problems were found during the set-up operation. These technical issues were related to providing enough aeration to increase manure pH and with the corrosive effect of the acidic solution on the plastic connectors. A new aeration system and new acid-resistant connectors were installed in the prototype. In addition, diverse acid leaks were observed during the operation. This fact forced stopping the prototype operation and carefully looking for the acid leak among the membrane modules. In this sense, membrane maintenance operation has been identified as the main challenge of this system. In the case of digestate treatment, the main problems were found during the set-up operation in the new location. First, diverse acid leaks in the membranes were identified. They were repaired and the pressure of acidic solution recirculation was decreased to 0.2 bar. It was found that this low pressure is a key parameter for increasing the life of the membranes. Second, one of the air diffusers broke and the prototype was stopped until a new one could replace it.

B.4. Evaluation of the final product for its suitability as a fertilizer.

Foreseen start date: 01/07/2018 Actual start date: 01/01/2020
Foreseen end date: 31/12/2018 Actual end date: 30/09/2020

Linked to the specific objective 2.4; **UVA** was responsible for the *evaluation of the final product in order to adequate it to be used as a fertilizer.*

In this action, the product obtained was evaluated from an agronomic point of view, taking into account first the characterization of the fertilizer obtained during the different experiences on the farms. In this case the fertilizer obtained during the experience of the pig farm was chosen, because the fertilizer with better agronomic qualities was obtained, i.e. nitrogen richness. This product was characterized according to the different regulations, verifying that the fertilizer obtained meets widely the minimums required by Regulation (EU) 2019/1009 in NT. The fertilizer obtained had a nitrogen content of 2.8% (minimum 1.5% N).

Once our fertilizer was defined, different crops were selected to determine their performance in different doses and soils, so that a better performance can be obtained if you know where, how and why better results are obtained based on that dosage, and in what soils and crops. It was used in cereals (barley) and in vegetables (spinach). Initially, the fertilizer was tested in pots with different soils to determine under which conditions they were most favourable and to see if there was any influence in the early stages of the crops and to compare the data with commercial fertilization. Therefore, it was calculated based on the surface of the pots, planting dose and actual fertilization, for both crops in the three different soils with two replications. Best results were obtained with the fertilizer obtained on the farm in all scenarios.

In the next phase of tests, developing a crop under real conditions in a plot. Despite the good results, inhibition of germination was observed in the case of spinach, so both the application time and its dosage (number of inputs or risks to be incorporated) must be taken into account. Another issue to consider is its dilution in water to balance its pH.

Spinach test on greenhouse plot: On the basis of the previous results, several tests were carried out and since the spinach results had some conditioning in their application, several tests were performed to obtain the best possible performance due to the pH variability of the product.

A smaller number of plants has been developed in the treatment with direct application at the time of sowing, probably due to the inhibition in the germination of seeds due to the effect of this mode of application. Spinach is a crop that grows better at pH 6-7.5 and does not tolerate well soils with higher pH, so it is likely that the slightly acidifying action of the fertilizer on the soil, which was initially basic (pH x 8.01), has had a beneficial effect on crop growth. Finally, it was tested to distribute the calculated dose of fertilization for spinach in 5 irrigations, obtaining the results in this case with F.G. with pH 7, being 20 and 30% higher than the other treatments in the weight of the aerial and root part, both fresh and dry. Likewise, the last test was carried out at different application rates with both pH values, obtaining the best results with F.G. at pH 7, achieving a 20% higher yield in the crop with a dose 30% lower than that recommended in fertilization for spinach, which implies savings in the use of fertilizers.

Cereal plot test: This test was carried out using the Chin wheat variety (native variety of the area) in different doses, 50% less than recommended, 25% higher and optimal, compared to a commercial fertilizer. The parameters: grain weight, number of grains per ear, number of ears per plant, number of plants per m2 and productive yield (kh / ha) were studied to evaluate the crop yield. The most significant parameter is productive performance, they indicate that the best results were obtained with both low-dose commercial fertilizer, as well as with the fertilizer obtained on the farm in optimal dose, this being 5% lower in its yield, both close to 5 t / ha. In the trial, a usual commercial fertilizer was used, so we equated the dose according to the nitrogen units provided by the commercial fertilizer. It is worth mentioning that, due to the attack of the yellow rust, the yield of the harvest was considerably reduced, affecting almost half of the grain, so the results could be altered.

Table 4. Planned output compared to final performance for action B4.

Action B4	Planned output	Performance
Foreseen Action description	Evaluation of the viability of the final product obtained on the farm as a potential fertilizer product.	Deviation from the planned completion date due to delay in the previous actions (A1 and B2).
Expected results (Progress indicators)	● Optimal doses of selected cultures	**Horticultural crop: Spinach** Low dose, it is estimated 30% lower than the normal fertilization recommendation **Cereal Crop: Wheat** Recommended optimal dose for cereal fertilization (200 kg N / ha) for farm fertilizer, compared to low dose for commercial fertilizer.

	• Crop productivity for different test doses	**Horticultural crop: Spinach** Low dose and pH 7: average weight of 136.51 gr of the usable part of the crop. **Cereal Crop: Wheat** Optimal dose: Crop yield: 4,725 kg / ha → (5% less than the maximum yield with low-dose commercial fertilizer: 4,951 kg / ha)
	• Crop productivity for different test doses	**Horticultural Crop:** Spinach 40% **Crop Cereal:** Barley 86%

The results support the use of farm fertilizer at a pH similar to 7 to obtain the best productivity results in horticultural crops. Therefore, it is advisable to reach that pH strip in the acidic solution where the final product is formed.

The subplots suffered a fairly intense rust attack, which was finally combated with the appropriate fungicide. Although the crop continued to develop, it is possible that the plants were affected in their development and growth, so this could have altered the results obtained, both in terms of production and nitrogen content in the grain.

A commercial potassium nitrate fertilizer 13 N - 45 K was used in the plots. Being a commercial fertilizer with added macronutrients, we think that by covering more nutritional needs of the crop, better yields are obtained in subplots with optimal dose of commercial fertilizer. Despite this, farm fertilizer, composed of ammonium sulfate, achieved productivity similar to commercial.

The prototype for the recovery of ammonia in the atmosphere has been transferred to a Santa María pig farm, located in the province of Segovia, owned by Agro-porcino Manso SL for the After Life Period and the ammonium sulfate produced will be used mixed with irrigation in its land located near the farm.

B.5. Transferability and replicability

Foreseen start date: 01/07/2018 Actual start date: 01/07/2019
Foreseen end date: 30/09/2019 Actual end date: 30/09/2020

Linked to specific objective 5; A *strategy of replicability and transferability* has been carried out to increase the impact of the project and transfer the project results to the livestock sector of other EU regions with similar technical, environmental and social challenges. **UVA** was responsible for this action.

This strategy included the development of a marketing, commercialization and internationalization plan, a report with recommendations to the EU on how current regulations can facilitate the incorporation of solutions such as Ammonia Trapping and a revision of the synergies between the Ammonia Trapping project and the political strategies of the European Union.

The marketing, commercialization and internationalization plan comprised: 1) The state of the art of the gas-permeable technology, 2) An study of the potential clients, 3) Main stakeholders

in the four targeted countries (Germany, Italy, France and Denmark), 4) Marketing and internationalization plan for the next 5 years, 5) Regulations for each targeted country and 6) A 3-phase implementation plan. This information is included in *Deliverable 5.1.* It is worth mentioning that the redaction of this deliverable product was subcontracted as partners' experience in this subject is minimal.

An overview of how current legislation in the EU territory could facilitate the incorporation of the technology used in the Ammonia Trapping project is reported in *Deliverable 5.2*. More specifically, two different approaches are presented. The first one is related to the end fertilizer product, since EU legislation contributes to boost fertilizers obtained from organic waste materials, such as that obtained in the Ammonia Trapping project. The second one is related to the Best Available Technologies for intensive rearing of pigs and poultry (BATs). In this case, the Ammonia Trapping project could contribute to the reduction of ammonia emissions from livestock sectors and from other industrial sectors. A document for describing the Ammonia Trapping technology as a potential candidate technique for BAT or Emerging Technique has been submitted to the Technical Working Group of the EU (*Annex B5.2*).

The synergies of the Ammonia Trapping project with the Common Agricultural Policy (CAP), the European Green Deal and the Research and Innovation Smart Specialisation Strategy (RIS3) have been identified and reported in *Deliverable B5.3*. The project is in line with the CAP with regards to 1) Increasing the competitiveness of the farming sector, 2) Protecting the environment and health quality, 3) Developing rural areas and 4) Fostering competitive and sustainable farming. With regards to the European Green Deal, this project presents a synergetic approach with the EU Circular Economy Plan of 2020 and the Farm to Fork Strategy. The RIS3 in Spain is reflected in the new Spanish Strategy for Science and Technology and Innovation, 2021-2027. One of the Strategic Research Topics is called "Intelligent and Sustainable Agrofood Chain" and LIFE Ammonia Trapping Project is in line with this research topic. More specifically, agro-food and natural resources are a thematic priority RIS3 of Castilla y León 2014-2020. According to this regional strategy, efforts must be focused on research and innovation for increasing the sustainability of the agricultural and livestock sector. This is one of the results of the LIFE Ammonia Trapping project.

The following activities are being carried out by the **Ammonia Trapping partners** to continue this action after the end of the project (see *Deliverable E3.1 After-LIFE Plan).*

- Activity 1. Prototypes maintenance and improvement in ammonia capture systems.
- Activity 2. After-LIFE Communication Plan. Including: 1) Motivating local farmers to replicate best practices, 2) Engaging social integration, 3) Fostering liaisons with and transferring of knowledge to diverse stakeholders and end-users and 4) Garnering press attention.

Major problems / drawbacks encountered, delays

One of the objectives of Ammonia Trapping was to develop a transferability and replicability plan to implement the technology in other EU countries. Unfortunately, this objective has not been completely fulfilled. Ammonia Trapping demonstrated that gas-permeable membrane technology is an efficient and cost-effective technology to capture ammonia from liquid wastes and from the air, recovering it as a fertilising salt. However, some constraints were found by farmers for handling when performing maintenance and replacing membrane panels. A new project, named **LIFE Green Ammonia**, has been submitted to scale up this technology as an industrial commercial model, easier to handle for the farmers, more robust and easier to transport and to install. Consequently, the exploitation agreement (*Deliverable B5.4*) has not

been completed, since the commercialization of the technology has not been started and therefore trying to establish commercial agreements among partners made no sense.

C. Monitoring of the impact of the project actions

C.1 Follow-up and monitoring of the Ammonia Trapping project

Foreseen start date: 01/01/2018 Actual start date: 01/01/2019
Foreseen end date: 30/09/2019 Actual end date: 30/09/2020

Linked to specific objective 6; The environmental, social, technical and economic viability of the two prototypes were carried out. **ITACyL** was responsible for this action. Experimental data from the different experiences with the prototypes were used to write three project deliverable products, namely C1.1, C1.2 and C1.3.

Deliverable C1.1. "Technical, Social and Environmental Evaluation of the prototypes" was divided into two sub-deliverables, corresponding to each work team. The main difference was that ITACyL related the environmental evaluation to the environmental impacts while UVA oriented the environmental evaluation to the implementation of GPM technology as a new BAT. Therefore, sub-deliverable C1.1A belonged to ITACyL, while C1.1 B belonged to UVA.

- For **ITACyL**, deliverable C.1.1A consists of: 1) a technical description for the liquid prototype including the main results and challenges, 2) an evaluation of the social benefits of the Ammonia Trapping project related to the reduction of ammonia losses to the environment and the recovery of nitrogen in form of mineral fertilizer, 3) a brief description of the environmental impacts related to the project for prototype.
- For **UVA**, deliverable C.1.1B consists of: 1) Environmental authorization of the project according to the pig and poultry farm scenarios and main technical results for the atmospheric prototype, 2) an evaluation of the social benefits of the Ammonia Trapping project related to the reduction of ammonia losses to the environment and the recovery of nitrogen in the form of mineral fertilizer.

Deliverable C1.2. "Economic Feasibility Analysis of the prototypes" reports an Economic Feasibility Analysis of both prototypes for each location they were evaluated. For the liquids prototype, the analyses were done to treat swine manure (Guardo) and anaerobic digestate from a biogas plant (Juzbado). In the case of the prototype to recover ammonia from the atmosphere, three locations were evaluated, namely a swine farm building (Guardo), a free-range laying hen farm building (Aldealafuente) and a composting unit (Aldealafuente). These analyses included the estimated initial investment, annualized costs and revenues as well as the estimated net cost of the technology.

Deliverable C1.3. "Complete Life Cycle Analyses (LCA) for the prototypes" reports a Life Cycle Analyses (LCA) for both prototypes. In the case of the liquids prototype, the LCA is aimed at evaluating the environmental impacts of the technology used in the Ammonia Trapping project compared to a baseline scenario. The data obtained in this LCA will be published in a scientific journal. For the air prototype, the LCA aims to evaluate the environmental impacts of the technology used in the ammonia capture project in an improved scenario (alternative scenario) compared to the base scenario (current prototype without improvements). The obtained results will serve UVA to analyse and improve the application of this technology from the point of view of sustainability in the future.

The following activities are being carried out by **ITACyL** to continue this action after the end of the project:

- The results obtained in the LCA let us identify hot spots during the application of GPM technology to recover N from livestock wastewater. These hot spots will be used to optimize the design of the new commercial model.

UVA has identified, based on the results obtained in the LCA of the base scenario (current prototype), the hot spots that have been affected to build the alternative scenario (improved prototype).

Major problems / drawbacks encountered, delays

Neither drawbacks nor delays were found during the performance of this action.

D. Public awareness and dissemination of results

D.1 Communication Plan and Networking with other LIFE projects

Foreseen start date: 01/10/2016 Actual start date: 01/01/2016
Foreseen end date: 30/09/2019 Actual end date: 30/09/2020

Action D1 is linked to the specific objective 2.7.

D1.1 Communication and dissemination Plan

The Communication Plan was drawn up according to the scope and objectives described in the proposal. It was entrusted to FGUVA and carried out by one person hired for this purpose.

Detailed information in *Deliverable D1.2.*

1.Web page: www.ammoniatrapping.com

An independent web dedicated to the project with a distinctive URL was designed and will remain active for at least 5 years after the project ends. The company in charge of carrying out this task, during the first 6 months of the project, was the same one that designed the corporate image of the project, in this way the same corporate identity is maintained.

The web contains all the relevant information about the project and a specific section for the LIFE Programme, whose logo was placed in a visible and relevant place. A first version was ready after the start of the project and since April 2017 fully operational. Content is available in Spanish and English, thus covering an international audience. Due to a host related problem the webpage had to be fully rebuilt between January and February 2020, so the analytics are shown in two periods, before and after January 2020.

It is periodically updated and offers the possibility of subscribing as followers to have access to the most up-to-date information in real time. It includes a download section with links to works and articles relevant to issues of mitigation of ammonia emissions in farms.

The 4,921 individuals who have visited the web have registered a total of 11,111visits to pages with an average duration of 1 minute and 39 seconds each. It is available in Spanish and English with the audience distributed approximately 50% in both languages.

Detailed information in *Deliverable D1.3.*

2. Social networks: The project counts on its own profile in the different social networks, such as Facebook, Twitter and YouTube as the main ones and in addition, as an added value element,

also LinkedIn and Instagram. The main social networks of the project (Facebook, Twitter, YouTube) were officially launched at the same time as the website.

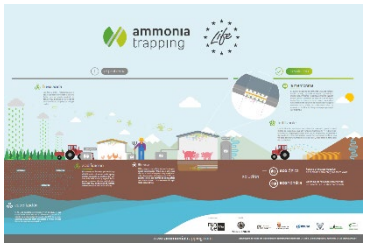
Main figures:

- Facebook: Ammonia Trapping's Facebook profile currently has 220 followers and a total of 354 posts. From the quantitative analysis of data, the 354 entries have generated a total of 17,141 impressions (number of times that users see the publication) and 5,001 interactions (number of times a user interacts with a publication; It includes all the clicks, comments and *Likes*). From these data an average interaction rate of 29,18% is obtained.
- Twitter: By project end, the Twitter profile had reached 1,979 followers. An audience analysis called "*Informe de nodos*" (*ANNEX 17_Twitter nodes report_ES*) allowed the identification of interests and relations of the project's followers.
- Youtube: A total of 19 videos of different themes related to the project were uploaded. On a quantitative level, they reached a total viewing time of 57,5 hours and 2442 views.
- LinkedIn and Instagram: these social networks were understood as platforms of added value and auxiliary. However, despite that a lower number of entries have been published compared to Facebook and Twitter, the analysis shows a good functioning of publications in LinkedIn, with a total amount of 77 followers and an interaction rate of 9,69%. In Instagram 113 posts have been published with 154 followers and 1,016 *likes* in total.

  Detailed information about impact in social networks in *Deliverable D1.1*.

3. Dissemination materials

- **Notice Boards:** although the proposal said that 12 notice boards would be developed, it was considered that only 10 would be necessary to cover proper dissemination; 7 were 60x90cm size to be located in partners' headquarters and 3 additional with much higher dimensions were printed to be located in the premises of DEPORCYL (200x130cm), LA CAÑADA (175x110cm) and the biogas plant of ENUSA (200x125cm).



- **Newsletter**: Coinciding with the most important milestones of the project (beginning of the project, installation of the prototypes, workshops and dissemination events) a project newsletter was launched. In total, 7 newsletters were edited and sent, 6 of them in Spanish and 1 in English, which were distributed through the website and email campaigns to an audience of 1,568 contacts of which 1,551 are subscribers.
- **Project brochure:** Following the Visual Identity Manual and the image resources it was produced the project brochure in Spanish and English. 1250 were printed in Spanish and 1000 in English. Also 1 roll up and merchandising materials were produced to be distributed in face-to-face events: 200 round pins with the project logo (size 38mm), 200 rectangular paper stickers (size 80x35mm), 500 biodegradable pens and 300 ecological notebooks.

See detailed information about dissemination materials in *Deliverable D1.2.*

- **Layman's Report:** To properly disseminate the results of the project a communication company specialized in scientific and technological dissemination was hired to design and print the Layman's Report. A 10 page full colour Layman's Report was produced of which 800 units were printed and distributed (400 in Spanish and 400 in English). Likewise, all digital channels were used for its online distribution.

4. Press dissemination: Under the coordination of UVA and ITACYL, beneficiaries contributed to press dissemination, resulting in **34 publications in written press**, **64 in digital press**, **6 scientific articles**, **another accepted for publicatio**n and **4 more in preparation**, **7 posters** accepted in congresses, **32 oral communications**, **3 extended abstracts** and **6 broadcasts** on radio and TV.

During the last months of the project, given the impossibility of holding the planned face-to-face final events, FGUVA hired the services of an agency specialized in technological dissemination with which a strategy of press dissemination was established at the local, regional, national and international level. The result was the creation of press releases and contact by email and phone with 335 media outlets. In addition, 20 independent professional associations from the agricultural, livestock and science communication sectors were approached with targeted communications regarding the LIFE Ammonia Trapping project.

Detailed information can be found in *Deliverable D1.4.*

D1.2 Networking and collaboration with other LIFE projects

As the basis of the networking strategy established at the beginning of the project, each partner made use of their own network of contacts to invite different interest groups aimed at improving and increasing the impact of the project and its international dimension. As the project became known through the different media, many projects contacted the partners to establish synergies. Likewise, all partners participated in various bilateral meetings in which specific collaboration and information exchange agreements were established.

The most fruitful and collaborative interaction (*Deliverable D1.6 Networking Strategy*), happened with the projects listed below:

- **LIFE CHIMERA** (LIFE15 ENV/IT/000631), **LIFE COMBASE** (LIFE15 ENV/ES/000416) and **LIFEPOSITIVEMgOFGD** (LIFE15 ENV/GR/000338) were contacted during the coordinators meeting in Brussels on 11/10/2016. This resulted in a visit of one representative of the coordinator to LIFE CHIMERA in October 2016.
- **LIFE REFOREST** (LIFE17 ENV/ES/000248) **and LIFE BIOXISOIL** (LIFE11 ENV/ES/000505) derived from the collaboration of ENUSA with partners of both projects.
- **LIFE OPERATION CO2** (LIFE11 ENV/ES/535) had been coordinated by UVA since 2011, so representatives of Ammonia Trapping were invited to participate in the project's final meeting. There were several subsequent meetings in which the coordinators of Operation CO2 gave advice and recommendations to the coordinators of Ammonia Trapping.
- **LIFE ANADRY** (LIFE14 ENV/ES/000524) and **LIFE In-BRIEF** (*LIFE14 ENV/ES/000427)*: visit of UVA and ITACYL to the project's premises in Murcia (Spain). A two-days visit that included a partners meeting with members of the 3 projects and visits to the facilities of the LIFE ANADRY and LIFE In-BRIEF.

- **LIFE RiverPhy** (LIFE11 ENV/ES/000506). Between 6-9 November 2017, the LIFE Ammonia Trapping project was invited by the LIFE RiverPhy's technical coordinator to attend the SEPOR fair (Livestock, Industrial and Agrifood Fair) and to participate in one of the days, presenting the Life Ammonia project Trapping. A visit to the project premises was scheduled in order to learn about its development and the results obtained in situ.

- **LIFE CHIMERA** (LIFE15 ENV/IT/000631). In October 2016 the Ammonia Trapping project was invited to the presentation of results of the LIFE Chimera in Ancona (Italy). One representative of FGUVA attended the meeting and had the opportunity to make a presentation about Ammonia Trapping's objectives.

- **LIFE+ REGROW** (LIFE16 ENV/ES/000331). On May 21, 2018, on the occasion of the celebration of the international Ammonia Trapping workshop in Palencia, Dr. Raúl Moral on behalf of the LIFE + REGROW project was invited to explain the project's main results and participated in the field visit to the Deporcyl farm in Guardo (Palencia), where both prototypes had been installed.

- **LIFE REGENERATE** (LIFE16 ENV/ES/000276). One of the members of Volterra Ecosystems, beneficiary of the LIFE REGENERATE project, got in touch with Dr. Mercedes Sánchez, from UVA, to find out more details about the LIFE Ammonia Trapping project. They met on 03/07/2018 at the Higher Technical School of Agricultural Engineers of UVA, in Palencia.

- **LIFE AGRIADAPT** (LIFE19 CCA/ES/001181). On 13-14 March, 2018 the Life Platform Meeting on Climate change in Agriculture and Forestry in the Mediterranean Region took place in Madrid, organized by the Life AgriAdapt project. Dr. Mercedes Sánchez attended the seminar on behalf of UVA and had the opportunity to exchange ideas and seek synergies with 10 other projects that participated in the conference.

- **H2020 ValueWaste** (ID: 818312): The final phase of Ammonia Trapping coincided with the final phase of H2020 ValueWaste in which INDEREN is taking part. This facilitated the exchange of information and continuous interaction between both projects.
- **LIFE ARIMEDA** (LIFE16 ENV/ES/000400). In June 2019 Dr. María Cruz García González from ITACyL participated in the workshop of Life Arimeda project, held in Ejea de los Caballeros (Zaragoza, Spain). In this workshop Dra. María Cruz visited demonstration plots of the project.

- During the participation of the project in the EU Clean Air Forum in Bratislava on 28-29/11/2019, project representatives got in touch with **LIFE PREPAIR** (LIFE15 IPE/IT/000013) and **LIFE CLEAN AIR FARMING** (LIFE17 GIE/DE/610). Representatives of both projects took part in the online final conference of Ammonia Trapping.
- **EIP AGRI AMMONIA WASHING MACHINE.** Bilateral meeting between representatives of ITACYL with Mr. Giuseppe Moscatelli, project representative, during the ManuREsource Conference 2019 held in Hasselt (Belgium).
- **H2020 SYSTEMIC**. Bilateral meeting between representatives of ITACYL with one project partner during the ManuREsource Conference 2019 held in Hasselt (Belgium).

- **LIFE FERTIRRIGATION** (LIFE14 ENV/ES/000640). Participation of Dr. Mercedes Sánchez in the final day of this project held at the headquarters of COPISO Soria Sociedad Cooperativa, presenting the results of the LIFE Ammonia Trapping project. In this event also participated representatives of LIFE AGRIADAPT (*LIFE19 CCA/ES/001181)* and LIFE ANADRY (LIFE14 ENV/ES/000524).
- **INTERREG SUDO CirRural 4.0.** Online bilateral meeting between representatives of Itacyl and representatives of the project in order to establish possible collaborations for the After-LIFE period of Ammonia Trapping project.
- **LIFE MEGA** (LIFE18 ENV/IT/000200). One project representative took part in the online final conference of Ammonia Trapping.

D.2 Transferability events and actions

Foreseen start date: 01/10/2016 Actual start date: 01/01/2016
Foreseen end date: 30/09/2019 Actual end date: 30/09/2020

D2.1 Dissemination events

Throughout the project, different events and transferability actions have been developed, in order to increase awareness regarding the mitigation of ammonia emissions in the agricultural sector and create awareness in the livestock sector so that farms owners can make the most appropriate decisions aimed at reducing the environmental impact of their activity.

General dissemination seminars

1. **Dissemination day 1**: On November 11, 2016, the presentation seminar of the project took place in Guardo (Palencia), which was held at the Town Hall with the participation of the Regional Minister of Agriculture, the Mayor of Guardo, the general director of Deporcyl, the Vice-Rector for Infrastructures of the University of Valladolid and the project beneficiaries. The presentation counted on 53 participants and the institutional representatives and project beneficiaries were invited before the event to visit the farm of San Pedro de Cansoles, where both prototypes would be installed. Invitations to the event were made directly by Deporcyl, who sent invitations to farm owners and other stakeholders.


2. **Dissemination day 2**: On May 21, 2018 took place the international conference entitled "*Problems and solutions of ammonia emissions in the agricultural sector*" in Palencia. The event counted on representatives of the Spanish Ministry of Agriculture, Fisheries and Food, of the regional government of Castilla and León and of the livestock sector, apart from one researcher from the USDA Agricultural Research Service, in the USA. The event had a total of 41 attendees, including representatives of agricultural organizations, farm owners, businessmen related to the sector and researchers. In the afternoon conference speakers visited the prototypes already installed in the Deporcyl facilities in San Pedro de Cansoles. In order to reinforce networking activities, among these speakers were the USDA



representative and one representative of the LIFE+ REGROW project (LIFE16 ENV/ES/000331).

On May 25 2018, ITACyL organized a seminar where Dr. Matias B. Vanotti gave a speech about “Future approach of nutrient recovery (N and P) from wastes”. The seminar was held in ITACyL headquarters (Valladolid), and 25 people from ITACyL and the University assisted.

3. **Dissemination day 3**: The third dissemination day of the project was scheduled for May-June 2020 in Madrid, organized by ENUSA and with the participation of representatives of the Ministry for the Ecological Transition and the Ministry of Agriculture, Fisheries and Food. The declaration of the pandemic situation and consequent confinement in March 2020 forced the event to be cancelled and the representatives of both Ministries, with whom contact had already been established, were invited to participate in the final event, which finally took place in online format on September 24, 2020.

<u>Stakeholder workshops and visits to pilot plants</u>

1. **Workshop 1**: On November 12, 2018, the equipment for capturing ammonia in atmosphere and liquid media was already installed and operating at the San Pedro de Cansoles farm, in Guardo. For this reason, the first seminar aimed at farmers and stakeholders in the sector was held with the title "*Best available techniques to reduce emissions in the pig sector*". The workshop had a total of 46 attendees, 34 of whom came after the seminar to visit the prototypes installed on the farm.



2. **Workshop 2**: On October 22, 2019, the prototype for capturing ammonia in liquid media was installed at the ENUSA biogas plant in Juzbado (Salamanca). For this reason, the workshop entitled "*The importance of ammonia capture. New strategy to manage slurry and digestates from biogas plants*" was organized at the same plant. Visiting groups were organized that were guided by representatives of ENUSA, UVA and ITACYL in the visit to the facilities and the liquids prototype. The requests for assistance were so numerous, that the groups had to be divided into morning and afternoon. The total number of attendees was 79 people, including representatives of livestock organizations, farm owners, researchers and other interested stakeholders.


3. **Workshop 3**: Given the great importance of the pig sector in the province of Segovia, the Cantalejo City Council agreed with UVA and ITACYL to hold a conference addressed to owners of pig farms in the region. The event took place at the Cantalejo Cultural Center (Segovia) on October 29, 2019 with the participation of 56 attendees. It was an informative conference on the technology developed by Ammonia Trapping, in which the beneficiaries of the project participated as speakers.


4. **Workshop 4**: On March 12, 2020, the event entitled "*New slurry management systems*" was scheduled in Soria. It was planned an informative seminar in the morning and a visit to the farm of La Cañada in Aldealafuente in the afternoon, to visit the prototype for capturing ammonia in the atmosphere. We had a list of 32 people registered, but few days before the seminar health authorities recommended the cancellation of events of more than 20 people. Following these recommendations, the seminar was cancelled just the day before. All speakers and registered people were informed and the cancellation of the day was disseminated on social networks until further notice. Finally, it was not possible to develop it in person and those registered were invited to participate in the final online session that took place on September 24 and 25.

5. **Workshop 5**: It was planned to be organized by Deporcyl in Cuéllar (Segovia) in May 2020. However, due to the persistence of the health emergency worldwide, the event was postponed and definitively cancelled in face-to-face format. Instead, it was decided to organize three online seminars on June 9, 10 and 11, 2020 in collaboration with the Network of Rural Innovation Agents of Castilla y León. These seminars were held with a clear networking approach with other related projects, and focused on the dissemination of results of the Ammonia Trapping project among stakeholders in the livestock sector.

The general title of the workshops was the same as of the workshop cancelled in March in Soria *"New slurry management systems"* and they were distributed in three days with the following titles:

- Day 1 on 06/9/2020: *"Emissions management and alternatives for the recovery of slurry"* with presentations of Ammonia Trapping results together with the Poctep project SYMBIOSIS.
- Day 2 on 06/08/2020: *"Towards a more efficient use of slurry"* with interventions from the projects LIFE AGROMOBILITY, LIFE SMART FERTIRRIGATION and LIFE ARIMEDA.
- Day 3 on 06/9/2020: *"Agronomic valorization of slurry"* with representatives of the Regional Government and an expert who spoke about manure in the Circular Economy.

The workshops were a real success with a total of 271 people registered in total for the three days.

Participation in events

Participation in both national and international networking events, conferences, congresses, seminars, etc. by all partners, but especially from the technical teams of UVA and ITACYL, provided great visibility to the project. Continuous participation in events definitely contributed

to promoting awareness about the technology among private companies and other stakeholders from both the participating sectors and other related ones (such as waste treatment centers).

Final project workshops (international and national)

The completion of the Ammonia Trapping project was planned through the realization of two face-to-face conferences to be held during the last months of the project in Palencia and Brussels. The health alert situation meant the elimination of face-to-face events, so that the final closing event of the project was carried out through a two-day international online conference.

During the first day, the interventions were of a more institutional nature with representatives of the European Commission, the Ministry of Agriculture, Fisheries and Food, the Ministry for Ecological Transition, the University of Lisbon, the European Office for the Environment, the National Association of Producers of Pig Cattle (ANPROGAPOR) and the Spanish Association of Egg Producers (ASEPRHU).

The second day, however, was focused on networking with other projects. After a presentation of the Ammonia Trapping project by its beneficiaries, representatives of other projects were invited to share their experiences and to participate in the open debate with questions from attendees connected online.

The audience was very significant on both days, with 145 people registered for the first day and 142 on the second. There was simultaneous English-Spanish translation for all the lectures, which were recorded in both languages and made available to the general public both through the website designed specifically for the project and through the Ammonia Trapping website.

D2.2 Bilateral meetings with national and international stakeholders

Although the bilateral meetings with stakeholders were planned for the last 12 months of the project, the truth is that once the first results began to be published and they were publicly exposed in seminars, conferences, etc. various agents contacted the partners requesting meetings to exchange information and establish future collaborations.

Likewise, the partners took advantage of their own contact networks and participation in national and international events to establish alliances with different stakeholders that could expand the international impact and the possibilities of commercialization of the technology when it is finally possible to achieve its full adaptation to the market needs.

The most significant meetings held were the following:

- 21/05/2018 Representatives of UVA and ITACYL met with Dr. David Fangueiro of the **University of Lisbon (PT)** in the ETSIIA (Palencia). The meeting focused on the importance of this kind of technology for farmers also in Portugal, where they face the same problems as in Spain.
- 22/05/2018 Taking advantage of the visit of one researcher of **ARS-USDA** (USA) who is expert in gas permeable membranes technology, representatives of UVA and ITACYL invited him to meet in ITACYL premises to discuss about possible uses of the technology in other sectors, such as the wastewater treatment sector.

- 22/05/2018 The same day in the afternoon, members of the technical team of UVA met Dr. Matias Vanotti from **ARS-USDA** in the premises of the University School of Agricultural Engineering of Palencia, to discuss the results that were obtained by Ammonia Trapping by using the gas permeable membranes in the prototype for the capture of ammonia in the atmosphere. They agreed about the possibility to publish a scientific paper based on the results.
- 09-01-2019 Representatives of DEPORCYL, UVA, FGUVA and ITACYL met with the CEO of **AGROCESA S.A.** (ES) in the company's premises in Aldeamayor de San Martín (Valladolid). AGROCESA is a large pig farming company interested in solutions to ammonia emissions in farms. As a result of this meeting and subsequent contacts, AGROCESA decided to collaborate as a partner in the preparation of a new proposal aimed at adapting the technology to market needs in order to be commercialized in the pig sector (the Concept Note of the **LIFE Green Ammonia proposal** was approved in November 2020 and the full proposal will be submitted in February 2021).

- 20/03/2019 One representative of ENUSA met in Juzbado (Salamanca) with the Deputy director of **GRUPO BLÁZQUEZ** (ES) and with the owner of three pig farms of the group located in Salamanca province. They showed big interest in future collaborations and expressed their willingness to disseminate among other farmers the information about the workshop to be organized by ENUSA by the end of 2019.

- 04/11/2019 Representatives of ITACYL and UVA met with representatives of **PyG Estructuras Ambientales S.L.** in the headquarters of the company in Madrid (ES), this is an engineering company specialized in the treatment of urban wastes. They suggested the possibility of testing the prototypes with municipal wastes leachates in order to determine the feasibility of the technology with this type of wastewater.

- 27/11/2019 Representatives of ITACYL held a meeting with Mr. Giuseppe Moscatelli, researcher of the **Centro Ricerche Produzioni Animali S.p.A. (CRPA)** (IT) during the ManuREsource Conference 2019 in Hasselt (Belgium). The CRPA is a partner of the EIP AGRI project called *Ammonia Washing Machine*. Due to the close connections between both projects, the researchers agreed upon future collaboration for the After-LIFE strategy of Ammonia Trapping project.

- 28/11/2019 Representatives of ITACYL held a meeting with Mr. Ludwig Hermann, partner of the **H2020 SYSTEMIC project** and President of the European Sustainable Phosphorus Platform during the ManuREsource Conference 2019 held in Hasselt (Belgium). The SYSTEMIC project includes five large-scale demonstration plants in Italy, Belgium, The Netherlands, United Kingdom and Germany. In these plants, new approaches for the valorization of bio waste into green energy, fertilizers and organic soil improvers are demonstrated. Since the Ammonia Trapping project is working with a biogas plant where a technology for nutrient recovery could be implemented, Ludwig Hermann proposed to co-organize a workshop for regional and national stakeholders in the frame of anaerobic digestion and nutrient recycling. This should have been organized in 2020, but the sanitary alert situation obliged to postpone it until it.

- 10/12/2019 Representatives of INDEREN organized a videoconference with representatives of **AD Solutions** in Germany. AD Solutions offers consultancy for biogas plants and recently they have studied various technologies to treat substrates with a high concentration of ammonia in order to improve the digestion of this type of waste. They showed big interest in the liquids prototype so proposed to hold a new meeting, this time in person, where they could visit some plants with nitrogen problems both in the substrate and in the digestate.

- 25/03/2020 Representatives of INDEREN organized a videoconference with representatives of **Genia Global Energy S.L.** (ES), an engineering company dedicated to renewable energy, specializing in biogas, solar energy and energy efficiency. The LIFE Ammonia trapping project is interesting for them because it is vital for Genia and other companies dedicated to anaerobic digestion, to find a solution for the treatment of digestates, and ammonia is an important element in the process.
- 08/04/2020 Representatives of ITACYL held an online meeting with researchers of the Provincial Council of Badajoz (Spain) which is a partner in the **INTERREG SUDOE CirRural 4.0** project in which the efficiency of dry anaerobic digestion of sludge from urban wastewater treatment plants and the subsequent extraction of phosphorus and nitrogen is evaluated at pilot scale. They considered that gas-permeable technology presents a great potential for recovering N from sludge after anaerobic digestion and it would be a novel application for this technology. Therefore, they agreed to collaborate as a part of the after-LIFE plan of Ammonia Trapping project.
- 07/05/2020 Representatives of ITACYL held an online meeting with representatives of **EnergyLab** (Vigo, Spain). The latter showed interest in the application of the gas-permeable technology developed in LIFE Ammonia Trapping project for ammonia recovery coupled with anaerobic digestion of hen manure and suggested the possibility of testing this new configuration at pilot scale.
- 10/06/2020 One representative of ENUSA organized a videoconference with one representative of **ENVITEC BIOGAS** (FR), one of the leading biogas plant technologists in Europe. The Manager Service Construction of Envitec Biogas expressed his interest in the new membrane technology and mobile design of the liquid prototype of the ammonia trapping project and is interested in analyzing future industrial developments of this membrane technology. He would like to be able to visit the liquids prototype that will be operating in the Vall de Uxó biogas plant (Castellón) in the coming years as part of the after-LIFE strategy.
- 15/06/2020 The director of AVÍCOLA CIRIA hold an online meeting with representatives of **COPISO** (an important cooperative society in Soria that operates in rural areas), **AVIALTER** (Professional Association of Alternative Poultry) and **ERPA** (European Poultry Association). The objective was to present the Ammonia Trapping project and to exchange ideas about technology use in the sector.

E.1 Project Management

Foreseen start date: 01/10/2016 Actual start date: 01/01/2016
Foreseen end date: 30/09/2019 Actual end date: 30/09/2020

UVA has been in charge of the technical coordination of the project in close collaboration with ITACYL. Administrative and financial coordination has been developed by FGUVA, which in turn is the managing entity of European projects for UVA by statutory delegation.

FGUVA and UVA share a specific convention by which, with regard to European projects, FGUVA handles the financial and administrative aspects of UVA's involvement in such projects, including all issues related to the employment and payment of additional staff, travels, purchase of equipment and consumables, etc. For that reason, any additional personnel needed by UVA have to be hired through FGUVA, and suppliers directly invoice FGUVA for costs which had been budgeted for UVA. In this regard, and following the recommendations of the letter from the EC of 03/05/2017, budget shifting flexibility possibility has been used, although no amendment is necessary because the budget shift between UVA and FGUVA does not surpass 20% of total budget.

Project management system as well as communication with EASME and the monitoring team have been extensively explained in *section 5.1* of this report.

At the beginning of the project, each partner appointed an administrative manager and a technical manager:

- The administrative manager of each organization was in charge of maintaining continuous contact with FGUVA for the resolution of administrative and financial issues, as well as for the preparation of the corresponding financial reports. The Consortium Agreement signed between the coordinator and the rest of the project's beneficiaries established an internal financial reporting calendar that allowed for proper monitoring of the project and meeting the formal deadlines for financial reporting to EASME.

- The technical manager of each organization was part of the Steering Committee of the project, which held continuous meetings with the technical coordinators of UVA and ITACYL and was in charge of periodically reporting to FGUVA all advances, problems encountered, solutions adopted and general progress in development of actions.

Communication and collaboration among partners progressed very satisfactorily. All partners performed a satisfactory internal project management and evidenced a high responsibility in the execution of their tasks. They contributed to reporting obligations though evidently this was not easy especially for the farms, who were not used to this kind of administrative work.

Partners meetings. Initially, the meetings of the partners were planned with a periodicity of 6 months. However, the milestones that were occurring in the development of the project or the mandatory monitoring visits made it necessary to call meetings on the following dates:

10/11/2016: Kick-off meeting that was organized in Guardo one day before the first dissemination day of the project.

07/03/2017: SCM and I MONITORING VISIT in the premises of FGUVA in Valladolid. During this meeting the monitor had the opportunity to meet and discuss project development details with all partners.

26/10/2017: SCM in the premises of UVA in Palencia.

11/04/2018: SCM in the premises of DEPORCYL in Guardo with a partners' visit to the prototypes that had been recently installed in the farm of San Pedro de Cansoles.

23/05/2018: SCM and II MONITORING VISIT in the premises of DEPORCYL in Guardo. During this meeting the project monitor had the opportunity to visit both prototypes installed in the farm of San Pedro de Cansoles.

12/11/2018: SCM held after the celebration of Workshop 1 with stakeholders. After the workshop partners met in the premises of DEPORCYL in Guardo.

23/05/2019: SCM and III MONITORING VISIT in the premises of UVA in Palencia.

17/03/2020: SCM held online because of the sanitary alert situation.

15/05/2020: SCM and IV MONITORING VISIT with the participation of the Project Officer. This meeting had been planned for the beginning of 2020 with visits to the prototypes that were installed in Juzbado (liquids prototype) and Aldealafuente (atmosphere prototype). For agenda issues this meeting was delayed several times and it finally had to be developed online and no visits to the prototypes could be scheduled because of the sanitary alert situation worldwide.

09/12/2020 SCM and V MONITORING VISIT. This was the final monitoring visit that had to be scheduled after the project ended. It was held online and the project monitor

was informed about last project conclusions and the status of development of the Final Report.

E.2 Indicators

Foreseen start date: 01/10/2016 Actual start date: 01/01/2016
Foreseen end date: 30/09/2019 Actual end date: 30/09/2020

The criteria followed to determine the project indicators are explained in detail in section *7. Key Project-level Indicators* of this report.

Likewise, all the indicators have been duly reported in the Program's KPI database on two occasions: when the MidTerm Report was submitted to the Commission in March 2018 and at the present time, with the Final Report submission.

E.3 After Life Plan

Foreseen start date: 01/10/2018 Actual start date: 01/10/2019
Foreseen end date: 30/09/2019 Actual end date: 30/09/2020

Action E is linked to the specific objective 2.10.
The goal of After Life aims to continue the application of both prototypes incorporating their operation with a dual objective, continue to learn to optimize their use and study their long-term profitability. To meet this, both prototypes of atmosphere and liquids have moved to two new destinations:

- ✔ The **prototype for the recovery of ammonia in the atmosphere** has been transferred to a swine farm in *Santa María Real de Nieva*, located in the province of Segovia, owned by *Agro-porcino Manso S.L*. The farm has a capacity of 840 fattening pigs in cattle sheds with forced ventilation, where air is evacuated through individualized chimneys, since the nave is distributed in several identical rooms.

  It is intended to connect the prototype to a chimney by flexible pipe to capture the most ammonia in the air outlet of the chosen room. In turn, we will have another twin room that we will use as a witness to compare and calculate its effectiveness, where we will measure the amount of ammonia emitted by both rooms. Another test that is planned to be carried out is to implement this technology in the slurry rafts of that holding.

  University Valladolid staff (UVA) will check the installation and proper operation of the prototype, paying special attention to the work with the operating conditions observed during the project (ammonia sensors, pump pressure, pH and electrical conductivity). Agro-porcino Manso SL staff will be responsible for the daily operation and maintenance of the prototype, as well as changes in the location of the prototype, when it is necessary.

  With regard to funding, UVA will be responsible for monitoring and costing the transport of the prototype to the farm, as well as financing, with its own funds, the displacement of its staff to the farm to monitor the work of the prototype. Agro-porcino Manso SL will be responsible for providing the necessary infrastructure to install the prototype in the most suitable places, at the expense of adaptation and installation works, materials, labor and finally will bear the cost of daily maintenance of the prototype. The prototype will remain on the Santa Maria farm for two years.

- ✔ At the same time, **the prototype for the recovery of ammonia in liquid media** will be installed in a *biogas plant in Vall D'Uixo (Castellón)*. The biogas plant has a power of 500

kWe and is located in the Industrial Park of the Mosque, Castellón de la Plana. This plant treats approximately 60,000 kg of slurry and daily waste. It has been decided to continue testing with high ammonium anaerobic digestion effluents.

During the After Life phase, the actions envisaged for the prototype capture of ammonia in liquids, is intended to increase the rate of recovery of ammonia in mesophilic anaerobic digestion effluents through advanced filtration pretreations. In addition to slurry, anaerobic digestion effluents (digestates) have high concentrations of ammonia.

The tests are expected to have a higher recovery rate and less effect on the membrane, also producing a more fluid digestate that will allow better management after ammonia recovery.

Laboratory tests show that digestate improves after the successive separation process to 500/50 and 5 microns. The main conclusion drawn from these tests is that the separation to 50 microns is presented as the best pretreated option, since although the separation to 5 microns improves the qualities of the fluid, on an industrial scale makes its handling complicated. Therefore, the actions to develop will be: Process of physical separation in a sieve of 500 and 50 microns.

To carry out this action the main actor involved will be the company Inderen. Whose source of funding will be your own funds, within your line of research.

After-LIFE communication Plan

Project partners will disseminate the results of the ammonia capture project for at least the next 5 years with the use of their own resources. To this end, a number of actions are expected to be carried out at regional, national and European levels following three pillars: Inform, Involve and Inspire. Beyond the limits of the project, a strong network of farmers is aware of the problem of ammonia emissions and the actions they can take to reduce it, not only through the technology developed in the project, but also through other good practices in farm management and in the field application.

In addition, project results are available on the project website that will be updated and maintained for at least 5 additional years after project ends.

6.2. Main deviations, problems and corrective actions implemented

There was a delay on the development of action A.1, due to a problem with the availability of membranes for ammonia capture. This fact delayed action B.1, the design and assembly of the prototypes. Furthermore, the form and nature of membranes forced INDEREN to modify the assembly of the prototypes. Concretely, it was necessary to introduce specific frames on the internal structure in order to hold and fix the membranes. In this sense, the rest of the technical actions related to the testing of prototypes at the poultry and pig farms (B.2, B.3, B.4 and B.5) were delayed. The prototypes were installed and monitored in the different locations, achieving successful results. The project management progressed correctly, as well as transferability and dissemination actions.

6.3. Evaluation of Project Implementation

6.3.1. Comparison of achieved results against objectives

FORESEEN Result		ACHIEVED Result	Evaluation
A.1	**Previous tests**		
Foreseen in the revised proposal		**Achieved**	**Evaluation**
Objectives: Determination of parameters required for design and operation of prototypes Expected results: 1. Ratio of ammonia capture/membrane surface 2. Rate of ammonia removal in liquid wastes and in the atmosphere 3. Recirculation rate of the concentrated solution. 4. Saturation of the concentrated solutions.		Yes	In spite of the delay of this action due to the problems with the supply of the membranes, a good development of the objectives for this action has been achieved.
B.1	**Design and development of mobile prototypes for ammonia absorption in liquid media and in the atmosphere**		
Objectives: Design and development of two mobile prototypes. Expected results: 1. Design and development of a prototype for ammonia capture in liquid media. 2. Design and development of a prototype for ammonia capture from the atmosphere.		Yes	A good development of the objectives for this action has been achieved.
B.2	**Installation, start-up and evaluation of the operation of the mobile prototype for atmosphere**		
Objectives: Installation, start-up and evaluation of the performance of the atmosphere prototype. Expected results: 3. Obtained prototype operational data. 4. Evaluation and adjustment of operating parameters to improve design criteria. 5. Analysis for the projection of the prototype on an industrial scale. 6. Environmental, technical and economic verification that the performances obtained by this prototype they improve other technologies for the same purpose applied in Europe.		Yes	A good development of the objectives of this action has been achieved. The results obtained in situ with the prototypes were below the range of those obtained in the laboratory experiments since they worked in atmospheres that were not very saturated in NH_3. In addition, the prototype was not hermetically sealed and the air passage was forced through a fan, it did not move by diffusion of the gas itself.
B.3	**Installation, start-up and evaluation of the operation of the mobile prototype for liquid media**		
Objectives: Installation, start-up and evaluation of the performance of the liquids prototype. Expected results: 1. Analysis of the efficiency of prototype in terms of ammonia capture rate. 2. Determination of optimal working pH. 3. Optimization of working conditions for maximum ammonia recovery.		Yes	A good development of the objectives for this action has been achieved. The obtained results *on-site* with the prototypes were in the range of those obtained in the lab experiments.

B.4	Evaluation of the final product for its suitability as a fertilizer	
Objectives: Evaluate the effectiveness of the final product for use as a fertilizer and soil corrector. Expected results: 1. Obtaining composition data of the final products. 2. Verify from the environmental, technical and economic point of view, if the product obtained is 3. viable for reuse as a fertilizer. For this, they will be compared with commercial products equivalents. 4. Carrying out an irrigation plan for each facility based on the concentrations obtained.	Yes	A final product was obtained that provided high yields in vegetable and cereal crops. The trials showed that the application of the finish in several doses during the growing cycle showed better results than the application of a single dose.
B.5	**Transferability and replicability**	
Objectives: To export a tested and optimized GPM technology to other EU regions with similar environmental, social and technical challenges within the livestock sector. . Expected results: 1. Percentage of swine manure treated. 2. Percentage of chicken manure treated. 3. Average nitrogen in the fertilizing product obtained.	Partially	Even if no budget had been provided for it, partners considered it important to invest a little amount of money to hire a specialized consultant able to develop a marketing and commercialization plan on the one hand and an internationalization plan on the other. Although both plans concluded that commercial possibilities for the technology are huge both at national and at international level, limitations found by farmers for handling when performing maintenance and replacing membrane panels led to conclude that no commercial exploitation was possible at this development stage.
C.1	**Project monitoring and follow-up**	
Objectives: To monitor and follow-up the prototypes from the technical, social, environmental and economic perspectives. Expected results: 1. Technical, social environmental evaluation of the performance of the prototypes. 2. Economical evaluation of the performance of the prototypes. 3. Performance of LCA analyses for both prototypes.	Yes	A good development of the objectives for this action has been achieved.
D.1	**Communication Plan and networking**	
Expected results: 1. Project website in 2 languages 2. Social networks: Facebook, Twitter, YouTube, LinkedIn, Instagram. 3. Notice boards	Yes	✔ 4,921 individual visitors with a total of 11,111visits with an average duration of 1' 39'' seconds each. ✔ Good reach specially for Facebook and Twitter, which showed as the best channels for the project. ✔ 10 placed on time and good looking, suitable to awake people's interest, especially those located in farms and the biogas plant.

1. Newsletter 2. Project brochure 3. Merchandising materials 4. Layman's report 5. Press dissemination 6. Networking and collaboration with other LIFE projects		✔ 7 launched coinciding with project milestones. Audience reached of 1,568 contacts. ✔ 1,250 printed in Spanish and 1,000 in English. Distributed in face-to-face events. ✔ 200 round pins with the project logo (size 38mm), 200 rectangular paper stickers (size 80x35mm), 500 biodegradable pens and 300 ecological notebooks. ✔ Published on the project's website and 400 copies were printed in Spanish and 400 in English). Sent to stakeholders and available on the website. ✔ 34 publications in written press, 64 in digital press, 6 scientific articles, another accepted for publication and 4 more in preparation, 7 posters accepted in congresses, 32 oral communications, 3 extended abstracts and 6 broadcasts on radio and TV. ✔ Close collaboration with 17 LIFE projects, 2 H2020 projects, 1 Interreg Sudoe and 1 EIP AGRI.
D.2 Events and transferability actions		
Expected results: 1. General dissemination seminars: 3 planned 2. Stakeholder workshops and visits to pilot plants: 5 planned 3. Final project conferences (international and national)	Partially (face-to-face events that had been planned had to be cancelled because of sanitary situation)	✔ 2 organized in face-to-face format and the third cancelled because of sanitary alert and all possible attendees invited to participate in the final online sessions of the project held in September 2020. Total of 94 attendees. ✔ 3 organized in face-to-face format and the other 2 cancelled because of sanitary alert and all possible attendees invited to participate in the final online sessions of the project held in September 2020. Total of 181 attendees of which 113 had the opportunity to visit the prototypes on site. ✔ Both had to be cancelled because of sanitary alert. Instead a two-days online seminar with national and international lecturers was held with good panel of experts and high number of people registered and connected. Total of 287 attendees.

E.1	Project Management		
1 Partnership Agreement signed by all partners. 9 Partners meetings 5 of which were made to coincide with project monitoring visits. 2 Amendments 1 MidTerm Report with payment request 1 Progress Report Sound financial administration		Yes	Project management and progress smoothly, with satisfying collaboration of all partners. All partners performed a satisfactory internal project management and evidenced a high responsibility in the execution of their tasks. They contributed to reporting obligations though evidently this was not easy especially for the farms, who were not used to this kind of administrative work.
E.2	**KPIs**		
KPIs database completed		Yes	The online KPIs database has been completed for those KPIs relevant for the project.
E.3	**After-LIFE Plan**		
After-LIFE Plan completed with contributions from all partners		Yes	All partners contributed to the elaboration of the After-LIFE Plan with firm intention of continuing to develop activities during the years after the end of the project.

6.3.2. Successes and failures of the applied methodology

ATMOSPHERE PROTOTYPE: UVA observed some specific shortcomings and improvements, which are listed below.

- **Problem 1. Extrapolation of results from laboratory scale to pilot prototype scale.**

During the time that the project has been developed, an attempt has been made to achieve the objectives set in the memory. But it was found very difficult to extrapolate the farm-scale laboratory results in the case of the gas prototype. This is mainly due to the following factors:

- Laboratory conditions are highly controlled. On the farm, the concentration of TAN in manures is highly variable and difficult to control, which affects ammonia emissions.
- The chamber used to perform the laboratory experiments is airtight. On a farm, the prototype structure is not airtight. On a laboratory scale, the gas concentration in the atmosphere has been found to be a key factor in the ammonia capture process. For this reason, on a pilot scale, this point could be influenced, since closing the compartment in an airtight way favours the presence of a more concentrated atmosphere.
- Poorly dimensioned between the volume of air to be treated and the surface of the membrane used.
- Ammonia measurement sensors are required to provide continuous measurements that require little maintenance and can use reliable data to perform mass balances. The sensors that have been used in the farm, gave continuous measurements but presented many problems and it was necessary to send them to a workshop for maintenance, having to look for alternatives on the fly. Also, this caused a lot of data to be discarded.
- Breaking of the fan that drives the air from inside the farms to the prototype. The air reached the prototype by its own diffusion, which slowed the rate of ammonia capture.

To try to solve this problem, a series of corrective measures were carried out:

- Sealing the structure of the prototype meant a greater tightness of the chamber where the membranes were located. Without having intervened in this way, the TAN recovery obtained would have been less.
- In the test in which the prototype was connected to a composter to clean its atmosphere, a TAN recovery efficiency of more than 50% was achieved in just a month and a half. This helped to verify that the relationship between the surface of the membrane used and the volume of air to be treated is better dimensioned than in the case of the connection for cleaning the air in buildings.
- During the prototype operating period, the fans that help the air movement between the farms and the prototype had to be changed several times. If they had not been changed, the air would have reached the prototype by simple diffusion. This would have been reflected in a reduction in ammonia capture.

- **Problem 2. Evaporation of water from the acid solution.**

During the operation of the prototype in both farms, it was detected that there were losses of liquid in the acid solution. We observed that the temperature of the liquid increased with respect to the outside ambient temperature, which caused the evaporation of part of the water that constituted the acidic solution. This generated an increase in the acid concentration in solution, which could cause damage and/ or rupture of the membranes. The problem was solved by manually filling the tank with an acidic solution, which made it possible to always maintain the same volume of capture liquid, compensating for water losses due to evaporation. If the problem had not been solved, the acid solution would have concentrated to the point of being able to deteriorate the membranes and even break them. This would have implied having to change all the membranes installed in the prototype and a delay in the execution time of the project.

- **Problem 3. Loss of pressure of the acidic solution in its circulation inside the membranes.**

In the second location (laying hen farm) head losses of the acid solution circulating inside the membranes were observed. The liquid did not have enough pressure to exceed the height of the installation and could not circulate through all the membranes. This fact meant that the acid solution was not continually renewed, reducing the ammonia capture rate. This problem was controlled by manual measurement of the acid solution flow. The regulation of the pressure of the acid solution within the membranes allowed the capture liquid to circulate continuously through the membranes, renewing itself and favoring the capture of ammonia. If the problem had not been solved, the acid solution would not have had enough pressure to circulate through all the membranes and the ammonia capture efficiency would have been greatly reduced.

We believe that this problem was only observed in Aldealafuente because the equipment arrived more deteriorated after its use in Guardo. Furthermore, in Soria some modifications were made to the structure of the prototype to improve the circulation of the acid within the membranes. We believe this may also have played a role in the liquid pressure problem.

LIQUIDS PROTOTYPE: In the case of the liquids prototype, after overcoming the technical difficulties reported in Action B.3., the results obtained in the farm/biogas plant were in the range of those achieved in laboratory assays. However, **ITACyL** has identified the following issues to further improve the performance of the liquids prototypes:

- Covering the manure tank could be useful to minimize ammonia emissions to the atmosphere.

- Since the recovery of N is highly dependent on the temperature in the manure, a heating system for the winter months should be considered.
- The evaluation of cheaper materials for the membranes and the use of recycled acids would be two examples of sustainable alternatives to reduce operational costs.

The project results showed that GPMT is environmentally effective and economically viable, but a scale-up is required to achieve a commercial model with the potential to be demonstrated as a Best Available Technology (BAT) and not only as an emerging BAT. For that, a new LIFE proposal has been elaborated for the construction of two commercial models to recover NH3 from the atmosphere and from liquids. The latter will be modular and easy to transport to the farms as many modules as necessary depending on their size.

6.3.3. Visibility of project results

All the results exhibited throughout this project have been obtained as a result of the work done at each location with the prototypes. Therefore, the data has been patented through news, technical days, congresses and scientific publications during these four years.

The proposal made for the After-life period considers the implementation of improvements in both prototypes and their location in different scenarios. These new locations and improvements made to the prototypes are aimed at improving the efficiency of ammonia capture. This objective should be verified by monitoring the results for the stipulated time.

6.3.4. Effectiveness of project amendments led to the results achieved and what would have been different if the amendment had not been agreed upon.

The main modification in the Life Ammonia Trapping project was the need for its one year extension due to the problems with finding the suitable membranes when the project began. It made it possible to work with an optimal membrane and thus achieve the final objective in terms of ammonia absorption both in the atmosphere and in liquid media. Without this extension, it would not have been possible to complete all the actions foreseen.

6.3.5. Results of the replication efforts

Both the commercialization and the internationalization plans concluded that commercial possibilities for the technology developed within the Ammonia Trapping project are huge both at national and at international levels. However, the limitations found by farmers for handling when performing maintenance and replacing membrane panels led to conclude that no commercial exploitation was possible at this development stage. A new project, named **LIFE Green Ammonia**, has been submitted to scale up this technology as an industrial commercial model, easier to handle for the farmers, more robust and easier to transport and to install.

6.3.6. Effectiveness of the dissemination activities.

No important drawbacks regarding dissemination activities have been identified. Just the last months of the project, from March to September 2020, due to COVID19 pandemic situation, some events that were programmed to be held face-to-face had to be organized online. Also other events such as the IWA, REC and Venice20 Congress, the Red Remedia Workshop and the REC Workshop have been postponed.

6.3.7. Policy impact

The most important achievements of the LIFE Ammonia Trapping project have been the reduction of environmental impacts of ammonia emissions and the production of a fertilizer end-product.

It is expected that current legislation in the EU territory could facilitate the incorporation of these achievements, at least, in two different ways: the first way is related to the fertilizer end-product obtained after recovering the ammonia from the swine manure, digestate and also from the atmosphere. An efficient nitrogen cycle is a major issue for a sustainable circular bioeconomy. In this context, recycled nutrients are considered in the EU Circular Economy Plan as an important category of secondary raw materials. The use of these recycled nutrients, as the Ammonia Trapping end-product (ammonium sulfate) would decrease the need for mineral-based fertilisers in agriculture. The second way is related to the Best Available Technologies for intensive rearing of pigs and poultry (BATs). In this case, the LIFE Ammonia Trapping project can contribute to the reduction of ammonia emissions from both sectors (i.e. pigs and poultry intensive rearing) as well as from industries from other sectors. So the procedure to consider this technology as a potential BAT has been carried out during the LIFE Ammonia Trapping project.

The project achievements are also related to the CAP (Common Agriculture Policy) after 2020, especially when it comes to:

- Increase the competitiveness of the farming sector through the valorisation of manure and the obtention of a high added value fertilizer while improving manure management.
- Protect the environment and health quality due to the reduction of ammonia release to the atmosphere.
- Give an opportunity for the development of the rural areas by increasing the competitiveness of the farming sector.
- Foster competitive and sustainable farming through knowledge and innovation.

Regarding national and regional policy, the project achievements also support the natural resources thematic priority within the Research and Innovation Strategy for Smart Specialisation (RIS3) of Castilla y León 2014-2020. According to this regional strategy, efforts are focused on research and innovation for increasing the sustainability of the agricultural and livestock sectors.

6.3.8. Main barriers identified and action(s) undertaken to overcome them

One barrier to consider the Ammonia Trapping technology (gas-permeable membranes) as a BAT was to know the mechanisms for the application procedure. However, this barrier was overcome after speaking with the Spanish National authorities and with the Technical Working Group of the EU in charge of this (European Commission Joint Research Center, Circular Economy and Industrial Leadership Unit). In this way, a document describing the Ammonia Trapping technology was successfully submitted to the Technical Working Group of the EU (Annex B5.2). The information will be evaluated to consider Ammonia Trapping technology as a potential candidate technique for BAT or Emerging Technique.

6.3.9. EU Added Value

Ammonia Trapping has been a successful project from the point of view of main goal achievements. Results obtained in the project have demonstrated that the GPMT is feasible to capture ammonia from manure, digestate and from the atmosphere. This will contribute to achieve the goals of the European Commission legislation, as with Directive 2010/75/EU

related to industrial emissions, as well as with Directive (EU) 2016/2284 on national emission ceilings for certain atmospheric pollutants (amending Directive 2003/35/EC and repealing Directive 2001/81/EC). According to our results and the LCA study carried out in this project, important impacts can be avoided by using this technology, as capture of more than 50% of ammonia from liquid effluents, thus reducing nitrogen from wastes. Among these impacts the most significant are related to: the net global warming (reduced by 18% compared with the baseline scenario), net fine particulate matter formation (reduced by 74% compared with the baseline scenario), lower net potential marine eutrophication (reduction of 86% compared with the baseline scenario). Reduction of nitrogen content in livestock effluents also will contribute to fulfill Directive 91/676/CEE concerning the protection of waters against pollution caused by nitrates from agricultural sources, as less N content will be applied to soil.

By applying this technology a fertilizer end-product is also obtained which is a commercial product fulfilling Regulation (EU) 2019/1009, this end-product is obtained from recycling and recovering nutrients from liquid wastes and from the contaminant ammonia from the atmosphere, therefore it is expected to contribute to reduce energy costs and fertilizers dependency in Europe.

6.4. Analysis of benefits

6.4.1. Environmental benefits

The GPMT has important benefits. The most important are the following: this technology directly reduces NH_3 emissions from liquid media and from the air, as well as indirectly contributes to the reduction of N_2O, CH_4 and the formation of particulate matter. GPMT implies a reduction of energy if it is compared to similar N-recovery technologies. Moreover, the application of GPMT to livestock sector could stimulate the development of the local economy of rural areas.

a. Direct/quantitative environmental benefits

The Ammonia Trapping project directly contributes to the NH_3 emissions reduction. As stated in the KPIs, for the specific context of Castilla y León, the initial NH_3 emissions correspond to the sum of emissions in the three scenarios where the prototypes were tested (sow farm, laying hen farm and biogas plant), accounting for 70.5 kg per day. The value at the end corresponds to the total reduction achieved (1 kg per day) in the three locations and with the two prototypes (reduction of ammonia from liquid wastes and atmosphere). So, the NH_3 emissions reduction accounts for 1.42% of the emissions in the specific context of Castilla y León. The Life Cycle Assessment (LCA) carried out during the project (*Deliverable C1.3*) reveals that the environmental impacts when applying the Gas Permeable Membrane technology for the treatment of livestock wastewater under optimized conditions were cut by 18%, 89%, 74% and 66% for global warming, marine eutrophication, fine particulate formation and terrestrial acidification potentials, respectively.

b. Qualitative environmental benefits

The long term sustainability of the GPM technology for NH_3 emissions reduction is ensured since two major companies (Agropor and Agrocesa) are involved in the new proposal LIFE Green Ammonia and they have a great interest in the development and the implementation of this technology in their respective farms. Other environmental benefits related to the Ammonia Trapping project are the improvement in the management of livestock wastewaters and its

contribution to the sustainability of the livestock and agricultural sectors. GPM technology contributes to the improved management of swine manure, which is nowadays the largest source of ammonia (NH_3) emissions,closely related to a variety of environmental problems and to human health risks. An ammonium sulphate solution, with an estimated value as fertilizer of 2.36 € per kg of N, is produced. The sale of this solution as fertilizer together with a lower cost of manure/digestate transportation would enhance livestock and agriculture sustainability.

6.4.2. Economic benefits related to preservation of the rural areas:

Two important benefits related to preservation of rural areas have been identified: one is related to the local economy of the rural areas, as livestock farming is an important industry for these areas, contributing to set and maintain rural populations. Reduction of ammonia emissions due to GPMT could allow new livestock farms construction in some EU countries (as Spain), or help to preserve the settled farms, preserving or increasing rural population and jobs development.

Another issue is related to nutrients preservation and redistribution for agriculture. Nowadays a huge amount of imported N fertilizers is used in agriculture. If the N end-product of Ammonia Trapping (that is ammonium sulfate) is obtained from manure, and it is redistributed in a local area nearby where it is produced it is expected that less N fertilizers would be imported. Therefore, the economics related to N fertilization could be more local, improving the economy in rural areas and creating new business opportunities related to this new technology.

6.4.3. Social benefits:

As mentioned before, positive effects on employment is expected from the development of the Ammonia Trapping technology. Another benefit is related to animal and human health since ammonia emissions are related to particulate matter production that is related with respiratory problems. However, in this project researchers did not take enough data to demonstrate this effect.

6.4.4. Replicability, transferability, cooperation:

Potential market

In the first stage, two different sectors are the most important for the market of the GPMT: The pig production sector and the poultry sector, as the technology has been proven in both. Furthermore, the fertilizers sector is of vital importance as they are end-consumers of the end-product ammonium sulfate. According to our business plan, the priority countries are Spain, France, Germany and Denmark, as they are the main pig producers, and in a second stage it is expected to expand to other EU countries as Poland, The Netherlands and Belgium.

South American Countries are also interesting as they have the same language than in Spain, and this can always facilitate commercial relationships. Other world countries such as China, USA and Brazil are not priority in the start-up period of the company as it is more complicated to establish commercial agreements, therefore, they will be our last stage expansion.

The GPMT has a high replicability to apply to other waste treatment and management sectors as representatives of multiple and different companies have shown to the consortium along the project. In this sense, the treatment of leachates from municipal sanitary landfills, slaughterhouse wastewater, urban wastewater and the ammonia emissions in urban waste management processes will be addressed in Spain and in parallel to commercialization of the technology in Europe. This replicability is market-driven as GPMT is an opportunity to strengthen Circular Economy strategy in the EU, as waste is transformed into a valuable end-product.

As indicated in the Marketing and Commercialization Plan deliverable, to market the commercial prototype in Europe the AT Company will establish commercial agreements with distributors of the livestock sector in the countries mentioned above. It is our intention to contact and take profit of the existing market players in the EU in order to accelerate the introduction of the GPMT.

6.4.5. Best Practice lessons:

The AT project had few problems during its development. The most important occurred at the beginning of the project and refers to the delay in the arrival of the membranes, as they came from a European supplier but they were manufactured outside of the EU. In this case, the lesson learned is to have more than one supplier and make the necessary purchases earlier than necessary. Technical problems were successfully and easily solved during the project, the lesson learned is to test the prototypes in a testing bench before using it in the final location.

6.4.6. Innovation and demonstration value: .

The level of innovation of the AT project has been very high, as this is the first on-farm GPMT prototype constructed and tested all over the world. Funding by the EU has been decisive for the boosting of the GPMT, which has allowed development of the technology from TRL3-4 to TRL7. This includes aspects as technology tools, methodologies, involvement of stakeholders, cooperation models and commercial feasibility.

6.4.7. Policy implications:

Achievements of AT project are related to environmental protection as well as human and animal welfare in livestock farms, as capturing ammonia from livestock effluents, anaerobic digestion and composting process have been achieved. As the efficiency of this technology has been proven, its implementation as a BAT will contribute to the European legislation. The Consortium is taking steps for the EU to adopt this proposal and include it in the next BREF, although these steps may encounter some barrier proposed by a partner member or stakeholder of the EU. The actions to overcome this barrier will involve national and international stakeholders interested in the results, presenting the targets achieved in the AT project.

7. Key Project-level Indicators

Final actual values of the KPIs for this project have been entered in the online KPI database. A comparison with the targets at the beginning of the project is provided for each KPI:

1.5 Project/area length: This indicator is related to the actual area where the project actions took place, that accounts for 73 km^2. The demonstration of the performance of the prototypes was successfully carried out in the three initially planned Spanish locations: San Pedro de Cansoles in Guardo (Palencia) with a surface of 6 km^2; Juzbado (Salamanca) with a surface of 22 km^2 and Aldealafuente (Soria) with a surface of 45 km^2.

1.6 Humans to be influenced by the project: This indicator is related to the people whose lives were directly and positively impacted by the ammonia emission reductions by the use of the GPMT. Linked to the indicator about the project/area length, it refers to the residents within the three villages where the project was carried out, that sums up to 270 inhabitants.

6.1 Air emissions - NH_3: Initially, this environmental indicator was referred at European level. However, following the recommendation of the Project Officer during the monitoring visit of May 15, 2020, this indicator was changed and now it is referred to the locations where the project was developed. Thus, the total ammonia emissions in Spain were considered as initial value. These emissions were estimated at 1,330,000 kg per day. The estimation of the value beyond 5 years, has been done considering the implementation of GPMT for the treatment of 10% of the swine manure produced in the Agropor and Agrocesa`s farms in the next 5 years. Both companies are involved in the new proposal **LIFE Green Ammonia** and they have a great interest in the development and the implementation of this technology in their respective farms. Thus, it was considered that the swine manure produced by 0.5 million pig heads would be treated by the GPMT. Assuming an ammonia emission default value of 6.5 kg NH_3 per animal and year (EMEP/EEA, 2019; Table 3.2), the avoided NH_3 emissions would account for 8,904 kg per day.

10.2 Involvement of Non Governmental Organizations (NGOs) and other stakeholders in project activities:

- Private for profit: The current value is based on private project beneficiaries + entities with whom bilateral meetings have been held and that have shown interest in monitoring technology and analyzing possible adaptations to their scope of action (Agrocesa, Grupo Blázquez, PyG Estructuras Ambientales SL, European Sustainable Phosphorous Platform, AD Solutions, Genia Global Energy SL, EnergyLab, ENVITEC BIOGAS, COPISO, AVIALTER and ERPA).

  In the 5-year calculation, an extrapolation is made subject to the development of the business model, either by the approval of the new project proposal submitted **LIFE Green Ammonia** or by obtaining private financing. In this case, the value taken as a reference is that of the sales estimate indicated in Figure 1 of the summary of *Deliverable B5.1-1*, according to which by 2025 the accumulated sales of commercial equipment in Spain in poultry farms would be 156 and the accumulated sales of commercial equipment in pig farms would be 312. This makes a total of 468 marketed equipments. Taking into account that there could be farms purchasing the two devices, this total is divided by 2 to establish an average of individual private entities that would acquire the technology.

- Public bodies: The current value is based on the public partners of the project + other public entities with whom bilateral meetings have been held and who have shown interest in monitoring the technology and analysing possible adaptations to its scope of action (University of Lisbon, Provincial Council of Badajoz). In the 5-year calculation, no additional value is specified because it will depend on the inclusion of technology as a **Best Available Technique**.

11.1 Website: values provided according to site metrics. 5,585 unique visits, which are the total number of sessions in the period (a session is the period during which the user interacts with the website) .

11.2 Other tools for reaching / raising awareness of the general public:

- **Project Reports:** MidTerm Report, Progress Report and Final Report submitted to the EC
- **Publications (journals/conferences):** 6 scientific articles, 1 scientific article accepted for publication, 4 scientific articles currently in preparation, 7 posters accepted in congresses, 32 oral communications and 3 extended abstracts.

- **Print media:** 7 newsletters published, 34 publications in written press, 64 publications in online press, 800 copies of Layman's Report distributed among stakeholders.
- **Other media (video/broadcast/leaflet):** This indicator includes broadcasts about the project in radio and TV (6), videos uploaded to the Youtube channel (19) and leaflets printed and distributed among stakeholders (2,250).
- **Hotline/information centre:** The project website has been conceived as an information centre with all the relevant information.
- **Events/exhibitions:** To calculate this indicator, it has been taken into account the participation of the beneficiaries in 17 networking events, as well as the organization of 2 general dissemination days, of 4 workshops for stakeholders and of 1 final conference.
- **Displayed information (poster, information boards):** For the calculation of this indicator it has been taken into account the 10 Notice Boards designed to be placed in the facilities of the partners, plus 7 posters designed for conferences and congresses that UVA and ITACYL have attended, plus 2 posters that were designed for the participation in the EU Clean Air Forum held in Bratislava in November 2019.

12.1 Networking: The starting value of this indicator had been erroneously established, based on the number of members of the different associations, organizations and stakeholders of various kinds that would be reached through the project. However, we consider that it is most correct to consider each of these organizations as a single individual and not as the sum of all its associates and members. Taking this as a basis, the values that had been provided initially have been corrected and for the calculation of this indicator we have taken into account: the interactions with other projects via social networks (98), the collaborators of other projects with which actions have been carried out (26), number of participants in bilateral meetings (19), the partners themselves (7) and number of people attending conferences and events organized by the project (833). The 5-year extrapolation is based on the possibility of developing the equipment in a commercial model with the corresponding marketing and commercialization campaign to bring the technology to market.

13. Jobs: The indicator has been based at the end of the project on the number of additional staff positions generated during its development. The beyond 5 years value is based on the number of FTE jobs that will be maintained by beneficiaries after project ends (2 in ITACYL). However, if the new project for effectively bringing the technology to market is approved, the beyond 5 years calculation should be based on the number of jobs created for the manufacture and marketing of the equipment, and for sure this figure could reach at least 30 people.

Calculation of current values:

- 4 women above 25 years old were hired by UVA-FGUVA (1) and ITACYL (3) with full time contracts.
- 1 grantholder male aged below 25 years old was giving support to communication activities in FGUVA during the last 8 months of the project for 3 hours per day (498 hours total that compared to 1760 hours total per year equals 0.28 FTE).
- 1 male over 25 years old hired by FGUVA with full time contract but partial dedication to the project for communication activities (0.47 FTE).
- 2 males over 25 years old hired by UVA-FGUVA with partial time contracts for the development of technical activities (0.67 FTE each)

14. Contribution to economic growth:

- Running cost/operating cost during the project and expected in case of continuation/replication/transfer after the project period: the current value corresponds to the eligible costs declared for project execution, and beyond 5 years it has been added the

costs for the after-LIFE Plan development (15,000) plus running costs for operating the equipments in the new locations (approximately 8,000€ for the purchase of spare parts). In addition, we have taken into account the development costs of the new plants in the event that the new LIFE project submitted (Green Ammmonia) is approved (approximately 563.000€).

- Future funding: The Ammonia Trapping project proved the technology to be efficient according to the objectives foreseen. However, its commercialization was not possible at the end of the project because of limitations found by farmers for handling when performing maintenance and replacing membrane panels. This led to conclude that no commercial exploitation was possible at this development stage.

  For this reason, a new proposal has been launched to the LIFE Programme called **LIFE Green Ammonia** that will put the technology definitively in the market. The value given to this indicator beyond 5 years corresponds to the approximate budget foreseen for the LIFE Green Ammonia project development in case that it was approved by the EC.

8. Comments on the financial report

8.1. Summary of Costs Incurred

Complete the following table to show the project costs incurred compared to the approved budget and comment on each of the cost categories focussing particularly on discrepancies compared to the allowed flexibility of the 20% limit (cf. Article II.22 of the General Conditions).

PROJECT COSTS INCURRED				
	Cost category	Budget according to the grant agreement in €*	Costs incurred within the reporting period in €	%**
1.	Personnel	942.345 €	1.080.924,80 €	115%
2.	Travel and subsistence	96.583 €	55.004,88 €	57%
3.	External assistance	66.058 €	77.518,02 €	117%
4.	Durables goods: total non-depreciated cost			
	- *Infrastructure sub-tot.*	4.000 €	3.655 €	91%
	- *Equipment sub-tot.*	0 €	1.157,55 €	
	- *Prototype sub-tot.*	320.039 €	314.782,76 €	98%
5.	Consumables	116.000 €	120.677,84 €	104%
6.	Other costs	66.575 €	45.248,29 €	68%
7.	Overheads	112.565 €	118.674 €	105%
	TOTAL	**1.724.165 €**	**1.817.643,14 €**	**105%**

*) If the EASME has officially approved a budget modification through an amendment, indicate the breakdown of the revised budget. Otherwise this should be the budget in the original grant agreement.
**) Calculate the percentages by budget lines: e.g. the % of the budgeted personnel costs that were actually incurred

Comments

Once the project implementation has been completed, the total final costs have overtaken the foreseen budget by 5% only. Taking into account that the project duration has required one more year, this excess of project costs incurred may be considered a reasonable higher total cost rate. By the same token, no category cost has exceeded the allowed flexibility of the 20% limit.

- Staff costs : The personnel costs make up 60% of the total project costs incurred, which is in line with the Grant Agreement. As reported below, the allocation of person-days of the beneficiaries' staff fits in with what was foreseen in the approved proposal. All beneficiaries have carried out their duties in terms of activities and objectives reached. Moreover, the staff profiles included in the project have been the same as those reported in the Grant Agreement. The project has involved highly qualified staff profiles in order to be able to reach the

ambitious objectives of the project. Finally, it is worthy of mention that additional staff members were hired as planned in the proposal, hence the project has had a direct positive socioeconomic impact.

- Travel and Subsistence: At the end of the project, this category cost has incurred lower expenses than the foreseen ones. The main reason is due to the COVID-19 impact in the last year of the project implementation. This situation made travel impossible as the beneficiaries had foreseen carrying out dissemination and networking activities, congress attendance, etc.
- External Assistance: these costs refer mainly to the external consultancy hired by partners to provide support in management and coordination activities. FGUVA also includes in this section, as foreseen, costs related to project's visual identity design, communication plan and website development, that was hired with a specialized company (Mil trescientos gramos S.L). UVA (through FGUVA on the basis of their management model) includes also in this section analysis activities entrusted to Fundación Parque Científico de la Universidad de Valladolid, an entity linked to UVA, but the only one able to make that kind of analysis (that require specialized equipment) at a really low prize. No economic benefit is derived from that activity and hiring those services to external providers would raise the price disproportionately.
- Equipment: the only cost declared here regards the purchase of a peristaltic pump by UVA, absolutely necessary for trial tests of Action A.1. Initially, no budget had been approved for UVA in this cost section. However, it was necessary to acquire a new peristaltic pump for laboratory tests, because the one that had the UVA broke down and fixing it was far more expensive than buying a new one. The corresponding depreciation rules have been applied when allocating the cost. Accounting documents related with this acquisition and depreciation methodology is available.
- Prototypes: the two prototypes have been developed, only in the absence of incorporating the membranes. ENUSA and INDEREN were responsible for the technical design of both prototypes and providers were selected offering best value for money, following the corresponding contracting procedures established. DEPORCYL and LA CAÑADA, as partners which offered their facilities to install both prototypes, purchased consumables to operate these. The costs incurred in this category have been nearly the same as foreseen.
- Consumables: almost all costs declared here correspond to consumable materials necessary for trial tests foreseen in Actions A.1., B.2., B.3., and B.4., by UVA, ITACYL and ENUSA. Some other costs correspond to the purchase of laboratory consumables during prototypes installation (Action B.2). The amount spent in this category is in line with the total foreseen.
- Other Direct Costs. The costs incurred in this category have been significantly lower than they were foreseen as most of them were related to attending several national and international congresses, services and materials for organising workshops, final events and other kinds of dissemination or communication activities which were to be attended in person.

8.2. Accounting system

Include among other aspects:

1. Brief presentation of the accounting system(s) employed and the code(s) identifying the project costs in the analytical accounting system

UVA-FGUVA

As previously explained, according to the specific management system between UVA and FGUVA, the latest handles the financial and administrative aspects of UVA's project involvement, including all issues relating to the employment and payment of additional personnel, travels, purchase of equipment and consumables, etc. Also the bank account held by Fundación General de la Universidad de Valladolid (FGUVA) is the one to which the Universidad de Valladolid receives all payments from the Community financial contribution.

According to this management system and on the basis of an analytical accounting system, the FGUVA's accounting system assigns two different codes to the participation of UVA-FGUVA in the project. The code assigned to FGUVA's participation in the project is 069/160001 and the code assigned to UVA's participation in the project is 069/161931.

DEPORCYL

Apart from the legally required, DEPORCYL created a separate account within its accounting system (PROYECTO LIFE AMMONIA TRAPPING) where the expenses incurred in the project can be traced. Concretely, the internal code for the project is 60700000001.

ENUSA

The accounting system used by ENUSA is based on a cost centre. The internal code for the project cost is P75006.

INDEREN

Apart from the legally required, INDEREN created a separate account within its accounting system (PROYECTO LIFE AMMONIA TRAPPING) where the expenses incurred in the project can be traced. Concretely, the internal code associated with the project is 20000003. Besides, INDEREN has different internal codes related to the kind of incurred cost, all of them associated with the global accounting system of AMMONIA TRAPPING. Thus, they have subsections for travel, prototype, external assistance costs, etc.

ITACYL

As suggested by LIFE guidelines, ITACYL has established an internal project code in its analytical accounting system. Concretely, ITACYL works with the official informatics system from the "Junta de Castilla y León" (Regional Government), denominated SICCAL. On this sense, to manage with this program, it has been necessary to create and specific number for the project LIFE AMMONIA TRAPPING: 2016/000850, denominated *PEP element*.

LA CAÑADA

Apart from the legally required, LA CAÑADA has created a separate account within its accounting system (PROYECTO LIFE AMMONIA TRAPPING) where the expenses incurred in the project can be traced. Concretely, the internal code for the project is LIF.PERSO for Personnel Costs; LIF.2VIAJE for Travel Costs; LIF.3ASEXT for External Assistance; LIF.4INFRA for Infrastructure; LIF.5PROTO for Prototype; LIF.6GG for Other Direct Costs.

2. Brief presentation of the procedure of approving costs

UVA-FGUVA

The General Foundation has established strict internal procedures for the approval of costs by type. Detailed information on each of the procedures listed below can be found in Annex 17 which was sent with the Midterm report.

Personnel selection procedure: There is a complete procedure for the selection of personnel assigned to projects (*Annex_AA13_FGUVA_procedure for selection of staff),* which details the personnel selection process with the aim of incorporating personnel through a labour contract and the different FGUVA labour processes.

To calculate staff costs, it has been taken into account the actual salary plus social security contributions. These amounts have been used as a basis for calculating the personnel costs included in the Financial Report.

Annex_AA14_ Salary elements of beneficiaries shows the different elements that have been taken into account for calculating the personnel costs, by each beneficiary.

Systematic procedure for collections, payments and treasury control: payment and collection deadlines to be carried out by FGUVA are determined, as well as monitoring and compliance with the conditions of collections and payments, and to control the movements of bank and cash accounts.

Procedure for the *contracting of works, supplies and services* (*Annex_AA15_FGUVA_procedure for contracting works, supplies and services):*

- Minor contracts: for supplies and services <€ 18,000, a Simplified Procedure is carried out (if >€ 6,000, three offers are requested and selection is based on best value for money).
- Negotiated procedure: Contracts of supplies and services >= € 18,000 and <€ 50,000.
- Open procedure: Contracts of supplies and services >= € 50,000

Each of these procedures has associated specific forms. At UVA the project director authorizes all costs on the basis of an assessment based on best value for money. Derived from the management model applied by UVA-FGUVA, after validation of the project director of UVA also the project director of FGUVA validates each expense charged to the project and approves its registration in the corresponding accounting code (069/161931).

At FGUVA the project director validates each expense charged to the project based on best value for money and approves its registration in the corresponding accounting code (069/160001).

Travel and subsistence: FGUVA counts on a complete internal procedure to regulate and approve travel and subsistence costs (*Annex_AA12_FGUVA_procedure for reimbursement of travel&subsistence costs*), while UVA must comply with the provisions of the Official Gazette of Castilla y León (Bocyl nr. 14 of January 19, 2007 and Bocyl nr. 129 of May 30, 2002).

DEPORCYL

To calculate the *personnel costs* involved in the project, it has been taken into account the actual salary plus social security contributions. These amounts have been used as a basis for calculating the personnel costs included in the Financial Report (see Annex 18 attached with the Midterm report).

The procedure of approving costs in DEPORCYL, is structured as follows: for amounts up to € 5,999 it is not necessary any order approval from the purchasing department. Nonetheless, if the

requested amounts are over € 6,000, 3 offers are necessary, the purchasing department must approve the order and the offer improvement is selected under efficiency criteria (service, quality and price).

In the case of *travel and subsistence* linked to actions of the project, the employees hand the expenses note based on real costs, such as hotel fee, meal tickets, parking, tolls, airline/train tickets, etc. In the particular case of trips by company car, according to the internal policy, when the car is picked up, it has a full tank and when the car is returned after the trip, it has to be left in the same conditions. The expenses that will be charged in the project will be the gasoline bills corresponding to date of completion of the trip. Besides, in the case of trips made with own private car, according to the internal policy of the company, each km will be paid at 0.25€, charging the corresponding amount to the project accounting system.

All these expenses are settled through bank transfer, the accumulation of these travel expenses by the worker and payment are fully recorded in the financial accounts of DEPORCYL.

ENUSA

To calculate the *personnel costs* involved in the project, it has been taken into account the actual salary plus social security contributions. These amounts have been used as a basis for calculating the personnel costs included in the Financial Report (see Annex 18 attached with the Midterm report). Notice that the salary component "Extra Bonus" was removed from the personnel costs calculation of ENUSA.

In case of *travel and subsistence* costs linked to actions of the project, before to the date of travel the employees had to fill a travel application form, which should be approved by its supervisor. After the travel, the worker has to present the official tickets of all the expenses such as hotel fee, meal tickets, parking, tolls, airline/train tickets, etc. Finally, once the supervisor confirms that all the imputed expenses are correct, the financial department proceeds to include the reimbursement in the next payslip. In the particular case of trips by particular car, according to the collective agreement of the company each km will be paid at 0.37 €, charging the corresponding amount to the project accounting system.

INDEREN

To calculate the *personnel costs* involved in the project, it has been taken into account the actual salary plus social security contributions. These amounts have been used as a basis for calculating the personnel costs included in the Financial Report (see Annex 18 attached with the Midterm report).

In the case of *travel and subsistence* linked to actions of the project, the employees hand the expenses note based on real cost, such as hotel fee, meal tickets, parking, tolls, airline/train tickets, the mileage realized with the private vehicles of the workers (0,25 €/Km). All these expenses are settled through bank transfer, the accumulation of these travel expenses by the worker and payment are fully recorded in the financial accounts of INDEREN.

ITACYL

To calculate the *personnel costs* involved in the project, it has been taken into account the actual salary plus social security contributions. These amounts have been used as a basis for calculating the personnel costs included in the Financial Report (see Annex 18 attached with the Midterm report).

In the case of travel and subsistence linked to actions of the project, the employees hand the expenses note based on real cost, such as hotel fee, meal tickets, parking, tolls, airline/train tickets, etc. All these expenses are settled through bank transfer, the accumulation of these travel expenses by the worker and payment are fully recorded in the financial accounts of ITACYL.

LA CAÑADA

To calculate the *personnel costs* involved in the project, it has been taken into account the actual salary plus social security contributions. These amounts have been used as a basis for calculating the personnel costs included in the Financial Report (see Annex 18 attached with the Midterm report).

The procedure of approving costs in LA CAÑADA, is as follows: For amounts up to € 5,999 it is not necessary any order approval from the purchasing department. Nonetheless, if the requested amounts are over € 6,000, 3 offers are necessary, the purchasing department must approve the order and the offer improvement is selected under efficiency criteria (service, quality and price).

In the case of travel and subsistence linked to actions of the project, the employees hand the expenses note based on real cost, such as hotel fee, meal tickets, parking, tolls, airline/train tickets, etc.

All these expenses are settled through bank transfer, the accumulation of these travel expenses by the worker and payment are fully recorded in the financial accounts of LA CAÑADA.

3. Type of time recording system used, i.e. electronic or manually completed timesheets

All the beneficiaries have used the model timesheet available on the LIFE website in the LIFE toolbox found at:

http://ec.europa.eu/environment/life/toolkit/pmtools/life2014_2020/timesheets.htm

Working hours have been registered by all partners on the LIFE timesheets. Hourly costs are thus generally calculated on the basis of gross salary costs and registered working hours.

As far as the first project year concerns, 2016, on which only the months October-December are to be accounted for, partners did not have a reliable time-registration system, so calculations have been done taking the staff costs corresponding to those months and working hours declared in timesheets corresponding to the same period. This same approach is used for staff that has not worked a full year in the project.

4. Brief presentation of the registration, submission and approval procedure/routines of the time registration system

The completed timesheet for a given month is signed and approved by the employee on the last working day of the month or during the first week of the following month. Also during the first week of the following month it is approved by his/her superior. Delays are properly explained in the same document.

5. Brief explanation on how it is ensured that invoices contain a clear reference to the LIFE project showing how invoices are marked in order to show the link to the LIFE project

All partners ask their providers to insert a project reference in their invoices. Where this is not possible (like in minor tickets for transport or small purchases), a project stamp is applied to the original invoice; the stamp is particularly important in the case of tickets where it is not

possible to put the project reference. For this reason, all partners ordered their own stamp at the beginning of the project.

The invoices from suppliers and subcontractors include the full project reference LIFE15 ENV/ES/000284 – LIFE AMMONIA TRAPPING.

8.3. Partnership arrangements (if relevant)

The distribution of the EU financial contribution has been made according to the Partnership Agreement signed at the beginning of the project by all beneficiaries (*Annex_AA16_Partnership Agreement*).

The financial reporting of the project has been carried out by each beneficiary, with the support of external experts. Periodically (every 4-5 months), project partners were sending their cost statements to both the coordinator and to APC Consultores S.L., the consultancy firm that was providing support in administrative issues to the coordinator. Towards the end of the project, the project coordinator decided to contract a new consultancy firm, EC-INNOVA, as substitute of APC Consultores, S.L. This change was conducted in order to support the technical and financial coordination duties as a result of poor communication between APC Consultores S.L. and the coordinator.

FGUVA is responsible for assessing the project's progress and its coherence with the incurred costs and the fulfilment of the LIFE requirements.

8.4. Certificate on the financial statement

According to article XI (Certificate on the Financial Statement and accounts) of Annex X to the Model LIFE Grant Agreement, beneficiaries of LIFE 2015 and onwards have no obligation to carry out individual financial audit if their total contribution in the form of reimbursement of actual costs as referred to in annex III is lower than 325.000 EUR. This is the case of all project partners. Nonetheless, as stated in Article II.27 of the Grant Agreement, the agency may carry out technical and financial checks and audits in relation to the use of the grant and thus, all beneficiaries will keep original documents stored on an appropriate medium in order to provide them in case the agency requires it, for a period of at least five years starting from the date of payment balance.

8.5. Estimation of person-days used per action

Action type	Budgeted person-days	Estimated % of person-days spent
Action A: Preparatory actions	504	126%
Action B: Implementation actions	3.385	95%
Action C: Monitoring of the impact of the project action	581	55%
Action D: Public awareness/Communication and dissemination of results	869	97%
Action E: Project management	493	112%
TOTAL	6.282	96%

9. List of Deliverables and Annexes

1. DELIVERABLES

- **Deliverable D2.2_BILATERAL MEETINGS.** Folder with the following information:
    - 2018-05-21_UVA-ITACYL-UNIVERSITY OF LISBON (PT)
    - 2018-05-22_ITACYL-ARS-USDA (USA)
    - 2018-05-22_UVA-ARS-USDA (USA)
    - 2019-01-09_Several partners-AGROCESA (ES)
    - 2019-03-20_ENUSA-BLAZQUEZ GROUP (ES)
    - 2019-11-04_UVA-ITACYL-PYG ESTRUCTURAS AMBIENTALES (ES)
    - 2019-11-27_ITACYL-CRPA (IT)
    - 2019-11-28_ITACYL- H2020 SYSTEMIC (BE)
    - 2019-12-10_INDEREN-AD SOLUTIONS (DE)
    - 2020-03-25_INDEREN-GENIA GLOBAL ENERGY (ES)
    - 2020-04-08_ITACYL-PROVINCIAL COUNCIL OF BADAJOZ (ES)
    - 2020-05-07_ITACYL-ENERGYLAB (ES)
    - 2020-06-10_ENUSA-ENVITEC (FR)
    - 2020-06-15_AVÍCOLA CIRIA-COPISO-AVIALTER-ERPA (EU)

  This deliverable appears first in the electronic list because it is not an individual document, but rather it is a folder containing each of the minutes that were drawn up after the various bilateral meetings held by the partners with various stakeholders. The folder contains a total of 14 minutes corresponding to the 14 main bilateral meetings held.

- **Deliverable B2.1_Report on environmental and technical assessment_prototype of atmosphere.**

  This deliverable corresponds to a document that contains a report on the environmental and technical evaluation of the mobile prototype for the capture of ammonia in atmosphere. It is divided into 3 sections: the first summarizes the main results obtained, the second explains the different actions carried out and the third contains a table of process indicators.

- **Deliverable B2.2_Atmosphere prototype use protocol.**

  This deliverable refers to the protocol for the use of the prototype to reduce the concentration of ammonia in the atmosphere in poultry farms, pig farms and composting plants. It describes the facilities developed in order to allow its operation, establishing a protocol for its use.

- **Deliverable B3.1_Report on environmental and technical assessment_prototype of liquid media.**

  This deliverable corresponds to a document that contains a report on the environmental and technical evaluation of the mobile prototype for the capture of ammonia in liquid media. This evaluation provides data on why we can conclude that it has correctly worked throughout the experimental periods treating swine manure in Guardo (Palencia) and digestate in a biogas plant in Juzbado (Salamanca), having periods of continuous operation of up to 30 days. It also indicates the main operational and design problems found during its operation.

- **Deliverable B3.2_Liquid media prototype use protocol.**

  This deliverable refers to the management protocol for slurry and anaerobically co-digested slurry by using the ammonia recovery system with membranes. The objective of this document is that any external personnel can operate this prototype without technical difficulties and prior knowledge.

- **Deliverable B4.1_Report on the evaluation of the fertilizer potential.**

  This deliverable refers to the report on the evaluation of the fertilizer potential of the final products obtained (ammonium bicarbonate solution and ammonium sulfate). It is intended to evaluate the final product (ammonic sulfate obtained on farms) from an agronomic point of view. For this purpose it was chosen the fertilizer with the highest concentration in nitrogen.

- **Deliverable B5.1-1_Marketing and Commercialization Plan.**

  Deliverable B5 was divided into two reports that were prepared separately. Specifically, this deliverable refers to a document that contains the marketing and commercialization plan of the project through the characterization of potential clients, the analysis of competition and barriers to commercialization and the development of a business plan.

- **Deliverable B5.1-2_Internacionalization Plan.**

  The second section of deliverable B5 refers to a document containing the Internationalization Plan. It determines the international potential clients and the business opportunities and key success factors.

- **Deliverable B5.2_Recommendations to the EU.**

  This deliverable refers to a document that contains a series of recommendations to the EU on how current regulations can facilitate the incorporation of solutions such as Ammonia Trapping. For this we have relied on two pillars: boosting the use of fertilizers end-products from organic waste materials (RENURE products) and GPM technology as a potential candidate technique for BAT or Emerging Technique.

- **Deliverable B5.3_Synergies between project and EU strategies.**

  This deliverable refers to a document that contains indications on the synergies between the project and the political strategies of the European Union based on the Common Agricultural Policy, the European Green Deal and the Research and Innovation Smart Specialization Strategy (RIS3).

- **Deliverable C1.1-1_Environmental-social-technical evaluation_prototype of atmosphere.**

  Deliverable C1.1 was divided into two reports that were prepared separately. This first report concerns the environmental, social and technical evaluation of the prototype for the capture of ammonia in the atmosphere. It contains information on the state of the art and methodologies in the development of an Environmental Impact Assessment, and the data obtained by the Ammonia Trapping project in both the pig and poultry farms are analyzed.

- **Deliverable C1.1-2_Environmental-social-technical evaluation_prototype of liquid media.**

  The second section of deliverable B5 refers to the report on the environmental, social and technical evaluation of the prototype for the capture of ammonia in liquid media.

- **Deliverable C1.2_Analysis of profitability and viability of prototypes.**

  This deliverable refers to the analysis of the profitability and economic viability of the prototypes. The document contains summaries of costs and revenues of using the liquids prototype with raw swine manure in Guardo and for treating anaerobic digestate in Juzbado on the one hand, and the costs and revenues of using the atmosphere prototype in a sow farm building in Guardo and in a free-range laying hen farm building in Aldealafuente.

- **Deliverable C1.3. Complete Life Cicle analysis.**

  This deliverable includes a Complete Life Cycle Analysis in prototypes for the absorption of ammonia in liquid media and in the atmosphere. Conclusions indicate that the liquids and atmosphere prototypes are very different and so they are their environmental performance and functions. For the liquids prototype, the LCA methodology allows to identify the use of more membrane surface as a hot-spot of this technology. The impacts when applying the GPM under optimized conditions were cut by 18%, 89%, 74% and 66% for global warming, marine eutrophication, fine particulate matter formation and terrestrial acidification potentials, respectively, in comparison with the baseline scenario. For the atmosphere prototype, which works uninterruptedly, electricity consumption required to pump the acidic solution through the membrane is the hot-spot.

- **Deliverable D1.4_Dissemination in online and written press.**

  This deliverable contains a summary of the dissemination actions related to the publication of project results in press and scientific journals. The document includes lists of publications in written press, publications in digital press, articles in scientific journals, posters of oral communications at congresses and other events, videos and broadcasts. Likewise, to boost dissemination during the last months of the project despite the global health crisis, a specialized communication agency was hired to carry out important dissemination work with both national and international media.

- **Deliverable D1.5-1_Laymans Report_EN**

  This deliverable contains the pdf document for printing the Layman's Report in English.

- **Deliverable D1.5-2_Laymans Report_ES**

  This deliverable contains the pdf document for printing the Layman's Report in Spanish.

- **Deliverable D1.6_Networking Strategy.**

  This deliverable contains complete information on the networking activities carried out by the project beneficiaries. A list of the different activities is provided, with the date on which they were carried out and the identification of the main projects with which they interacted.

- **Deliverable D2.1_List of European stakeholders.**

  List of the main European stakeholders that have been taken into account for dissemination purposes, organized by public entities, companies and LIFE and H2020 projects with which networking actions have been developed, both in person and through social networks.

- **Deliverable E3.1_After-LIFE Plan.**

  The after-LIFE plan deliverable takes a tour of the main achievements of the project and sets out the plans for the continuity of the actions carried out, which are based on the following actions: maintenance of the equipment, which have been transferred to La Vall D ' Uxó (Castellón) the liquid and Santa María pig farm in the province of Segovia. The two teams will continue to operate in these facilities and it is expected that they will be used to organize visits and thematic workshops that will allow the technology developed

to continue being disseminated. On the other hand, the after-LIFE incorporates a complete Communication Plan that is based on three pillars: Inform, Involve and Inspire.

2. ANNEXES

ADMINISTRATIVE ANNEXES

- **Annex_AA1**. Rocio_Blanco_FGUVA. Folder with all the information requested in EASME letters about FGUVA staff member Mrs. Rocío Blanco. The folder contains the following documents:
    - a) SalaryCostCalculation_2019_RB
    - c) Employment contract_RocíoBlanco
    - d) Salary_Slips_RocioBlanco_2019
    - e) Timesheets_RocioBlanco_2019
- **Annex_AA2**. Mercedes_Sánchez_UVA. Folder with all the information requested in EASME letters about UVA staff member Mrs. Mercedes Sánchez. The folder contains the following documents:
    - a) Detailed_Calculation_MercedesSanchez_Costs
    - c) SANCHEZ BASCONES, MERCEDES
    - d) Salary_Slips_MercedesSanchez
    - e) Timesheets_MercedesSanchez
- **Annex_AA3**. Berta_Riaño_ITACYL. Folder with all the information requested in EASME letters about ITACYL staff member Mrs. Berta Riaño. The folder contains the following documents:
    - a) SALARY COST ITACYL Berta Riaño
    - b.1.1) Declaración Conceptos Retributivos de Nóminas ITACYL
    - b.1.2) Resolución de Retribuciones de Nóminas Año 2019-2 ITACYL (10_07_2019)
    - b.1.3) Resolución de Retribuciones de Nóminas Año 2019-1 ITACYL (16_01_2019)
    - c) Contrato Berta Riaño Iriazábal ITACYL
    - d) Nóminas Año 2019 Berta Riaño ITACYL
- **Annex_AA4**. HighestInvoicesPerBeneficiary. Folder with all the information requested in EASME letters about the three highest invoices per beneficiary. The folder contains one sub-folder per beneficiary, with the three highest invoices inside.

  DEPORCYL:
    - 1_INF. Invoice of Construcciones y Excavaciones Fernández Espinosa.
    - 2_ODC. Invoice of Grupo Ke! Invoice nr 2016-242
    - 4_ODC. Invoice of Construcciones y Excavaciones Fernández Espinosa.

  ENUSA:
    - C11. FRA FVS63 SIERRA DEL PIMPOLLAR (Factura y Pago) (OK).
    - P1. FRA 228 ELECTROMAQ (Factura y Pago) (OK).

- P2. FRA 174 TALLERES ÁNCORA (Factura y Pago) (OK).

FGUVA:

- 1. ECS. Folder with the following documents:
  - PPTOS: folder with 3 different budgets of providers:
    - ✓ Ppto 1_AWATS
    - ✓ Ppto 2_BIOVIC
    - ✓ Ppto 3_ECS
  - 2018-01-31 Remesa 6 RI – Proof of payment
  - 2018-01-31 Remesa 6 – Payment remittance
  - PRO1_ENERGY CONTAINER SOLUTIONS (B98552250) R6-L277.
- 3. TALLERES ÁNCORA. Folder with the following documents:
  - PPTOS: folder with 3 different budgets of providers:
    - ✓ Ppto 1_SOLDAVAL
    - ✓ Ppto 2_TALLERES ÁNCORA
    - ✓ Ppto 3_BIOVIC
  - 2018-01-31 Remesa 6 RI – Proof of payment
  - 2018-01-31 Remesa 6 – Payment remittance
  - PRO3_TALLERES ANCORA S.L. (B97321616) R6-L278.
- 4. DABAR. Folder with the following documents:
  - PPTOS: folder with 3 different budgets of providers:
    - ✓ Ppto 1_MANUEL TORRES RECIO
    - ✓ Ppto 3_BIOVIC
    - ✓ Ppto 4_DABAR
  - 2018-01-16 Remesa 4 RI – Proof of payment
  - 2018-01-16 Remesa 4 – Payment remittance
  - PRO4_DABAR INGENIEROS SL (B98747959) R4 -L218. 2. PR_METAL BAVARRO FRA14-2017_Factura_Pago.
- 8. PR_ENERGY FRA37_Factura_Pago.
- 10. PR_ZEUS FRA70008601_Factura_Pago.

ITACYL:

- FRA APC ECONOMIA E INNOVACIÓN S.L.U.
- FRA. APC ECONOMIA E INNOVACIÓN
- FRA. VIDRIOLAB SCIENTIFIC S.L.U. (AC. SULFÚRICO) 1800185

LA CAÑADA:

- 1_Prototype
- 2_Infrastructure
- FRA 20200412 COSMA 30-04-20 y PAGO
- FRA 20200912 COSMA 30-09-20 y PAGO

- Annex_AA5. Collective_Agreement_DEPORCYL
- Annex_AA6. SalaryConcept_Deporcyl_report
- Annex_AA7. Collective_Agreement_INDEREN
- Annex_AA8. Collective_Agreement_LACAÑADA
- Annex_AA9. RD1086_1989
- Annex_AA10. Collective_Agreement_FGUVA
- Annex_AA11. SalaryConcept_ITCYL_report
- Annex_AA12_FGUVA_procedure for reimbursement of travel&subsistence costs
- Annex_AA13_FGUVA_procedure for selection of staff
- Annex_AA14_ Salary elements of beneficiaries
- Annex_AA15_FGUVA_procedure for contracting works, supplies and services
- Annex_AA16_Partnership Agreement
- Annex_AA17_New Form FC according to budget shift between UVA and FGUVA

COMMUNICATION ANNEXES

- ANNEX 15_Posters-Oral Communications: folder containing posters and oral communications done, ordered sequentially according to the list on pages 25 to 32 of Deliverable *D1.4_Dissemination in online and written press*.
- ANNEX 1_Communication Plan_EN
- ANNEX 2_Proposals graphic image
- ANNEX 3_Making off logotype
- ANNEX 4_Visual identity manual
- ANNEX 5_Leaflet Spanish
- ANNEX 6_Leaflet English
- ANNEX 7_Flyer Spanish
- ANNEX 8_Rollup
- ANNEX 9_Notice Board
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TECHNICAL ANNEXES

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