Nutri2Cycle
Nurturing the Circular Economy

Nutri2Cycle

D4.1 Report on transferability and potential uptake of lighthouse prototypes of nutrient management approaches and innovations

Deliverable:	Report on transferability and potential uptake of lighthouse prototypes of nutrient management approaches and innovations
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Abbreviations

ABC: Animal Bone Char

AD: Anaerobic Digestion

BBF: Bio-based Fertiliser

CAPEX: Capital Expenditure

CNP: Carbon Nitrogen Phosphorus

GHG: Greenhouse Gas

NTF: National Task Force

OPEX: Operating expense

RDF: Recycled Derived Fertiliser

SOM: Soil Organic Matter

TRL: Technology Readiness Level

WP: Work Package

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Glossary

Agro-typologies: or agricultural typologies describes grouping farms by the type of farm or activities that are predominant on the farm e.g. dairy production, cereal production etc.

Biogas: Primary product of anaerobic digestion. A renewable gas composed of 50% to 65% methane, 35% to 50% carbon dioxide.

Bio-based fertilisers: Organic fertilisers produced from organic residues following some treatment. This would suggest that animal manure is a bio-based fertiliser only following a treatment of the raw manure. Furthermore, bio-based fertilisers may also comprise inorganic materials, e.g. after thermal treatment of organic waste leading to a carbon free ash product.

Chemical fertiliser: Also termed 'mineral fertiliser' or 'synthetic fertiliser', chemical fertilisers are a product created to provide a crop or plant with required nutrition in order to improve yield. Chemical fertilisers are manaufactured or artificially enhanced, unlike organic manures. Benefits include consisstency of nutritional value and high potency; negatives include cost of chemical fertilisers and emissions related to their manufacture and application.

Digestate: Secondary product of anaerobic digestion. An organic fertiliser with a high concentration of nitrogen, phosphourous and potassium.

Feedstock: The matrix fed to the technology from which a new product develops. Often a waste material such as animal manure or wastewater.

National Task Force: A network of relevant local Operational Groups, local farmers/farmer organisations, other stakeholders at national/regional level interested in nutrient recovery and recycling and operating in the target countries.

Nutrient recycling: The continued movement and use (with possible temporary accumulations) of nutrients between different compartments (soil, plants, animals, humans, water, air) and trophic levels in the biosphere.

Research line: is defined as a research domain that characterizes a cluster of solutions being researched in frame of the project ; Nutri2cycle has 5 distinct research lines

Solution: A Nutri2Cycle solution is a proposed optimized farming system, aimed at closing nutrient loops and efficient mitigation measures

Technology readiness level: Technology readiness levels are a method for estimating the maturity of technologies during the acquisition phase of a program

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Technology numbers used across the project relating to lighthouse demos

- Technology No.1: Farm-Scale Anaerobic Digestion (LL10)
- Technology No.2: Adapted Stable Construction for Manure Processing (LL24)
- Technology No.3: Crop Farmer Using a Variety of Manure & Dairy Processing Sludges to Recycle & Build Soil C, N, P Fertility (LL17)
- Technology No.4: Floating Wetland Plants Grown on Liquid Agro-Residues as a New Source of Protein (LL41)
- Technology no.5: Algae Grown on Liquid Agro-Residues as a New Source of Protein (LL41b)
- Technology no.6: Using Recycling-Derived Fertilisers Ammonium Nitrate, Ammonium Sulphate, Digestate from Co-Digestion of Pig Manure & Liquid Fraction of Digestate (LL1+2+9)
- Technology No.7 Using Bio-Based Fertilisers to Optimise the Organic Carbon Storage in Soil and N, P Cycling (LL15)
- Technology No. 8: Ammonia Recovery from Raw Pig Slurry in a Vacuum Evaporation Field Plant (LL20)
- Technology no.9: ABC Animal Bone Char for Phosphorous Recovery (LL22)
- Technology no.10: Transferability of Pig Manure Refinery into Mineral Fertilisers (LL23)
- Technology No.11: Using Digestate, Precision Agriculture & No-Tillage to Improve Soil Organic Matter (LL16)
- Technology no.12: Evaluation of Poultry Compost and Pig Slurry to Replace Mineral Fertilisers as Basal Fertilisation in Maize Crops within Northern Europe (LL57)
- Technology No.13: Application of Sensor Technologies in Plant Cropping Systems (LL13)
- Technology No.14: Potato Growing with Refined Pig Manure Fractions (LL43+73)

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Executive Summary

This report aims to summarise the transferability of 14 trialled technology solutions also known as 'lighthouse demonstrations' across Europe, and, to link previous progress made within the Nutri2Cycle project to upcoming required deliverables. The premise of Nutri2Cycle is to research and demonstrate technologies, through the use of lighthouse demonstrations, as means to reduce losses in C, N, P nutrients within current European agricultural systems, with the aim of moving towards nutrient loop closure and improved use and recycling of nutrients within the agricultural sector. The project aims to offer solutions for a variety of agricultural types, within a range of European geographical locations, and subsequently propose options that farmers from across Europe can make use of to improve C, N and P loop closure in their respective agricultural systems.

Within this report 14 lighthouse demonstration technologies from WP6 are assessed in length and a view as to their respective real life transferability within given European regions is analysed based on expert, stakeholder and national taskforce feedback. The term 'transferability' relates to how likely or unlikely a given technology will be implemented by members of the farming community. Assessing the transferability of the 14 lighthouse demonstration technologies is undertaken by utilising two sources of data i) national expert evaluations and ii) national task force (NTF) surveys. The data from both of these two sources followed a qualitative format of discussing the benefits and challenges associated with implementing a given technology within a given region, and, provided a quantitative numerical transferability rankings from low to high based on the expert and NTF participant feedback. The expert evaluators provided such feedback through a technology by technology basis, whereas the NTF participants provided their feedback through a guided survey which they partook in.

Across Europe the technologies with the highest transferability in both the short-term (2025) and medium-term (2030) timeframes were the use of poultry compost and pig slurry to replace mineral fertiliser as basal fertilisation in a maize crop technology, and, the usage of a variety of manure and dairy processing sludges to recycle and build soil C,N, P technology. However, the transferability of these demonstrations displays some variability across the evaluated European regions.

When assessing the transferability data from the expert evaluators and NTF participants for the 14 technology demonstrations there are both commonalities and differences to be recognised within the feedback. Often the commonalities centre on critical aspects such as:

i) Economy – will the technology save the farming enterprise money; are there subsidies or grant supports available; what is the investment or operation costs associated with the technology.

ii) Labour – will the technology save the farming operation time; will the technology require more labour units to operate successfully.

iii) Understanding – the technicalities of correctly operating the technology; any legal requirements associated with the technology.

iv) Environment – will the technology improve the sustainability of the farming operation; can the farming operation make use of any environmental benefits in terms of marketing.

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Differences found within the transferability data often displayed a regional influence. Two main factors were apparent, namely:

i) Tradition – the traditional agricultural practices of a nation or region influenced the transferability feedback. Where there is a tradition of a certain form of agriculture e.g. dairy farming, pig production, vineyards etc. there is knowledge, interest and relevant infrastructure already in place for that type of agriculture within that region. Therefore, at times, technologies relating to the dominant, traditional industry in a given region displayed greater transferability scoring than technologies linked to forms of agriculture that are not widely represented within a given area.

ii) Familiarity – within certain regions of Europe certain technologies are already well known, whereas for a different region the very same technology may be at a developmental stage and may not be well known amongst the agricultural community. An example of this was the anaerobic digester technology, which will be discussed further in the report. In certain nations states this form of technology is already producing electricity for the national grid, whereas in other European nations the technology is non-existent. Therefore, the two nation states are assessing the same technology through a different experience or viewpoint.

By identifying and elaborating on both the similar and dissimilar benefits and challenges associated with the 14 targeted technologies described within this report, deliverable 4.1, 'D4.1', can provide policy makers in national governments, or, within the European Union, with information that can assist in important decision making, such as deciding which of the 14 technologies warrant further research; what measures can governments take to encourage adoption of a given technology, or, determining what technologies are best suited to a given European region.

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Introduction

1.1 Background

The purpose of this report, identified as Nutri2Cycle Project Task 4.1, is to summarise and quantify the transferability of 14 lighthouse demonstration solutions to real-life farms and agricultural communities within the European Union. The 14 technologies were set a common task under the Nutri2Cycle framework to reduce losses of nutrients, namely nitrogen, phosphorous and carbon, from European agricultural systems, whilst considering the necessities of agricultural productivity, food quality and environmental stewardship within those same agricultural systems. In Work Package 4 (WP), Task 4.1 is a link between previous works undertaken within the Nutri2Cycle project such as WP2, WP3 & WP6, and, a link to upcoming stages of the project such as Task 4.2.

WP2 and WP3 were focused on the initial stages of the project such as developing a long-list of 60 technologies, which was filtered down to a short-list of 24 technologies, which was filtered further to the final 14 selected technologies of which trials or 'Lighthouse Demonstrations' were undertaken. A consortium of experts with relevant backgrounds in agricultural research, agricultural advisory boards, and/or, agricultural companies were assigned the task of determining the most appropriate 14 technologies. The consortium considered the goals of the Nutri2Cycle project, along with the technology readiness level (TRL) of each proposed technology, when identifying which would have the greatest propensity to meet the projects purpose. Two additional criteria also had to be met within the technology selection process, namely, that 5 established research lines and 8 agro-typologies had to be represented at least once within the 14 technologies. Table 1 and table 2 list the 5 research lines and 8 agro-typologies respectively. Undertaking the 14 lighthouse demonstrations at a relevant farm-scale and the gathering of the data that arose from these trials was the main focus of WP6 and lead into analysing the collected data which aligns with the aims of Task 4.1.

Table 1 Description of the 5 research lines that need to be represented at least once within the 14 trialled Lighthouse Demonstration technologies

	Research Lines
1	Optimise nutrient, carbon dioxide, methane & nitrous oxide management within animal husbandry systems.
2	Implement soil fertilisation and crop management practices to enhance nitrogen & phosphorous efficacy, along with increase soil organic carbon content.
3	Develop tools & techniques to promote high-precision fertiliser application practices.
4	Develop bio-based fertilisers & soil enhancers from agro-residues.
5	Create novel animal feeds from agro-residues.

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Table 2 Description of the 8 agro-typologies that need to be represented at least once within the 14 trialled Lighthouse Demonstration technologies

	Agro-Typologies
1	Pig Production
2	Poultry Production
3	Cattle Farming
4	Cereals & Maize Production
5	Vegetable Crops
6	Orchards and Agroforestry
7	Agro-Energy Systems
8	By-Product Processing

The assessment of the transferability of the 14 technologies across Europe within Task 4.1 will contribute towards the aims of the subsequent work package 4.2. Task 4.2 will build on the findings from Task 4.1 and will strive to model various aspects of the technologies evaluations on a European wide scale, such as factors influencing technology uptake or the impact a given technology has on nutrient flows.

To introduce the 14 technologies they are explained in concise detail in the following paragraphs. A more detailed description of each technology can be found within Annex 1 of the report. Table 3 lists the 14 technology titles along with the research lines and agro-typologies each technology compliments.

Table 3 Listing of 14 trialled technologies and the relevant research line and agro-typologies

Technology	Research Line	Agro-Typology
1) Farm-Scale Anaerobic Digestion	1	7,8
2) Adapted Stable Construction for Manure Processing	1	1,8
3) Crop Farmer Utilising a Variety of Manure & Dairy Processing Sludges to Recycle & Build Soil C,N, P	2	3,8,4
4) Floating Wetland Plants Grown on Liquid Agro-Residues as a New Source of Protein	5	8
5) Algae Grown on Liquid Agro-Residues as a New Source of Protein	5	8
6) Using Recycling-Derived Fertilisers Ammonium Nitrate, Ammonium Sulphate, Digestate from Co-Digestion of Pig Manure & Liquid Fraction of Digestate	4	1,4,5,8
7) Using Bio-Based Fertilisers to Optimise the Organic Carbon Storage in Soil and N, P Cycling	4	6, 8
8) Ammonia Recovery from Raw Pig Slurry in a Vacuum Evaporation Field Plant	4	1, 8
9) ABC Animal Bone Char for Phosphorous Recovery	4	4,8
10) Pig Manure Refinery into Mineral Fertilisers	4	1,7,8

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11) Using Digestate, Precision Agriculture & No-Tillage to Improve Soil Organic Matter	2	4,8
12) Use of Poultry Compost & Pig Slurry to Replace Mineral Fertilisers as Basal Fertilisation in a Maize Crop	4	1,2,3,4
13) Application of Sensor Technologies in Plant Cropping Systems	3	4, 5
14) Trial Potato Growing with Refined Pig Manure Fractions	3	1,5,8

Technology No. 1: Farm-Scale Anaerobic Digestion – Demonstration Country Belgium – TRL 7-9
Farm-scale anaerobic digesters are appropriately sized reactors fed on agro-resides such as livestock manure and crop-residues. In the absence of oxygen, the agro-residues ferment in the reactor, with this fermentation resulting in biogas and digestate production. Biogas is mainly composed of methane and can be used to generate heat and electricity for the farm when processed through a combined heat and power unit. The digestate is a nutrient rich fermented biomass, which can be used as an organic fertiliser on the farm.

Technology No.2: Adapted Stable Construction for Manure Processing – Demonstration Country Belgium – TRL 9
This technology centres on a commercial animal housing design where the animals waste passes through a slatted floor, after which it enters a chamber where the liquid fraction of the waste is collected by passing through a channel and the solid fraction of the waste is scrapped away to a separate holding tank.

Technology No.3: Crop Farmer Utilising a Variety of Manure & Dairy Processing Sludges to Recycle & Build Soil C,N, P – Demonstration Country Ireland – TRL 6
This technology looks to using cattle manure; poultry & broiler manure; dairy food processing sludge, and, dissolved air flotation (DAF) dairy sludge in arable field-scale trials to determine phosphorus fertiliser value and crop yield performance when compared against mineral fertilisers.

Technology No.4: Floating Wetland Plants Grown on Liquid Agro-Residues as a New Source of Protein – Demonstration Country Belgium – TRL 6
Within this demonstration, duckweed was grown on the surface of a pond system which contained processed pig manure. Duckweed was selected as it is floating wetland plant capable of extracting nutrients from wastewaters and has a dry matter protein content of approximately 35%. The technology aimed to display the potential of producing protein for animal feed from duckweed and provide another avenue for agricultural waste processing.

Technology No.5: Algae Grown on Liquid Agro-Residues as a New Source of Protein – Demonstration Country Belgium – TRL 4
This technology centres on the novel production of protein for animal feed from microalgae. Within the technology trial the microalgae fed off nutrient rich digestate, an agro-residue produced from anaerobic digestion. The algae were grown in photo-bioreactors.

Technology No.6: Using Recycling-Derived Fertilisers Ammonium Nitrate, Ammonium Sulphate, Digestate from Co-Digestion of Pig Manure & Liquid Fraction of Digestate – Demonstration Country Belgium – TRL 7-9

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This technology originated in Belgium, where, due to intensive livestock production, certain regions are experiencing excessive livestock manure availability. As a result, manure application rate limits are in place and large volumes of manure are currently processed and exported to other countries. As excess livestock manure is exported, chemical fertilisers are still imported into the country. This technology aims to assist in this nutrient management challenge by trialling four recycled derived fertilisers (RDF's) that display predictable nitrogen release and low phosphorous qualities, which could act as replacements to chemical fertiliser products. The four RDF's trialled are ammonium nitrate, ammonium sulphate, digestate from co-digestion of pig manure, and, the liquid fraction of digestate.

Technology No.7: Using Bio-Based Fertilisers to Optimise the Organic Carbon Storage in Soil and N, P Cycling – Demonstration Country France – TRL 6-7

This technology centres on using bio-based fertilisers such as oil seed cake, goose slurry and solid goose manure as an organic fertiliser on two trial plots. One plot is under agroforestry and was treated with the goose fertiliser for 3 years, while the other plot is a managed vineyard treated with goose fertiliser for 1 year. The technology aims to improve nitrogen and phosphorous cycling.

Technology No.8: Ammonia Recovery from Raw Pig Slurry in a Vacuum Evaporation Field Plant – Demonstration Country Spain – TRL 4

This demonstration involves processing livestock manure through low temperature vacuum evaporation technology in order to recover ammonia from the livestock manure and produce ammonium sulphate and/ or a lactate salt solution which could be used to replace mineral nitrogen fertilisers. The technology is termed 'decentralised' and can be set-up on-site.

Technology No.9: ABC Animal Bone Char for Phosphorous Recovery – Demonstration Country Hungary – TRL 8-9

In this technology, sterilised animal bones from abattoirs and meat processing facilities are processed under very high temperature conditions, a process known as pyrolysis, to produce a phosphorous rich char. The char also contains a high concentration of calcium, with lower concentrations of potassium and magnesium. The technology proposes that by processing the char to make it available to plants the product could reduce the current reliance on synthetic phosphorous fertilisers.

Technology No. 10: Pig Manure Refinery into Mineral Fertilisers – Demonstration Country Italy – TRL 9

Within this technology, livestock manure undergoes three stages of processing. Firstly, screw press separation is used to isolate the solid fraction of the manure from the liquid fraction. Then the remaining liquid fraction passes through vibrating screens and a 3-stage filtration system to create a concentrated nitrogen liquid, with the remaining liquid fraction to be classified as clean water safe for release. The concentrate produced can be exported to receiving farms, or used as a topdressing fertiliser.

Technology No.11: Using Digestate, Precision Agriculture & No-Tillage to Improve Soil Organic Matter – Demonstration Country Italy – TRL 9

This demonstration utilises anaerobic digestion and ammonia stripping technology to treat wastewaters and agricultural industrial wastes, producing two fertilisers, namely digestate and ammonium sulphate. These fertilisers are applied under no-till and precision agriculture systems, and are purported to close nutrient loops. The biogas produced from the anaerobic digestion plant can be passed through a combined heat and power unit to generate electricity for the facility.

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Technology No.12: Use of Poultry Compost & Pig Slurry to Replace Mineral Fertilisers as Basal Fertilisation in a Maize Crop – Demonstration Country Portugal – TRL 9
This technology aims to demonstrate the benefits and limitations of applying only poultry compost and pig manure as a basal or pre-planting fertiliser on maize crops. Aims of the technology include closing nutrient loops, reducing consumption of mineral fertilisers and improved soil health.

Technology No.13: Application of Sensor Technologies in Plant Cropping Systems – Demonstration Country Hungary – TRL 9
This technology centres on utilising a YARA N-Sensor when applying nitrogen fertilisers. The sensor determines the appropriate fertiliser application rate in real-time and can take into account different crop types and the availability of nutrients in the soil. This demonstration proposes that by using the YARA N-Sensor the risk of over application of nitrogen fertiliser and nitrogen leaching is reduced.

Technology No.14: Trial Potato Growing with Refined Pig Manure Fractions – Demonstration Countries Belgium & The Netherlands – TRL 5-6
This demonstration involves processing raw pig manure through solid-liquid separator technology, which results in the production of three organic fertiliser types, namely, solid digestate fraction, and liquid digestate fraction and ammonium sulphate. This demonstration proposes that using the created bio-based fertilisers could reduce the reliance on chemical fertilisers within potato production.

1.2 Objectives

The main objective of this report is to analyse the transferability feedback from both the national expert evaluations and the National Task Force (NTF) survey data for the 14 lighthouse demonstrations, see figure 1 for the regional distribution of lighthouse demonstrations across Europe. The Nutri2Cycle project is interested in technologies that exhibit relatively condensed implementation timeframes, technologies that could be taken-up by agricultural communities within the coming years. Therefore, there are two transferability timelines used; 'Short-Term Transferability' which represents the likelihood of successfully implementing the technology by the year 2025, and 'Medium-Term Transferability' which represents the likelihood of successfully implementing the technology by the year 2030. Both the expert evaluators and the national taskforce survey participants were asked to provide a numerical ranking for both short-term and medium-term transferability per technology. These ranking values will be referred to throughout this report, and will contribute towards identifying the foreseen benefits and challenges adopting each technology could entail. A further objective of the report is to assess the transferability of the technologies in terms of both a European wide scale and a European regional scale. By assessing both the quantitative and qualitative feedback provided by the expert and national taskforce groups the report aims to recognise any European wide commonalities or differences within the evaluations and, further still, if there are any geographical or regional influences on transferability. In this way the report aims to satisfy a main objective of WP4 by providing generalised national, regional and E.U. wide evaluations of the 14 trialled technologies across the aforementioned scales. In addition, this report will build on the progress made and data collated from the previous work packages 2, 3 & 6 in order to fulfil the objectives of Task 4.1 and provide a foundation from which Task 4.2 can develop.

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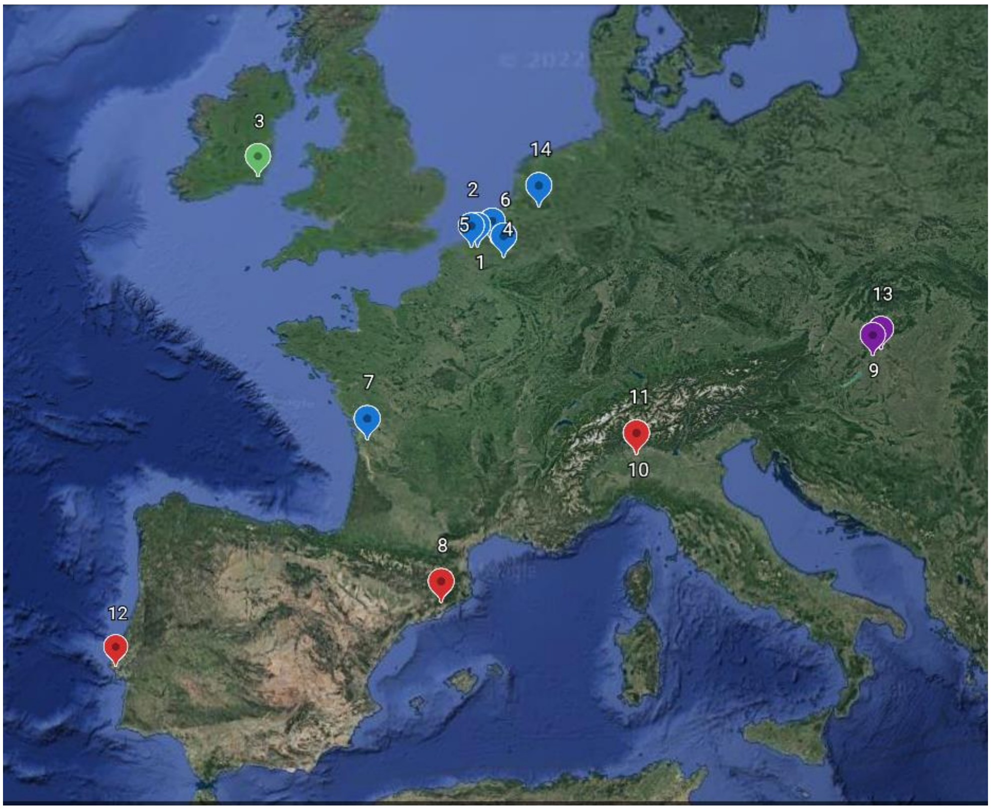

Figure 1. Map displaying the location of the 14 lighthouse demonstrations across Europe. The technologies are identified by numerical code, see table 3. Note as a means to assist in differentiating regions the colour green has been assigned to Northern Europe, red to Southern Europe, purple to Eastern Europe and blue to Western Europe throughout the report in terms of graphs, such as Venn diagrams and bar-charts. In the legend below a simple reiteration of the technologies identification can be found.

Figure 1 Identification Legend	
1 = Anaerobic Digestion, Belgium	8 = Vacuum Evaporation, Spain
2 = Adapted Stable Design, Belgium	9 = Animal Bone Char, Hungary
3 = Dairy Sludges, Ireland	10 = Pig Manure Refinery, Italy
4 = Floating Wetland, Belgium	11 = No-Tillage, Italy
5 = Algae Production, Belgium	12 = Poultry Compost, Portugal
6 = Recycling-Derived Fertilizers, Belgium	13 = Sensor Technologies, Hungary
7 = Bio-Based Fertilisers – Vineyards, France	14 = Potato Growing, The Netherlands

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1.3 Summary on how the benefits/challenges found in this work compare with results from the scientific literature.

The Nutri2Cycle lighthouse demonstration network of technologies and approaches to improve C,N and P loop closure covered a wide range of agro-typologies and regions. Morse et al. (1998) highlighted that co-operation and leadership by government is required to progress towards phosphorus sustainability. They were speaking in the context of phosphorus recovery technologies from wastewater. The funding of Nutri2Cycle project is one example of how the EU Commission have engaged to advance the sustainability of nutrient use in Europe since Morse et al. (1998) published. Within each technology and region of the Nutri2Cycle network several benefits and challenges emerged from the point of view of the stakeholders. At a high level some of the key benefits that came to the fore in stakeholder perceptions of the technologies were improved compliance with legal frameworks, improved overall system nutrient use efficacy through improved loop closure, reductions in reliance on and the cost of mineral fertiliser inputs along with potential for reduced environmental losses of ammonia and greenhouse gases for example. A number of opportunities for practical and easily adopted options were present and even the potential to improve work-life balance. Unlike in the survey of Case et al. (2017) the benefit to soil structure did not feature as prominently in the current survey work perhaps because not all lighthouses were involved in soil application of products.

In the view of the stakeholders there were also challenges. These included high capital investment required for a relatively low financial return, there are challenges on the legal framework side such as permitting to build or fertiliser registration bottlenecks or hurdles which hamper development of the recycled fertiliser sector. Kurniawati et al. (2023) also highlight the challenge for farmers and for small and medium enterprises to comply with and register under the EU Fertiliser Product Regulation (FPR). They do highlight that farmers and producers can rely on national regulations. Again, however it can be cumbersome to gain entry to national regulations. Public acceptance of bio-based fertilisers is also highlighted by Kurniawati et al. (2023). Similarly, Chojnacka (2023) highlights practical barriers such as legal and technologies but also opportunities relating to the availability and cost of conventional mineral fertilisers, which increases the importance of biorefining to recycle nutrients. Other challenges noted by stakeholders in the current work were the practicality of some technologies along with the knowledge of users about the technologies or products. Similar issues were noted in survey work by Egan et al. (2022) where known nutrient content of bio-based fertilisers along with ease of application or practicality were some of the desirable characteristics for end-users. Overall the survey indicates the need for on-going support to promote and ease development cost of the technologies which can improve C,N and P loop closure in Europe.

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2. Methodology

2.1 National Expert Evaluations

This report centres on the transferability ranking evaluations allocated to the 14 lighthouse demonstrations described in the introductory section. Note throughout the report the terms 'technology' and 'lighthouse demonstration' are used interchangeably. The transferability rankings were provided by means of two data collection pathways, namely national expert evaluation data and national taskforce evaluation data. The expert evaluations were provided by selected members of the consortium involved in the Nutri2Cycle project. The experts provided a one-page review per technology where the foreseeable benefits and challenges associated with adopting the technology within their given country were discussed. The expert evaluation culminated in providing a numerical ranking of 1 to 5 for the transferability of the aforementioned technology, with '1' equating a low transferability and '5' equating a high transferability. The national expert evaluators were as follows:

Table 4 Listing of participating nation states and origin of representatives for the expert evaluation feedback.

Country	Expert Representative
Belgium	National expert evaluations from Belgium were provided by staff from Biogas-E, Ghent University, United Experts & Inagro
Denmark	National expert evaluations from Denmark were provided by staff from the University of Copenhagen
Germany	National expert evaluations from Germany were provided by staff from agricultural research organisation the Thünen Institute
Hungary	National expert evaluations from Hungary were provided by staff from 3R-BioPhosphate Ltd., SOLTUB Ltd. and from the producer organization M-TESZ
Ireland	National expert evaluations from Ireland were provided by staff from agricultural research organisation Teagasc
Italy	National expert evaluations from Italy were provided by staff from the University of Milan
Portugal	National expert evaluations from Portugal were provided by staff from the Institute of Agronomy, University of Lisbon
Spain	National expert evaluations from Spain were provided by staff from agricultural research organisation IRTA
The Netherlands	National expert evaluations from the Netherlands were provided by staff from Wageningen University

Within the consortium of national expert evaluations, a variety of geo-climatological regions were represented. To further consolidate the regional aspect of the projects findings the national expert evaluations were divided into the geographic regions of Northern Europe, Southern Europe, Eastern Europe and Western Europe, following the boundary guidelines of the United Nations Statistics Divison[1], see figure 1. This step was taken to allow the report to have both a European wide view and a European regional view, which would allow for comparison between regions and assist in identifying

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relationships between a technology and a given European region. By taking this step the report aims to satisfy the objective discussed in the introductory section of provided a regional and European wide evaluation of the trialled technologies. The expert evaluation participants were divided as follows:

Northern Europe – Denmark & Ireland

Southern Europe – Italy, Portugal & Spain

Eastern Europe – Hungary

Western Europe – Belgium, Germany & the Netherlands

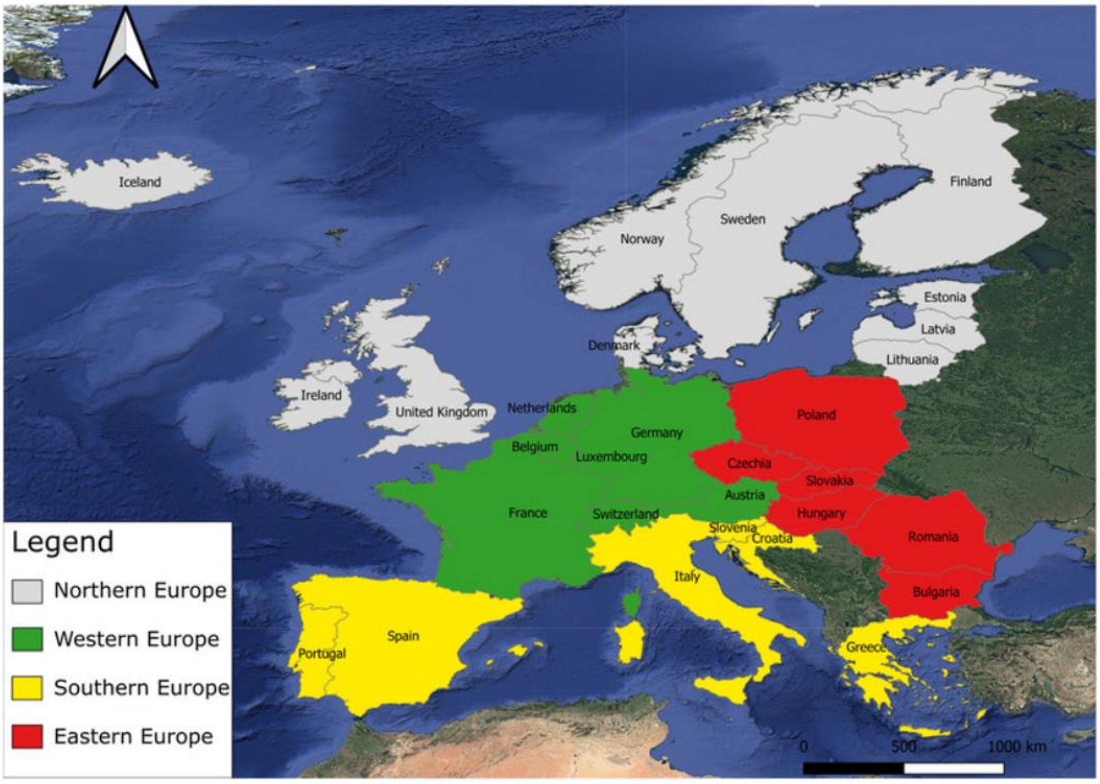

Figure 2. Visual representation of the U.N. geographic regions of Europe[2]

In the situation where the national expert evaluator also carried out a lighthouse demonstration when it came to review the specific technology in question an unbiased staff member from the designated national organisation or a staff member from a different appropriate national organisation reviewed the technology. This measure was undertaken in an attempt to mitigate national biases for technologies that originated in a given country. The raw data from the national expert evaluations can be found in Annex 1.

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2.2 National Task Force Survey

Relevant stakeholders within the participating countries provided NTF evaluation data by means of a questionnaire survey. The survey's questions and layout was developed by the Nutri2Cycle team and was linked to online seminars which discussed the 14 lighthouse demonstrations in detail, the 14 technologies were discussed over three online seminars or 'webinars' in April 2022. The national project leaders across Nutri2Cycle were asked to try to encourage relevant parties in their respective countries to partake in the survey. The value of the NTF survey is such that the participants largely work within the agricultural sector and are asked to select their occupation when completing the survey. Therefore, the data generated from the survey is derived from an informed population and a population to which the technologies are directed. Options for the participants' occupation were as follows: 'researcher'; 'policy maker'; 'agricultural industry'; 'farm advisor'; 'crop farmer'; 'cattle farmer'; 'pig farmer'; 'consumer/ citizen' or 'other'. Graphs detailing the breakdown of national taskforce participant's occupation by technology plus region can be found in annex 2.

In addition the survey participants were provided with a list of benefits and challenges of technology uptake from which they were asked to select three of each per technology. The responses were tallied to determine out of the total number of respondents for a given technology in a given region how many considered e.g. environmental benefits as a benefit to technology uptake. Graphs detailing the benefits and challenges responses can be found in Annex 3.

Table 5 Options for benefits to technology uptake selection within the NTF survey

NTF Survey Response Options - Benefits to Technology Uptake
Better compliance with legal framework
Better nutrient management (higher nutrient use efficiency, etc.)
Economic benefits (cost savings for mineral fertilizer, energy etc.)
Environmental benefits (reduced nutrient losses, reduced ammonia or GHG emission, etc…)
Novel local job and income opportunities
Improve life-work balance
Practicability (not complex and easy to be adopted)
Ability to use environmental benefits for branding/advertisement (meet market trends)

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Table 6 Options for challenges to technology uptake selection within the NTF survey

NTF Survey Response Options - Challenges to Technology Uptake
Economic consideration (too expensive, not worth the investment as no returns are expected, etc.…)
Legal framework (construction permits difficult to obtain, product cannot be legally used as fertilizer in the country, etc.…)
Practicability (too complex and difficult to be adopted)
Knowledge and training of potential users
Absence of grant support, economic subsidies or other incentives
Too much work for little results
Social acceptance

The aim of the NTF is to create an exchange of thoughts on the trialled technologies between the demonstration leader, the expert evaluation panels and the national taskforce participants in order to synthesize what the benefits and challenges of implementing a given technology will be within Europe. Furthermore, by encouraging stakeholders to participate in the survey the stakeholders learn of the developments within the Nutri2Cycle project and the demonstration technologies, and, when considering their occupation, can subsequently bring this information to other parties within the agricultural community. The NFT survey provided a transferability ranking per technology, the scale used was 0 to 100.

A weighted mean transferability value was calculated for the transferability ranking score within the NTF survey data by tallying the transferability rankings contributed by participants from a given nation and then dividing that sum but the number of said participants from that nation state. This resulted in a weighted mean for both the short-term and medium-term timelines for each of the 14 technologies per participating country. All the countries that were represented by the stakeholders were sorted using the same U.N geographical region system as was used in the expert panel evaluations. Therefore, analysis of the results gave a European wide view and European regional view, just as the expert panel assessments. The NFT survey transferability scale was also converted from 0 - 100 to 0 - 5 in order for the survey data to be plotted against the expert data on the one graph. In this case 0 represented a technology ranking of 'not transferable' while a value of 5 signified a classification of 'extremely transferable'.

2.3 Transferability Rankings

To evaluate the transferability of each technology, the averaged ranking was plotted under four conditions, namely:

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i) Short-term transferability ranking ordered by highest to lowest expert evaluation value

ii) Short-term transferability ranking ordered by highest to lowest nation task force survey evaluation value

iii) Medium-term transferability ranking ordered by highest to lowest expert evaluation value

iv) Medium-term transferability ranking ordered by highest to lowest nation task force survey value

Graphs displaying these averaged transferability rankings can be found in the following results and discussion sections, figures 3 to 7.

2.4 Technology Readiness Levels

Each of the 14 lighthouse demonstrations had an associated Technology Readiness Level or 'TRL' ranking, as is common practice within E.U. Horizon 2020 projects. The TRL scale ranges from 1 to 9, with the lower value representing a technology at a lower developmental stage and a higher value representing a technology at a greater developmental stage, see table 9 below. The TRLs for the 14 technologies ranged from a low of 4 to a high of 9. Within the results and discussion section of this report the TRL assigned to a technology is compared against the averaged transferability rankings allocated by the experts and NTF participants, as this is a means of highlighting any commonalities or discrepancies between the developmental stage of a given technology and the likelihood of that same technology actually being implemented within the European farming community. This is considered worthwhile as it may assist in further understanding the nuances between a technology that technically fulfils its aim and a technology that farmers and individuals within the agricultural community will actually implement. These nuances or conditions will lead onto the next stages of the Nutri2Cycle project, as foreseen roadblocks or challenges may well need to be understood and addressed if governments want the farming community to uptake such technologies which are shown to close nutrient loops.

Table 7 Breakdown of Technology Readiness Levels used within E.U. Horizon 2020 projects[3]

TRL Value	Developmental Stage
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

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3. Results & Discussion

3.1Trends in Transferability Ranking

3.1.1 High Transferability Rankings

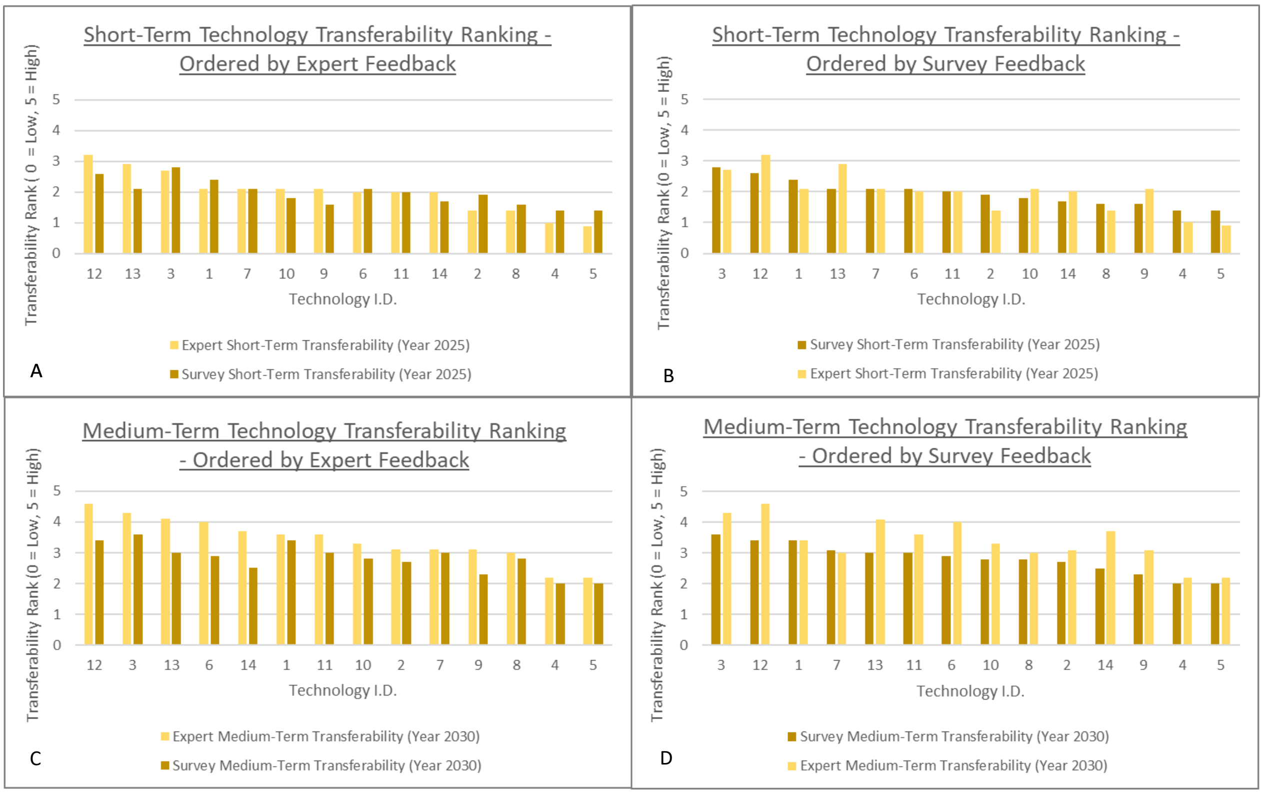

Figure 3. Side-by-side graphing of the average transferability ranking of the 14 technologies across Europe over the short-term and medium-term timeframes. Graphs are ranked from highest to lowest transferability in both the expert evaluation and the survey evaluation to display any similarities or discrepancies there. See legend below in table 8 to assist in identifying the technologies by their numerical code. A total of 313 NTF survey responses were tallied, while a grouping of 24 national experts from 9 countries provided the expert assessments.

Table 8 Legend reiterating which numerical code relates to which technology.

Technology I.D. Legend
1 = Farm-Scale Anaerobic Digestion
2 = Adapted Stable Construction for Manure Processing
3 = Crop Farmer Utilising a Variety of Manure & Dairy Processing Sludges to Recycle & Build Soil C,N, P
4 = Floating Wetland Plants Grown on Liquid Agro-Residues as a New Source of Protein
5 = Algae Grown on Liquid Agro-Residues as a New Source of Protein
6 = Using Recycling-Derived Fertilisers Ammonium Nitrate, Ammonium Sulphate, Digestate from Co-Digestion of Pig Manure & Liquid Fraction of Digestate
7 = Using Bio-Based Fertilisers to Optimise the Organic Carbon Storage in Soil and N, P Cycling
8 = Ammonia Recovery from Raw Pig Slurry in a Vacuum Evaporation Field Plant
9 = ABC Animal Bone Char for Phosphorous Recovery
10 = Pig Manure Refinery into Mineral Fertilisers
11 = Using Digestate, Precision Agriculture & No-Tillage to Improve Soil Organic Matter
12 = Use of Poultry Compost & Pig Slurry to Replace Mineral Fertilisers as Basal Fertilisation in a Maize Crop
13 = Application of Sensor Technologies in Plant Cropping Systems
14 = Trial Potato Growing with Refined Pig Manure Fractions

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Assessing the European wide view, the poultry compost technology (technology no.12) was ranked the most transferable in both the short-term expert evaluation and the medium-term expert evaluation (see graphs A & C in figure 3 above), whilst the dairy sludge technology (no.3) was ranked the most transferable in both the short-term survey evaluation and the medium-term survey evaluation (see graphs B & D in figure 3). In addition, across the four European regions both demonstrations were ranked within the top four technologies for transferability. From this, it is clear that both the expert and national task force evaluations considered these two technologies to have attributes that could accommodate wide uptake across the European Union in the timeframes given. Further to this, the farm-scale anaerobic digestion technology (no.1) and sensor technology (no. 13) both ranked high within the European wide evaluations, with both technologies ranking within the top 4 technologies for three out of the four scenarios.

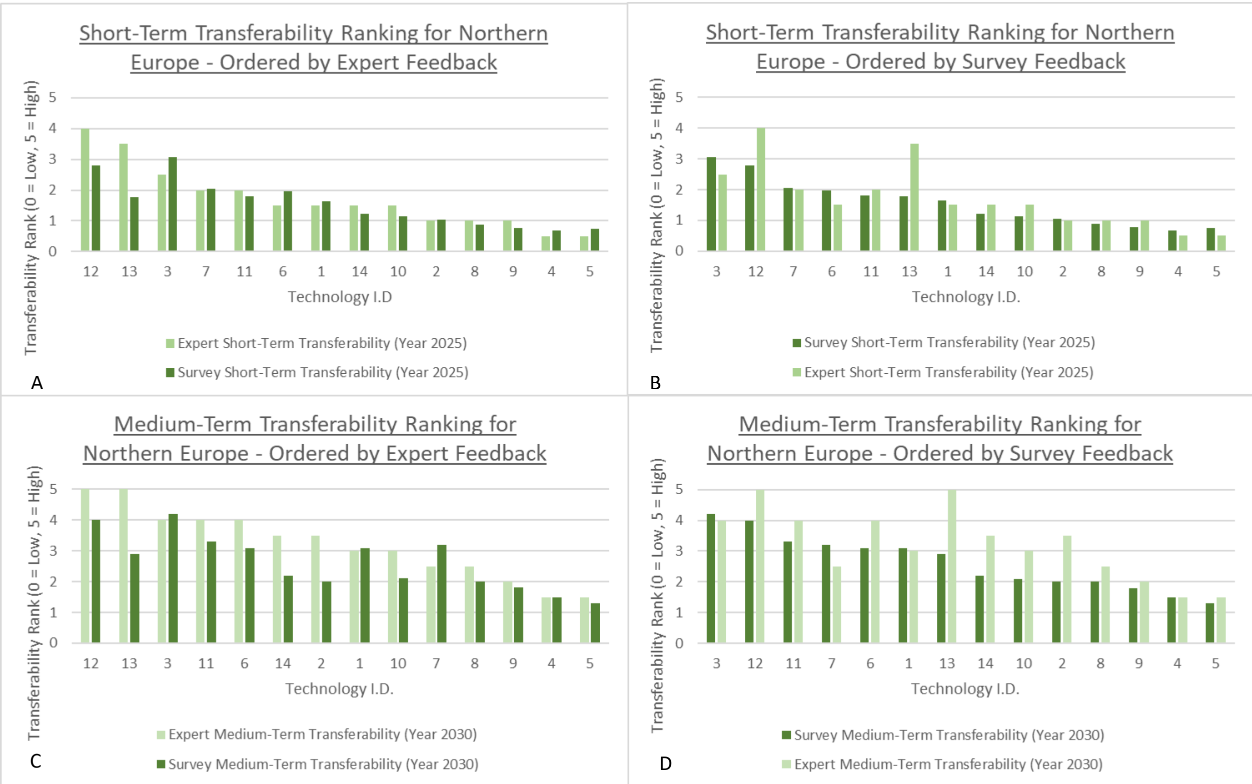

Figure 4. Side-by-side graphing of the average transferability ranking of the 14 technologies across Northern Europe over the short-term and medium-term. Graphs are ranked from highest to lowest transferability in both the expert evaluation and the survey evaluation to display any similarities or discrepancies there.

When assessing the averaged transferability rankings for Northern Europe both the poultry compost (no.12) and dairy sludge technologies (no.3) are ranked within the top three in both the short-term and medium-term time-frames within the expert and survey evaluations. The poultry compost technology was ranked the most transferable in both the short-term expert evaluation and the medium-term expert evaluation (see graphs A & C, figure 4), whilst the dairy sludge technology was ranked the most transferable in both the short-term survey evaluation and the medium-term survey

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evaluation (see graphs B & D, figure 4) for Northern Europe. This follows the same pattern as the European wide averaged rankings. The sensor technology (no.13) ranked high within both the expert evaluations time-frames but fell in ranking to mid-table within both the NTF survey evaluations.

Figure 5. Side-by-side graphing of the average transferability ranking of the 14 technologies across Southern Europe over the short-term and medium-term. Graphs are ranked from highest to lowest transferability in both the expert evaluation and the survey evaluation to display any similarities or discrepancies there.

Within Southern Europe's evaluations, again, the poultry compost (no. 12) and dairy sludge (no. 3) technologies ranked within the top three for transferability. In fact, across both timeframes and data groups, the poultry compost technology is ranked as the most transferable, followed by the dairy sludge technology as the second most transferable, see figure 5. In addition, the soil organic carbon technology using goose manure trialled in vineyards (no.7) ranked third most transferable across all four scenarios for Southern Europe.

Likewise, within the Western Europe ranking evaluations both the poultry compost and dairy sludge technologies are ranked in the top four for transferability across all four conditions, with the poultry compost technology ranked the most transferable over both the expert and NFT evaluation over the medium-term (figure 6). However, within the short-term the expert evaluation considered the sensor technology to be the most transferable while the NTF survey evaluation listed the dairy sludge technology as the most transferable. Over the medium-term within both the expert and NTF survey data the goose manure plus vineyard technology ranked high, coming in at third most transferable,

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which showcased a significant improvement in transferability perception from the mid-range ranking seen in the short-term time-frame to third most transferable within the medium-term time-frame.

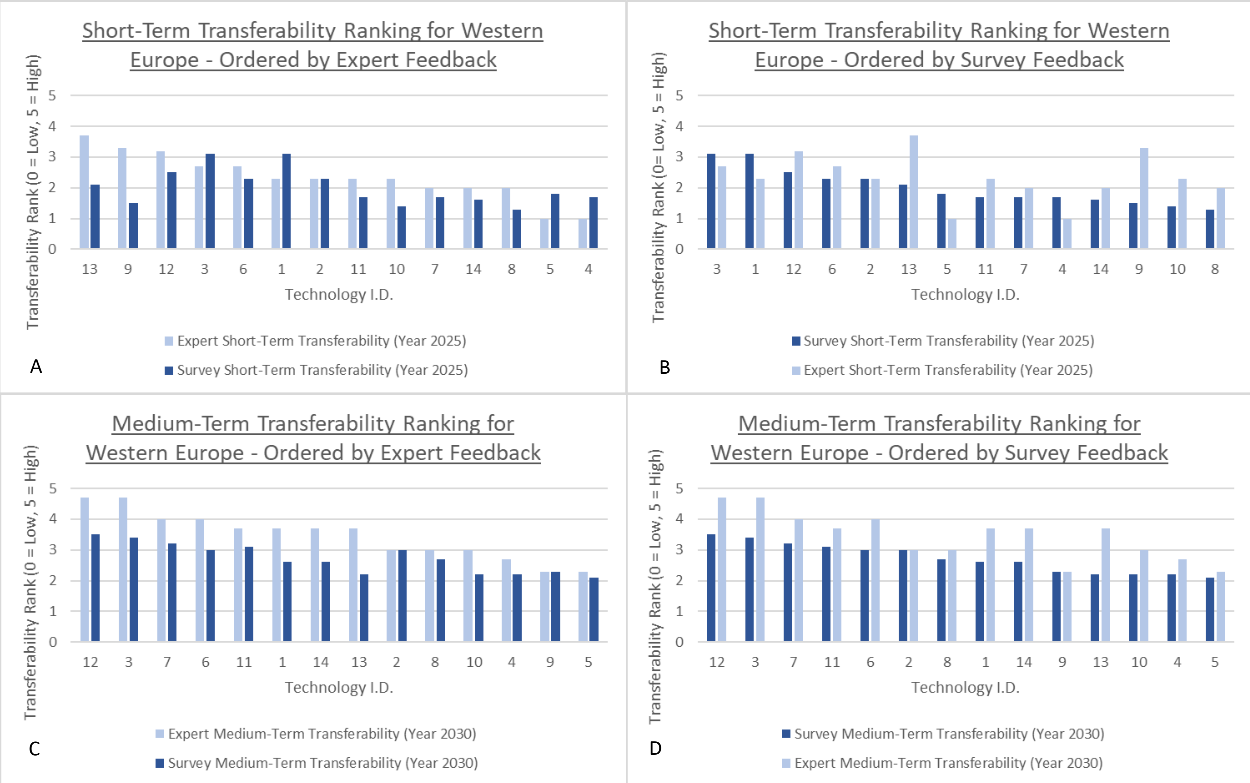

Figure 6. Bar-charts displaying averaged transferability rankings across the four conditions for Western Europe.

When considering both the poultry compost and dairy sludge technologies there are certain common attributes that have led to the high transferability ranks. For example, within the evaluations it was understood that both technologies could assist in greater understanding of the optimal balance and mix of organic and synthetic fertiliser application rates within arable systems. It was highlighted that arable crops, and, subsequently, the sustainability of arable farming, is critically dependent on sufficient fertiliser application to support maximum yield. By optimising manures, composts and sludges to fertilise arable crops the evaluators recognised the benefits that such technologies could behold i.e. reduced reliance on synthetic fertilisers, maintaining crop yield, and, improved soil health and quality by applying appropriate levels of organic fertiliser. Furthermore, given that farmers are largely familiar with spreading manures and have access to spreading equipment investment costs were not considered a significant challenge in adopting these two technologies.

However, within the Eastern European feedback (see figure 7) only the short term and medium-term expert evaluations ranked both the poultry compost and dairy sludge technologies within the top three for transferability, while the survey feedback ranked the dairy sludge technology as 4th and the poultry compost technology as 5th in both the short-term and medium-term transferability ranking. Within the Eastern European feedback, the bone char technology was ranked the most transferable across all conditions. There may be regional characteristics influencing this result as it was noted that many soils in Hungary are low in phosphorous. The reliance on expensive, imported synthetic

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phosphorus fertilisers was highlighted as a challenge within Hungarian agriculture by the expert evaluation. Within the national task force review, the economic and environmental benefits the bone char technology could provide were listed as the main advantages to technology adoption. Additionally, there may be some familiarity to this technology within Eastern Europe as a research company focused on producing phosphorous from animal bone char is located in Hungary. The high transferability rank of this technology within Eastern Europe is at odds with the rankings from other European regions. Within Northern Europe the bone char technology is consistently ranked as the third least transferable throughout the four ranking conditions. Within Southern Europe's data the expert evaluation ranked the bone char technology as the 2nd least transferable in both the short-term and medium-term, while the survey evaluation ranked the technology 3rd least transferable in the short-term and 5th least transferable in the medium-term. Furthermore, within the European wide evaluation the highest-ranking the bone char technology receives is 7th, which was received in the short-term expert evaluation.

Figure 7. Bar-charts displaying averaged transferability rankings across the four conditions for Eastern Europe.

This variation in transferability ranking regarding the bone char technology highlights the value of having both a European wide view and a regional view. We see regional influence again with regards to the goose manure plus vineyard technology which involves utilising goose manure in orchards and agroforestry systems. This technology was consistently ranked 3rd most transferable throughout the four conditions for Southern Europe, where wine and goose production is prominent. Whereas, the technology was ranked in the mid-range of transferability for Eastern Europe, where the tradition of vineyards and goose production is not as widely represented. However, the technology received a

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high transferability ranking within the survey evaluation for Northern Europe, which highlights the interdisciplinary quality many of these technologies have. Although the specific forms of agriculture investigated in the technology may not apply to a given region the premise of the technology might well be applicable under altered conditions, such as applying the technology to a fruit farm as opposed to a vineyard.

Assessing further the technologies that obtained high transferability rankings, the lighthouse demonstrations of anaerobic digestion and sensor technology received high transferability ranks in both the short-term and medium-term from Eastern Europe's national taskforce survey evaluation. The anaerobic digestion technology was ranked 2nd most transferable over the short-term and 3rd most transferable over the medium-term, while the sensor technology was ranked 2nd most transferable over the medium-term and 3rd most transferable over the short-term. The reasoning behind this was the foreseen economic and environmental benefits, along with improved nutrient management, that could result from implementing these technologies within Eastern Europe. Western Europe also ranked the anaerobic digestion technology as the 2nd most transferable demonstration within the short-term survey evaluation, but within the medium-term survey evaluation the technologies transferability rank was lowered to 8th. These are the only two incidences where the anaerobic digestion technology was ranked within the top three; across the other conditions from Eastern and Western Europe along with the evaluations from Northern and Southern Europe, the technology typically ranked 6th out of the 14 technologies. The Western European region is familiar with the concept of anaerobic digestion, as the technology already assists in manure processing, energy generation and environmental government policy within the region. However, the evaluations from Western Europe sighted challenges in adopting the technology such as future availability of labour, future subsidy schemes and future research in feedstock options, which may have influenced the fall in transferability of the technology over the medium-term to 8th place. The no-till plus soil organic matter technology also obtained a high transferability ranking of 3rd place within the medium-term Northern Europe survey evaluation, as the survey feedback understood the technology to lead to better nutrient management and reduced fertiliser reliance. The technology garnered mid-range transferability rankings within the other evaluations throughout Europe, most likely due to the financial cost and skillset required to implement the technology.

When considering the technology readiness levels of the high ranked technologies the poultry compost and sensor technologies had the highest TRL rank of 9 indicating the technology has been proven in an operational environment. The dairy sludge technology had a TRL of 6 indicating the technology has been proven in a relevant environment. The anaerobic digester technology had a TRL of 7-9 while the bone char technology was assigned a TRL of 8-9.

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3.1.2 Mid-Range Transferability Rankings

Certain technologies were continually ranked in the median area of the ranking scale e.g. adapted stable design, no-till plus soil organic matter and potato plus pig manure technologies . This indicates that there is interest in adopting these technologies, but groundwork such as increasing understanding of and familiarity with the technology amongst stakeholder groups, providing operator training, and, amending legislation to encourage and legitimise the adoption of by-products from the technology may all need to be undertaken in order to encourage uptake of mid-range technologies.

Technologies involving utilising pig manure fractions, such as the recycling derived fertilisers, pig manure to mineral fertiliser and potato plus pig manure technologies had a noticeably better short-term transferability within Southern, Eastern and Western Europe when compared against Northern Europe. This is likely due to national differences in farming practices such as the large scale of pig production in countries such as Germany and Spain versus the smaller pig production scale represented in Ireland. In addition, pig manure is currently widely used as a fertiliser in Denmark and Ireland, and therefore this is an example of the nuances of introducing a new technology into a given region. Even in an environment where pig production in taking place and pig manure is available, with arable farmers interested in organic fertilisers, the new technology still needs to compete with the current systems in place. Especially systems that are proving worthwhile such as slurry acidification. If the competitiveness is marginal, then the technology may be more suited to large-scale operations where economies of scale can come into play. Such large-scale operations are not widely represented throughout Europe.

The TRL values assigned to the mid-range technologies did not clearly align with the medium transferability scores allocated to the technologies. For example the adapted sable design, no-till soil organic matter and pig manure to mineral fertiliser technologies all had a TRL of 9, the maximum score, but were not considered the most transferable within either the expert of NTF evaluations.

3.1.3 Low Transferability Rankings

Both of the technologies centred on novel protein production were ranked the least transferable throughout the European wide evaluation under all four conditions. Excluding Western Europe's short-term survey evaluation, across the four regions the wetland plant and algae technologies were always ranked within the lowest four for transferability, and often listed as the two least transferable technologies. The consensus surrounding these two lighthouse demonstrations was that the technologies represented a niche market that was not very familiar to the farming community. Although the need to develop novel protein feed sources for livestock production was acknowledged within the evaluations, the practicalities of both of these technologies resulted in a low transferability rank. Within both the expert and national task force reviews certain adoption challenges were foreseen such as the scale of protein the system could produce, the land area the duckweed technology would require, the skillset to operate the facilities correctly, and, also, the need to develop legislation that would enable novel protein sources to be safely used in animal feed. However, the national taskforce evaluation from Western Europe highlighted the ability to use the environmental

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benefits of the novel protein produced as a means to market the product and capitalise on the sustainability aspect of the technology. Therefore, the survey evaluation from Western Europe gave the algae production technology a rank of 7th and the duckweed technology a rank of 10th. The vacuum evaporation plant technology also obtained a low transferability rank of 12th within the European wide expert evaluation. Likewise, the technology was ranked 12th in Eastern Europe's short-term survey evaluation. This technology was considered complex within the evaluations and would require operator training considering the array of equipment it entails. Within the western European medium-term expert and survey evaluations as well as the Western European short-term survey evaluation, the pig manure to mineral fertiliser received a low ranking of between 12th and 13th. As with the vacuum plant technology, the infrastructure and skill required to implement the pig manure technology were considered barriers to technology uptake.

Again the TRL values did not fully align with the transferability rankings garnered. For example the duckweed technology, which was typically ranked the second least transferable out of the 14, had the same TRL value as the dairy sludge technology of 6. The vacuum evaporation plant technology had a TRL of 9, the maximum value, as did the pig manure to mineral fertiliser technology. This is a good demonstration of the discrepancy between a technology that has been shown to fulfil its aim on an operational scale and a technology that members of the farming community would actually be interested in adopting. Perhaps this is an aspect of the project that could be assessed further as it's critical that what solutions are being put forward by industry leaders they are realistically applicable within a given farming community. If there is minimal interest in trialling a technology, even though it has been shown to work theoretically, then there may be conflict between policy makers and the farming community, as the farmers will feel they are being offered unsuitable solutions while legislatures may feel there is an unwillingness to try within the farming community if the uptake is very low.

Technology Transferability Evaluation

3.2.1 National Task Force Participants Occupation/ Background

The 14 trialled technologies were discussed over three separate online webinars organised by members of the Nutri2Cycle project team. The three webinars took pace over 3 different days, with different technologies discussed each day. The table below lists which technologies were discussed on which day.

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Table 9 Technologies discussed per online webinar

Webinar Day 1 – *121 NTF Survey Respondents*	**Webinar Day 2 – *107 NTF Survey Respondents***	**Webinar Day 3 – *85 NTF Survey Respondents***
Farm-Scale Anaerobic Digestion	Recycling-Derived Fertilizers	No-Tillage to Improve Soil Organic Matter
Adapted Stable Construction for Manure Processing	Bio-Based Fertilisers - Vineyards	Poultry Compost & Pig Slurry to Replace Mineral Fertilisers
Crop Farmer Utilising a Variety of Manure & Dairy Processing Sludges	Vacuum Evaporation Field Plant	Application of Sensor Technologies
Floating Wetland Plants Grown on Liquid Agro-Residues	Animal Bone Char	Potato Growing with Refined Pig Manure
Algae Grown on Liquid Agro-Residues	Pig Manure Refinery into Mineral Fertilisers	

Following the webinars, surveys were made available to be filled in by willing NTF participants. The surveys were divided by day, with one survey available for each day. Therefore for the five technologies listed for day 1 there is one set of data available relating to the occupation break-down of the respondents per region and the same is true of day 2 and day 3.

For the five day 1 technologies, listed in table 9 above, the occupation of the survey respondents were as follows:

Northern Europe – 26% of respondents were crop farmers; 22% of respondents were researchers; 17% of respondents were farm advisors; a joint 13% of respondents were either cattle farmers or worked in the agricultural industry, and, 9% of respondents classified themselves as other.

Southern Europe – 62% of respondents were researchers; 12% of respondents were farm advisors; 7% of respondents were pig farmers; a joint 5% of respondents classified themselves as either policy makers, working in the agricultural industry or other; 3% of respondents were consumers/citizens, and, 2% of respondents were cattle farmers.

Eastern Europe – 33% of respondents were researchers; 22% of respondents were consumers/ citizens; 17% of respondents were farm advisors, 11% of respondents were policy makers, a joint 6% of respondents were either working in the agricultural industry, a crop farmer or a cattle farmer.

Western Europe – 42% of respondents were researchers; a joint 14% of respondents were farm advisors or cattle farmers; a joint 8% of respondents were crop farmers or consumer/ citizens; a joint 6% of respondents classified themselves as either policy makers or pig farmers.

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For the five day 2 technologies listed in table 10 above the occupation of the survey respondents were as follows:

Northern Europe – 33% of respondents were researchers; a joint 17% of respondents classified themselves as either a crop farmer, a farm advisor or working within the agricultural industry; 11% of respondents were cattle farmers; 6% of respondents classified themselves as other.

Southern Europe – 58% of respondents were researchers; 18% of respondents were farm advisors; 9% of respondents were policy makers; 6% of respondents were cattle farmers; a joint 3% of respondents were either working in the agricultural industry, pig farming or other.

Eastern Europe – 27% of respondents were researchers; a joint 23% of respondents were either farm advisors or consumer/ citizens; 18% of respondents were crop farmers; 9% of respondents worked in the agricultural industry.

Western Europe – 38% of respondents were researchers; a joint 17% of respondents were either cattle farmers or other; a joint 8% of respondents classified themselves as either policy makers or crop farmers; 4% of respondents were either farm advisors, pig farmers or consumers/citizens.

For the four day 3 technologies listed in table 8 above the occupation of the survey respondents were as follows:

Northern Europe – joint 29% of respondents were farm advisors or worked in the agricultural industry; 18% of respondents were crop farmers; 12% of respondents were researchers; a joint 6% of respondents were either cattle farmers or policy makers.

Southern Europe – 64% of respondents were researchers; 11% of respondents were farm advisors; a joint 7% of respondents were either pig farmer or policy maker; a joint 4 % of respondents classified themselves as either cattle farmer, working in the agricultural industry or other.

Eastern Europe – 39% of respondents were researchers; 17% of respondents were crop farmers; a joint 11% of respondents were farm advisors, consumer/ citizens or other. A joint 6% of respondents were working in the agricultural industry or as a policy maker.

Western Europe – 41% of respondents were researchers; 23% of respondents were cattle farmers; 14% of participants classified themselves as other; 9% of participants were crop farmers; a joint 5% of respondents were consumer/ citizen, policy maker or working in the agricultural industry.

From this assessment of the participants' occupation it can be confirmed that the majority of the participants were from relevant backgrounds to the agricultural sector which brings a certain weight and validity to their informed evaluations. Graphs displaying the breakdown of the survey participants' occupation can be found in Annex 2.

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3.2.2 Technology No.1: Farm-Scale Anaerobic Digestion

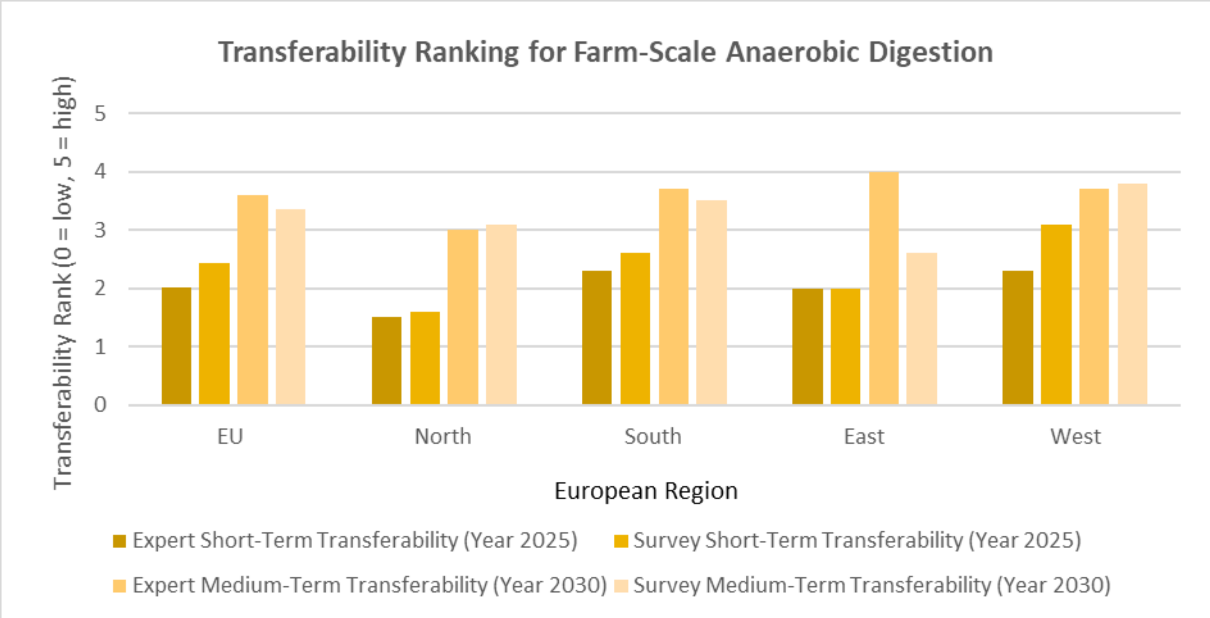

Figure 8. The above bar chart displays the averaged transferability rankings for the farm-scale anaerobic digestion technology across Europe

At EU level farm scale anaerobic digestion was ranked as the third most transferable over the short-term and medium-term within the survey feedback, with a mean short-term transferability rank of 2.4 (out of a maximum of 5), and a mean medium-term transferability rank of 3.4. Within the expert evaluations, the technology was ranked fourth most transferable with a mean rank of 2, and the sixth most transferable over the medium-term with a mean rank of 3.6. The results show that farm-scale anaerobic digestion could be particularly relevant for Southern and Western Europe in the short and medium term.

3.2.2.1 Farm-Scale Anaerobic Digestion - European Wide Evaluation

Foreseen Benefits to Technology Adoption

Within both the expert assessments and survey respondents feedback, the environmental benefits and improved nutrient management such a technology could provide were considered the main adoption benefits. Further benefits to technology adoption across Europe were listed as farmer's familiarity with the concept of anaerobic digestion; the production of biogas to compliment national energy plans and using digestate to reduce reliance on synthetic fertilisers. By producing an energy source (biogas) and nutrient rich organic fertiliser (digestate) from livestock manure, this technology was considered to contribute towards circular economy goals.

Foreseen Challenges to Technology Adoption

Within the survey feedback, the economics of the technology was listed as the main foreseeable uptake challenge. Likewise, the expert assessments observed the financial cost of establishing and operating an AD plant would be substantial for most farmers. Additionally, current incentives and

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governmental supports fall into the category of subsidies based on quantity of power produced (kWh), but, it was noted that a farm-scale AD plant may only provide enough energy to meet the demands of the farm itself and therefore such subsidies may not prove sufficient to attract technology uptake. Within both the expert and survey reviews, legislation surrounding establishing a farm-scale AD plant was highlighted as a challenge due to the cost and complexity of the planning process and the possibility of reluctance amongst the surrounding community to accept the new AD development. In addition, adequate training of operators in order to ensure optimal plant performance was also considered a challenge to technology uptake.

3.2.2.2 Farm-Scale Anaerobic Digestion - European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The national expert evaluation from Denmark, provided by staff from the University of Copenhagen, explained that anaerobic digestion (AD) technology has been present in the country for the past 20 to 30 years, albeit, the majority of anaerobic digesters in operation are large in scale and increasingly are jointly funded by investor groups and farming co-operatives, as opposed to farm-scale projects. The current set-up of Denmark's national power grid was deemed capable of distributing power generated from biogas, a product of AD. The Danish evaluation observed that farmers were familiar with the concept of AD plant operations and especially aware of the nutrient rich digestate produced during the anaerobic digestion process. The national experts from Denmark noted that the increased nutrient value of AD digestate, when compared against raw manure or slurry, is a valued product within the Danish farming community. Their evaluation stated that presently some Danish farmers send their livestock manure to AD plants primarily to acquire the digestate. The expert evaluation from Ireland, provided by staff from Teagasc, also noted the fertiliser value of the digestate and observed that appropriate application methods of the digestate, e.g. trailing shoe slurry spreading, should help in minimising losses of nitrogen during application. The national experts from Ireland felt the digestate produced during AD could contribute towards the E.U. Farm to Fork programme aim of reducing fertiliser usage by 20% by 2030. Furthermore, Ireland's expert group noted the suitability of farm-scale anaerobic digesters to the Irish agricultural system, as this technology could contribute to a commitment within the Irish National Climate Action Plan of producing 1.6-terawatt hours electricity via biomethane from agricultural feedstocks by the year 2030. When analysing the NTF survey responses for Northern Europe a joint 80% of participants believed a farm-scale AD plant would lead to better nutrient management and provide environmental benefits within a farming system; 45% of respondents thought the technology would lead to economic benefits such as reduced purchasing of synthetic fertilisers; 30% of participants thought the technology could utilise its environmental credentials as an advertising or marketing tool; 25% of participants believed introducing such a technology could lead to new local employment opportunities; a joint 15% of respondents agreed the technology could provide better compliance with legislation and be socially acceptable within the community.

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Table 10. Main expert evaluation benefits of technology no.1 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Familiarity with AD	✓	
Suitable national Power Grid	✓	
Nutrient Rich Digestate	✓	✓
Compliments National Legislation	✓	✓

Foreseen Challenges to Technology Adoption

Both nations' experts saw the financial cost of constructing and maintaining a farm-scale anaerobic digester as a challenge. Both Denmark and Ireland felt the initial cost of a farm-scale AD on a given farmer is significant, Denmark noted that farmers might consider being a shareholder in a larger co-operative AD plant over investing in their own farm-scale AD due to the financial costs involved. Within the Danish evaluation, it was noted that current support and subsidy schemes did not take into account the cost of constructing an AD plant, and only provided financial incentives in terms of network energy feed-in tariffs. Such a support system may not be sufficiently beneficial to farm-scale anaerobic digesters, where, due to the scale of the operation, less energy will be produced when compared against larger industrial AD plants. The Irish panel recognised that any potential subsidies towards the costs of constructing and operating an AD plant are at a legislative developmental stage, given how energy generation from anaerobic digesters is a new technology within the country. If legislation clarifying any subsidies or supports for AD plants could be made available to the farming community, it may assist in developing interest in adopting the technology. The national experts from Ireland stated that both labour units and training of said labour units are present challenges when considering farm-scale AD. If investing in a farm-scale AD resulted in the need for additional on-farm labour units then this could act as a barrier in uptake of the technology. Furthermore, in order for the AD to function optimally, the farmer or farm labourer would need appropriate training. Where a farmer could obtain this training and any further costs associated with this training were noted as current challenges by Ireland's national experts.

When analysing the NTF survey responses for Northern Europe 71% of participants selected economic considerations as an obstacle to technology uptake; 67% of respondents noted the absence of grant support as a barrier to adoption; 57% of participants believed the legalities surrounding the technology such as planning permission would act as a hindrance to uptake; a joint 38% considered the practicability and the knowledge required to successfully operate the technology as challenges; 24% listed social acceptability as an obstacle, such as issues relating to odour etc. Graphs depicting breakdown of NTF survey responses for all regions and technologies can be found in annex 3.

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Table 11. Main expert evaluation challenges of technology no.1 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Farmers prefer large scale AD plants run by co-operatives	✓	
Financial costs	✓	✓
Future subsidy schemes	✓	✓
Operator skillset		✓
Labour units		✓

Southern Europe

Foreseen Benefits to Technology Adoption

The national experts representing Italy were from the University of Milan and stated that a series of decrees since 2008 have been critical in encouraging the adoption of AD technology within the country. Italy has already seen some of the benefits of adopting AD technologies, with currently 9,368 GWh of electricity generated per annum from AD biogas production. The Italian expert assessment stated that if financial and legislative incentives were to continue towards biogas production then there would be a continued willingness to adopt the technology amongst the farming community. Since 2008 legislation has provided a variety of support tools, such as price boosts for electricity derived from biogas and updated legislation for the certification of sustainable biofuels. Considering that AD technology is well-known within the country the Italian panel thought further investment in this technology would be appropriate and critical for Italy to meet its National Renewable Energy Action Plan goals for 2030. Furthermore, the Italian expert assessment noted using the digestate produced as an organic fertiliser could assist in reduced reliance on chemical fertilisers. Additionally, the Italian assessment noted processing livestock waste via an AD plant, as opposed to holding the waste in traditional storage tanks, could lead to reduced uncontrolled emission losses from the animal waste. The Portuguese expert evaluation, provided by staff from the Higher Institute of Agronomy University of Lisbon, also listed the production of biogas as a considerable benefit to adopting the technology within the country. The Spanish evaluation was provided by staff from the Institute of Research & Agri-Food Technology (IRTA). Within the Spanish assessment it was noted that AD is becoming a widely recognised technology across the country, with 150 AD plants established to date. The Spanish panel also noted the technology could compliment national legislation such as the Strategic Framework for Energy & Climate which aims to produce a minimum of 10.41TWh of electricity from biogas per annum by 2030. The Spanish expert panel stated how producing 10.41TWh of electricity from biogas per annum could result in a reduction of 2.1 million tonnes of CO2 equivalent per year. Furthermore, Spain has developed a Biogas Roadmap in which the promotion of biogas by different means, such as minimum consumer and producer quotas, is being investigated. The Spanish panel thought there was potential for Farm-Scale AD plants within the country as the production of biogas would assist in meeting targets associated with the Biogas Roadmap.

When analysing the NTF responses for Southern Europe 88% of respondents felt the technology could provide environmental benefits, such as reduced emissions, within farming systems; 73% of

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respondents selected the economic benefits associated with the technology as an advantage to uptake; 50% of respondents agreed the technology would lead to better nutrient management on farms; 30% of respondents considered the technology as a means to provide new job opportunities in the local community; 20% of respondents selected the practicability of the technology as a benefit to uptake; 15% of respondents believed the technology would led to better compliance with national legislation, while a joint 8% of respondents selected improved work-life balance for farm operators, the ability to use environmental credentials of technology as a marketing tool and social acceptance of such a technology within the wider community as benefits to uptake.

Table 12. Main expert evaluation benefits of technology no.1 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Nutrient rich digestate	✓		
Reduced reliance on chemical fertiliser	✓		
Compliments legislation	✓	✓	
Familiarity with technology	✓	✓	
Biogas production	✓	✓	✓
Reduced livestock waste emissions		✓	

Foreseen Challenges to Technology Adoption

The national experts from Italy considered adequate operator training a challenge. They noted that in order to optimise production from an AD plant certain skills were required and therefore training of farmers or farm labourers would need to be prioritised. The Italian panel understood that the digestate formed within the AD process could be used as an organic fertiliser, but stressed the need for appropriate fertiliser application methods, as otherwise losses in nitrogen via emissions could occur. Within the feedback from both Portugal and Spain, the financial cost of investing in an AD plant was considered a barrier to technology adoption. The Spanish evaluation also listed the ability to navigate the various regulations and organisations involved in establishing an AD on a private farm as a significant challenge in successful adoption of the technology. Further to this, the Spanish panel stated that swine manure is far more readily available than bovine manure within the country. If a farm-scale AD design could be optimised for a feedstock of swine manure then the technology may have more scope within the country.

When analysing the NTF survey responses for Northern Europe 73% of participants selected economic considerations as an obstacle to technology uptake; 58% of respondents considered the training and skillset required to operate the technology as a barrier to uptake; 55% of respondents selected the legalities associated with an anaerobic digester as a challenge, such as planning permission; 53% of respondents considered the absence of grant supports as a barrier to uptake; 30% of the survey participants listed the practicability of the technology as a challenge to technology adoption; 20% of

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respondents selected social acceptance of the technology as a barrier e.g. noise, change to landscape etc.; 5% of participants considered the technology represented too much work for too little reward.

Table 13. Main expert evaluation challenges of technology no.1 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Operator skillset	✓		
Digestate management	✓		
Legislation		✓	
Alternative feedstocks		✓	
Financial cost		✓	✓

Eastern Europe

Foreseen Benefits to Technology Adoption

The assessment from Hungary, provided by staff from 3R-BioPhosphate Ltd. and SOLTUB Ltd., stated that the use of the nutrient rich digestate produced from AD could assist in the E.U. Farm to Fork programme aim of a 20% reduction in mineral fertiliser consumption by 2030. Furthermore, the assessment noted that the majority of farms within the country are classified as Small or Medium Enterprises (SMEs) and, therefore, a farm-scale AD plant could work within the current scale of operation of Hungarian farms. The expert review noted producing biogas and digestate within Hungary could aid in developing both national fuel and fertiliser security.

When analysing the NTF survey responses for Eastern Europe, 89% of participants selected the environmental benefits associated with AD technology as an advantage to uptake; a joint 83% of Eastern European respondents selected better nutrient management and associated economic benefits when undertaking the survey; 17% of participants considered better compliance with national legislation as a benefit to the technology; 11% of respondents felt the technology could lead to the creation of new job opportunities within the community, whilst a joint 6% of respondents selected improved work-life balance for farm operators, the ability to use environmental credentials of technology as a marketing tool and the practicability of such a technology as benefits to uptake.

Table 14. Main expert evaluation benefits of technology no.1 for Eastern Europe

Benefits of Technology Uptake	Hungary
Compliments legislation	✓
Improved self-sufficiency	✓
Farm-scale applicable to Hungarian farms	✓

Foreseen Challenges in Successful Adoption of the Technology

The expert assessment noted the financial cost of constructing and operating a farm-scale AD as a significant challenge in adoption of the technology within Hungary. It was observed that, largely,

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farmers would not have the financial means to commit to such an investment. The scale of production was also noted as a barrier to uptake, with concern raised over the economic competitiveness of producing power by AD when compared against other means. The national expert did not consider farm-scale AD plants to be sustainable in the long-term if they were to be reliant on government subsidies. Within Hungary a current difficulty amongst SME farms is securing qualified labour. If operating an AD plant required additional on-farm labour units then this could inhibit uptake of the technology throughout the country. Additionally, along with the possibility of further labour demands, any plant operator will need training to ensure the anaerobic digester is managed correctly. The expert feedback from Hungary made a point that if a single larger AD plant were constructed it would likely involve less investment costs and training of operators than the construction of multiple farm-scale AD plants for a similar quantity of energy produced. The assessor stressed the importance of sufficient training of plant operators, as otherwise emission savings from the technology may be impeded.

When analysing the NTF survey responses for Eastern Europe 83% of participants selected the absence of grant supports as a barrier to technology uptake; in addition, 72% of respondents considered the training and skillset required to operate the technology as a barrier to uptake; the legalities of developing such a technology were selected by 50% of survey participants as a foreseeable challenge; a joint 28% of respondents selected either the economic considerations, practicability or social acceptability of the technology as respective challenges.

Table 15. Main expert evaluation challenges of technology no.1 for Eastern Europe

Challenges of Technology Uptake	Hungary
Investment costs	✓
Labour units	✓
Operator skillset	✓
Competitiveness of electricity production	✓

Western Europe

Foreseen Benefits to Technology Adoption

All three national expert evaluations noted that farm-scale AD could contribute towards energy self-sufficiency within their respective countries. The Dutch assessment, provided by staff from Wageningen University, stated within national legislation aims to increase biomethane production by 10 times the current rate to 2 billion m^3 by the year 2030. Belgium's expert assessment, provided by staff from Biogas-E, noted farm-scale AD could result in the farm itself becoming energy self-sufficient in terms of electricity usage. If there were appropriate scale, the biogas produced could also be transformed into transport fuel for farm vehicles. Government subsidies were highlighted within the German assessment, provided by staff from the Thünen Institute, stating that within German law small biogas plants of a size of 75kW or less, fed by a minimum of 80% animal manure, receive a unit price of €0.22 per kWh of electricity. Under the continuation of such a subsidy scheme the German assessors noted there may be a market for farm-scale AD plants. Furthermore, both the Netherlands and Germany highlighted the availability of feedstock for AD within their respective nations; AD technology could assist in surplus manure management. Additionally, the evaluation from Belgium noted the high nutrient quality of the digestate produced during anaerobic digestion. It was stated that the digestate has greater nutrient availability than standard raw animal manure and can be used

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as an organic fertilizer in Belgium. Concerns over N emissions from digestate spreading were noted, but in their expert opinion undertaking digestate processing steps such as ammonia stripping-scrubbing would significantly reduce any related N emissions.

When analysing the NTF survey responses for Western Europe, 90% of participants selected the environmental benefits associated with AD technology as an advantage to uptake; better nutrient management was selected by 80% of survey participants as an associated benefit while the foreseen economic benefits were selected by 70% of participants; 20% of participants considered social acceptability or goodwill towards such a technology as an advantage to technology uptake; 10% of participants associated the technology with improved compliance with government legislation; ability to use the environmental credentials of the technology as a marketing tool was selected by 7% of participants as an advantage while a joint 3% of respondents selected improved work-life balance for farm operators and the practicability of such a technology as benefits to uptake.

Table 16. Main expert evaluation benefits of technology no.1 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Nutrient rich digestate	✓		
Energy production	✓	✓	✓
Compliments legislation		✓	
Availability of livestock manure		✓	✓

Foreseen Challenges to Technology Adoption

Belgium recognised that there would be more scope for adoption of this technology if a greater variety of feedstocks could be used within AD technology. Currently bovine manure (cattle manure) is considered the best and most widely used feedstock; the expert evaluation from Belgium noted using pig manure may be possible in the future, but research on the use of other feedstocks is limited. Both Belgium and Germany noted labour availability and training of plant operators as current challenges in adoption of the technology. Both expert panels noted the operator of a digester requires training in order for the digester to function at its optimum and for any potential emission reductions to be secured. Such training would need to be made available to farmers and farm labourers. If investing in a farm-scale AD resulted in the additional need for labour units then this could act as a barrier in adoption of the technology. The expert evaluation from Germany stated installing a larger AD plant as opposed to multiple farm-scale operations could result in less investment costs and less required training of operators for a similar output of power. Belgium too noted the additional investment costs associated with multiple farm-scale AD plants versus one larger AD plant. Both the Dutch and German panels noted the overall financial cost of investing in a farm-scale AD as a barrier to uptake, with the cost considered substantial for most farmers.

When analysing the NTF survey responses for Western Europe 83% of respondents selected economic considerations as a barrier to technology adoption; 77% of respondents considered the legal framework of such a technology as a barrier to uptake; the knowledge required to operate the technology was selected by 50% of respondents as a challenge; absence of grant support was selected by 33% of respondents as an obstacle to uptake;

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Table 17. Main expert evaluation challenges of technology no.1 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Feedstock variety	✓		
Labour units	✓		✓
Operator skillset	✓		✓
Financial cost	✓	✓	✓
Efficiencies vs larger AD plants			✓

3.2.3 Technology No.2: Adapted Stable Construction for Manure Processing

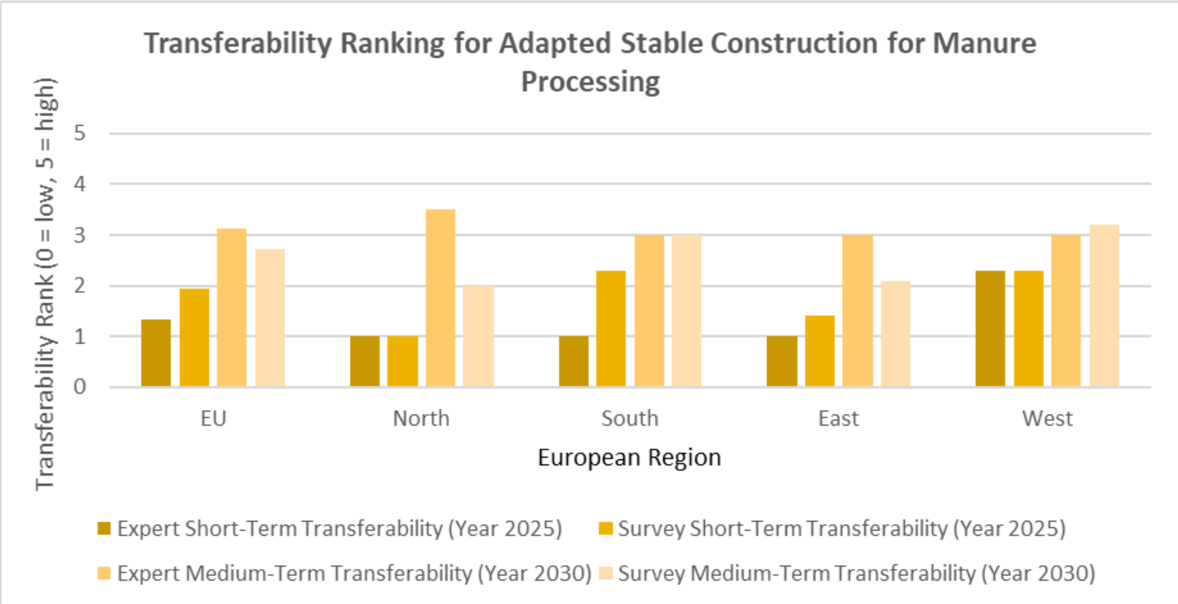

Figure 9. The above bar chart displays the averaged transferability rankings for the adapted stable construction for manure processing technology across Europe.

At EU level under the short-term transferability timeframe, the expert panel ranked the technology 11th out of the 14 technologies trialled (mean rank value of 1.3). The survey respondents ranked the technology 8th in short-term transferability (mean rank value of 1.9). For medium-term transferability the expert panel ranked the technology 9th (mean rank value of 3.1), while the mean survey ranking considered the technology to be less transferable over the medium-term than the short-term and ranked it 10th out of the 14 technologies (mean rank value of 2.7). In figure 17 it can be seen that adapted stable construction for manure processing is particularly relevant for Western Europe with a short-term transferability rank of 2.3 for the expert evaluation and the survey and a medium-term expert rank of 3, medium-term survey rank of 3.2.

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3.2.3.1 Adapted Stable Construction - European Wide Evaluation

Foreseen Benefits to Technology Adoption

Although all the ranking's allocated to the technology are such values so that the technology is best ranked an 8th out of 14, some benefits were still foreseen in its successful adoption. Within both the expert evaluations and survey respondents feedback the environmental benefits such a technology could provide were listed as considerable benefits. By separating the solid manure fraction from the liquid fraction, urea and the enzyme urease have limited contact time which then limits ammonia emissions from the animal waste during storage. Furthermore, by separating the manure into fractions farmers can acquire the organic fertiliser type they need and this can assist in improved use of fertiliser, reduced reliance on synthetic fertilisers and reduced transportation costs of manure fractions.

Foreseen Challenges to Technology Adoption

Economic considerations were listed as the main challenge to technology uptake within the survey respondents' data. The expert evaluations also noted the financial cost of altering a stables construction would be considerable, especially when, at present, such modifications or developments are not covered under farm modernisation grant schemes. Although by separating the animals' urine waste from the solid waste less ammonia is lost during manure storage, such an advantage is in competition with already practiced technologies in some parts of Europe, such as slurry acidification, and, therefore, this lessens the foreseeable benefits in implementing the adapted stable design technology. As the technology enables solid manure to be stored separate to liquid wastes this solid manure could be readily fed to an AD plant. But, throughout the evaluation feedback the concept of combing adapted stable construction with an AD plant was noted as too great a financial investment for the majority of farmers. Within some expert evaluations, it was also highlighted that a grassland farmer would need to apply the potassium rich liquid digestate with caution as there could be a risk of grass tetany in livestock when using the product.

3.2.3.1 Adapted Stable Construction - European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The Danish assessment, provided by staff from University of Copenhagen, noted that animal waste separation technologies have been previously researched in the country, however, to date, none of the researched technologies have been implemented within the agricultural sector. Their evaluation culminated with the observation that such adaptions to animal housing may gain attention into the future if further legislation regarding reducing ammonia and methane emissions from the agriculture sector is introduced. The Irish assessment, provided by staff from Teagasc, explained that one advantage of the technology is that the phosphorous within the animals waste would be concentrated in the solid manure faction, while the nitrogen and potassium found in the animals waste would be concentrated in the liquid faction. Separating the animal waste into solid and liquid factions could

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reduce transport costs of moving manure to pastures that are at a distance from storage tanks, such as out-farms. Ireland's evaluators also noted the altered animal housing design could reduce ammonia emissions from stored animal waste, which, presently, are a prominent source of emissions in Ireland. The loss of ammonia and nitrous oxide by way of current storage and spreading techniques contributes to Irish framers continued reliance on chemical nitrogen fertilisers to meet nitrogen demands on the farm. Their evaluation stated that this technology, combined with good manure management practices, could reduce the reliance on chemical nitrogen fertilisers in Ireland.

When evaluating the feedback from the NTF survey for Northern Europe environmental benefits were selected by 95% of respondents as an advantage to uptake; better nutrient management was selected by 63% of respondents as an advantage; 47% of participants listed the economic benefits associated with the technology as an advantage; better compliance with legal frameworks was selected by 42% of participants; the ability to use the environmental credentials of the technology for marketing was selected by 26% of participants while the creation of new job opportunities was listed by 5% as a benefit to technology adoption.

Table 18. Main expert evaluation benefits of technology no.2 for Northern Europe

Benefits of Technology Uptake	**Denmark**	**Ireland**
Applicable to Danish animal housing	✓	
Reduced emissions	✓	✓
Reduced slurry transportation costs		✓

Foreseen Challenges to Technology Adoption

Both assessments from Denmark and Ireland listed the financial cost of investing in this technology as a barrier to adoption. Additionally, most farmers already have a form of animal storage in place e.g. slatted tanks or storage tanks. The assessors were unsure of the interest farming communities would have in this new housing design considering the resources they have already invested in their current storage infrastructure, also, the Irish assessment were unsure if this housing design would be covered in the national grant scheme for agricultural modernisation (TAMS). The Danish assessment stated current success in using technologies such as slurry acidification to reduce ammonia losses from livestock waste may well reduce the interest in this proposed technology. The Irish assessment warned that the concentration of potassium in the liquid waste faction could lead to incidences of grass tetany when applied on grazing ground. If the solid waste faction were to be used as a feedstock in anaerobic digestion then this too would be a challenge in Ireland as access to such plants is very limited within the country.

When evaluating the feedback from the NTF survey for Northern Europe economic considerations were selected by 79% of participants as a challenge to adoption; a joint 58% of participants selected absence of grant supports and the practicability of the technology as barriers to uptake; 53% of respondents thought the technology represented too much work for too little gain; legal framework

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issues were selected by 21% of participants, while 5% of survey respondents from northern Europe thought social acceptability would be an issue.

Table 19. Main expert evaluation challenges of technology no.2 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Competition from current slurry treatments	✓	
Financial cost	✓	✓
Retrofitting animal housing	✓	✓
Limited access to AD plants		✓
Grass tetany		✓

Southern Europe

Foreseen Benefits to Technology Adoption

Expert evaluations from Italy, Portugal and Spain all stated that the technology could contribute towards national legislation of reducing emissions from the agriculture sector. Furthermore, the assessors noted that separating the animal waste inhibits the urease enzyme found in solid manure interacting with urine in the liquid faction and thus reduces ammonia losses via emissions. Reducing ammonia losses from slurry contributes towards optimising nitrogen cycling in current agricultural systems. Both the Italian and Spanish expert panels observed such a technology could reduce a farmer’s reliance on chemical nitrogen fertilisers. Furthermore, the Spanish evaluation, provided by staff from IRTA, noted such a technology compliments national legislation focused on reducing ammonia emissions from manure storage, stabilising nitrogen content in livestock urine waste and encouraging farmers to use Best Available Techniques. The Italian expert assessment, provided by staff from the University of Milan, stated the solid manure could also be used to produce biogas via an anaerobic digestion plant.

When evaluating the feedback from the NTF survey for Southern Europe environmental benefits were selected by 69% of survey respondents as a positive to technology uptake while economic benefits were selected by 64% of respondents; better nutrient management was selected by 61% of participants as a bonus of the technology; the practicability of the technology was selected by 31% of respondents while 22% selected better compliance with legal frameworks as an advantage; 17% of participants felt the technology could lead to improvements in work-life balance; the creation of new local jobs was listed by 14% of participants as an advantage while a joint 11% of respondents considered the social acceptability and option of using the environmental credentials of the technology as a marketing tool as benefits to technology adoption.

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Table 20. Main expert evaluation benefits of technology no.2 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Biogas from solid manure	✓		
Reduced reliance on N fertiliser	✓	✓	
National legislation	✓	✓	
Urine nitrogen concentration		✓	
Reduced emissions	✓	✓	✓

Foreseen Challenges to Technology Adoption

In order to optimise the value of the solid manure the technology proposed feeding the solid manure into an anaerobic digester in order to produce biogas. The Italian expert evaluation listed this as a possible challenge to technology adoption due to the scale of investment in infrastructure that would be required when combining an adapted animal housing design with an AD plant. Furthermore, regulations and possible government incentives around the correct use of the manure and liquid fractions may need to be developed. The Portuguese assessment, provided by staff from the School of Agronomy at University of Lisbon, stated the technology would only be suitable for new animal housing builds. Likewise, the Spanish review stated it might be challenging to adapt existing animal housing units to include this technology.

When evaluating the feedback from the NTF survey for Southern Europe , economic considerations were listed by 69% of the respondents as a challenge to technology uptake; 58% of respondents selected the legal framework requirements as a barrier while 53% of participants selected the absence of grant supports as a barrier; the knowledge to implement the technology was selected by 47% of the respondents as a disadvantage; 19% of the respondents thought the technology represented too much work for too little reward; a joint 17% of respondents listed the practicability and social acceptance of the technology as barriers to uptake.

Table 21. Main expert evaluation challenges of technology no.2 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Legislation	✓		
Financial cost	✓	✓	✓
Combination with AD plant	✓		
New builds only		✓	✓

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Eastern Europe

Foreseen Benefits to Technology Adoption

Separating livestock waste into solid and liquid fractions had some benefits within the Hungarian review provided by staff from the environmental company 3R-BioPhosphate Ltd. Currently Hungary imports all its chemical phosphorous products. The reliable sourcing of affordable mineral phosphates was considered to be a future challenge due to changes in supply chains across the E.U. The expert panel stated the significance of this challenge is magnified when considering that the majority of soils in Hungary have sub-optimal phosphorous levels. The evaluation stated this technology could contribute towards reduced dependence on mineral fertilisers, such as phosphorous and nitrogen, if the separated animal wastes were used in accordance with best manure management practices.

When evaluating the feedback from the NTF survey for Eastern Europe the environmental benefits associated with the technology was selected by 83% of respondents; a joint 72% of survey participants selected economic benefits and better nutrient management as benefits of adoption; better compliance with legal frameworks was selected by 22% of participants; a joint 17% of participants selected improved work-life balance and creation of new local employment opportunities as benefits to uptake; the availability to use the environmental credentials of the technology for marketing was seen as an advantage by 11% of respondents, while the practicability of the technology was listed by 6% of participants as a bonus to adoption.

Table 22. Main expert evaluation benefits of technology no.2 for Eastern Europe

Benefits of Technology Uptake	Hungary
Reduced reliance on fertilisers	✓
Reduced reliance on imports	✓

Foreseen Challenges to Technology Adoption

The evaluation from Hungary noted the phosphorous found in animal waste would now be concentrated within the solid manure fraction, but the concentration would not be enough to reduce manure application rates per hectare. As a result any financial benefits in applying the more concentrated manure would be minimal. The finances required to implement the technology would be considerable for most farmers. The Hungarian expert evaluation was unsure if the technology would be covered under national agricultural modernisation grant scheme.

When evaluating the feedback from the NTF survey for Eastern Europe 67% of respondents listed the absence of grant supports as a challenge; the practicability of the technology was selected as a barrier to adoption by 56% of the respondents; a joint 44% of participants selected economic considerations, the skillset required and legal framework requirements as barriers to technology uptake; a joint 22% of respondents considered the technology as too much work for too little reward and considered social acceptability as possible challenges to uptake.

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Table 23. Main expert evaluation challenges of technology no.2 for Eastern Europe

Challenges of Technology Uptake	Hungary
Investment cost	✓
High manure application rates to meet phosphorus demand	✓

Western Europe

Foreseen Benefits to Technology Adoption

The expert evaluation from the western European nations all agreed that the separation of solid manure from liquid waste could reduce emissions from the agricultural sector by reducing the contact time between urease and urea. The German evaluation, provided by staff from the Thünen Institute, also stated that reduced emissions within an animal housing unit could also improve animal welfare standards. All three expert evaluations stated that there is scope for such a technology within their respective countries, as targets for emission reductions and progression towards a circular economy have been set by government. The German expert review noted similar technology recently won an award from the German agricultural society, which implies there is potential interest in the technology within the country. The Belgian evaluation, provided by staff from Ghent University, explained separating the livestock waste into solid manure and liquid fractions could result in an increase in quality and quantity of biogas production, as the solid waste can be fed to an anaerobic digestion plant.

When evaluating the feedback from the NTF survey for Western Europe 89% of respondents considered environmental benefits of the technology as an advantage to adoption; better nutrient management was selected by 68% of respondents, while the economic benefits were selected by 50% of respondents; 25% of respondents listed the practicability of the technology as a benefit; a joint 21% of respondents selected better compliance with legal requirements and the ability to use the environmental credentials of the technology for marketing as an advantage; 18% of respondents considered the social acceptability surrounding the technology as an advantage, while an improvement in work-life balance was selected by 4% of respondents.

Table 24. Main expert evaluation benefits of technology no.2 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Solid manure for biogas	✓		
Environmental legislation	✓	✓	✓
Reduced emissions	✓	✓	✓
Furthers stable design research		✓	
Improved animal welfare			✓

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Foreseen Challenges to Technology Adoption

The German evaluation thought this was not an ideal time for pig farmers to invest in such a technology due to declining numbers within the country's pig herd. Both evaluations from the Netherlands and Belgium listed the financial cost of constructing adapted stables as a barrier to technology uptake. Furthermore, Belgium stated the operation would work best in conjunction with an AD plant, which is an additional investment cost that most farmers could not meet. The Belgian panel felt that if the liquid urine produced did not receive beneficial licensing or product status then it would not be as economically profitable as chemical fertiliser options.

When evaluating the feedback from the NTF survey for Western Europe 68% of respondents selected economic considerations as a disadvantage; 57% of participants listed the absence of grant supports as a challenge; the practicability of the technology was listed by 50% of the respondents as a barrier to uptake; the legal framework requirements were listed by 46% of the respondents as an obstacle; the knowledge required to implement the technology was selected by 43% of the respondents as a disadvantage to uptake; 11% of the respondents considered the technology as an example of too much work for too little gain; the social acceptability of the technology was listed by 4% of the respondents as a barrier to uptake.

Table 25. Main expert evaluation challenges of technology no.2 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Marketability vs synthetic fertilisers	✓		
Additional AD technology	✓		
Considerable financial investment	✓	✓	✓

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3.2.4 Technology No.3: Crop Farmer Using a Variety of Manure & Dairy Processing Sludges to Recycle & Build Soil C, N, P Fertility

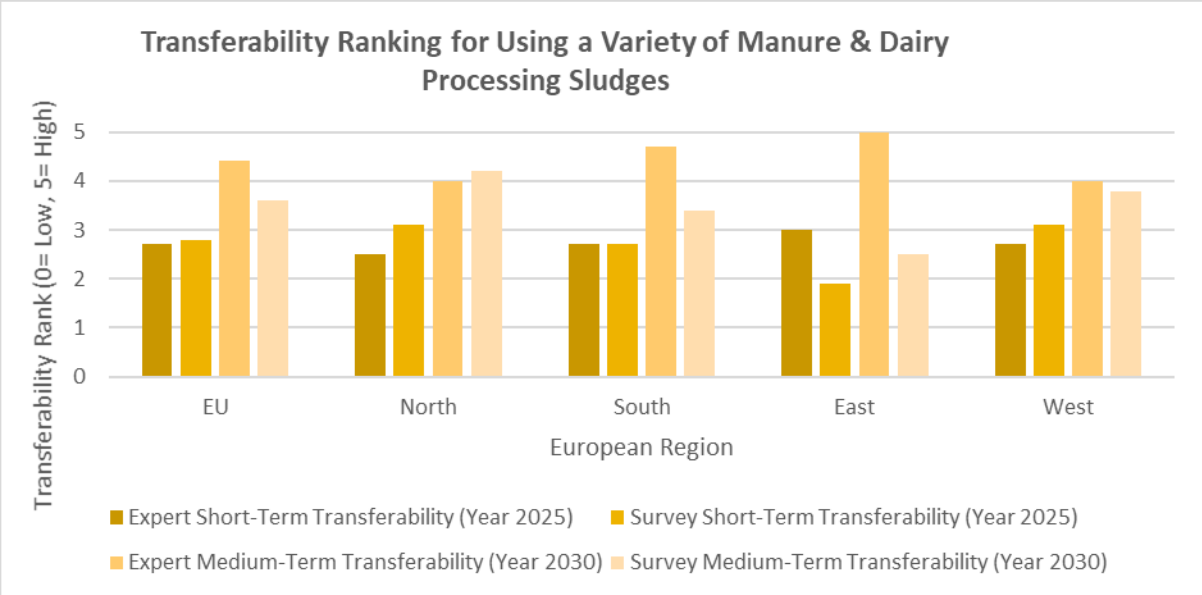

Figure 10. The above bar chart displays the averaged transferability rankings for the variety of manure & dairy processing sludges to recycle and build soil N, C, P

The use of a variety of manure & dairy processing sludges to recycle and build soil N, C, P for crop farmers received high transferability ratings through the European evaluations. At EU level in the short-term (transferability rank 2.8) and the medium-term (transferability rank 3.6) it is ranked as the most transferable technology within the survey feedback. For the expert evaluation this technology is ranked as the third most transferable technology in the short-term (transferability rank 2.7) and the second most transferable in the medium-term (transferability rank 4.4). The technology was ranked in the top three technologies for the four charted Northern and Southern Europe conditions (see figures 4 and 5). The technology was also ranked within the top three for both the expert assessments within Eastern Europe and all but the short-term expert evaluation for Western Europe, please see figures 6 and 7.

3.2.4.1 Manure & Dairy Processing Sludges - European Wide View

<u>Foreseen Benefits in Technology Adoption</u>

Within the NTF survey evaluations the technology was considered to have economic and environmental benefits, along with the ability to promote better on-farm nutrient management. Benefits foreseen in adoption of the dairy sludge technology were a further use stream for livestock manure and waste diary sludge; working to assist arable farmers in researching transportable organic manures; introduction of organic manures into an arable holding to improve the soil quality and organic matter content and researching means to reduce synthetic fertiliser reliance while maintaining crop yield.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Foreseen Challenges in Technology Adoption

One challenge foreseen was the availability of cattle manure and dairy sludges throughout Europe, as cattle manure is in demand as an organic fertiliser and is also considered the best feedstock for anaerobic digestion plants. Additionally, milk processors have systems in place for processing waste sludges. If the technology were to gain traction then perhaps steady supplies of in particular the dairy sludge would need to be arranged with milk processors. In addition, ensuring the crop receives the required fertiliser nutrition was also highlighted as a barrier to technology implementation, as manure can have varied nutritional qualities and there needs to be assurance that such organic fertilisers contain consistent adequate nutrition.

3.2.4.2 Manure & Dairy Processing Sludges - European Regional View

Northern Europe

Foreseen Benefits in Technology Adoption

The Danish evaluation, provided by staff from the University of Copenhagen, noted that due to the medium-high density of dairy farms in the country there is likely to be both animal manure and dairy processing waste available as soil enhancers. The Danish assessment explained that, presently, there are regional discrepancies in soil fertility across the country; as a result, there could be a demand for such organic fertiliser technology in certain localities. The Irish expert evaluation, provided by staff from Teagasc, highlighted the increased cost and reduced availability of chemical fertilisers in recent months as a significant difficulty currently facing the farming community. Within the Irish evaluation, it was noted that the technology described could reduce national reliance on imported chemical fertilisers. Furthermore, the use of chemical fertilisers that contain no carbon combined with conventional tillage methods on arable holdings reduces soil organic matter content. By introducing manure and dairy processing sludges to arable systems, the quantity of soil organic matter (SOM) could increase and an improvement in soil quality could follow.

When evaluating the feedback from the NTF survey for Northern Europe 79% of respondents considered environmental benefits of the technology as an advantage to adoption; better nutrient management was selected by 95% of respondents, while the economic benefits were selected by 90% of respondents; a joint 5% of respondents selected better compliance with legal requirements and the ability to use the environmental credentials of the technology for marketing as an advantage and the social acceptability surrounding the technology as an advantage; while the creation of new job opportunities was selected by 10% of respondents.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Table 26. Main expert evaluation benefits of technology no.3 for Northern Europe

Benefits of Technology Uptake	**Denmark**	**Ireland**
Availability of manure & dairy sludge	✓	
Could satisfy region specific demands	✓	
Reduce reliance on synthetic fertilisers		✓
Improve SOM/quality		✓

Foreseen Challenges in Technology Adoption

The Danish assessment observed that currently large dairy processing companies have systems in place for utilising any waste sludges produced. If the technology proposed displayed no greater circular economy qualities than the current systems, the dairy companies might not be willing to modify their business model. The evaluation from Ireland highlighted the importance of accurate application rates of fertiliser for successful arable farming. Their evaluation listed developing information on the nutrient profile of the manure and dairy sludges versus synthetic fertilisers as important, as, from this, appropriate application rates could be deduced. The assessment noted that currently this information is at a developmental stage.

When evaluating the feedback from the NTF survey for Northern Europe 21% of respondents selected economic considerations as a disadvantage; 53% of participants listed the absence of grant supports as a challenge; the practicability of the technology was listed by 32% of the respondents as a barrier to uptake; the legal framework requirements were listed by 47% of the respondents as an obstacle; the knowledge required to implement the technology was selected by 84% of the respondents as a disadvantage to uptake; 10% of the respondents considered the technology as an example of too much work for too little gain; the social acceptability of the technology was listed by 26% of the respondents as a barrier to uptake.

Table 27. Main expert evaluation challenges of technology no.3 for Northern Europe

Challenges of Technology Uptake	**Denmark**	**Ireland**
Dairy processors may have alternative uses for sludge	✓	
Further research on nutrient quality of sludges required		✓

Southern Europe

Foreseen Benefits in Technology Adoption

The Italian evaluation, provided by staff from the University of Milan, highlighted the increased cost and reduced availability of chemical fertilisers experienced in recent months as a significant challenge

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currently facing the farming community. Recycled-derived fertilisers, as used in this technology, offer a possible means of reducing reliance on imported chemical fertilisers. The technology also offers a further avenue for manure usage, which the expert Italian panel noted as beneficial, particularly in regions producing high volumes of animal waste. Furthermore, the Italian assessment stated that by using manure and dairy processing sludge, soil organic matter concentrations are likely to increase which would improve the soils nutrient cycling capacity and health. The expert Spanish panel noted how this technology could align with government legislation such as the Spanish Circular Economy Strategy and assist with increased sustainability and resource use efficiency within Spanish agriculture. As with the Italian assessment, the Spanish evaluation noted the proposed technology using manure and food industry waste products as fertilisers could contribute towards reduced reliance on chemical fertilisers, with no ill effect on crop yields.

When evaluating the feedback from the NTF survey for Southern Europe 67% of respondents considered environmental benefits of the technology as an advantage to adoption; better nutrient management was selected by 81% of respondents, while the economic benefits were also selected by 81% of respondents; 17% of respondents selected better compliance with legal requirements as an advantage; the practicability of the technology was listed by 22% of the respondents as a benefit to uptake; the possibility of new local job opportunities was considered an advantage by 11% of survey respondents; the ability to use the environmental credentials of the technology for marketing was considered benefit to uptake by 8% of the participants; improvements in work-life balance was selected by 6% of respondents as an advantage to this technology; 3% of the respondents considered the social acceptability surrounding the technology as an advantage to technology uptake.

Table 28. Main expert evaluation benefits of technology no.3 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Additional avenue for manure use	✓		
Increased soil health	✓		
Reduced reliance on chemical fertilisers	✓	✓	✓
Complements legislation		✓	

Foreseen Challenges in Technology Adoption

Both the Italian and Spanish assessments listed the cost of transporting bio-based fertilisers as a possible barrier to technology uptake. The Italian panel highlighted the importance of determining the mineral fertilizer replacement rate for organic manures and understood this to be a challenge given the variable nature of organic fertilisers. The Spanish evaluation considered making use of the organic fertilisers may not be appropriate in nitrate vulnerable zones due to their concentration of nitrogen and phosphorus, with the Italian assessment highlighting the need for correct application methods to reduce risk of nutrient losses through emissions. If such technologies are to be developed further, the Italian panel noted legislation and possibly government incentives may need to be established.

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When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	31%
Legal framework requirements	83%
Practicability	28%
Knowledge and skillset required	47%
Absence of grant supports	50%
Too much work for too little reward	11%
Social acceptability	31%

Table 29. Main expert evaluation challenges of technology no.3 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Ensuring correct application rate & method	✓		
Legislation & incentives	✓		
Transportation costs	✓	✓	✓
Not applicable in Nitrate Vulnerable zones		✓	

Eastern Europe

Foreseen Benefits in Technology Adoption

The Hungarian expert assessment, provided by staff from 3R-BioPhosphate Ltd. & SOLTUB Ltd., stated that arable soils within the country are typically farmed using conventional tillage. Losses of SOM is a recognised issue in arable farming within the country. The assessment concluded by stating implementing this technology could assist in increasing SOM and reduce reliance on chemical fertilisers.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	17%
Better nutrient management	83%
Economic benefits	94%
Environmental benefits	89%
New employment opportunities	6%
Improved work-life balance	0%
Practicability	11%
Ability to use environmental credentials as a marketing tool	0%
Social acceptability	0%

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Table 30. Main expert evaluation benefits of technology no.3 for Eastern Europe

Benefits of Technology Uptake	Hungary
Improved soil organic matter	✓
Reduced reliance on chemical fertilisers	✓

Foreseen Challenges in Technology Adoption

The expert evaluation from Hungary listed the storage and transportation of animal manure and dairy sludges as a challenge to technology uptake. An understanding of appropriate manure and sludge application rates was also listed as critical for optimal crop yields. Within the Hungarian assessment the nutrient density of the organic fertilisers was noted as a possible hindrance to technology uptake, as low nutrient density will lead to higher application rates which could lead to the introduction of contaminants into the food system e.g. pathogens in the manure of dairy sludge.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	44%
Legal framework requirements	67%
Practicability	44%
Knowledge and skillset required	50%
Absence of grant supports	83%
Too much work for too little reward	0%
Social acceptability	11%

Table 31. Main expert evaluation challenges of technology no.3 for Eastern Europe

Challenges of Technology Uptake	Hungary
Knowledge of appropriate bio-based application rates for optimal crop yield	✓

Western Europe

Foreseen Benefits in Technology Adoption

Both the Belgian and Dutch evaluations observed that there would be a considerable supply of manure and dairy waste sludge available in each country due to intensive dairy farming enterprises. The Belgian evaluation further stated that such a technology could encourage circular economy principals by recycling nutrients from waste products and reducing reliance on synthetic fertilisers. The German evaluation understood the technology to be a good fit to national aims, such as reduced mineral fertiliser consumption and improved nutrient cycling, if, the dairy processing sludge could gain approval for safe use by the German fertiliser regulators.

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When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	30%
Better nutrient management	85%
Economic benefits	74%
Environmental benefits	59%
New employment opportunities	11%
Improved work-life balance	0%
Practicability	11%
Ability to use environmental credentials as a marketing tool	7%
Social acceptability	19%

Table 32. Main expert evaluation benefits of technology no.3 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Promotes circular economy legislation	✓		
Reduced reliance on chemical fertilisers	✓		✓
Supply of manure & dairy sludge		✓	✓

Foreseen Challenges in Technology Adoption

Due to intensive agricultural systems, soils typically have a high phosphorus concentration in the Netherlands. Therefore, any increased soil phosphorous concentration this technology might provide would be of no advantage to Dutch arable holdings. Additionally, the Dutch assessment stated the increased financial cost associated with processed manures versus raw manures might act as a barrier to technology uptake. Both the Dutch and Belgian assessments noted that strict application rates apply to manure and bio-based fertilisers, with the Belgian panel explaining that due to the Nitrates Directive legislation the volume of manure that can be applied cannot exceed 170 kg N ha-1 yr-1. The evaluation from the German panel listed training in how to appropriately mix and apply the various organic fertilisers described in this technology, while preventing losses in yield or nutrient leaching, could act as a challenge to technology adoption.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	56%
Legal framework requirements	63%
Practicability	48%
Knowledge and skillset required	56%
Absence of grant supports	15%
Too much work for too little reward	30%

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Social acceptability 15%

Table 33. Main expert evaluation challenges of technology no.3 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Application rate limits	✓	✓	
Soil phosphorus levels		✓	
Financial costs vs raw slurry		✓	
Understanding of appropriate application rates			✓

3.2.5 Technology No.4: Floating Wetland Plants Grown on Liquid Agro-Residues as a New Source of Protein

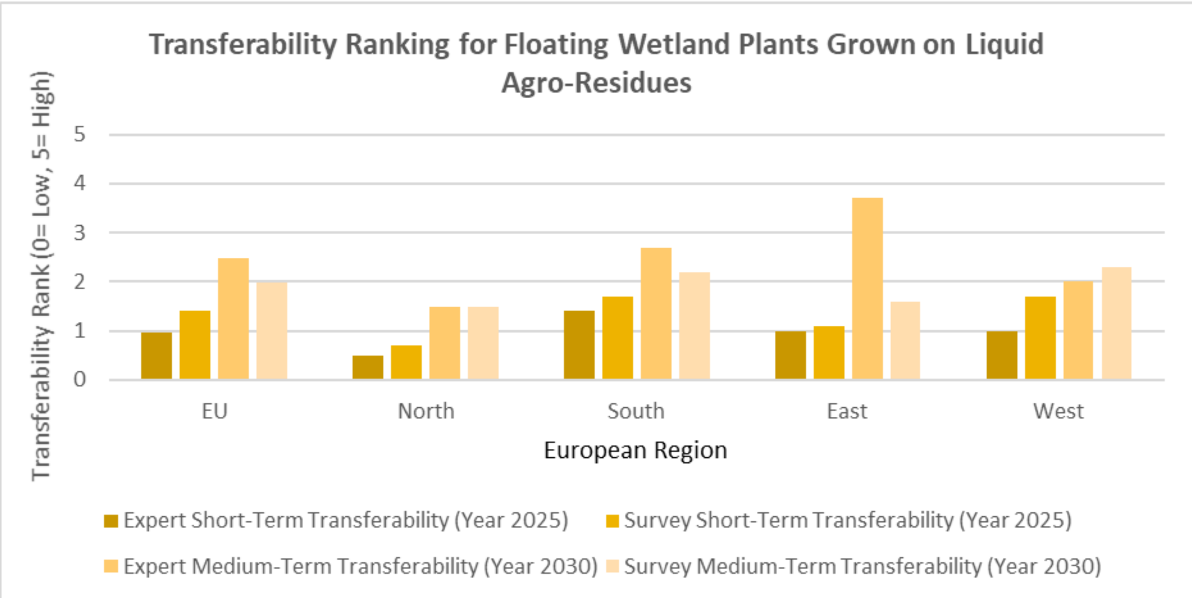

Figure 11. The above bar chart displays the averaged transferability rankings for the floating wetland plants grown on agro-residues as a new protein source technology across Europe

At EU level floating wetland plants grown on liquid agro-residues as a new source of protein garnered one of the joint lowest transferability ranking both in the short-term and medium-term from the expert panels and survey respondents' feedback. In the short- and medium term for both the survey and the expert evaluations this technology is ranked as the 13th most transferable and received a rank of 1 from the expert evaluation and a rank of 1.4 from the survey evaluation for short-term transferability. The technology received a rank of 2.5 from the expert evaluation and a rank of 2 from the survey evaluation for medium-term transferability. The lowest transferability is in Northern

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Europe with a short-term expert rank of 0.5, short-term survey rank of 0.7, medium-term rank of 1.5 for both the expert evaluation and the survey feedback from the NTFs.

3.2.5.1 Floating Wetland Plants - European Wide Evaluation

Foreseen Benefits to Technology Adoption

Both the expert evaluations and survey feedback noted such a technology could contribute towards better nutrient management by utilising available nutrients in waste agro-residues to produce a protein source for animal feed. Presently, the majority of concentrated animal feeds used in Europe contain imported ingredients, such as soya. The evaluators agreed that by producing a local source of animal feed protein a reduction in the reliance on imported animal feed could develop. Further to this, some national governments have introduced polices to encourage research in sourcing alternative protein sources for animal feed, which such a technology could compliment. The evaluators observed an additional benefit of locally produced protein could be reduced transportation emissions from importing non-domestic feed sources. Further benefits of implementing the technology were seen in its compatibility with the aims of the Nutri2Cycle project, such as closing nutrient loops.

Foreseen Challenges to Technology Adoption

A variety of challenges were foreseen in successful implementation of the technology, including practical aspects such as the land area such a technology would require in order to produce sizable quantities of protein when considering the cost of land throughout Europe. It was observed that legislation may need to be developed in order to ensure protein derived from algae plants is a safe feed source for livestock animals. There were also concerns over the possibility of odours and emissions, such as methane, being released from the open wetland design. The technology was considered to have more scope if the wetland plants could extract nutrients from a variety of feedstocks including wastewaters, as opposed to animal manures, as primarily animal manures are already used as fertilisers. The need for using a native variety of duckweed was also highlighted within the assessments to prevent the introduction of a non-native species.

3.2.5.2 Floating Wetland Plants - European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The Danish expert evaluation, provided by staff from the University of Copenhagen, could only offer limited feedback for this proposed technology. Within their assessment they stated their experts currently did not have enough insight regarding this technology in order to fully assess its suitability for the Danish market. The Irish expert evaluation, provided by staff from Teagasc, thought the

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technology may have more scope in Ireland if it could be adopted to a feedstock of wastewater from treatment plants as pig slurry is mainly consumed as an organic fertiliser presently within the country.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	28%
Better nutrient management	44%
Economic benefits	28%
Environmental benefits	61%
New employment opportunities	50%
Improved work-life balance	0%
Practicability	17%
Ability to use environmental credentials as a marketing tool	50%
Social acceptability	22%

Foreseen Challenges to Technology Adoption

Although the feedback from Denmark was limited, they did list the financial cost of establishing the infrastructure as a potential challenge with regards to technology update. The Irish assessment also listed financial investment costs as a barrier to uptake. Furthermore, the Danish panel listed labour units required to operate the system and the subsequent training said labour units would need as potential challenges in technology uptake. The Irish evaluation noted that the design of pond holding system for pig manure could result in increased emissions and may also lead to issues with odour which could hamper acceptability of such technologies within the community. The Irish panel also noted the importance of using a native variety of duckweed to avoid promoting the spread of a non-native variety.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	74%
Legal framework requirements	58%
Practicability	47%
Knowledge and skillset required	42%
Absence of grant supports	32%
Too much work for too little reward	21%
Social acceptability	16%

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Table 34. Main expert evaluation challenges of technology no.4 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Operator Skillset	✓	
Labour Units	✓	
Financial Cost	✓	✓
Emissions and Odour from Pond System		✓

Southern Europe

Foreseen Benefits to Technology Adoption

The expert evaluation from Spain, provided by members of IRTA, highlighted a benefit of the technology as a means to close nutrient loops by removing nutrients from agriculture wastewaters and producing a potential animal feed source with a protein content of 35% DM. Additionally, the production of duckweed as a local feed source could reduce the reliance on imported animal feed. The expert assessment from Italy, provided by staff form the University of Milan, also highlighted the potential benefits of this technology by way of producing local protein that has a low heavy metals concentration. Within Spain, it was stated that the technology is currently undergoing trials at a pilot plant.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	28%
Better nutrient management	81%
Economic benefits	47%
Environmental benefits	61%
New employment opportunities	31%
Improved work-life balance	11%
Practicability	19%
Ability to use environmental credentials as a marketing tool	6%
Social acceptability	6%

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Table 35. Main expert evaluation benefits of technology no.4 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Quality protein source	✓		
Close nutrient loops		✓	
High protein content		✓	
Reduced reliance on imported feed		✓	

Foreseen Challenges to Technology Adoption

Both assessments from Italy and Spain noted that any potential emissions associated with a pond of agro-residues (pig manure) would need to be assessed if considering adopting this technology. The Italian panel also listed potential odours from the system as a possible barrier. Within their evaluations both panels from Italy and Spain noted that legislation around the use of duckweed as a feed source for animals would need to be developed to ensure that it is a safe option. Both panels also listed the treatment of the feedstock (pig manure) as potential challenges; the Spanish panel stated that pig manure needs to be diluted for duckweed to be feed from it and this then increases the storage volume required for the technology, while the Italian panel wondered how the post-treatment feedstock, or any by-products, are managed or safely released into the environment. The Italian panel also highlighted the need to use native species of duckweed to avoid introduction of a non-native variety. Additionally, the evaluation from Spain noted the financial cost of investing in the infrastructure required along with the necessary training as further challenges in adoption of this technology.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	50%
Legal framework requirements	56%
Practicability	56%
Knowledge and skillset required	50%
Absence of grant supports	25%
Too much work for too little reward	33%
Social acceptability	22%

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Table 36. Main expert evaluation challenges of technology no.4 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Odours	✓		
Ensuring native species only	✓		
Emissions	✓	✓	
Legislation	✓	✓	
Land area required		✓	
Financial cost		✓	
Operator Skillset		✓	

Eastern Europe

Foreseen Benefits to Technology Adoption

The Hungarian expert evaluation was provided by staff from the environmental company 3R-BioPhosphate Ltd & SOLTUB Ltd. In terms of assessing the fit of the technology into the Hungarian agricultural landscape the evaluators noted it was difficult to secure planning permission or permits for such developments in Hungary.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	0%
Better nutrient management	72%
Economic benefits	50%
Environmental benefits	94%
New employment opportunities	17%
Improved work-life balance	17%
Practicability	22%
Ability to use environmental credentials as a marketing tool	11%
Social acceptability	17%

Foreseen Challenges to Technology Adoption

The expert evaluation stated the financial cost of developing/ establishing the technology could be a barrier in adoption with Hungary. Emissions from the floating wetland such as methane, ammonia and odours along with the safety aspect of using duckweed protein as an animal feed stuff were also listed as the challenges in successful adoption of this technology in Hungary.

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When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	39%
Legal framework requirements	17%
Practicability	83%
Knowledge and skillset required	44%
Absence of grant supports	67%
Too much work for too little reward	50%
Social acceptability	0%

Table 37. Main expert evaluation challenges of technology no.4 for Eastern Europe

Challenges of Technology Uptake	Hungary
Investment cost	✓
Emissions	✓
Safety of Product	✓

Western Europe

Foreseen Benefits to Technology Adoption

Members of 'Inagro', a Belgian agricultural research and advisory company, provided the expert assessment for Belgium. Their assessment of the technology found that it aligned with recent legislation in developing new protein sources, such as the Protein Transition Roadmap. Further to this, the Belgian evaluation noted such a technology would contribute towards closing nutrient loops by utilising available nutrients in agricultural wastewaters to produce a novel protein. The evaluator remarked on the high protein content of duckweed as 30-35%. The Dutch assessment, provided by staff from Wageningen University, recognised a need to reduce reliance on imported animal feed stocks. Their evaluation stated reducing importation of animal feed could also reduce related transportation emissions, such as carbon dioxide and methane. The German evaluation, provided by staff from the Thünen Institute, noted the technology may have scope for adoption if it could work with a variety of feedstocks.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	12%
Better nutrient management	56%
Economic benefits	32%
Environmental benefits	76%
New employment opportunities	24%
Improved work-life balance	4%
Practicability	20%

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Ability to use environmental credentials as a marketing tool	60%
Social acceptability	28%

Table 38. Main expert evaluation benefits of technology no.4 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Compliments legislation	✓		
Close nutrient loops	✓		
Quality feed	✓		
Need to reduce reliance on imported protein feed		✓	

Foreseen Challenges to Technology Adoption

Within both the Belgian and German evaluations, the financial costs associated with establishing this technology were considered challenges to adoption. The German panel considered the open storage of agro-residues to be undesirable, as it could result in methane and ammonia emissions. The expert evaluation from Belgium and the Netherlands both highlighted the land area such a technology could require and the challenges in allocating such area due to other pressures, such as the cost of land. Due to the volume of protein produced the Dutch evaluation understood the technology to remain a niche market, while the Belgian assessment stated legislation may need to be developed to ensure the protein produced is a safe ingredient in livestock feed.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	59%
Legal framework requirements	52%
Practicability	70%
Knowledge and skillset required	44%
Absence of grant supports	22%
Too much work for too little reward	33%
Social acceptability	7%

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Table 39. Main expert evaluation challenges of technology no.4 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Legislation for safe use	✓		
Financial costs	✓		✓
Emissions from pond system			✓
Land area required	✓	✓	
Niche Technology		✓	

3.2.6 Technology no. 5: Algae Grown on Liquid Agro-Residues as a New Source of Protein

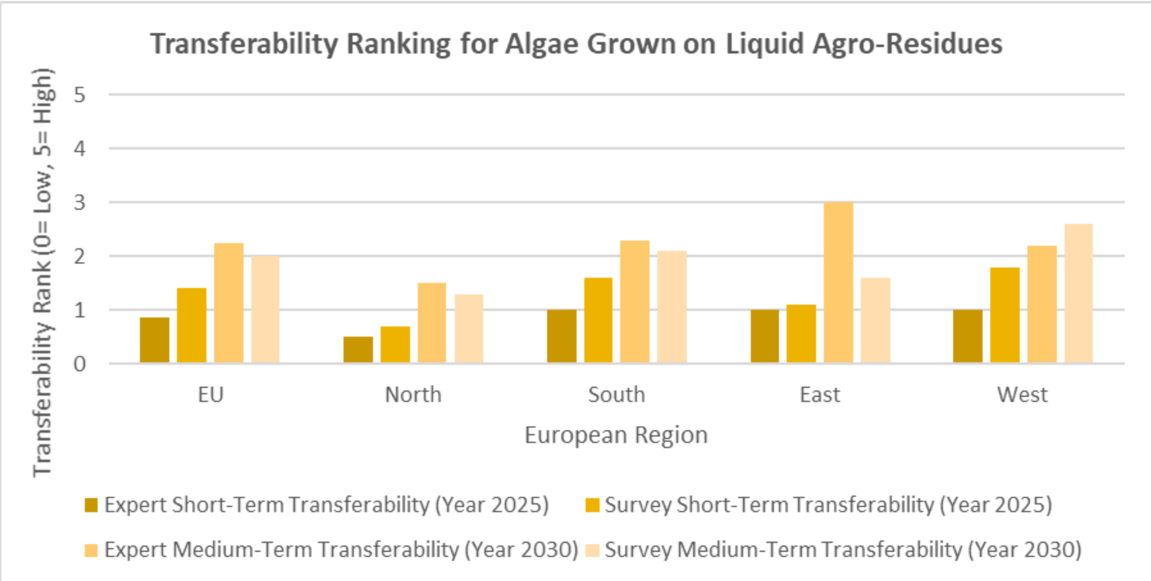

Figure 12. The above bar chart displays the averaged transferability rankings for the algae grown on liquid agro-residues as a new source of protein technology across Europe.

Algae grown on liquid agro-residues as a new source of protein received the lowest transferability ranking within all four ranking conditions for the European wide average (see figure 3). Figure 42 shows that the transferability of this technology is comparably high in Southern and Western Europe in the short- and medium-term. The lowest transferability is in Northern Europe with a short-term expert rank of 0.5, short-term survey rank of 0.7, medium-term expert rank of 1.5 and medium-term survey rank of 1.3 from the NTFs.

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3.2.6.1 Algae Technology – European Wide Evaluation

Foreseen Benefits to Technology Adoption

Within the expert and national taskforce survey evaluations, this technology's main benefit was seen as closing nutrient loops by transforming waste agro-residues into novel protein feed. The evaluations accepted producing native livestock protein feed as a valid research topic considering Europe's dependency on imported concentrate livestock feed. Furthermore, a foreseen benefit in adoption of technology no.5 was listed as the ability to market the technology and the protein produced on its green or sustainable credentials. Such products tend to command a higher price than conventional products, which could mitigate for the small scale of protein produce.

Foreseen Challenges to Technology Adoption

The technology also has the joint lowest technology readiness level of 4, the other technology with a readiness level of 4 is technology no.8. Although the lighthouse demonstration had some foreseeable benefits and satisfied research line 5, within the expert and national taskforce surveys it was considered too complicated to anticipate wide transferability across Europe. The volume of protein produced and the legislation uncertainty as to approving algae as an alternative animal feed contributed towards the low transferability ranking obtained.

3.2.6.2 Algae Technology – European Regional Evaluation

Northern Europe

Foreseen Benefits in Adoption of Technology

The Danish expert evaluation, provided by staff from the University of Copenhagen, stated that currently within the country there are other research and development projects being undertaken in relation to algae cultivation, which could assist in the transferability of this specific technology described. The expert evaluation from Ireland, provided by staff members from Teagasc, observed that producing protein within the E.U. from nutrient rich digestate could satisfy two policy aims, namely, increased self-sufficiency by means of reduced importation of protein sources and also closure of CNP loops by using nutrients available in agro-residues to grow a new protein source.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	21%
Better nutrient management	58%
Economic benefits	42%
Environmental benefits	79%
New employment opportunities	58%
Improved work-life balance	0%
Practicability	0%
Ability to use environmental credentials as a marketing tool	32%
Social acceptability	5%

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Table 40. Main expert evaluation benefits of technology no.5 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Danish research institutions also investigating such technology	✓	
Promoting self-sufficiency		✓
Close nutrient loops		✓
Novel protein production		✓

Foreseen Challenges in Adoption of Technology

The Denmark assessment listed the financial cost of establishing such a technology, along with the trained labour required to operate the facility, as the main foreseeable challenges with regards to technology uptake. The Irish assessment also listed the investment costs required as a barrier to technology adoption. Furthermore, the Irish panel thought the use of cattle slurry as a form of agro-residue feedstock would be limited as most of the slurry produced is already used as fertiliser within the country. The Irish panel queried how inconsistencies in the nutrient value of agro-residues could be overcome and furthermore how the agro-residues would be stored before use in order to minimise losses of nitrogen and phosphorous through emissions.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	68%
Legal framework requirements	47%
Practicability	68%
Knowledge and skillset required	53%
Absence of grant supports	37%
Too much work for too little reward	16%
Social acceptability	11%

Table 41. Main expert evaluation challenges of technology no.5 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Operator skillset	✓	
Financial cost	✓	✓
Agro-residue options, storage and quality		✓

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Southern Europe

Foreseen Benefits in Adoption of the Technology

Both evaluations from Italy and Spain considered the production of local protein to be a considerable advantage to this technology. The evaluations noted by producing local protein for animal feed Italy and Spain could reduce their respective reliance on imported feedstuff and reduce the energy demands associated with feed transportation. In terms of using livestock waste as a potential feedstock both Spain and Italy considered this a positive of the technology, as within Italy spreading livestock waste as fertiliser is coming under growing scrutiny due to application limits and decreased availability of land area on which to spread. In Spain, legislation has been introduced to protect waterways from nutrient enrichment, which has resulted in restrictions in fertiliser application rates within certain vulnerable regions. In both nations using livestock waste as a feedstock for algae production could be seen as a way to divert superfluous volumes of this waste into a new industry. According to the Spanish expert panel, this technology would be a suitable fit to Spain's warm, sunny climate, as the algae need both light and warmth to grow.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	19%
Better nutrient management	86%
Economic benefits	47%
Environmental benefits	64%
New employment opportunities	42%
Improved work-life balance	6%
Practicability	3%
Ability to use environmental credentials as a marketing tool	19%
Social acceptability	6%

Table 42. Main expert evaluation benefits of technology no.5 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Local protein	✓	✓	
Reduced reliance on protein imports	✓	✓	
Additional avenue for manure processing	✓	✓	
Complimentary Spanish climate		✓	

Foreseen Challenges in Adoption of the Technology

All three assessments from Italy, Portugal and Spain considered the technical aspect of operating such a facility as a challenge. Within the Italian evaluation, it was noted that the composition of agro-residues can vary but measures would need to be taken to prevent contamination of the algae pool

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or the introduction of an undesired algae species. The Spanish evaluation stated operating the plant would require training, and, additional processing stages such as pre-treatment steps could be required, especially when working with pig slurry as it is considered too concentrated for algae to successfully feed on. Furthermore, both Italy and Spain considered the current financial cost of producing the product versus the volume of product produced as a current hindrance. The Italian expert panel also noted a legal framework centred on using algae grown from agro-resides as an animal feed would need to be developed.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	61%
Legal framework requirements	67%
Practicability	53%
Knowledge and skillset required	53%
Absence of grant supports	31%
Too much work for too little reward	14%
Social acceptability	8%

Table 43. Main expert evaluation challenges of technology no.5 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Agro-residue quality	✓		
Legislation	✓		
Financial cost	✓	✓	✓
Operating training	✓	✓	✓
Scale of production	✓		✓
Agro-residue pre-treatment		✓	

Eastern Europe

Foreseen Benefits to Technology Adoption

The Hungarian expert evaluation was provided by staff from the environmental company 3R-BioPhosphate Ltd. In terms of assessing the fit of the technology into the Hungarian agricultural landscape, the evaluators noted it was difficult to secure planning permission or permits for such developments in Hungary.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	11%

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Better nutrient management	78%
Economic benefits	56%
Environmental benefits	94%
New employment opportunities	17%
Improved work-life balance	11%
Practicability	22%
Ability to use environmental credentials as a marketing tool	5%
Social acceptability	5%

<u>Foreseen Challenges to Technology Adoption</u>

The expert evaluation stated the financial cost of establishing the technology could be a barrier in adoption within Hungary. Additionally, when using agro-residues as the feedstock, measures to prevent pollutants and contaminates entering into the algae growth chambers would need to be taken. The safety aspect of using algae fed from agro-residues as an animal feed stuff was also noted as a possible barrier to technology adoption.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	33%
Legal framework requirements	17%
Practicability	56%
Knowledge and skillset required	56%
Absence of grant supports	83%
Too much work for too little reward	56%
Social acceptability	0%

Table 44. Main expert evaluation challenges of technology no.5 for Eastern Europe

Challenges of Technology Uptake	**Hungary**
Investment cost	✓
Risk of contamination of growth chambers	✓
Safety of Product	✓

Western Europe

<u>Foreseen Benefits in Successful Adoption of the Technology</u>

The expert assessment from Belgium was provided by members of 'Inagro', a Belgian agricultural research and advisory company. Within their evaluation they stated implementing such a technology could contribute to national goals of encouraging circular economics, by creating a useful product from a waste product, and, contribute towards nutrient loop closing, with the algae being fed from

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agro-residues and digestates. Also, the Belgian assessment noted how such a technology could ease pressures on regions with surplus livestock waste. The evaluation from the Netherlands, provided by staff from Wageningen University, also listed production of local protein and reduced reliance on imported supplies as a benefit to this technology. The German assessment, provided by members of the Thünen Institute, considered using algae as an animal feed product may lead to reductions in methane produced by ruminants, based on studies done to date on macroalgae such as seaweed.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	19%
Better nutrient management	58%
Economic benefits	31%
Environmental benefits	69%
New employment opportunities	31%
Improved work-life balance	4%
Practicability	4%
Ability to use environmental credentials as a marketing tool	54%
Social acceptability	35%

Table 45. Main expert evaluation benefits of technology no.5 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Close nutrient loops	✓		
Resolve nutrient surpluses	✓		
Local protein production	✓	✓	✓
Quality animal feed			✓
Increased self-sufficiency		✓	

<u>Foreseen Challenges in Successful Adoption of the Technology</u>

Within all three expert assessments the financial costs associated with installing and operating the technology, along with the presently limited production streams for algae, were listed as challenges in terms of technology uptake. The German evaluation also stated that the consumer may not be accepting of products from algae fed from agriculture digestates and residues due to hygiene reasons. Within the Dutch evaluation the economic competitiveness of the technology was queried particularly

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when considering competition from other protein feed sources and the length of the growing season in the Netherlands.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	78%
Legal framework requirements	48%
Practicability	63%
Knowledge and skillset required	52%
Absence of grant supports	26%
Too much work for too little reward	26%
Social acceptability	7%

Table 46. Main expert evaluation challenges of technology no.5 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Limited commercial application to date	✓		
Marketability			✓
Financial Cost	✓	✓	✓
Length of growing season		✓	
Cost competitiveness		✓	

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3.2.7 Technology no. 6: Using Recycling-Derived Fertilisers Ammonium Nitrate, Ammonium Sulphate, Digestate from Co-Digestion of Pig Manure & Liquid Fraction of Digestate

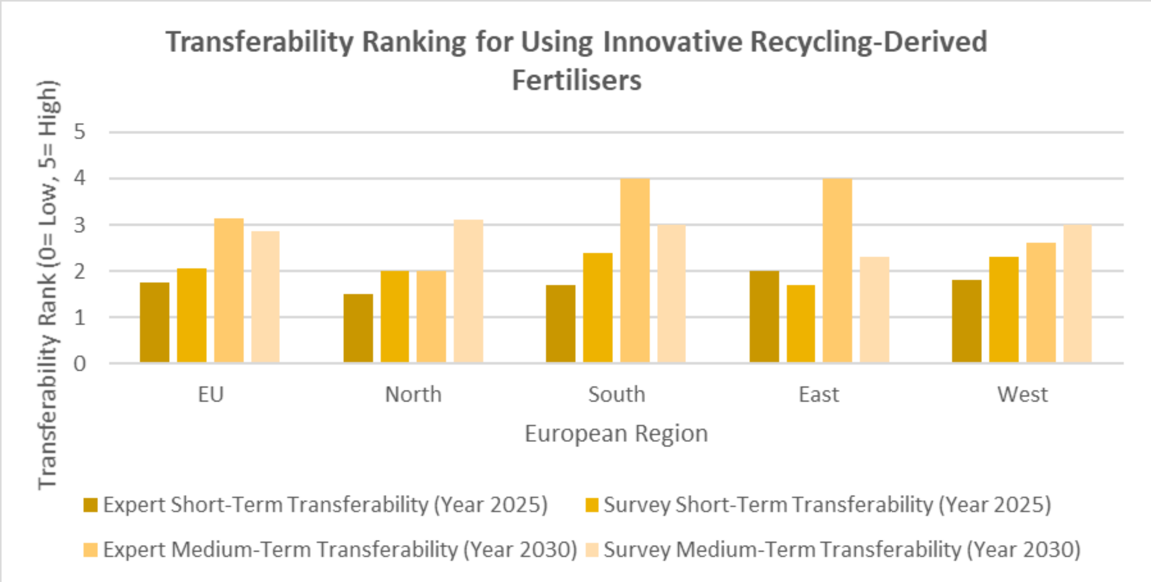

Figure 13. The above bar chart displays the averaged transferability rankings for the using recycling-derived fertilisers ammonium nitrate, ammonium sulphate, digestate from co-digestion of pig manure & liquid fraction of digestate technology across Europe.

This technology consistently ranked between 4th and 7th throughout the averaged transferability ranking across Europe (see figures 4-7). Figure 50 shows that using recycling-derived fertilisers could be particularly relevant for Southern Europe with short-term expert rank of 1.7, short-term survey rank of 2.4, medium-term expert rank of 4 and medium-term survey rank of 3.

3.2.7.1 Pig Manure Liquid Fractions - European Wide Evaluation

Foreseen Benefits to Technology Adoption

The transferability rankings indicate there is interest in such a technology and benefits to its adoption. Namely within the expert and stakeholder survey evaluations improved nutrient management, reduced reliance on synthetic fertilisers, alternative avenues to manure processing, suitability for use in high phosphorous soils and promotion of circular economy principals were listed as some of the foreseen benefits.

Foreseen Challenges to Technology Adoption

As with many of the technologies, the investment cost was considered a barrier to uptake. Furthermore, the skillset and training required to operate the technologies required too provided hindrances, as it was highlighted that such skills are not readily available within the farming community. Within certain legislation manure derived fertilizers are classified, in terms of maximum

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application rates, as manure. This classification system may need to be reassessed by policy makers in order to promote RDFs usage.

3.2.7.2 Pig Manure Liquid Fractions - European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The Danish expert evaluation, provided by staff from the University of Copenhagen, observed that farmers in Denmark are well accustomed to using manures and slurries as fertilisers and therefore would have the skill and equipment to apply certain RDFs e.g. digestates. The evaluation further stated that within Denmark some soils have displayed elevated phosphorus levels, with the majority of cases associated with intensive pig farms. As a result, phosphorus application limits have been established across the country in order to inhibit further elevations of soil phosphorous. Additionally, the Danish agricultural community is familiar with anaerobic digestion and the digestate products produced, which would assist in uptake of the technology described. From the Irish panel assessment, provided by staff from Teagasc, it was understood that the technology may have scope within the country, particularly on intensive farming operations where large volumes of livestock waste are produced and sufficient near-by land area is not available for manure spreading. The Irish evaluation further noted concentrated RDF's could also be used in arable farming systems, which would provide another avenue for excess manure use.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	17%
Better nutrient management	89%
Economic benefits	78%
Environmental benefits	78%
New employment opportunities	17%
Improved work-life balance	0%
Practicability	0%
Ability to use environmental credentials as a marketing tool	17%
Social acceptability	0%

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Table 47. Main expert evaluation benefits of technology no.6 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Familiarity with digestate	✓	
Solution to excess manure	✓	✓
Excess animal manure offloaded to arable holdings		✓

Foreseen Challenges to Technology Adoption

Both the Danish and Irish evaluations foresaw the skill required to manage, handle and apply the four RDF's trialled in this technology as a potential challenge for farmers. Both nations' experts also considered the cost of processed manure, when compared against the cost of raw manure or chemical fertilisers as a barrier to technology uptake. Additionally, both evaluations listed the financial cost associated with the required infrastructure as a significant barrier, with Ireland's assessment noting there is a low availability of solid-liquid manure separators in the country.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	50%
Legal framework requirements	33%
Practicability	67%
Knowledge and skillset required	61%
Absence of grant supports	56%
Too much work for too little reward	17%
Social acceptability	6%

Table 48. Main expert evaluation challenges of technology no.6 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Financial cost	✓	✓
Skillset required	✓	✓
Unfamiliar with equipment/ infrastructure required		✓

Southern Europe

Foreseen Benefits to Technology Adoption

All three national panels considered the technology to have potential in terms of supplementing and possibly replacing synthetic fertilisers currently used in agriculture. The Spanish assessment, provided

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by staff from IRTA, noted that legislation limits application of animal manure on areas designated as Nitrate Vulnerable Zones. However, in order to encourage biogas production, digestate has been granted special allowances over raw animal manure. Therefore, with guidance from agricultural authorities, digestate could be applied more widely than conventional animal manure or slurry. The Italian expert assessment, provided by staff form the University of Milan, observed the technology could compliment the RENURE (Recovered Nitrogen from Manure) programme if such RDF's could obtain safe use status in Nitrate Vulnerable Zones.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	25%
Better nutrient management	84%
Economic benefits	63%
Environmental benefits	81%
New employment opportunities	9%
Improved work-life balance	6%
Practicability	3%
Ability to use environmental credentials as a marketing tool	13%
Social acceptability	6%

Table 49. Main expert evaluation benefits of technology no.6 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Possibly applicable in nitrate vulnerable zones	✓		
Reduced reliance on chemical fertilisers	✓	✓	✓
Use of digestate fertilisers encouraged		✓	

Foreseen Challenges to Technology Adoption

The Portuguese assessment, provided by staff from the University of Lisbon, observed the technology required investment in processing infrastructure such as anaerobic digestion plants, which could act as a barrier to technology adoption. Likewise, the Italian assessment noted the high investment costs such a technology could entail due to the array of infrastructure required for producing the four RDF's trialled. Furthermore, it was noted that in order to fully capitalise on RDF's, farm operators would need training in precision agricultural practices such as correct application rates. Both the Italian and Spanish evaluations observed that RDF's may carry with them application rate limits, as under legislation manure derived RDF's are classified as manures. This may limit RDF's suitability in certain regions and discourage interest in the technology. The Spanish evaluation highlighted the need to undertake further research in order to match best RDF's with specific crop types, which would help promote the use of recycle-derived fertilisers.

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When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	47%
Legal framework requirements	59%
Practicability	50%
Knowledge and skillset required	63%
Absence of grant supports	31%
Too much work for too little reward	13%
Social acceptability	19%

Table 50. Main expert evaluation challenges of technology no.6 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Operator skillset	✓		
Infrastructure investment costs	✓		✓
Classification of RDF's	✓	✓	
Application rate limits	✓	✓	
Further research required		✓	

Eastern Europe

Foreseen Benefits to Technology Adoption

The Hungarian expert evaluation, provided by staff from 3R-BioPhosphate Ltd. & SOLTUB Ltd., stated how developing such RDFs could allow for greater input of nitrogen from animal farming systems into arable farming systems than what is presently being achieved.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	14%
Better nutrient management	67%
Economic benefits	86%
Environmental benefits	76%
New employment opportunities	14%
Improved work-life balance	14%
Practicability	10%
Ability to use environmental credentials as a marketing tool	14%
Social acceptability	5%

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Table 51. Main expert evaluation benefits of technology no.6 for Eastern Europe

Benefits of Technology Uptake	Hungary
Greater utilisation of animal manures on arable farms	✓

Foreseen Challenges to Technology Adoption

The evaluation from Hungary listed a lack of familiarity with the skills required to produce RDF's, such as ammonium stripping, as a barrier to technology adoption. As a result, operator training and knowledge transfer would need to be undertaken. The assessment further stated that any recycle-derived fertilisers need to be homogenous in quality, safe to handle and stable during storage periods in order to act as a substitute for synthetic fertilisers.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	48%
Legal framework requirements	43%
Practicability	62%
Knowledge and skillset required	52%
Absence of grant supports	71%
Too much work for too little reward	14%
Social acceptability	10%

Table 52. Main expert evaluation challenges of technology no.6 for Eastern Europe

Challenges of Technology Uptake	Hungary
Operator skillset	✓
Consistency of RDFs	✓
Storage and handling of RDFs	✓

Western Europe

Foreseen Benefits to Technology Adoption

The German evaluation, provided by staff from Thünen Institute, listed the production cost for ammonium nitrate of 0.65-0.75 €/kg N as a positive development from this technology. Further to this, the German evaluation reiterated findings of the demonstration stating that during the trial the RDFs had the same impact on crop yield as mineral fertiliser had. The expert evaluation from the Netherlands stated such a technology could compliment current national infrastructure such as AD plants with Dutch famers also familiar with the concept of manure processing. Due to intensive agricultural practices, many soils in the Netherlands are rich in phosphorus and therefore developing

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a RDF programme that is both low in phosphorous but provides adequate reliable nitrogen would have a market in the country. Such a RDF product also would align with national legislation such as promoting the circular economy in the agricultural sector. The expert review from Belgium, provided by staff from Ghent University, listed some findings from the technology trial as indicators of the benefits such a technology could provide, such as a similar risk of nitrate leaching and comparable crop yields when using RDF's versus mineral fertilisers. The Belgian assessment further noted by encouraging the use of nitrogen recycling-derived fertiliser's reliance on synthetic nitrogen fertilisers could reduce.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	20%
Better nutrient management	75%
Economic benefits	70%
Environmental benefits	50%
New employment opportunities	10%
Improved work-life balance	10%
Practicability	5%
Ability to use environmental credentials as a marketing tool	30%
Social acceptability	20%

Table 53. Main expert evaluation benefits of technology no.6 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Reduced reliance on chemical fertilisers	✓		
No increased risk of nitrate leaching	✓		
Comparable crop yields vs mineral fertiliser	✓		✓
Reasonable production cost for ammonium nitrate			✓
Compliments current infrastructure		✓	
Familiarity with manure processing		✓	
Suitable for soils high in phosphorous		✓	
Promotes circular economy		✓	

<u>Foreseen Challenges to Technology Adoption</u>

The Belgian review considered the main challenge associated with the successful adoption of this technology as the classification of the various RDF's. At present only ammonium sulphate from air scrubbing technology is authorised as a substitute for chemical nitrogen fertilisers, as within the

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legislation it is identified as a product of air scrubbing, as opposed to a manure based product. The Belgian assessment stated the proposed RENURE programme may amend legislation to allow ammonium nitrate and ammonium sulphate from stripping-scrubbing technologies to be authorised as a substitute for chemical nitrogen fertiliser. Such modifications to legislation would give the technology more scope within the country. The German evaluation noted the RDF's would need to display such qualities as consistent grade, stability, safe to handle and homogeneity in nature for easier spreading in order to be used as a chemical fertiliser substitute. The Dutch expert assessment noted processed manure products are often more expensive than traditional chemical fertilisers which could act as a barrier to technology uptake within the farming community.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	40%
Legal framework requirements	75%
Practicability	50%
Knowledge and skillset required	40%
Absence of grant supports	30%
Too much work for too little reward	25%
Social acceptability	20%

Table 54. Main expert evaluation challenges of technology no.6 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Legislation classifying RDF's	✓		
Consistency, homogeneity, stability and safety qualities of RDF's			✓
Cost of processed manure vs chemical fertilisers		✓	

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3.2.8 Technology No.7 Using Bio-Based Fertilisers to Optimise the Organic Carbon Storage in Soil and N, P Cycling

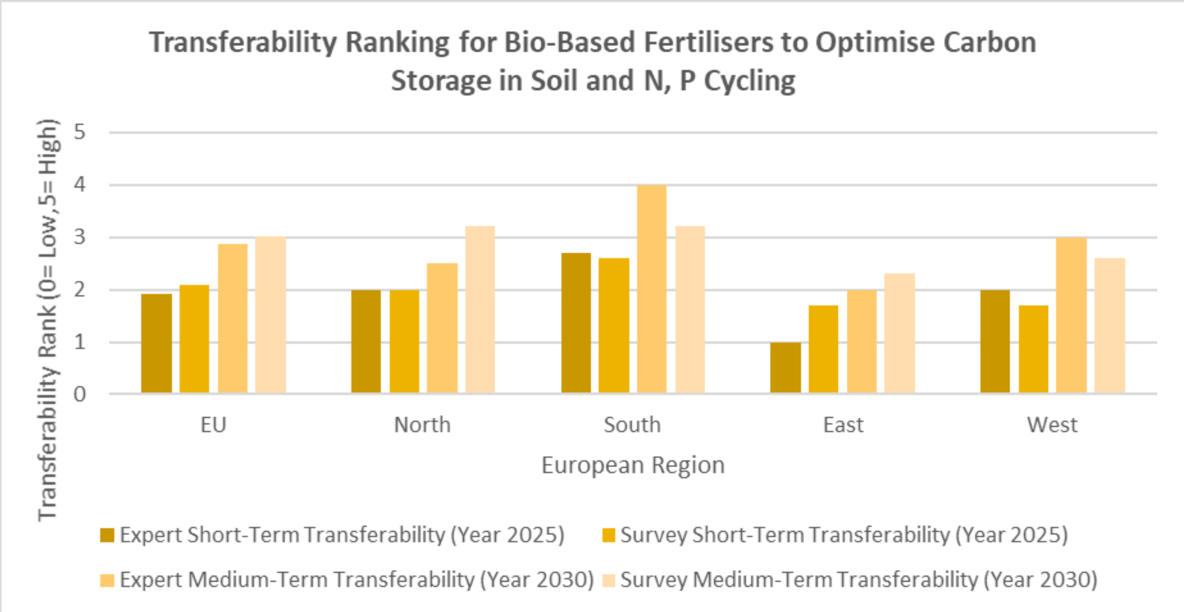

Figure 14. The above bar chart displays the averaged transferability rankings for the using bio-based fertilisers to optimise the organic carbon storage in soil and N, P cycling technology across Europe.

At EU level the short-term transferability for the bio-based fertilisers technology to optimise carbon storage in soil and N, P cycling is comparably high, ranked as the 5th most transferable technology for both the expert evaluation and the survey feedback from the NTFs. In the medium-term the survey results showed that the transferability is also comparably high (4th rank). The expert evaluation however showed that the transferability of other technologies in the medium-term is higher as the technology is only ranked 10th most transferable out of the 14 innovations. In figure 59 it can be seen that such bio-based fertiliser technologies to optimise carbon storage in soil and N, P cycling could be particularly relevant to Southern Europe. The transferability of this technology is lowest in Eastern Europe with a short-term expert rank of 1, short-term survey rank of 1.7, medium-term expert rank of 2 and medium-term survey rank of 2.3.

3.2.8.1 Bio-Based Fertilisers – European Wide Evaluation

Foreseen Benefits to Technology Adoption

Even though the case study for technology no. 7 is quite specific i.e. using oil seed cake, goose slurry and solid goose manure as an organic fertilisers in vineyards and agroforestry settings, the technology is consistently ranked within the mid-range. This highlights the interdisciplinary nature of some of the technologies and how different regions may adapt a lighthouse demonstration to suit different agricultural practices. For example within Ireland's assessment it was made clear that the nation has very few vineyards and almost no commercial goose production units, yet because the expert evaluators understood that the principal of the demonstration is using bio-based fertilisers to close

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nitrogen and phosphorous cycles they ranked the technology 4 out 5 in terms of medium-term transferability. The Irish evaluation noted if different fertilisers and production systems could be used then the technology premise would have scope within the region. Benefits illustrated within the expert and stakeholder survey evaluations were centred on promotion of nutrient cycling and circular economy goals. Improvements in soil health and quality, which also feeds into better nutrient management was also listed as a benefit to uptake.

Foreseen Challenges to Technology Adoption

Inconsistencies in the nutrient value of bio-based fertilisers was considered a significant barrier to production, especially in orchard fruit production setting. Furthermore, the possibility of increased labour units and training requirements by introducing animals into an orchard/ agroforestry setting was listed as a challenge to technology uptake. Additionally it was noted oil seed cake can be used as a form of livestock feed.

3.2.8.2 Bio-Based Fertilisers – European Regional Evaluation

Northern Europe

Foreseen Benefits in Technology Adoption

The Irish assessment, provided by staff from Teagasc, noted benefits this technology could provide in terms of assisting national policy by encouraging circular economics and a bio-economy where resources are recycled. The Irish assessment also concluded the technology could assist in nutrient cycling on farms.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	24%
Better nutrient management	76%
Economic benefits	65%
Environmental benefits	76%
New employment opportunities	0%
Improved work-life balance	6%
Practicability	18%
Ability to use environmental credentials as a marketing tool	12%
Social acceptability	24%

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Table 55. Main expert evaluation benefits of technology no.7 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Compliments circular economy principals		✓
Recycling of nutrients		✓

Foreseen Challenges in Technology Adoption

The Danish expert evaluation, provided by staff from the University of Copenhagen, did not consider the technology applicable to Denmark, as Denmark does not have a significant amount of the forms of agriculture discussed, such as goose farming, agroforestry or vineyards. Likewise, the Irish assessment highlighted the nation's limited goose production and vineyard enterprises as barriers to this technologies adoption but queried if the technology could be applied to different farming systems. If so, then the technology may have scope within the country.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	35%
Legal framework requirements	24%
Practicability	65%
Knowledge and skillset required	59%
Absence of grant supports	47%
Too much work for too little reward	35%
Social acceptability	24%

Table 56. Main expert evaluation challenges of technology no.7 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Agro-typologies trialled not widespread in native country	✓	✓

Southern Europe

Foreseen Benefits in Technology Adoption

Both the Italian and Spanish expert evaluations stated that adopting such a technology could assist in promoting Circular Economy principals and the closing of nutrient cycles within each nation state. The Spanish evaluation noted such a technology aligns with government legislation, namely the Spanish Circular Economy Strategy that aims to tackle waste generation & losses of resources by promoting modified production and consumption systems. In addition, both the Italian and Spanish assessments noted implementing such a technology could improve the soil organic matter content. The Spanish

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evaluation stated that approximately 50 percent of soils in the country are low in organic matter, which increases the risk of soil degradation such as desertification. The Italian expert feedback further highlighted the applicability of this technology given that Italy is the second largest producer of grapes in the world. Furthermore, the low heavy metals content found in the bio-based fertilisers makes the goose slurries sustainable for vineyards.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	13%
Better nutrient management	69%
Economic benefits	78%
Environmental benefits	66%
New employment opportunities	19%
Improved work-life balance	6%
Practicability	28%
Ability to use environmental credentials as a marketing tool	6%
Social acceptability	9%

Table 57. Main expert evaluation benefits of technology no.7 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Vineyard quantity	✓		
Circular economy	✓	✓	
Close nutrient loops	✓	✓	
Improve SOM	✓	✓	
Improved Soil resilience		✓	

Foreseen Challenges in Technology Adoption

One challenge noted by the Italian panel was the possibility of increased labour units and training required on a farm operation if incorporating such bio-based fertilisers into polycultures of agroforestry and vineyards. In addition, the Italian evaluation explained that topography could act as barrier to technology uptake as many vineyards are grown on slopes, which may not be able to accommodate integration of other forms of agriculture such as livestock or agroforestry. The Spanish assessment listed two main challenges to technology uptake, with one being the cost of transporting bio-based fertilisers. The other foreseen challenge was listed as the nitrogen and phosphorous content in the bio-based fertilisers which may inhibit their application in regions with high animal density.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

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Economic considerations	31%
Legal framework requirements	69%
Practicability	22%
Knowledge and skillset required	69%
Absence of grant supports	34%
Too much work for too little reward	22%
Social acceptability	31%

Table 58. Main expert evaluation challenges of technology no.7 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Labour units	✓		
Typography	✓		
Not applicable in nitrate vulnerable zones		✓	
Transportation cost		✓	

Eastern Europe

Foreseen Benefits in Technology Adoption

The Hungarian assessment provided by staff from 3R BioPhosphate Ltd., noted there may be scope for such a technology within the country if the method could be applied to other bio-based fertilisers and arable crop types.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	19%
Better nutrient management	76%
Economic benefits	67%
Environmental benefits	67%
New employment opportunities	5%
Improved work-life balance	5%
Practicability	24%
Ability to use environmental credentials as a marketing tool	29%
Social acceptability	10%

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Foreseen Challenges in Technology Adoption

The Hungarian evaluation stated further research on the economic benefits of the technology could assist in determining the suitability to Hungary. Additionally, legislation authorising the use of bio-based fertilisers on arable crops might need to be developed.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	52%
Legal framework requirements	57%
Practicability	33%
Knowledge and skillset required	52%
Absence of grant supports	81%
Too much work for too little reward	24%
Social acceptability	0%

Table 59. Main expert evaluation challenges of technology no.7 for Eastern Europe

Challenges of Technology Uptake	Hungary
Further research needed regarding suitability to Eastern Europe	✓

Western Europe

Foreseen Benefits in Technology Adoption

The Belgian and Dutch expert evaluations both highlighted the need to reduce their respective nation's reliance on chemical fertilisers and encourage circular economy practices within agriculture. It was noted that such a technology could help towards these goals. The Belgian evaluation, provided by staff from Inagro, stated similar research into the optimal use of bio-based fertilisers is already being undertaken in Belgium which signifies a genuine interest in discovering more about bio-based fertiliser usage.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	29%
Better nutrient management	82%
Economic benefits	53%
Environmental benefits	71%
New employment opportunities	0%
Improved work-life balance	0%
Practicability	18%
Ability to use environmental credentials as a marketing tool	29%
Social acceptability	29%

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Table 60. Main expert evaluation benefits of technology no.7 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
National interest in bio-based fertiliser research	✓		
Reduced reliance on synthetic fertilisers	✓	✓	
Promotes circular economy	✓	✓	

Foreseen Challenges in Technology Adoption

The German evaluation, provided by staff from the Thünen Institute, and the Dutch evaluation, provided by staff from Wageningen University, considered this technology a poor fit to their respective nations. Within Germany, seed oil cakes are already used as a fertiliser within vineyards, and, agroforestry holdings are limited in scale. The Dutch evaluation also listed the small scale of agroforestry and vineyards as a barrier to technology uptake. Furthermore, their evaluation observed it may be challenging to apply organic fertilisers, particularly in liquid form, in amongst perennial or agroforestry systems. In addition, the expert review form the Netherlands considered using oil seed cake as an animal feed instead of a bio-based fertiliser may be a better use of the product. Within the Belgian evaluation the nutritional inconsistency of bio-based fertilisers versus synthetic fertilisers was listed as a potential barrier to technology uptake. Furthermore, bio-based fertilisers require different application methods to synthetic fertilisers which may lead to investment in equipment. Currently, bio-based fertiliser products do not carry the same status as synthetic fertilisers and therefore are at a commercial disadvantage when compared against chemical fertilisers.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	67%
Legal framework requirements	56%
Practicability	44%
Knowledge and skillset required	44%
Absence of grant supports	39%
Too much work for too little reward	22%
Social acceptability	22%

Table 61. Main expert evaluation challenges of technology no.7 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Nutrient value inconsistency	✓		
Reduced commerciality vs. synthetic fertilisers	✓		
Limited national agroforestry and vineyard production		✓	✓
Alternative uses for oil seed cake		✓	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

3.2.9 Technology No. 8: Ammonia Recovery from Raw Pig Slurry in a Vacuum Evaporation Field Plant

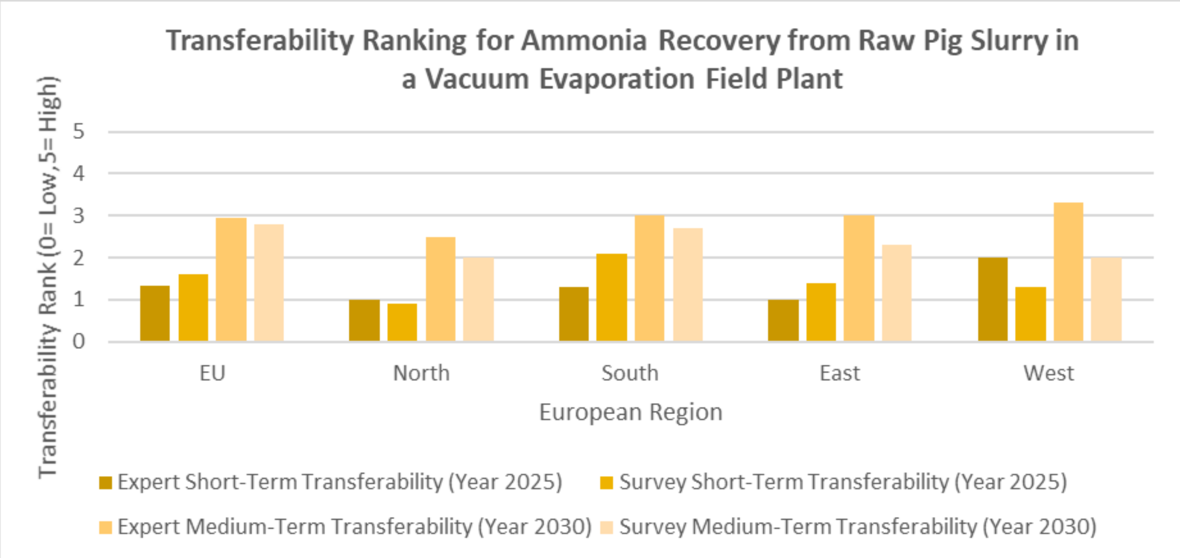

Figure 15. The above bar chart displays the averaged transferability rankings for the ammonia recovery from raw pig slurry in a vacuum evaporation field plant technology across Europe.

At the EU level ammonia recovery from raw pig slurry in a vacuum evaporation field plant is comparably low and ranked as the 12th most transferable technology in the short-term (transferability rank 1.3) and medium-term (transferability rank 2.9) within the expert evaluations with only minor differences to the survey feedback. The highest rank technology no. 8 achieves is a rank of 7th, achieved in both the medium-term survey evaluation for Southern and Western Europe. At all other times technology no.8 is ranked within the lower 5 technologies (see figures 4-7).

3.2.9.1 Vacuum Evaporation- European Wide Evaluation

Foreseen Benefits to Technology Adoption

When assessing the expert and NTF evaluations of technology no.8 the main benefits to adoption are for regions experiencing manure management pressures, such as regions with high concentrations of livestock production, particularly housed livestock production i.e. pig production. By processing the pig manure with the vacuum evaporation technology the volume of the manure reduces and the available nutrients are concentrated into 4 recycled derived fertilisers. The technology was considered advantageous in scenarios where manure is transported from the source point to a receiving point some distance away. Any reduction in manure volume will reduce the cost of manure transportation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Foreseen Challenges to Technology Adoption

This technology had the joint lowest technology readiness level of 4 and this issue with transferability is also seen the average rankings throughout Europe. A main barrier to technology uptake is the array of equipment required and the training an operator would need in order to run the vacuum evaporation field tank.

3.2.9.2 Vacuum Evaporation- European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The Irish evaluation noted the technology could be particularly useful in exporting the nitrogen rich liquid concentrate produced from animal farming operations to arable farming operations that may be some physical distance from one another. The Danish expert review stated that there is generally not a large surplus of slurry within the country as most is used either by spreading onto land through modern low emission techniques (e.g. online slurry acidification) or fed to AD plants to produce digestate and biogas. Therefore this technology is not an ideal fit to the present Danish farming system.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	29%
Better nutrient management	59%
Economic benefits	47%
Environmental benefits	82%
New employment opportunities	24%
Improved work-life balance	0%
Practicability	24%
Ability to use environmental credentials as a marketing tool	18%
Social acceptability	6%

Table 62. Main expert evaluation benefits of technology no.8 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Means of exporting animal manures to arable holding		✓

Foreseen Challenges to Technology Adoption

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Both country's expert evaluations listed applying a liquid fertiliser as a potential challenge as currently farmers have the equipment and skill to apply granular fertilisers, digestate fertilisers, or, slurries, which are a mix between solid and liquid manure. Further equipment challenges were highlighted within Ireland as no vacuum separators are known to be available within the country. The Danish evaluation also made the point that even in the situation that ammonia is recovered from a slurry, current Danish legislation would not allow for the resulting liquid fertiliser to be applied at a different rate or method than traditional slurries and as a result the economic benefit to the farmer is not obvious.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	59%
Legal framework requirements	29%
Practicability	59%
Knowledge and skillset required	47%
Absence of grant supports	47%
Too much work for too little reward	29%
Social acceptability	18%

Table 63. Main expert evaluation challenges of technology no.8 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Equipment for liquid fertiliser application	✓	✓
No vacuum evaporators established in country		✓
Unfamiliar with equipment		✓

Southern Europe

Foreseen Benefits to Technology Adoption

The expert evaluators from Southern Europe agreed this technology could contribute to reducing ammonia emissions from the agricultural sector. Recovering ammonia from livestock waste is a means of nitrogen loop closing as recycled fertilisers are produced e.g. ammonium sulphate. The Spanish expert panel noted that regulation protecting waterways from eutrophication means it is necessary within Spain to transport excess livestock slurry from regions of high livestock density to regions with lower livestock density. Subsequently, Italy noted that as the recovered fertiliser from the technology is rich in nitrogen but has a reduced volume it is a good candidate for transportation across distances from regions of intensive agricultural production to arable regions in need of N fertilisers. Furthermore, the expert Italian panel considered the recovered fertiliser produced could be safely

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used in Nitrate Vulnerable Zones. The assessment from Spain noted positives to the technologies design such as the use of vacuum stripping which can operate at a lower temperature than conventional ammonia stripping resulting in reduced operation costs. Additionally the design is modular and can be scaled accordingly to different size farms.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	19%
Better nutrient management	81%
Economic benefits	61%
Environmental benefits	84%
New employment opportunities	23%
Improved work-life balance	3%
Practicability	6%
Ability to use environmental credentials as a marketing tool	13%
Social acceptability	6%

Table 64. Main expert evaluation benefits of technology no.8 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Additional manure processing option	✓		
Reduced volume of manure	✓		
Nitrate vulnerable zones	✓		
Nutrient loop closure	✓	✓	✓
Recycled derived fertilisers	✓	✓	✓
Modular design		✓	

Foreseen Challenges to Technology Adoption

The expert evaluations from Italy and Spain listed the financial capital required to establish such a technology as a limiting factor to its uptake. To operate the plant successfully training would also be required as vacuum evaporation is not a widely known practice.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	68%
Legal framework requirements	35%
Practicability	55%
Knowledge and skillset required	61%

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Absence of grant supports	35%
Too much work for too little reward	26%
Social acceptability	10%

Table 65. Main expert evaluation challenges of technology no.8 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Financial cost	✓	✓	
Operator skillset	✓	✓	

Eastern Europe

Foreseen Benefits to Technology Adoption

The expert evaluation from Hungary noted such a technology could contribute towards greater fertiliser self-sufficiency and provide opportunities for excess nitrogen from livestock systems to be used within arable systems.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	29%
Better nutrient management	71%
Economic benefits	67%
Environmental benefits	81%
New employment opportunities	14%
Improved work-life balance	10%
Practicability	10%
Ability to use environmental credentials as a marketing tool	14%
Social acceptability	5%

Table 66. Main expert evaluation benefits of technology no.8 for Eastern Europe

Benefits of Technology Uptake	Hungary
Greater utilisation of animal manures on arable farms	✓
Reduced reliance on imported fertiliser	✓

Foreseen Challenges to Technology Adoption

The technology is very novel within Hungary and training would be required to successfully operate the plant.

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When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	52%
Legal framework requirements	48%
Practicability	52%
Knowledge and skillset required	52%
Absence of grant supports	86%
Too much work for too little reward	10%
Social acceptability	0%

Table 67. Main expert evaluation challenges of technology no.8 for Eastern Europe

Challenges of Technology Uptake	Hungary
New concept within region	✓
Training required	✓

Western Europe

Foreseen Benefits to Technology Adoption

The German evaluation had queries as to the pig production unit scale required to warrant investing in this technology. Therefore, the German evaluation could not provide further feedback on the technology. Both the Dutch and Belgian assessments remarked that the technology could assist in managing manure surpluses. Both expert panels noted certain regions within their respective countries have high-density livestock production and therefore manure needs to be off-loaded from these pressure zones to other regions with less manure volume challenges. By processing the manure, it could become more economical to transport from high manure pressure zones to manure receiving zones. The Belgian evaluation, provided by staff from the University of Ghent, noted additional feedstocks other than pig manure could be fed into such a technology design, the technology could be a means of recycling nutrients from sewage sludge also. Both the Dutch and Belgian evaluations agreed the technology could contribute towards circular economy goals.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	41%
Better nutrient management	88%
Economic benefits	53%
Environmental benefits	88%
New employment opportunities	6%
Improved work-life balance	6%

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Practicability	0%
Ability to use environmental credentials as a marketing tool	18%
Social acceptability	12%

Table 68. Main expert evaluation benefits of technology no.8 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Variety of feedstocks	✓		
Circular economy goals	✓	✓	
Manage manure surpluses	✓	✓	

Foreseen Challenges to Technology Adoption

The Belgian expert review noted the recycled derived fertilisers do not have the same nutrient concentration as synthetic fertilisers. Further to this, the Belgian assessment noted the RDF's from the pig manure have the same manure maximum applicate rate criteria applied to them. Considering they are not as nutrient dense as synthetic fertilisers this combination of factors may lead to sub-optimal application of nutrients within a holding. The Netherlands' assessment noted the cost of the technology as a barrier to adoption. When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	89%
Legal framework requirements	50%
Practicability	67%
Knowledge and skillset required	28%
Absence of grant supports	33%
Too much work for too little reward	17%
Social acceptability	11%

Table 69. Main expert evaluation challenges of technology no.8 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Manure derived fertilisers classified as manures	✓		
RDFs less nutrient dense than synthetic fertilisers	✓		
Investment cost		✓	

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3.2.10 Technology no.9: ABC Animal Bone Char for Phosphorous Recovery

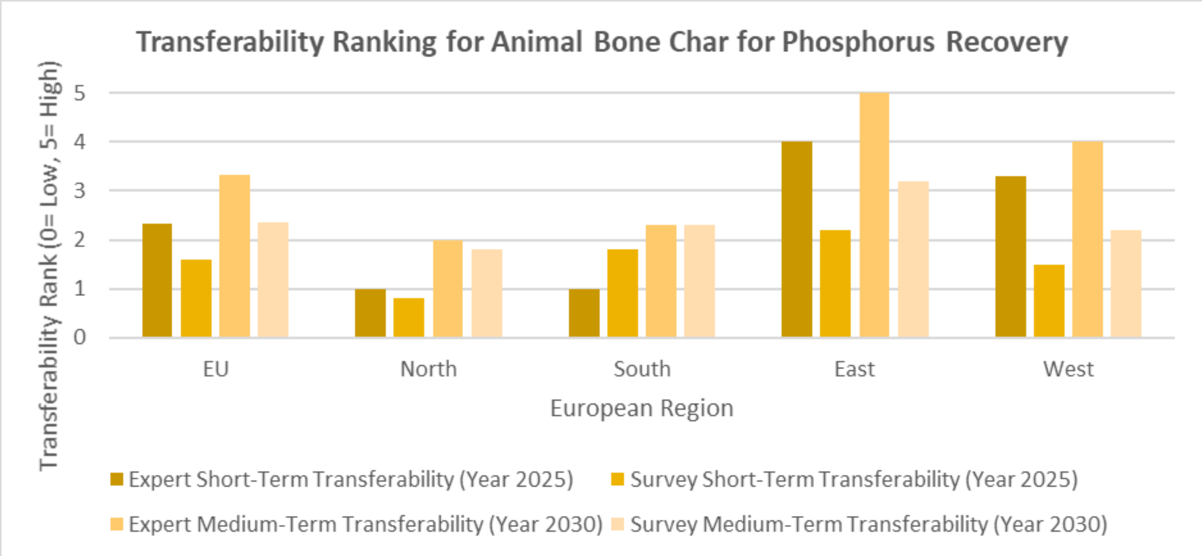

Figure 16. The above bar chart displays the averaged transferability rankings for the ABC animal bone char for phosphorous recovery technology across Europe.

At the EU level the usage of animal bone char for phosphorus recovery is ranked as the 12th most transferable technology in the short and medium-term within the survey feedback. The evaluations from the experts are more positive, ranking this technology as the 7th most promising technology in the short-term (transferability rank 2.3) and the 11th most transferable innovation in the medium-term (transferability rank 3.3). Figure 76 shows that animal bone char for phosphorus recovery could be particularly relevant for Eastern Europe in the short and medium-term with regards to both the expert evaluations and the NTF survey feedback.

3.2.10.1 Animal Bone Char – European Wide Evaluation

<u>Foreseen Benefits to Adoption</u>

Across both the expert and NTF evaluations the main benefits associated with adopting the animal bone char technology included environmental benefits such as producing a fertiliser that displays controlled release and minimal leaching qualities. By using a waste material of livestock bones and converting it into a source of phosphorous the technology can assist in closing nutrient loops and satisfy criteria of the Nutri2Cycle project. In addition within the evaluations the bone char was seen as a means to reduce the dependence on imported rock phosphate, boosting the local economy by improving self-sufficiency and creating new employment opportunities.

<u>Foreseen Challenges to Adoption</u>

Throughout the evaluations the investment cost associated with such a technology along with the skillset required to operate the technology were seen as significant barriers to adoption. In addition

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as the technology centres on the burning of livestock bones at a high temperature there may be some opposition within the community to a pyrolysis plant due to concerns over emissions. The technology ranked, on average, within the mid to low range in terms of transferability across Europe. Even when considering the clear benefits of such a technology, the bone char has to compete against alternative sources of phosphorous. Furthermore, certain regions within Europe are in less need of phosphorous fertiliser than other regions and therefore the technology could be considered region specific, for example the technology received the highest transferability rankings within Eastern Europe where phosphorous demands are high, but received low transferability rankings in Northern Europe where, due to livestock density, phosphorus fertiliser demand is low.

3.2.10.2 Animal Bone Char – European Regional Evaluation

Northern Europe

Foreseen Benefits to Adoption

Both the Danish and Irish expert evaluators listed the availability of livestock bones within their respective nations as an aid to technology uptake. The Danish evaluation further explained that such a technology could address regional demands for phosphorous fertiliser, as regions within the country with a low livestock population generally require greater quantities of phosphorous than regions heavily populated with livestock. The Irish evaluation observed that the ABC phosphorous product is a controlled release fertiliser with minimal propensity for leaching and could contribute to reduced national reliance on imported rock phosphate fertilisers. Combining these attributes with the bone char's high phosphorus supply and demonstrated improvements on crop yield led the Irish evaluators to consider the technology to be a good fit within the country.

When evaluating the feedback from the NFT surveys from Northern Europe 65% of respondents selected a positive of the technology as the creation of new jobs within the community; 59% of survey respondents selected better nutrient management as a benefit to uptake; environmental benefits were considered by 47% of respondents as a benefit, while 41% considered economic benefits associated with the technology as an advantage to uptake; the ability to use the environmental credentials of the technology as a marketing tool was considered by 29% of participants as a benefit while a joint 24% of participants selected better compliance with legal framework and good will from the public as foreseen benefits to the technology.

Table 70. Main expert evaluation benefits of technology no.9 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Satisfy regional demands for phosphorous	✓	
Availability of livestock bones	✓	✓
Reduced nutrient leaching		✓
Reduce reliance on imported fertilisers		✓

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Foreseen Challenges to Adoption

Both national expert panels agreed that interest in adopting such a technology will depend on the competitiveness of the bone char phosphorous versus traditional phosphorous supplies, competitiveness in terms of price and nutrient effectiveness. The Danish evaluation further noted that meat processors are likely to have systems currently in place for utilising animal bone waste and therefore this technology needs to compete with the current processing systems. The Irish evaluation listed the skillset required to operate the technology and initial investments costs as further challenges to technology uptake.

When evaluating the feedback from the NFT surveys from Northern Europe 59% of respondents considered the skill required to operate the technology as a barrier to adoption; a joint 47% of respondents listed the absence of grant supports and legalities involved, such as planning permission, as foreseen challenges; 41% of participants thought the technology represented too much work for too little reward; a joint 35% of respondents listed social acceptability and economic considerations as hindrances; the practicability of the technology was selected by 24% of participants as an obstacle.

Table 71. Main expert evaluation challenges of technology no.9 for Northern Europe

Challenges of Technology Uptake	**Denmark**	**Ireland**
Competition from current carcase waste processing systems	✓	
Competition from traditional phosphorous supplies	✓	✓
Operator skillset		✓
Investment costs		✓

Southern Europe

Foreseen Benefits to Adoption

Both the Italian and Spanish expert evaluators listed the availability of livestock bones within their respective nations as an aid to technology uptake. The Italian evaluation explained currently there is little recycling of animal bones within the nations meat processing industry, with the Spanish panel noting converting waste animal bones to fertiliser is an example of closing nutrient loops. Further to this, both national expert panels agreed such a technology could reduce the reliance on imported phosphorous fertilisers. The Italian panel also highlighted the controlled nutrient release and reduced risk of leaching qualities of the animal bone char.

When evaluating the feedback from the NFT surveys from Southern Europe 68% of participants considered economic benefits associated with the technology as an advantage to uptake; 65% of respondents selected a positive of the technology as better nutrient management, while 58% of participants selected environmental benefits associated with the technology; 39% of respondents thought the technology would lead to new local job opportunities; a joint 19% of respondents selected the practicability of the technology and better compliance with legal frameworks as advantages to

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uptake; 13% of participants selected improved work-life balance as a positive to adoption; the ability to use the environmental credentials of the technology as a marketing tool was considered by 10% of participants as a benefit, while 3% of participants considered the social acceptability of the technology as a benefit.

Table 72. Main expert evaluation benefits of technology no.9 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Controlled nutrient release	✓		
Reduced nutrient leaching	✓		
Availability of livestock bones	✓	✓	
Reduced reliance on imported phosphorous fertiliser	✓	✓	
Close nutrient loops		✓	

Foreseen Challenges to Adoption

The evaluations from Italy, Portugal and Spain all agreed the investment costs for such a technology would be considerable and therefore could act as a barrier to technology uptake. Both the Italian and Portuguese evaluators observed potential challenges in relation to the regulations associated with such a technology, such as the safety of the product and the inclusion of bio-char in national fertiliser regulations. The Italian evaluation also noted the skillset required to successfully operate the technology may act as a hindrance to uptake. The Spanish evaluation also observed the technology may face resistance from the local community due to possible emissions from the pyrolysis system.

When evaluating the feedback from the NFT surveys from Southern Europe 65% of respondent's considered the legalities associated with implementing such a technology as a hindrance to uptake; a joint 61% of respondents listed economic considerations and the skillset required to operate the technology as foreseeable challenges; 32% of respondents selected the practicability of such a technology as a challenge, while 26% of participants listed the absence of grant supports as a barrier to adoption; 23% of participants selected the social acceptability of the technology as a possible challenge while 13% felt the technology represented too much work for too little gain.

Table 73. Main expert evaluation challenges of technology no.9 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Operator skillset	✓		
Regulation of bone char	✓		✓
Investment costs	✓	✓	✓
Possible emissions from pyrolysis technology		✓	

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Eastern Europe

Foreseen Benefits to Technology Adoption

The expert evaluation from Hungary was provided by the president of M-TESZ, an organisation which represents horticulture producers within the country. Within the Hungarian assessment it was felt that encouraging the use of bio-phosphate from pyrolyzed animal bones could lead to reduced reliance on synthetic phosphorous fertilisers. The evaluation noted the recent price increases in synthetic fertilisers as a significant financial pressure, a pressure such a technology could relieve, with chemical fertilisers in Hungary 60% more expensive in the third quarter of 2021 than when compared against the third quarter of 2020. Further to this, it was stated that typically Hungarian soils are low in plant available phosphorous, as rock phosphate based phosphorous (traditional synthetic phosphorous) can become fixed to calcium or leach from the soil. The evaluation observed animal bone char bio-phosphate to be a complete replacement for synthetic phosphorous in terms of its efficiency and production cost. It was also observed that the pyrolysis process is a zero emissions process. Producing phosphorous in such a manner would contribute towards improved self-sufficiency as the organic fertiliser would be produced within the country and would not be as susceptible to import-export issues or trade restrictions. Within the Eastern European NTF evaluation 90% of respondents listed the economic benefits such a technology could offer as an advantage to uptake, such as reduced expenditure on synthetic fertilisers. This was followed by 81% of respondents who selected the environmental benefits associated with such a technology as an advantage to technology adoption. 67% of respondents considered the technology as a means of better nutrient management within farming systems while 43% of respondents felt utilising such a technology could compliment governmental legal requirements relating to food production and fertiliser application. A lesser portion or participants considered the practicability as a benefit to uptake at 14%, while only 5% of participants felt the animal bone char could use its sustainable credentials as a marketing advantage.

Table 74. Main expert evaluation benefits of technology no.9 for Eastern Europe

Benefits of Technology Uptake	Hungary
Reduced reliance on synthetic fertilisers	✓
Plant available phosphorous	✓
Safe product	✓
Zero emissions processing	✓

Foreseen Challenges to Technology Adoption

The Hungarian evaluation noted animal bones from chickens & pigs are already in use via the pet food industry, therefore this technology would possibly have access to ruminant bones only i.e. sheep and cattle. Within the evaluation hesitancy over the safety of the product was noted as in the past sterile pig bone meal was used as a cheap fertiliser, but due to its form of processing it contained protein which acted as a vehicle for introducing pathogens into the farms where it was used. The ABC Bio-Phosphate producers would need to ensure farmers understand the value of their product and how it's processed to guarantee safety and provision of plant available phosphorus at a concentration

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compatible with synthetic phosphorous fertilisers. Within the Eastern European evaluation 85% of respondents (17 out of 20) listed the absence of grant supports or subsidies as a barrier to technology adoption, while 60% of respondents listed both the required training and practicability of the technology as an obstacle to technology uptake. 40% of respondents considered both the economic and legal aspects of the technology as a challenge, such as the investment costs required and the legislation surrounding the use of the product. 10% of respondents listed too much work for too little gain as a hindrance, while 5% of respondents considered social acceptance issues as a challenge to technology adoption.

Table 75. Main expert evaluation challenges of technology no.9 for Eastern Europe

Challenges of Technology Uptake	Hungary
Only ruminant bones available	✓
Good communication required with farming bodies	✓

Western Europe

<u>Foreseen Benefits to Technology Adoption</u>

Both the Belgian and Dutch evaluations agreed such a technology aligns with national circular economy goals. The Belgian evaluation, provided by staff from United Experts, explained that national legislation has developed criteria to include safe usage of bone meal in fertilisers. Promoting such a fertiliser is believed within the national policy to decreased reliance on synthetic fertilisers. The Belgian evaluation also noted that due to the pyrolysis system devised, the animal bone char displays no contamination risks on application. The Dutch assessment also highlighted the availability of livestock bones from the meat processing industry as an aid to technology uptake. The German evaluation noted this type of technology is already in use within the country.

When evaluating the feedback from the NFT surveys from Western Europe better nutrient management was selected by 67% of respondents as a benefit to uptake; economic benefits were selected by 61% of respondents while environmental benefits were selected by 50%; 33% of respondents believed the environmental credentials of the technology could be used as a benefit in marketing or branding; better compliance with legal frameworks was selected by 28% of participants; a joint 22% of respondents considered social acceptability and creation of new local jobs as advantages; the practicability of the technology was selected by 5% of participants as a benefit to adoption.

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Table 76. Main expert evaluation benefits of technology no.9 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Minimal contamination risk	✓		
Promotes nutrient recycling and circular economy	✓	✓	
Availability of livestock bones		✓	
Familiarity with technology			✓

Foreseen Challenges to Technology Adoption

The Belgian evaluation stated the composition of the animal bone char would need to consistently meet national fertiliser standards. The Dutch evaluation observed how, within the meat processing industry, systems are in place for utilising waste animal bone. The animal bone char would need to compete against the current processing systems in terms of economics or effectiveness.

When evaluating the feedback from the NFT surveys from Western Europe 71% of participant's listed economic considerations as a barrier to technology uptake; 65% of respondents selected legal framework requirements as a challenge; practicability was selected by 47% of survey respondents while the knowledge to operate the technology was selected by 41% of respondents; 29% of participants selected social acceptability of the technology as a barrier, while a joint 24% of respondents listed the absence of grant support and too much work for too little gain as hindrances to uptake.

Table 77. Main expert evaluation challenges of technology no.9 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Consistency of product	✓		
Competition from current carcase processing systems		✓	

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3.2.11 Technology no. 10: Transferability of Pig Manure Refinery into Mineral Fertilisers

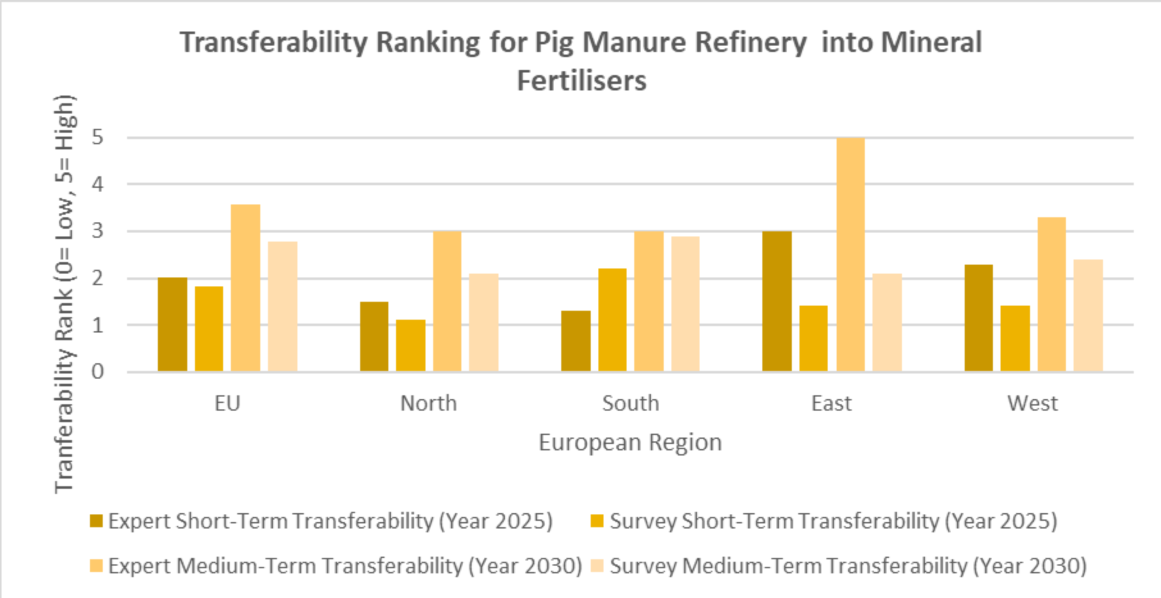

Figure 17. The above bar chart displays the averaged transferability rankings for the pig manure refinery into mineral fertilisers across Europe

At the EU level the pig manure refinery into mineral fertilisers technology is ranked in the short-term as the 5th and 9th most transferable technology within the expert evaluation (averaged transferability rank 2) and the survey feedback (averaged transferability rank 1.8) respectively. In the medium-term this technology is ranked as the 8th most transferable innovation for both the experts and the NTFs. Figure 85 shows that the experts see a high potential for this technology particularly in Eastern Europe, whereas, when evaluating the NTF survey data, the technology received the highest transferability rank for Southern Europe.

3.2.11.1 Refined Pig Manure – European Wide Evaluation

<u>Foreseen Benefits to Technology Adoption</u>

Throughout the expert and NTF evaluations the main benefits foreseen with the technology adoption were environmental benefits and better nutrient management. These benefits related to the ability of this technology to reduce the volume of the livestock manure, concentrated the nutritional value into fractions and also producing a fraction of water that in some regions meets standards for safe release into the environment. Economic benefits were also foreseen in terms of the possibility of reduced reliance on synthetic fertilisers and reduced transportation costs of manure from source point to receiving point due to the division of the manure into fractions and reduction in overall volume.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Foreseen Challenges to Technology Adoption

The financial element of adopting such a technology was considered the main challenge across the board. This technology requires both infrastructure and trained labour units, two costly items for farmers, particularly in the absence of subsides or grant supports. In addition, substituting chemical fertilisers with bio-based fertilisers poses its challenges, as the pig manure fractions may not display the same nutrient profile consistency as synthetic fertilisers do. Such inconsistencies were listed as a current hindrance to uptake within the evaluations.

3.2.11.2 Refined Pig Manure – European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The Danish expert review stated that there is generally not a large surplus of slurry within the country as most is used either by spreading onto land through modern low emission techniques (e.g. online slurry acidification) or fed to AD plants to produce digestate and biogas. Therefore, this technology is not an ideal fit to the present Danish farming system. The Irish assessment noted separating the solid fraction from the liquid fraction reduces the overall volume of the manure. Reducing the volume reduces any related transport costs that would arise in exporting the manure from a region of high concentration to a receiving region. The Irish evaluation also highlighted how through the technology's separation process a portion of the pig manure is refined to clean water, which is safe for release back into the environment.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	18%
Better nutrient management	82%
Economic benefits	41%
Environmental benefits	82%
New employment opportunities	35%
Improved work-life balance	6%
Practicability	0%
Ability to use environmental credentials as a marketing tool	18%
Social acceptability	12%

Table 78. Main expert evaluation benefits of technology no.10 for Northern Europe

Benefits of Technology Uptake	**Denmark**	**Ireland**
Reduced volume of manure		✓
Reduced costs of transporting surplus manure		✓

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Foreseen Challenges to Technology Adoption

Both the Irish and Danish assessments noted the financial cost in investing in and operating the technology as a hindrance to adoption. The Danish evaluation remarked that the clean water produced through the process would not meet the required standards within Danish law and therefore would not be directly released to the environment; this eliminates one advantage of the technology. The Irish assessment noted farmers might be unwilling to invest in a sequential manure separator given the additional labour and operator training that would be required.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	53%
Legal framework requirements	29%
Practicability	76%
Knowledge and skillset required	65%
Absence of grant supports	41%
Too much work for too little reward	24%
Social acceptability	6%

Table 79. Main expert evaluation challenges of technology no.10 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Clean water does not meet quality standards	✓	
Financial costs	✓	✓
Additional labour units		✓
Operator skillset		✓

Southern Europe

Foreseen Benefits to Technology Adoption

The Spanish panel highlighted that Spain is both a large cereal producer and a large pig producer. Such a technology could allow for reduction in manure volumes and the more economical transport of organic fertilisers to arable holdings. The Spanish panel considered the technology to be a means of reducing synthetic fertiliser consumption also. The Italian assessment considered the technology to be complimentary to 'REcovered Nitrogen from manURE' E.U. policy (RENURE) and the refined products may be applicable in nitrate vulnerable zones.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

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Better compliance with legal frameworks	32%
Better nutrient management	90%
Economic benefits	55%
Environmental benefits	81%
New employment opportunities	10%
Improved work-life balance	10%
Practicability	13%
Ability to use environmental credentials as a marketing tool	0%
Social acceptability	10%

Table 80. Main expert evaluation benefits of technology no.10 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Compliments EU legislation	✓		
Nitrate vulnerable zones	✓		
Reduced reliance on synthetic fertilisers		✓	
Transport manure to arable holdings		✓	

Foreseen Challenges to Technology Adoption

All three expert surveys agreed the cost of both establishing the technology and the operational costs associated with it would be considerable. The cost of consumables such as fuel and reverse osmosis membranes would also need to be factored in. Therefore both Spain and Italy reviewers queried the scale of a pig manure operation that would be required to run the technology economically.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	58%
Legal framework requirements	42%
Practicability	61%
Knowledge and skillset required	55%
Absence of grant supports	52%
Too much work for too little reward	13%
Social acceptability	10%

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Table 81. Main expert evaluation challenges of technology no.10 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Investment and operational costs	✓		✓
Scale of operation required	✓	✓	

Eastern Europe

Foreseen Benefits to Technology Adoption

The Hungarian expert assessment, provided by staff from 3R-BioPhospahte Ltd., stated that arable soils within the country are typically farmed using conventional tillage. Losses of SOM is a recognised issue in arable farming within the country. The assessment stated that implementing this technology could assist in increasing SOM and reduce the reliance on chemical fertilisers.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	38%
Better nutrient management	86%
Economic benefits	57%
Environmental benefits	76%
New employment opportunities	19%
Improved work-life balance	5%
Practicability	10%
Ability to use environmental credentials as a marketing tool	5%
Social acceptability	5%

Table 82. Main expert evaluation benefits of technology no.10 for Eastern Europe

Benefits of Technology Uptake	Hungary
Improved soil organic matter content	✓
Reduced reliance on chemical fertilisers	✓

Foreseen Challenges in Technology Adoption

The expert evaluation from Hungary listed the storage and transportation of animal manure as a challenge to technology uptake. An understanding of appropriate manure application rates was also listed as critical for optimal crop yields. Within the Hungarian assessment the nutrient density of the organic fertilisers was noted as a possible hindrance to technology uptake as low nutrient density will lead to higher application rates which could lead to the introduction of contaminants into the food system e.g. pathogens in the refined manures.

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When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	48%
Legal framework requirements	48%
Practicability	62%
Knowledge and skillset required	43%
Absence of grant supports	81%
Too much work for too little reward	14%
Social acceptability	5%

Table 83. Main expert evaluation challenges of technology no.10 for Eastern Europe

Challenges of Technology Uptake	Hungary
Knowledge of appropriate bio-based application rates for optimal crop yield	✓
Storage and transportation of manure	✓

Western Europe

Foreseen Benefits to Technology Adoption

The German evaluation had queries as to the pig production unit scale required to warrant investing in this technology. Therefore, the German evaluation could not provide further feedback on the technology. Both the Dutch and Belgian assessments remarked that the technology could assist in managing manure surpluses. Both expert panels noted certain regions within their respective countries have high-density livestock production and therefore manure needs to be off-loaded from these pressure zones to other regions with less manure volume challenges. By processing the manure, it could become more economical to transport from high manure pressure zones to manure receiving zones. The Belgian evaluation, provided by staff from the University of Ghent noted the water fraction produced does meet national discharge limits and could be safely released into environment or recycled for use on the farm holding e.g. for washing sheds etc.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	33%
Better nutrient management	83%
Economic benefits	61%
Environmental benefits	78%
New employment opportunities	11%
Improved work-life balance	0%
Practicability	0%
Ability to use environmental credentials as a marketing tool	22%
Social acceptability	11%

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Table 84. Main expert evaluation benefits of technology no.10 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Variety of feedstocks	✓		
Circular economy goals	✓	✓	
Manage manure surpluses	✓	✓	
Clean water fraction for reuse	✓	✓	

Foreseen Challenges to Technology Adoption

The Belgian expert review noted the recycled derived fertilisers do not have the same nutrient concentration as synthetic fertilisers. Further to this, the Belgian assessment noted the RDF's from the pig manure have the same manure maximum application rate criteria applied to them. Considering they are not as nutrient dense as synthetic fertilisers this combination of factors may lead to sub-optimal application of nutrients within a holding. The Netherlands' assessment noted the cost of the technology as a barrier to adoption.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	89%
Legal framework requirements	61%
Practicability	72%
Knowledge and skillset required	28%
Absence of grant supports	17%
Too much work for too little reward	17%
Social acceptability	11%

Table 85. Main expert evaluation challenges of technology no.10 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Manure derived fertilisers classified as manures	✓		
RDFs less nutrient dense than synthetic fertilisers	✓		
Investment cost		✓	

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3.2.12 Technology No.11: Using Digestate, Precision Agriculture & No-Tillage to Improve Soil Organic Matter

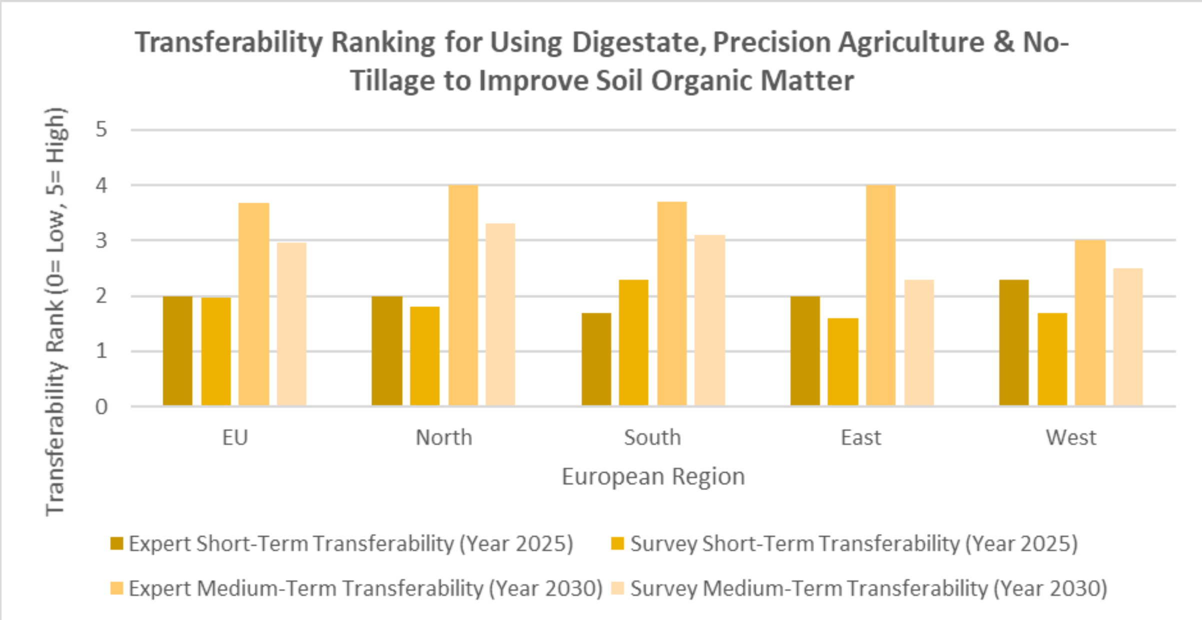

Figure 18. The above bar chart displays the averaged transferability rankings for the using digestate, precision agriculture & no-tillage to Improve soil organic matter technology across Europe

The use of using digestate, precision agriculture & no-tillage to Improve soil organic matter received mid-range transferability rankings through the European evaluations. At the EU level this technology is ranked as the 9th most transferable within the expert evaluations (transferability rank 2), and 7th within the survey feedback (1.9) evaluations in the short-term. For the medium-term timeframe, transferability rankings are slightly higher for both the expert evaluation (7th rank) and the survey feedback (6th rank). Figure 97 shows that the use of digestate, precision agriculture & no-tillage to improve soil organic matter could be particularly relevant for Northern and Southern Europe in both the short and medium-term.

3.2.12.1 Digestate & No-Till - European Wide View

Foreseen Benefits to Technology Adoption

The environmental benefits such a technology could provide was the main observation in terms of advantages to uptake. Environmental benefits such as reduced reliance on synthetic fertilisers, recycling of nutrients, better nutrient management, adherence to government legislation and a means of wastewater treatment were all listed within the evaluations.

Foreseen Challenges to Technology Adoption

This technology was ranked within the mid-range in terms of averaged transferability across Europe. Although advantages to the technology were recognised in both the expert evaluations and NTF

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survey feedback, several challenges remained. A common barrier to adoption was the financial cost and skills associated with implementing the technology. An array of equipment would be required, including AD plants, ammonium stripping technology and even combined heat and power units. To finance such infrastructure and to operate the system correctly was deemed a considerable challenge across Europe. The German and Hungarian expert evaluations had particular issue with the feedstock of wastewaters and sewage sludges due to concerns over contamination of soils and groundwaters.

3.2.12.2 Digestate & No-Till - European Regional View

Northern Europe

Foreseen Benefits to Technology Adoption

Both evaluations from Denmark and Ireland agreed such a technology could be utilised in wastewater treatment systems. The Dutch evaluation noted there is some familiarity within the country in relation to aspects of the technology described such as treating wastewaters via anaerobic digesters. Dutch farmers are familiar with using digestate and therefore already have some skill and equipment that aligns with what is required of the technology described. The Irish evaluation noted such a technology could reduce reliance on chemical fertilisers by producing bio-based fertilisers such as digestate and ammonium sulphate. In addition, the technology is a means to close nutrient cycles and aligns with government legislation to reduce nutrient losses by 50% and reduce chemical fertiliser usage by 20%. The Irish assessment noted the biogas produced can be used to meet the power needs of the farm operation.

When evaluating the feedback from the NFT surveys from Northern Europe better nutrient management was considered a benefit to technology uptake by 76% of participants; 71% of respondents selected environmental benefits, while 65% of respondents selected economic benefits associated with the technology; the ability to use environmental credentials of the technology in marketing was selected by 35% of participants as a benefit to adoption; 24% selected social acceptability surrounding such a technology as a benefit, while better compliance with legal frameworks was selected by 12% of respondents; a joint 6% of participants selected the practicability and creation of new employment opportunities as advantages to the technology.

Table 86. Main expert evaluation benefits of technology no.11 for Northern Europe

Benefits of Technology Uptake	**Denmark**	**Ireland**
Familiarity with aspects of technology	✓	
Means of wastewater treatment	✓	✓
Reduce reliance on synthetic fertilisers		✓
Close nutrient loops		✓

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Foreseen Challenges to Technology Adoption

Both the Dutch and Irish expert evaluations listed the investment costs associated with the digestate and no-till technology as considerable and would act as a barrier to uptake. Further to this the Irish evaluation listed the additional labour units to operate such a technology along with the current national grid infrastructure as challenges in encouraging technology uptake.

When evaluating the feedback from the NFT surveys from Northern Europe the absence of grant supports was selected by 65% of participants as a challenges to technology uptake; the practicability of the technology was listed by 59% of respondents as a further challenges to uptake; a joint 53% of respondents selected the knowledge required to operate the technology and economic considerations as barriers to adoption; 29% of respondents felt the legal frameworks associated with such a technology could act as a hindrance, while a joint 18% of participants listed social acceptance and too much work for too little gain as challenges to adoption within northern Europe.

Table 87. Main expert evaluation challenges of technology no.11 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Investment costs	✓	✓
Additional labour units		✓
National infrastructure		✓

Southern Europe

Foreseen Benefits to Technology Adoption

Both the Italian and Spanish expert evaluations considered this technology as complementary to government legislation such as nation climate and energy plans. A further advantage observed by both national expert panels was the promotion of bio-wastes as alternative fertilisers and the use of digestates as a means to reduce reliance on imported chemical fertilisers.

When evaluating the feedback from the NFT surveys from Southern Europe environmental benefits was selected by 85% of respondents; a joint 74% of respondents selected economic benefits and better nutrient management as positives to adoption; the creation of local employment opportunities was selected by 22% of respondents as an advantage, while 15% of respondents felt the technology would lead to better compliance with legal frameworks; a joint 7% of respondent's selected the practicability and social acceptability of the technology as benefits to adoption, while a joint 4% of respondents selected improved work-life balance and the ability to use the environmental credentials of the technology in marketing as benefits to uptake.

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Table 88. Main expert evaluation benefits of technology no.11 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Compliments environmental legislation	✓	✓	
Reduced reliance on chemical fertilisers	✓	✓	

Foreseen Challenges to Technology Adoption

The investment costs associated with this technology such as an anaerobic digester plant was considered by the Spanish, Portuguese and Italian reviewers as a significant barrier to uptake. The technology is an example of the integrated use of a variety of technologies and therefore the Italian evaluation noted it would be best suited to large companies or co-ops, as opposed to individual farmers while the Spanish review felt operating the array of technologies described would require significant operator skillset and knowledge.

When evaluating the feedback from the NFT surveys from Southern Europe legal framework challenges were selected by 70% of respondents, such as planning permission; the knowledge to operate the technology successfully was listed as a challenge by 56% of respondents; economic considerations were selected by 52% of respondents as a challenge; a joint 30% of respondents selected both the practicability and social acceptability of the technology as barriers to uptake; the absence of grant supports was considered a hindrance by 26% of the participants while 15% felt the technology represented too much work for too little gain.

Table 89. Main expert evaluation challenges of technology no.11 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Best suited to larger operations	✓		
Investment costs	✓	✓	✓
Operator knowledge and skillset		✓	

Eastern Europe

Foreseen Benefits to Technology Adoption

The expert evaluation from Hungary did not feel this technology would be best suited to the region due to a movement away from using wastewaters and sewage sledges as fertilisers. However given the array of technologies utilised within the technology the evaluations recognised the advantages of the technology if the feedstocks could be amended for the Hungarian market.

When evaluating the feedback from the NFT surveys from Eastern Europe environmental benefits were selected by 87% of survey respondents, with associated economic benefits selected by 80% of the survey participants as positives to adoption; better nutrient management was selected by 73% of respondents as an advantage to the technology; 20% of respondents felt the technology could lead to

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new local employment opportunities; a joint 13% of respondents selected either improved work-life balance or better compliance with legal frameworks as advantages to uptake while a joint 7% of respondents considered the practicability and the ability to use the environmental credentials of the technology in marketing as further benefits to adoption.

Foreseen Challenges to Technology Adoption

The use of wastewaters as a feedstock would not be suitable in Hungary given government policy and the regions geography and water table attributes. The investment costs associated with this technology was listed by the expert evaluation as a considerable challenge to uptake. The infrastructure within Hungary is not presently suitable for transporting power from microgeneration sites such as AD plants.

When evaluating the feedback from the NFT surveys from Eastern Europe the absence of grant supports was selected by 67% of respondents as a barrier to uptake; a joint 60% of respondents considered the practicability and knowledge required to implement the technology as foreseeable challenges; 53% of respondents considered the associated legal frameworks as a hindrance to uptake; economic considerations were listed by 27% of respondents as barrier; the social acceptability of the technology was selected by 20% of the respondents as a barrier to adoption while 13% of respondents considered the technology as too much work for too little gain.

Table 90. Main expert evaluation challenges of technology no.11 for Eastern Europe

Challenges of Technology Uptake	Hungary
Feedstock of wastewater unsuitable in region	✓
Investment costs	✓
Power grid infrastructure	✓

Western Europe

Foreseen Benefits to Technology Adoption

The Belgian evaluation, provided by staff from United Experts, considered this technology to compliment circular economy goals by encouraging nutrient recycling. The Belgian evaluation implied there is some familiarity with some of the technologies associated with this technology within the country at present as recovering nutrients from wastewaters through digestion is a known system. Both the Belgian and Dutch evaluations noted capitalising on the digestate and ammonium sulphate produced could lead to a reduced reliance on chemical fertilisers.

When evaluating the feedback from the NFT surveys from Western Europe better nutrient management was selected by 83% of respondents as an advantage to technology uptake; economic benefits were selected by 67% and environmental benefits were selected by 61% of respondents in terms of foreseeable benefits; 17% of respondents selected either better compliance with legal framework, practicability, social acceptance or ability to use environmental credentials of the

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technology as a marketing tool as advantages to adopting the technology; the creation of new job opportunities was selected by 11% of the survey respondents.

Table 91. Main expert evaluation benefits of technology no.11 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Compliments circular economy	✓		
Familiarity with concept	✓		
Reduced reliance of synthetic fertilisers	✓	✓	

Foreseen Challenges to Technology Adoption

The German evaluation highlighted the challenges in using wastewaters and sewage sludges as feedstocks due to hygiene, pollution and heavy metals concerns. The German evaluators explained that the use of sewage as a fertiliser within Germany is highly regulated and has many restrictions applied to it. The Belgian evaluation noted the need for the bio-based fertilisers of ammonium sulphate and digestate to display consistent nutrient values in order for the products to meet agricultural demands. In addition the Dutch evaluation stated the ammonium sulphate can only partially replace the demands of synthetic fertilisers as the bio-based fertiliser can lead to decreases in soil pH/ soil acidification overtime.

When evaluating the feedback from the NFT surveys from Western Europe a joint 61% of respondents selected economic considerations and operator knowledge as challenges to technology uptake; a joint 44% of respondents considered the practicability and legal framework of the technology aa further obstacles; the absence of grant support was selected by 39% of the respondents as a barrier to uptake; 28% of respondents noted social acceptability of such a technology as a hindrance to development while 11% of respondents considered the technology a representation of too much work for too little gain.

Table 92. Main expert evaluation challenges of technology no.11 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Consistency of nutrient value of bio-based fertilisers	✓		
Soil acidification risk		✓	
Feedstock of wastewater and sewage sludge			✓

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3.2.13 Technology no.12: Evaluation of Poultry Compost and Pig Slurry to Replace Mineral Fertilisers as Basal Fertilisation in Maize Crops within Northern Europe

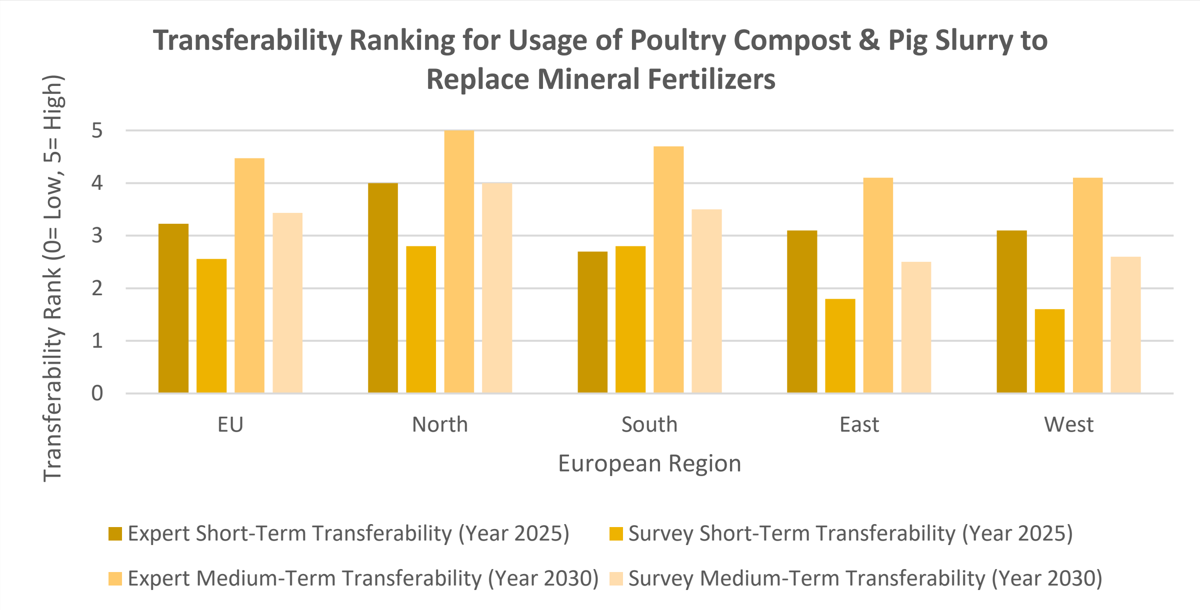

Figure 19. The above bar chart displays the averaged transferability rankings for the use of poultry compost & pig slurry to replace mineral fertilisers as basal fertilisation in a maize crop technology across Europe.

Across Europe the use of poultry compost & pig slurry to replace mineral fertilisers as basal fertilisation in maize crops is listed as one of the most transferable technologies throughout the evaluations. At EU level this technology has the highest transferability ranking within the expert evaluation and is ranked second most transferable within the survey feedback in both the short and medium-term timeframes. Figure 102 shows that the highest potential of using poultry compost & pig slurry to replace mineral fertilisers is in Northern Europe with a short-term expert rank of 4, short-term survey rank of 2.8, medium-term expert rank of 5 and medium-term survey rank of 4.

3.2.13.1 Poultry Compost & Pig Slurry – European Wide Evaluation

<u>Foreseen Benefits to Technology Adoption</u>

Across Europe there were common benefits observed with the adoption of technology no.12. Such widespread benefits were noted as improved soil health on arable holdings due to the increased use of organic fertilisers; reduced reliance on synthetic fertilisers if appropriate application rates could be met; there is an availability of both pig manure and poultry waste, providing the raw products for this technology; widespread familiarity with applying manures and slurries. In addition it was felt that by

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researching such technologies a greater understanding on the ideal balances between organic and synthetic fertilisers on arable holdings could be further developed.

Foreseen Challenges to Technology Adoption

The importance of sufficient fertiliser application when growing a cereal crop was emphasised within the evaluations and concerns were raised over the inconsistent nature of composts and slurries versus synthetic fertilisers. In addition, training may be required for operators to develop best practice in applying and mixing different animal manures as a base fertiliser within an arable holding. This could result in addition workload and labour requirements when compared against spreading raw slurry or chemical fertilisers.

3.2.13.2 Poultry Compost & Pig Slurry – European Regional Evaluation

Northern Europe

Foreseen Benefits in Technology Adoption

The Danish expert evaluation, provided by staff from University of Copenhagen, noted this form of technology is already practiced within the country, as farmers are familiar with the benefits of combining solid and liquid manures with mineral fertilisers. Furthermore, Danish farmers are familiar with composted manures, particularly green waste compost from gardens or town parks. Within the Irish assessment, provided by staff from Teagasc, the availability of pig and poultry manure was listed as an aid to successful technology adoption within the country. The Irish assessment further explained that such a technology could assist in Ireland's aim of reducing reliance on mineral fertilisers. The evaluators noted the technology proposed could replace up to 30% of the current volume of mineral nitrogen fertiliser consumed in the country and provide phosphorus to the soil as well.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	0%
Better nutrient management	88%
Economic benefits	88%
Environmental benefits	82%
New employment opportunities	6%
Improved work-life balance	0%
Practicability	12%
Ability to use environmental credentials as a marketing tool	0%
Social acceptability	12%

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Table 93. Main expert evaluation benefits of technology no.12 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Farmers familiar with manure application	✓	
Availability of manure		✓
Reduced reliance on synthetic fertilisers		✓

Foreseen Challenges in Technology Adoption

Both evaluations from Denmark and Ireland listed composts reduced nutritional efficacy when compared against mineral fertilisers as a possible hindrance to technology uptake. In addition, the Irish assessment noted ensuring consistency within the composts nutritional value could be challenging. Lastly, the evaluation from Ireland considered there could be additional labour required to apply both poultry compost and pig slurry as a base fertiliser in a maize crop as opposed to applying just mineral fertilisers.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	41%
Legal framework requirements	29%
Practicability	53%
Knowledge and skillset required	65%
Absence of grant supports	41%
Too much work for too little reward	18%
Social acceptability	41%

Table 94. Main expert evaluation challenges of technology no.12 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Reduced nutrient concentrations vs synthetic fertilisers	✓	✓
Inconsistences in manure quality		✓
Labour units		✓

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Southern Europe

Foreseen Benefits in Technology Adoption

Both evaluations from Italy and Spain noted the availability of pig manure within the country could assist in implementation of the technology. The Spanish evaluation, provided by staff from IRTA, observed that the technology could help develop greater understanding of the benefits and limitations of organic manures within the farming community, and work towards nutrient loop closures. The Italian assessment, provided by staff from the University of Milan, stated that applying poultry compost and pig manure could result in increased soil organic matter content, which could help improve soil health.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	7%
Better nutrient management	89%
Economic benefits	74%
Environmental benefits	67%
New employment opportunities	0%
Improved work-life balance	7%
Practicability	30%
Ability to use environmental credentials as a marketing tool	4%
Social acceptability	11%

Table 95. Main expert evaluation benefits of technology no.12 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Improved soil health	✓		
Availability of pig manure	✓	✓	
Develop further understanding of organic manure uses		✓	
Close nutrient loops		✓	

Foreseen Challenges in Technology Adoption

The feedback from the Italian panel included the observation that knowledge relating to best practices in organic fertiliser choices and application within the agricultural community may need to be developed in conjunction with this technology. The Italian and Spanish panels listed a further uptake challenge as the cost of transporting organic manures to land for spreading, particularly when transporting manure from pig farms with little adjoining land to receiving arable farms that may be at some distance away. In addition, the Spanish expert review observed that the nitrogen and

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phosphorus concentration in poultry compost and pig slurry might limit application rates in regions susceptible to excessive nutrient application.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	35%
Legal framework requirements	69%
Practicability	19%
Knowledge and skillset required	69%
Absence of grant supports	50%
Too much work for too little reward	12%
Social acceptability	38%

Table 96. Main expert evaluation challenges of technology no.12 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Manure management knowledge	✓		
Manure transportation cost	✓	✓	
Suitability within nitrate vulnerable zones		✓	

Eastern Europe

<u>Foreseen Benefits in Technology Adoption</u>

The Hungarian feedback, provided by 3R-BioPhostae Ltd., noted how soils within the country are typically low in organic matter. The technology described could help in improving soil health by increasing organic matter content. Further to this the Hungarian assessment noted the technology could contribute towards the national aim to reduce mineral fertiliser consumption within the country.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	13%
Better nutrient management	67%
Economic benefits	87%
Environmental benefits	87%
New employment opportunities	13%
Improved work-life balance	7%
Practicability	13%
Ability to use environmental credentials as a marketing tool	7%
Social acceptability	7%

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Table 97. Main expert evaluation benefits of technology no.12 for Eastern Europe

Benefits of Technology Uptake	Hungary
Improved soil organic matter content	✓
Reduced reliance on chemical fertilisers	✓

Foreseen Challenges in Technology Adoption

The expert feedback from Hungary listed the possibility of the poultry compost and pig slurry having a low nutrient density and harbouring contaminants, such as pathogens or hormones, as a barrier to technology uptake. Additionally, logistical issues such as storing and transporting the organic fertilisers from the source to an arable holding were also listed as challenges in implementing the technology.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	47%
Legal framework requirements	67%
Practicability	53%
Knowledge and skillset required	40%
Absence of grant supports	80%
Too much work for too little reward	7%
Social acceptability	7%

Table 98. Main expert evaluation challenges of technology no.12 for Eastern Europe

Challenges of Technology Uptake	Hungary
Quality of manures-risk of pollutants	✓
Storage and transportation of manure	✓

Western Europe

Foreseen Benefits to Technology Adoption

The Belgian evaluation, provided by staff from Inagro, listed a positive of the technology's adoption as increased input of organic matter into arable holdings, which is likely to increase soil quality and soil organic matter content. Both the Belgian and German elevations noted optimising organic manures and composts could result in reduced reliance on synthetic fertilisers within the arable holding. In addition, the Belgian evaluation along with the Dutch assessment highlighted the familiarity farmers have towards manure and slurry spreading which could assist in technology uptake.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	6%
Better nutrient management	71%
Economic benefits	100%
Environmental benefits	35%
New employment opportunities	6%
Improved work-life balance	0%
Practicability	53%
Ability to use environmental credentials as a marketing tool	6%
Social acceptability	18%

Table 99. Main expert evaluation benefits of technology no.12 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Increased soil organic matter content	✓		
Familiarity with technology principal	✓	✓	
Reduced reliance on synthetic fertilisers	✓		✓

Foreseen Challenges to Technology Adoption

The Belgian assessment highlighted inconsistencies in compost and slurry quality and nutritional value as a challenge associated with this technology particularly when considering the technology is applied to an arable holding. The German evaluation stated training of operators would be required in order to appropriately mix and apply different organic fertilisers in order to inhibit yield losses or nutrient leaching. The Dutch evaluation was unsure if such a technology could apply to soils high in phosphorous, as certain regions within the Netherlands experience high soil phosphorus levels. The Dutch assessment noted composts and treated slurries are more expensive to produce than the currently used raw slurries.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	12%
Legal framework requirements	65%
Practicability	18%
Knowledge and skillset required	59%
Absence of grant supports	24%
Too much work for too little reward	24%
Social acceptability	71%

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Table 100. Main expert evaluation challenges of technology no.12 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Inconsistences in manure quality	✓		
Nitrates directive limited application rates	✓		
Operator skillset			✓
Phosphorous concentration of manure		✓	
More expensive than raw slurry		✓	

3.2.14 Technology No.13: Application of Sensor Technologies in Plant Cropping Systems

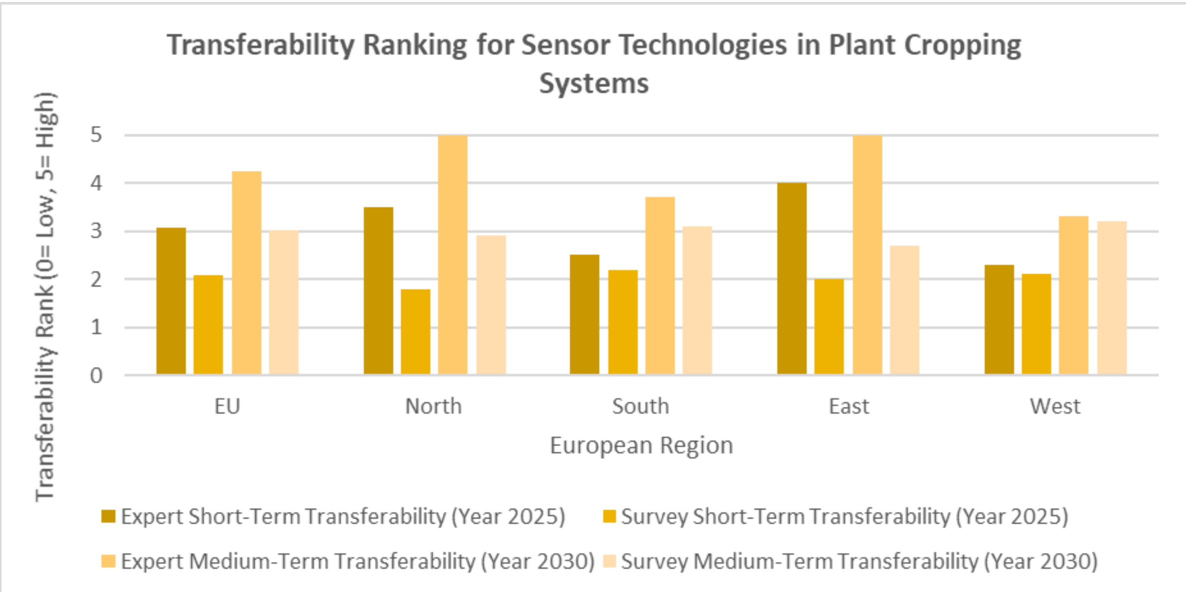

Figure 20. The above bar chart displays the averaged transferability rankings for the application of sensor technologies in plant cropping systems across Europe.

The use of sensor technologies in plant cropping systems is one of the most transferable technologies across Europe. This technology ranked 2nd most transferable in the short-term and 3rd most transferable in the medium-term European wide expert evaluation. The technology ranked 4th most transferable in the short-term and 5th in the medium-term European wide NTF survey evaluation. Figure 111 shows that with regard to expert evaluations the transferability of the application of sensor technologies in plant cropping systems is highest in Northern and Southern Europe in both the short and medium-term.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

3.2.14.1 Sensor Technology – European Wide Evaluation

Foreseen Benefits to Technology Adoption

Within both the national expert evaluations and the national taskforce evaluations, this technology was seen as a means to develop further use of a sensor tool that would assist in precision agriculture practices such as crop specific fertilizer application rates. The economic and environmental benefits the YARA N-sensor could provide were considered the main benefits to technology uptake. There was a consensus that implementing such a technology could reduce the likelihood of both over application of fertilisers and the subsequent economic losses and nutrient leaching, and, under application of fertilisers, which would lead economic losses also. It was felt such a technology could compliment some of the other technologies trialled, technologies that are researching ideal mixes of organic fertilisers and mineral fertilisers on arable farms. A challenge with these technologies was ensuring the crop received sufficient nutrition when using organic-synthetic mixes, the YARRA-N sensor could assist in this challenge by taking into account pastures that had received organic manure and adjusting the required fertiliser rates accordingly.

Foreseen Challenges to Technology Adoption

The investment cost along with the training required to operate the sensor were the two main barriers to technology adoption within the evaluations. It was felt a certain farming scale would be required to justify the investment in the technology. Within the evaluations from the NTF absence of subsidy/ grant support schemes was ranked as a significant barrier to technology uptake implying there may be more interest in adopting such a technology if subsidies were made available to assist in investment cost.

3.2.14.2 Sensor Technology - European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The Irish expert evaluation stated encouraging precision agricultural practices is one of the key aims set by the Irish government. A movement towards increased modernisation and use of helpful technologies is considered the path Irish agriculture needs to travel on. Furthermore the Irish assessment noted implementation of such a technology could reduce mineral fertiliser consumption, which is particularly beneficial at present given the high cost of mineral fertilisers. Within Denmark the technology has been used by some farmers for upwards of 20 years therefore there is far greater familiarity with the technology in Denmark than in Ireland.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	18%
Better nutrient management	94%

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Economic benefits	76%
Environmental benefits	71%
New employment opportunities	12%
Improved work-life balance	12%
Practicability	0%
Ability to use environmental credentials as a marketing tool	6%
Social acceptability	12%

Table 101. Main expert evaluation benefits of technology no.13 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Familiarity with technology	✓	
Reduced mineral fertiliser consumption	✓	✓
Aligns with government policy		✓

Foreseen Challenges to Technology Adoption

The Danish evaluation did not consider the cost of the sensor as a barrier to uptake whereas the Irish assessment consider the cost the most significant barrier to uptake. Nevertheless, both expert panels agreed the technical skills to operate the sensor's software amongst different brands of GPS systems could be considered a challenge for some operators. In addition the Irish assessment felt older farmer's would be less likely to uptake such a technology due to the IT skills required.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	71%
Legal framework requirements	6%
Practicability	65%
Knowledge and skillset required	82%
Absence of grant supports	41%
Too much work for too little reward	12%
Social acceptability	6%

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Table 102. Main expert evaluation challenges of technology no.13 for Northern Europe

Challenges of Technology Uptake	Denmark	Ireland
Optimising sensor software amongst different tractor brands	✓	✓
Financial cost		✓
Operator age		✓
IT skillset		✓

Southern Europe

Foreseen Benefits to Technology Adoption

Both the Italian and Spanish expert evaluations stated that such a technology aligns well with both national policy and E.U. agricultural policy relating to the promotion of precision agricultural systems within modern farming. In addition, by utilising a sensor such as the YARRA N-sensor precise application rates of fertiliser can be applied which promotes good crop/ grass growth and reduced over application of fertilisers. Further to this reduced nutrient leaching would result. The Spanish assessment noted the technology could be utilised in nitrate vulnerable zones due to reduced risk of nutrient run-off.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	22%
Better nutrient management	81%
Economic benefits	59%
Environmental benefits	63%
New employment opportunities	11%
Improved work-life balance	26%
Practicability	19%
Ability to use environmental credentials as a marketing tool	7%
Social acceptability	7%

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Table 103. Main expert evaluation benefits of technology no.13 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Aligns with national and EU legislation	✓	✓	
Precision fertiliser application	✓	✓	
Reduced nutrient leaching	✓	✓	
Applicable in nitrate vulnerable zones		✓	

Foreseen Challenges to Technology Adoption

All three expert evaluations considered the cost of the technology as a barrier to adoption. The Italian panel noted the technology may be best suit to an agricultural contractor as opposed to an individual farmer. Both the Italian and Spanish evaluations stated operators of the sensor technology would need training and time to learn how to process and interpret the data collected, the Italian panel remarked that support systems to provide information as to how to best utilise the technology might need to be developed.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	85%
Legal framework requirements	4%
Practicability	52%
Knowledge and skillset required	85%
Absence of grant supports	37%
Too much work for too little reward	19%
Social acceptability	0%

Table 104. Main expert evaluation challenges of technology no.13 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
May be more suitable investment for agri-contractors than farmers	✓		
Operator knowledge and skillset	✓	✓	
Time to learn skill	✓	✓	
Financial cost	✓		✓

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Eastern Europe

Foreseen Benefits to Technology Adoption

The Eastern European expert evaluation was provided by staff from the Hungarian food & agriculture consultancy firm SOLTUB Ltd. A foreseen benefit to the technologies adoption was improved fertiliser application efficiency; by using the YARA N sensor determining the actual fertiliser needs of a crop in real-time can be achieved. Therefore, there is greater opportunity for crop homogeneity and reduced risk of incorrect fertiliser application rates and any subsequent leaching.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	21%
Better nutrient management	57%
Economic benefits	79%
Environmental benefits	64%
New employment opportunities	21%
Improved work-life balance	29%
Practicability	7%
Ability to use environmental credentials as a marketing tool	21%
Social acceptability	0%

Table 105. Main expert evaluation benefits of technology no.13 for Eastern Europe

Benefits of Technology Uptake	Hungary
Improved fertiliser usage	✓
Improved crop homogeneity	✓
Reduced leaching of nutrients	✓

Foreseen Challenges to Technology Adoption

The expert evaluation noted the cost of the sensor could be a challenge to adoption, but also commented that the cost is decreasing over time and second-hand sensors are available for purchase at a reduced price.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	43%
Legal framework requirements	36%
Practicability	50%
Knowledge and skillset required	71%
Absence of grant supports	86%

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Too much work for too little reward	7%
Social acceptability	0%

Table 106. Main expert evaluation challenges of technology no.13 for Eastern Europe

Challenges of Technology Uptake	Hungary
Cost of sensor	✓

Western Europe

Foreseen Benefits to Technology Adoption

The German evaluation understood the technology to be widely used in the country already, with the interest in the technology growing as the benefits are seen in both precise fertiliser application rates and improvements in water body quality. The Belgian assessment, provided by staff from United Experts, too agreed pollution into water bodies would reduce if such a technology were implemented, as the likelihood of over applying fertilisers is removed. Not only would this lead to less leaching and polluting of waterways but it would also lead to financial savings on fertiliser purchases. The Dutch evaluation observed precision agriculture is a focus of government policy and along with policy pressure the increased prices of mineral fertilisers in recent months may lead to greater uptake of such technologies within the Netherlands.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	35%
Better nutrient management	82%
Economic benefits	71%
Environmental benefits	59%
New employment opportunities	6%
Improved work-life balance	12%
Practicability	12%
Ability to use environmental credentials as a marketing tool	12%
Social acceptability	12%

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Table 107. Main expert evaluation benefits of technology no.13 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Precise fertiliser application rates	✓		
Improved waterways	✓		✓
Familiarity with technology			✓
Aligns with government policy		✓	

Foreseen Challenges to Technology Adoption

The Belgian assessment highlighted the need for the sensor to be able to quantify appropriate application rates for many different kinds of fertilisers. As, if the technology is only best suited to mineral or liquid fertilisers then there remains the possibility of excessive application of solid manure wastes within holdings. The Dutch evaluation noted the investment cost of such a technology along with the ease of use of software between different tractor GPS systems could act as a hindrance to technology uptake. Additionally the Dutch evaluation observed the average farm size, and, even field size in the Netherlands, may not possess the appropriate scale to support or justify such a technology.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	88%
Legal framework requirements	12%
Practicability	59%
Knowledge and skillset required	88%
Absence of grant supports	41%
Too much work for too little reward	6%

Table 108. Main expert evaluation challenges of technology no.13 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Suitability to different fertiliser types	✓		
Investment cost		✓	
Technical skill		✓	
Scale of Dutch farms		✓	

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3.2.15 Technology No.14: Potato Growing with Refined Pig Manure Fractions

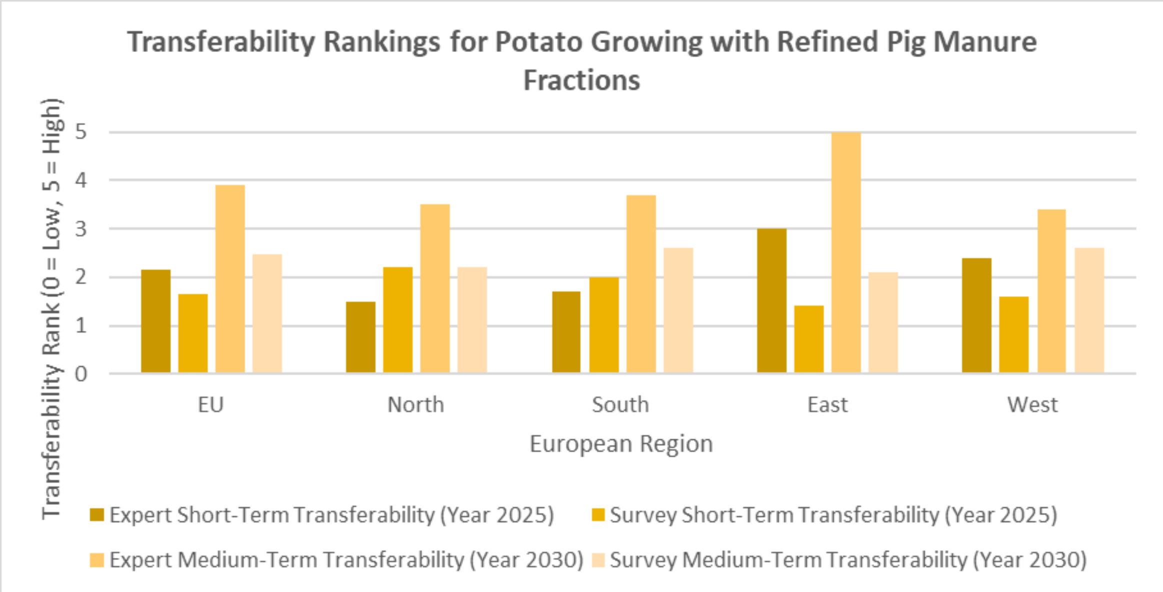

Figure 21. The above bar chart displays the averaged transferability rankings for potato growing with refined pig manure fractions across Europe.

Potato growing with refined pig manure fractions is ranked 10th in short-term transferability by both the expert panels (rank of 2) and survey participants (rank of 1.7). The technology improved in ranking over the medium-term within the expert evaluation to 5th place (rank of 3.7, but within the NTF survey participant's evaluation the technology fell further to 11th place (rank of 2.5) over the medium-term. Figure 120 shows that with regard to expert evaluations the transferability of potato growing with refined pig manure fractions is highest in Northern Europe, whereas the transferability is highest in Southern and Northern Europe within the survey feedback.

3.2.15.1 Potato Growing – European Wide Evaluation

<u>Foreseen Benefits to Technology Adoption</u>

The national expert evaluations agreed that potatoes are a high nutrient demand crop, which is widely grown across the European Union. Therefore, this technology was considered to have scope for use across the member states. Correctly managing pig manure surpluses was recognised by the expert panels as a current challenge within the industry, as pig farms typically have large numbers of housed animals with little accompanying land area on which to distribute the volume of slurry produced. One difficulty in offloading excess animal slurry from the source point to a receiving point, such as an arable holding, is the financial cost associated with transporting the animal waste. The evaluators noted this technology could help mitigate this issue by processing the raw pig slurry into three distinct fertiliser products i.e. digestate solid fraction, digestate liquid fraction and ammonium sulphate. By refining the raw pig manure, farmers can avail of a fertiliser that suits their needs which also exhibits a concentrated nutrient value and a reduced physical volume. By refining the manure and lowering its total volume, reductions in transportation costs, and, the emissions related to transport, are likely to

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reduce for both the pig farmer and potato grower. Additionally, farmers across Europe are familiar with applying manure as a fertiliser, which could assist in the technology's uptake in terms of readily available skills and equipment. Within the expert evaluations, it was noted that ammonium sulphate could be approved for use in Nitrate Vulnerable Zones under the RENURE policy framework due to its improved stability and reduced propensity for nutrient loss when compared against e.g. raw manure. Further benefits of implementing the technology were seen as its compatibility with the aims of the Nutri2Cycle project, such as complimenting circular economy principals and recycling nutrients, which could reduce the potato grower's reliance on chemical fertilisers. It was also remarked that this technology premise could possibly be applied to other crops into the future.

Foreseen Challenges to Technology Adoption

One of the main considerations made by the expert assessors was ensuring consistency in the nutrient value of the refined pig manure products. It was noted that for successful arable farming, or potato production, sufficient application of nutrients is critical. Within the expert feedback, it was noted that if the nutrient value of the refined manure is variable and does not meet the crops requirements then the farmer may mismanage the refined manure by applying additional volume which could result in the introduction of contaminants into the holding, such as pathogens. Information relating to the correct application rates of the digestate solid fraction, digestate liquid fraction and ammonium sulphate for a given crop and given soil type would need to be made available to the farmer. A further challenge highlighted within the expert evaluations was the infrastructure and technical skills required to refine the pig manure, such as ammonium stripping technology or solid-liquid separators, which weren't considered to be widely represented skillsets throughout Europe. As refining manure requires certain technical skills and infrastructure it is a more expensive fertiliser than raw pig slurry. Along with the additional financial cost, the reviewers highlighted the practical challenges of applying the refined manure derived fertilisers when the crop canopy has developed. Furthermore, within the expert evaluations it was stated that legislation may need to be modified to encourage the use of refined manure fertilisers, as currently they carry the same application limits as raw manure.

3.2.15.2 Potato Growing – European Regional Evaluation

Northern Europe

Foreseen Benefits to Technology Adoption

The expert evaluation from Denmark was provided by staff from the University of Copenhagen, while, for Ireland, staff from Teagasc provided the expert evaluation. Both evaluations agreed that, typically, potatoes are a high nutrient demand crop. As a result, a technology that could reduce the reliance on chemical fertilisers while providing the required nutrition for crop yield would be applicable to potato growing. The Danish evaluation also considered Dutch farmers familiarity with the concept of recycled fertilisers as an aid to technology uptake. Within the Irish assessment, it was noted that the majority of pig farms are concentrated on small land areas. As a result, the farmer needs to off-load some of the on-farm slurry produced, most often off-loaded to fellow farmers. By separating the pig manure into solid and liquid fractions, the cost of transporting surplus pig slurry could be reduced. This would

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not only benefit the pig farmer but also the farm receiving the slurry, such as arable potato farms, which may be some distance from the pig farm.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	6%
Better nutrient management	82%
Economic benefits	59%
Environmental benefits	71%
New employment opportunities	29%
Improved work-life balance	0%
Practicability	18%
Ability to use environmental credentials as a marketing tool	18%
Social acceptability	18%

Table 109. Main expert evaluation benefits of technology no.14 for Northern Europe

Benefits of Technology Uptake	Denmark	Ireland
Familiarity with concept of recycled fertilisers	✓	
High nutrient demand of potatoes	✓	✓
Reduced manure transportation costs		✓

Foreseen Challenges to Technology Adoption

Both assessments noted there may well be operator training and infrastructure investments required to successfully manage and apply the three fertiliser's produced i.e. the solid manure fraction, the liquid manure fraction and the ammonium sulphate solution. The Irish assessment stated how a lack of solid-liquid manure separators within the country could act as a barrier to technology uptake. Furthermore, the Danish expert panel noted the financial cost of processing pig slurry would likely be greater than the current cost to farmers of applying either raw animal slurry or chemical fertilisers.

When evaluating the feedback from the NTF survey for Northern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	76%
Legal framework requirements	35%
Practicability	53%
Knowledge and skillset required	41%
Absence of grant supports	47%
Too much work for too little reward	29%
Social acceptability	6%

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Table 110. Main expert evaluation challenges of technology no.14 for Northern Europe

Challenge of Technology Uptake	Denmark	Ireland
Financial cost vs traditional fertilisers	✓	
Necessary infrastructure and training	✓	✓
Unfamiliar with technology		✓

Southern Europe

Foreseen Benefits to Technology Adoption

The three expert evaluations from Italy, Portugal and Spain observed how developing manure processing technologies could assist in reducing emissions from said manure spreading and reduce the reliance on chemical fertilisers. Such measures can overall increase the sustainability of the farming enterprise. Both the Italian and Spanish expert review noted that such a technology could promote Circular Economy goals by closing nutrient loops and transforming a surplus waste product on a pig farm into nutrient rich transportable fertilisers for potato farms. Additionally, both the Italian and Spanish assessment observed that by separating manure into the three fractions described the cost of transporting the fertilisers to an arable potato farms should decrease, which would benefit the farmers involved and reduce emissions related to transport. The evaluation from the Italian panel also stated that ammonium sulphate has increased stability against losses in emissions when compared against traditional fertilisers and therefore could be proposed for use as a fertiliser in Nitrate Vulnerable Zones.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	15%
Better nutrient management	81%
Economic benefits	65%
Environmental benefits	88%
New employment opportunities	8%
Improved work-life balance	8%
Practicability	15%
Ability to use environmental credentials as a marketing tool	4%
Social acceptability	8%

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Table 111. Main expert evaluation benefits of technology no.14 for Southern Europe

Benefits of Technology Uptake	Italy	Spain	Portugal
Possibly applicable in nitrate vulnerable zones	✓		
Compliments circular economy goals	✓	✓	
Reduced transportation cost	✓	✓	
Reduced reliance on chemical fertilisers	✓	✓	✓
Reduced emissions from manure	✓	✓	✓

Foreseen Challenges to Technology Adoption

Both the Italian and Spanish panel noted there may well be operator training and infrastructure investments required to successfully manage and apply the three fertilisers produced i.e. the solid manure fraction, the liquid manure fraction and the ammonium sulphate solution. Furthermore, the Spanish expert panel noted processing pig slurry in the manner described would involve anaerobic digestion, belt filters and vacuum evaporation technology. Both the Italian and Spanish evaluations observed processing the pig manure via such technologies would involve considerable investment from the manure processor and/ or farmer.

When evaluating the feedback from the NTF survey for Southern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	50%
Legal framework requirements	54%
Practicability	54%
Knowledge and skillset required	62%
Absence of grant supports	35%
Too much work for too little reward	12%
Social acceptability	19%

Table 112. Main expert evaluation challenges of technology no.14 for Southern Europe

Challenges of Technology Uptake	Italy	Spain	Portugal
Operator training	✓	✓	
Investment costs of required infrastructure	✓	✓	

Eastern Europe

Foreseen Benefits to Technology Adoption

The Hungarian expert assessment noted how processing the manure in the manner described could increase its suitability for use on arable farms. The Hungarian evaluation stated if the fertilisers

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produced could be stored safely and have a homogenous quality then they could have scope for use within the country.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	21%
Better nutrient management	79%
Economic benefits	79%
Environmental benefits	86%
New employment opportunities	14%
Improved work-life balance	0%
Practicability	7%
Ability to use environmental credentials as a marketing tool	7%
Social acceptability	7%

Table 113. Main expert evaluation benefits of technology no.14 for Eastern Europe

Benefits of Technology Uptake	Hungary
Increased usage of organic fertilisers	✓
Reduced reliance on chemical fertilisers	✓

Foreseen Challenges to Technology Adoption

The expert evaluation from Hungary observed how ammonia-stripping technology is uncommon within the country and implementing such a technology would require investment in operator training. Developing legislation to allow for the production and safe use of the fertilisers described could also be required.

When evaluating the feedback from the NTF survey for Eastern Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	43%
Legal framework requirements	50%
Practicability	50%
Knowledge and skillset required	50%
Absence of grant supports	79%
Too much work for too little reward	14%
Social acceptability	14%

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Table 114. Main expert evaluation challenges of technology no.14 for Eastern Europe

Challenges of Technology Uptake	Hungary
Operator skillset	✓
Legislation relating to bio-based fertilisers	✓

Western Europe

Foreseen Benefits to Technology Adoption

The Dutch expert evaluation, provided by staff from Ghent University, along with the German evaluation, provided by staff from the Thünen Institute, both listed potatoes as a widely grown crop within their respective countries. The German evaluation further noted that farmers there are already familiar with using pig manure in potato production. Within the Belgian assessment, reduced consumption of chemical fertilisers was listed as a potential benefit to technology uptake, as the refined manure-based fertilisers could replace the need for synthetic nitrogen fertilisers. The Dutch expert assessment stated that due to high livestock density there is a national manure surplus within the country. Often pig farmers need to export slurry to arable farms at some distance, as the pig farm does not have the land area itself on which to apply the pig slurry. By refining the pig manure into solid and liquid fractions, transportation costs to distant arable farms could be reduced. Furthermore, the evaluation from The Netherlands noted the refined manure products displayed higher concentrations of nitrogen and potassium with lower concentrations of phosphorous, when compared against raw pig manure. Through their assessment, they explained that, presently, many soils within the Netherlands have high phosphorous concentrations. As a result, using the refined manure fertilisers, which display lower phosphorus with higher nitrogen and potassium concentrations, could represent an optimal fertiliser for potatoes grown in soil with high phosphorous values.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen benefits to technology adoption was deduced:

Better compliance with legal frameworks	6%
Better nutrient management	76%
Economic benefits	88%
Environmental benefits	65%
New employment opportunities	12%
Improved work-life balance	0%
Practicability	12%
Ability to use environmental credentials as a marketing tool	24%
Social acceptability	12%

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Table 115. Main expert evaluation benefits of technology no.14 for Western Europe

Benefits of Technology Uptake	Belgium	Netherlands	Germany
Reduced reliance on chemical fertilisers	✓		
Familiarity with using pic manure			✓
Widely grown crop		✓	✓
Manure surplus solution		✓	
Reduced transport costs		✓	
Concentrated nutrient fertilisers		✓	

Foreseen Challenges to Technology Adoption

The German evaluation considered the interaction proposed by the technology between a pig farmer, a manure processor and a potato grower as very specific and wondered how likely such a dynamic would be within Germany. The Belgian assessment considered current legislation to be the main challenge to technology uptake. At present, manure-derived fertilisers are categorised the same as raw manure fertilisers with the same application rate limits applied. It was noted that if legislation were amended, refined fertilisers such as ammonium sulphate could be accepted as substitutes for synthetic fertilisers and amended application rates could be developed. The Dutch evaluation listed the financial cost of refining pig manure along with the required equipment to apply the refined products, particularly the liquid fraction, as challenges to technology adoption. Additionally, it was observed that the refined products would not be able to completely replace synthetic fertilisers as some fertiliser needs to be applied during the growing season for the potato crop; it was understood that the solid or liquid fractions could not be easily applied when crop canopy had developed.

When evaluating the feedback from the NTF survey for Western Europe the following percentage breakdowns of the survey responses relating to foreseen challenges to technology adoption was deduced:

Economic considerations	59%
Legal framework requirements	71%
Practicability	59%
Knowledge and skillset required	47%
Absence of grant supports	24%
Too much work for too little reward	12%
Social acceptability	29%

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Table 116. Main expert evaluation challenges of technology no.14 for Western Europe

Challenges of Technology Uptake	Belgium	Netherlands	Germany
Current legislation	✓		
Interaction between stakeholders			✓
Financial cost		✓	
Difficulty with application during growing season		✓	

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4. Conclusions

By visually displaying the expert and national taskforce transferability rankings from highest to lowest in both a European wide and regional fashion, any patterns in ranking of the given 14 lighthouse demonstrations can be readily investigated. Although there are some differences within the ranking order between the expert and the national taskforce evaluations, for the most part the same technologies were allocated the most transferable and least transferable rankings. Likewise, when assessing the qualitative data from the expert evaluations and NTF survey selections there was consistency throughout e.g. both parties were generally in agreement as to the main benefits and main challenges associated with each technology, such as environmental benefits or financial challenges. It is helpful to see some familiarities within the polarising technologies as it confirms both the expert evaluations and national task force evaluations were assessing the technologies along a common paradigm. In addition, identifying some commonalities in ranking throughout the evaluations will assist in the next stages of the Nutri2Cycle project, as some lighthouse demonstrations may be selected for future trials, to study further the realities of implementing such technologies within European agricultural systems.

However, there was also some variety in the ranking of the technologies across both the expert evaluations and NTF evaluations, analysing these differences in transferability scores showcases the marginal variation between some of the technologies. In addition, disparity in ranking can be based on regional characteristics and traditions. Some of the technologies are similar in nature or involve similar components e.g. both technology no.1 and no.6 involve anaerobic digestion technology to produce digestate. Showcasing the interdisciplinary aspects some of the technologies have with one another could assist in future stages of the project in terms of assessing what aspects of a given technology are most beneficial or problematic, and to consider if technologies could by amended, combined or altered to improve uptake potential.

Across the evaluations, technologies for which there was greater understanding or familiarity with scored highest on the transferability ranking, whereas technologies for which there was limited familiarity received the lowest transferability rank. Familiarity was a signal that the technology had some concepts which were either already practiced in some regions of Europe; were readily implementable; were undergoing trials; promotion in government agricultural policy, or, a technology with a high transferability readiness level (TRL). Both the poultry compost and sensor technology had a high TRL of 9 and scored well in terms of transferability across Europe. However, a high TRL did not automatically result in a high transferability ranking. This was evident for some technologies which have been shown to work in theory but were not seen as readily implementable by either the expert evaluations or NTF participants, such as the adapted stable design technology (TRL of 9) or bone char technology (TRL of 8 – 9). This highlights the discrepancy between technology trials versus wide-scale adoption. Certain technologies that work well in theory but obtained low transferability ratings were reliant on out-competing traditional products or retrofitting current infrastructure. It is possible these technologies may increase in transferability over a longer timescale than the two timescales referred to in this report, particularly if traditional systems become more costly or harder to manage in time.

On-occasion the transferability ranking reduced over the medium-term. This is an example of future uncertainties within the agricultural community influencing the medium-term ranking and leading to

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hesitancy over the transferability of the technology to the year 2030. National policy makers and legislatures could attempt to address such uncertainties through communication with the agricultural communities to clarify future agricultural policy directions and the future of supports, such as training schemes and subsidies. Further to this, the regional influence was observed within the transferability rankings with local enterprises, such as specific agricultural practices, traditional enterprises, or local agricultural research ventures, greatly influencing technology transferability ranking.

For more nuanced technologies marketing and promotion of the environmental benefits of the product may be necessary to capitalise on the investments made and to validate adoption of the technology. This situation was highlighted for the novel animal feed protein technologies; both the duckweed and algae technologies received low transferability rankings throughout the expert and survey feedback. However, the technology received the highest allocation of ‘use of environmental branding/ meet market trends’ responses within the national taskforce surveys.

In addition, the soil organic carbon technology using goose manure trialled in vineyards ranked third most transferable across all four scenarios for Southern Europe. This represents the most consistent ranking of this technology across all regions and may be an example of traditional agricultural practices of a given regional influencing transferability scores. Within Southern Europe vineyards and goose production are more widely represented than, for example, in Eastern Europe where the technology consistently ranked in the mid-range. This is an example of the need to recognise historic and current agricultural industries within a region and how that will inform on which technologies have the highest propensity for successful uptake.

Such factors will need to be taken into account within the following stages of the Nutri2Cycle project particularly when assessing which of the 14 technologies warrant further investigation for a given region.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Annex 1 – Expert Evaluation Raw Data

i) Denmark

Technology: LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9

Evaluator: Lars Stoumann Jensen, University of Copenhagen.

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Denmark has a relatively industrialised and medium density animal farming sector (pigs and dairy, producing around 30-35 million tonnes (FW) of manure and slurry per year. Approximately 20% of this is currently being processed for bioenergy recovery in anaerobic digesters; the far majority though in large, centralised communal biogas plants operated by private investors and farmers cooperatives (many newer as joint ventures).
- Currently, approximately 60 farm-scale biogas digesters are in operation, most of them build over the past 2-3 decades; in recent years nearly all new development has been with larger scale AD facilities (+100 000 tonnes of biomass per year).
- Danish farmers are highly accustomed to using manures and slurries as fertilisers (two thirds use manures, though only less than every fourth farm has animal production, due to manure ceilings and redistribution to neighbouring farms), and with relatively high efficiency (slurry tankers equipped with trailing hoses/injectors/online acidification, splash-plate or broadspreading methods have been banned for + 10years). Farmers are well aware of the increased fertiliser value of AD digestate compared to the raw feedstock manure, and this is a main motivation factor for sending manure for AD; however not of sufficiently high economic benefit to warrant investment in farm-scale digesters.
- Infrastructure for putting electricity generated by a farm-scale biogas-plant to national grid from is in most places OK.
- In particular organic farmers have a strong potential interest in farm-scale AD, as it is seen as one way to achieve more available nutrients (higher WTP due to no mineral alternative).

Adoption challenges for this technology:

- The cost of a farm-scale digester is substantial for most farmers – this is often evaluated negatively against being share-holder in a larger cooperative AD plant.

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- Support and subsidy schemes are not based on investment for construction, only on network energy-feed-in tariffs, which disfavours smaller scale digesters.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **1-3** depending on subsidy scheme or technology development Rank: 1-5 (1= low, 5= high**Technology:**

LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- In Denmark most of the sewage treatment plants have anaerobic digestion plants for processing the concentrated sludge and recovering energy, producing a dewatered (mechanical liquid-solid separation) digestate solid suitable for land spreading. Approximately 20% of all Dansih manure is being processed for bioenergy recovery in anaerobic digesters; the far majority in large, centralised communal biogas plants. However, only a few of these plants have simple digestate processing such as mechanical liquid-solid separation, and none yet have advanced processing like scrubbing.
- Danish farmers are highly accustomed to using manures, slurries and digestates as fertilisers (two thirds of Danish farmers apply manures to their field, although only every fourth farm has animal production of their own; this is due to manure ceilings and consequent redistribution of manure to neighbouring plant farms). For this reason, and because Danish environmental and fertiliser regulation requires relatively high fertiliser replacement value from application of slurry, all farmers are using slurry tankers equipped with trailing hoses/injectors/online acidification (either via contractors or own if vcery large farms); splashplate or broadspreading methods have been banned for >10 years. Farmers are well aware of the increased fertiliser value of AD digestate compared to the raw feedstock manure, and this is a main motivation factor for sending manure for AD; however not of sufficiently high economic benefit to warrant investment in the further processing.

Adoption challenges for this technology:

- The cost of advanced separation/scrubbing technology vs. the benefits achieved.

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- Unwillingness amongst Danish farmers to handle / appl solid manures.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4** (depending on the cost of synthetic fertilisers and subsidies) Rank: 1-5 (1= low, 5= high)

Technology: LL[43+73]: Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Potato-production in Denmark only occupies around 2-3 % of the cultivated area, mainly potatoes for industrial starch production, but also chips (www.statistikbanken.dk). Quality criteria for starch potatoes are quite strict and can be greatly influenced by fertilisation, why farmers are reluctant to use manures if uncertainty about nutrient efficiency prevails. However, most potato growers receive back potato cell water, from the industrial processing, which is rich in potassium (K) and nitrogen (N), so this substitutes mineral NK fertilisers to some extent and they are not unfamiliar with using recycled products.
- Although Denmark has a relatively industrialised and medium density animal farming sector (pigs and dairy), producing around 30-35 million tonnes (FW) of manure and slurry per year, the intensity is not sufficient that a lot of manure processing takes place. Danish farmers are highly accustomed to using manures and slurries as fertilisers and with relatively high efficiency (slurry tankers equipped with trailing hoses/injectors/online acidification).

Adoption challenges for this technology:

- The cost of direct slurry/digestate application in Denmark is much less than listed in the lighthouse info sheet – and hence processing costs would often make these products much more expensive than raw manure/digestate or mineral fertilisers in Denmark.
- Infrastructure and cost framework for managing, handling and applying the ammonium sulphate solution as a liquid fertiliser and at the same time also dealing with the liquid/solid digestate product.

Short-term transferability (to 2025): **1**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

Technology: LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Although Denmark has a relatively industrialised and medium density animal farming sector (pigs and dairy), producing around 30-35 million tonnes (FW) of manure and slurry per year, the intensity is generally not sufficient that a lot of manure processing takes place.
- Although there is some P accumulation on farms with intensive pig production, recent introduction of P ceilings limit the total input of P per ha from any type of fertiliser, manure or waste, in order to cap any further increase in soil P status.
- Danish farmers are highly accustomed to using manures and slurries as fertilisers and with relatively high efficiency (slurry tankers with trailing hoses/injectors/online acidification).
- Furthermore, improved feeding standards and feed additives means that less P is being excreted in the animal manure, and hence the N:P ratio of manures or slurries on especially pig farms has become more optimal compared to crop demand – hence the need for separation to pure N products is not high.
- Surplus manures (exceeding N or P ceilings) are being transported to nearby plant farms and in some case to centralised AD biogas plants. Anaerobic digestion plants are generally expanding in Denmark, and hence in the medium to long term, the technology may have some scope.

Adoption challenges for this technology:

- The cost of direct slurry/digestate application in Denmark is mostly not high and hence processing costs would often make these products much more expensive than raw manure/digestate or mineral fertilisers in Denmark.
- Infrastructure and cost framework for managing, handling and applying the ammonium sulphate, ammonium nitrate solutions as a liquid fertiliser and at the same time also dealing with the liquid or raw digestate products would be a barrier for many farmers.

Short-term transferability (to 2025): **1**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Nutri2Cycle
Nurturing the Circular Economy

Technology: **LL24: Adapted stable construction for manure processing (Belgium), TRL 9**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- In Denmark, where intensive pig production and dairy farming are the two dominating animal production systems, by far the majority of the animal manure is handled in slurry systems (>90%), using various forms of partly slated floors, slurry ring channels with relatively frequent flushing into outdoor storage tanks, which are mostly covered with either a fixed cover or a floating crust (mandatory). Most of these installations are relatively new, and due to the high capital investment, farmers are reluctant to change their housing and manure management systems unless they are forced to by new regulations.
- However, over the past decade or so, some in-house separation systems have been developed and tested in both public research organisations and private animal sector R&D, in order to verify if emissions of NH3, GHG and odour can be further reduced compared to the existing systems, and against other mitigation measures like ventilation air scrubbers, manure acidification (currently implemented in ≈15% of all slurry installations). However, none of these were successful in adaptation within the animal sector.
- Further tightening of environmental regulations demanding reductions not only in NH3 but also GHG emissions may promote these in-house separation technologies – according to recent farm-press articles, this is gaining some interest.

Adoption challenges for this technology:

- The cost of reconfiguring the animal housing system to the in-house separation, considering the current large investment in slurry systems.
- Considerable scepticism towards the technical stability and operational costs of the in-house separation.
- Current success of installation, operation and emission mitigation efficiency of especially slurry acidification (in-house, in-storage, and online during application) can probably limit interest in the in-house mechanical separation.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **4**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: **LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Denmark has a relatively industrialised and medium density animal farming sector (pigs and dairy mainly), producing around 30-35 million tonnes (FW) of manure and slurry per year, but the intensity is generally not sufficient that a lot of manure processing takes place. Although we have N and P ceilings for manure application, causing many animal farms to export excess manure to neighbouring plant farms who can utilise the manure N and P, there is not a large surplus at the regional level and for sure not at the national level, and hence not a driver to remove N from the slurry.
- Danish farmers are highly accustomed to using manures and slurries as fertilisers and with relatively high efficiency and the logistic capacity is available (slurry tankers with trailing hoses/injectors/online acidification, operated by contractors or owned by the larger farms). So generally, slurries and liquid fractions can be applied effectively with relatively low/minimal losses.

Adoption challenges for this technology:

- Even if slurries or liquid fractions were processed to fully or partly remove/recover ammonium, Danish environmental regulations would not allow the remaining permeate/treated liquid to be discharged or land applied in any different way than the raw slurry/liquid fraction, and hence there would not be a cost saving by the technology.
- Infrastructure and cost framework for managing, handling and applying the ammonium sulphate solution as a liquid fertiliser and at the same time also dealing with the liquid/solid digestate product.
- Current success of installation, operation and emission mitigation efficiency of especially slurry acidification (in-house, in-storage, and online during application) can probably limit interest in the in-house mechanical separation.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: LL23: Pig manure refinery into mineral fertilisers (Italy), TRL 9

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Denmark has a relatively industrialised and medium density animal farming sector (pigs and dairy mainly), producing around 30-35 million tonnes (FW) of manure and slurry per year, but the intensity is generally not sufficient that a lot of manure processing takes place. Although we have N and P ceilings for manure application, causing many animal farms to export excess manure to neighbouring plant farms who can utilise the manure N and P, there is not a large surplus at the regional level and for sure not at the national level, so not a driver to process manures. The only processing that takes place to any greater extent is anaerobic digestion for production of renewable energy (heat/electricity/gas-to-the-grid) and this is growing (currently around 20% of manure is put through AD)
- Furthermore, Danish farmers are highly accustomed to using raw manures, slurries and digestates as fertilisers with relatively high efficiency and the logistic capacity is available (slurry tankers with trailing hoses/injectors/online acidification, operated by contractors or owned by the larger farms). So generally, slurries and digestates can be applied effectively with relatively low/minimal losses.

Adoption challenges for this technology:

- Danish environmental regulations have extremely strict limits for discharge water, and hence the treated permeate would not be allow for discharge. Hence cost savings from reduced logistics would not be valid in Denmark.
- Infrastructure and cost framework for managing, handling and applying the solid fractions and concentrates liquid fertiliser would be a barrier.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL22: ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary), TRL 8-9**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Due to the relatively industrialised and medium density animal farming sector (pigs and dairy mainly) in Denmark, slaughterhouses do have substantial amounts of animal bone waste which could potentially be utilised through this technology.
- Due to the medium-high density of animal farming, the overall demand for mineral fertiliser P is not high, with 3-4 times more P being imported in animal feed than in mineral fertiliser P. However, there is a regional imbalance, which means that there could potentially be a market for such a fertiliser in regions with lower animal density – however, this entirely depends on effectiveness and price of the Bio-NPK-C vs. traditional alternatives.

Adoption challenges for this technology:

- Currently, all the major slaughterhouse companies (the main one being Danish Crown https://www.danishcrown.com/) have already set up an extremely efficient utilisation system for all animal-by-product and side-streams they produce.
- Furthermore, Daka Ltd. (https://www.secanim.dk/) is a Danish large scale recycling operator within animal-by-products, bones, dead animals, etc, and they already have existing technologies for converting various types of ABP into bio-based fertilisers.
- These two above competitors could make it difficult to introduce the technology on the Danish market, unless it can be proven either much more effective or economicalluy for recycling P in animal bones than current technologies

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **1**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL41: Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- *I am sorry, but I do not have the insight to evaluate how this technology would fit in Denmark or what sort of challenges it may meet*

Adoption challenges for this technology:

- The cost ….
- The skillset to run and optimise
- Labour …
- Infrastructure and cost framework…

Short-term transferability (to 2025): **?**

Medium-term transferability (to 2030): **?**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL41b: Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- *I am sorry, but I do not have the insight to evaluate how this technology would fit in Denmark or what sort of challenges it may meet*
- What I can say though is that there is substantial R&D effort in Denmark within this field of microalgae closed photo-reactor systems (e.g. led by the Danish Technological Insititute, https://www.teknologisk.dk/ydelser/plante-og-algedyrkningsteknologi/alger/37314,3), so I presume there is quite some opportunity for transferability at least in medium-term

Adoption challenges for this technology:

- The cost ….
- The skillset to run and optimise
- Labour …
- Infrastructure and cost framework…

Short-term transferability (to 2025): **?**

Medium-term transferability (to 2030): **?**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL13: Application of sensor technologies in plant cropping system (Hungary), TRL 9**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- The Yara N-sensor technology has been implemented and used by a number of farmers in Denmark for quite many years since it was introduced more than two decades ago, however in the first decade a limited number as only few farmers had the technological knowledge and the physical technology for variable rate application of fertilisers (tractor GPS-control and fertiliser spreaders with graduation capability). However, in the most recent 5-10 years, GPS-controlled auto-steering of tractors has become much widely available (more brands and cheaper), so many more farmers have now invested in this. At the same time producers of fertiliser spreaders have put many new versions on the market, which are capable of variable rate application (VRA), and many farmers have invested in this. It is estimated that at least a third of the farmed area can now (2022) be fertilised with VRA fertiliser spreaders (chief consultant Leif Knudsen, pers. Comm.) and the technology is now also entering slurry tankers and liquid fertiliser applicators. Also pesticide sprayers and sowing machines are now commonly equipped with VRA technology.
- Furthermore, a pilot scheme for farmers implementing VRA technologies has been set up, which frees them from some of the general environmental regulations if they implement and document VRA technology.

Adoption challenges for this technology:

- The cost of the technology has come down significantly, and not really a barrier anymore.
- The technical standards for communicating between the software of different brands of tractor GPS control, appliances etc. has up until now been considered a major barrier for non-specialist farmers, but improved industry standards, and consultancy services are gradually freeing up this barrier – though there is still some way to go.
- It is difficult to prove that VRA technology in itself has a huge environmental benefit– it may be more of a cost saving for the farmer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5** Rank: 1-5 (1= low, 5= high)

Technology: LL15: Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Agro-forestry production is very limited in Denmark, and therefore the case is not really applicable to Danish conditions
- Vineyard production exists in Denmark, but is area-wise a very small proportion of agricultural land and therefore not relevant

Adoption challenges for this technology:

- Not valid

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **1**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL17: Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- Due to the relatively industrialised and medium density animal farming sector (pigs, dairy mainly but also poultry) in Denmark, dairy processing companies and slaughterhouses do have substantial amounts of dairy processing waste and side streams which could potentially be utilised through this technology.
- Due to the medium-high density of animal farming, the overall demand for mineral fertiliser P is not high, with 3-4 times more P being imported in animal feed than in mineral fertiliser P. However, there is a regional imbalance, which means that there could potentially be a market for such a fertiliser in regions with lower animal density – however, this entirely depends on effectiveness and price of the RDF-products vs. traditional alternatives.

Adoption challenges for this technology:

- Currently, all major dairy companies (main one Arla https://www.arla.com/) have already set up rather efficient utilisation system for all the side-streams they produce, so they may be reluctant to change these – but they are also focused on greater circularity as one their sustainability indicators.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL57: Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9**

Evaluator: Lars Stoumann Jensen, University of Copenhagen

Transferability to: Denmark

Fit of the technology in providing a solution to national challenges:

- The efficient combined use of solid and liquid manures with mineral fertilisers has been common practice by Danish farmers for many decades, due to the early introduction of relatively strict environmental regulations on farm fertiliser use and nutrient management (starting in the late 1980ies). Therefore the described technology is already common practice on much of the cultivated land in Denmark (Case et al., 2017)

Adoption challenges for this technology:

- The typically lower N use efficiency from composted manures would normally make farmers hesitant to implement composting as a treatment technology. However, composted garden-park waste from the urban areas is a soil amelioration amendment product well accepted by Danish farmers (more than 2/3 of the national garden-park waste compost is applied to agricultural land), so farmers do value the input of organic matter for soil fertility.

Short-term transferability (to 2025): **5**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

Case S., Oelofse M., Hou Y., Oenema O., **Jensen L.S.** (2017) Farmer perceptions and use of organic waste products as fertilisers – a survey study of potential benefits and barriers. *Agricultural Systems* 151, 84–95 http://dx.doi.org/10.1016/j.agsy.2016.11.012.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

ii) Ireland

Technology: LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9 (Anerobic Digestion (BE))

Evaluator: Patrick Forrestal and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- The National Climate Action Plan (2021) calls for production of 1.6 terawatt hours of biomethane production from agricultural feedstock's by 2030 which will be injected in to the national gas grid. Currently, there are few anaerobic digesters in the Republic of Ireland. This farm scale digestion technology is a good fit particularly for an initial pilot cluster of AD plants to be funded in Q4 of 2024 under the national strategic investment fund. It is envisaged that this cluster of plants would be up-scaled.
- Nationally Irelands ruminant animal dominated agriculture faces a challenge to reduce greenhouse gas emission which are dominated by methane. This technology has potential to help agriculture to meet this goal which will become increasingly important in view of the national emissions reduction commitments to 2030.
- Reduced reliance on high cost fertiliser N: the anaerobic digestion process increases the plant available fraction of the total N pool in slurries. This can be good for the plant availability of N potentially displacing mineral N fertiliser. However, increased ammonia losses are a risk if the digestate is not spread using low ammonia emission methods. Fortunately the existence of a grant scheme (TAMS) in Ireland over the past years has dramatically increased the availability of trailing shoe and trailing hose slurry spreaders. The national policy is moving towards phasing out of splashplate or broadspreading methods on more heavily stocked farms. This technology could contribute to the EU goal of a 20% reduction in N fertiliser usage.

Adoption challenges for this technology:

- The cost of a pocket digester is very substantial for most farmers
- The skillset to run and optimise the efficiency of the digester is lacking amongst farmers
- Labour is a challenge on farm and an extra workload will serve as a disincentive
- Infrastructure and cost framework for infection of gas or electricity to national grid from microgeneration is poorly developed. National legislation is advancing.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9 (Digestate, Precision, NT (IT))

Evaluator: Patrick Forrestal/Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- The Environmental Protection Agency (EPA) in Ireland has prioritised the protection of the environment from the harmful effects of wastewater discharges to the rivers, estuaries, lakes and coastal waters. This innovative solution can take part in process wastewaters and agro/food industrial waste which is a good fit under the national strategic investment fund.
- The circular bio-based economy is still largely untapped potential for farmers in Ireland. This technology has the potential of replacing energy-intensive and fossil-based fertilisers by providing digestate and ammonium sulphate (NH_4^+-N) and thus contributing to the closing of nutrient cycles in the Irish agricultural system.
- Ireland has set targets in line with the EU Farm to Fork Strategy target of reducing nutrient losses by 50% and reducing chemical fertiliser use of 20% by 2030. This technology is aligned with the government policy of reducing the use of chemical fertilisers and utilizing waste.
- Ireland is challenged to meet its ammonia reduction targets. This technology could contribute to reduced ammonia loss if coupled with best practices in the manure management chain.
- This biogas production technology producing heat and electric energy can be used for the farm operational needs, thus savings in energy consumption and lower environmental impact in Irish farms which align with the National Climate Action Plan (2021).

Adoption challenges for this technology:

- The cost of setting up the anaerobic digester is very high for the farmers. The availability of labour and the skillset to run and optimise the efficiency of the digester is lacking amongst farmers.
- The prospect of electricity-producing from such a plan is not very attractive in Ireland. Infrastructure and cost framework for installation and transfer of gas or electricity to the national grid from microgeneration is poorly developed. However, due to the climate change priorities, Irish national legislation is advancing which will benefit this in the medium-term transferability.

Open questions for this technology:

- The product of digestion tends to be labile carbon, therefore may not build soil organic carbon.
- Many technologies are combined here, e.g. digested, no-till, precision agriculture. The question remains which technologies have more benefits or are there any synergies between them.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

- There is a contradiction between no-till and precision agriculture and how these can be addressed is not clear.

Short-term transferability (to 2025): **-2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

Technology: **LL[43+73] Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6 (Separated Pig Manure (NL+BE))**

Evaluator: Patrick Forrestal and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- Pig farmers face a challenge of spread lands to apply their slurries to. Often pig units are concentrated on small land areas and the producers need to find farmers willing to take the slurry. Doing so within nutrient management plans and considering transport cost and distance is often an issue. The separation of solids and the concentration of nutrients in the solids increases the economic distance over which nutrients can be moved. The same is true for the ammonium sulphate liquid concentrate making this technology useful for the pig-potato and other combinations of animal-crop production.
- Potato growers in Ireland face challenges to secure and pay for the level of fertilisation required for potatoes which is very significant. Potatoes are a high demanding crop in terms of nutrients to match their relatively high yield potential. Access to recycled nutrients as described in this technology is attractive.

Adoption challenges for this technology:

- Low availability of solid-liquid separators in Ireland
- Ammonium stripping using sulphur is uncommon and thus the experience and equipment to do so needs development
- The economic case may not always be present but restrictions on concentrated units such as pigs means that innovative solutions are needed

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9 (Liquid N/ fractions (BE))

Evaluator: Patrick Forrestal and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- Manure derived recycled fertilisers such as the ammonium nitrate, ammonium sulphate, digestate and liquid fraction of digrestate have some scope for application in Ireland. On many ruminant animal farms there is adequate spread lands for the unprocessed slurry and the nutrients are needed on farm to grow grass and silage. However, for the concentrated operations that are importing feedstuffs in large quantities e.g. pig and poultry or ruminant systems where there is a large distance to return nutrients to silage ground there is potential here.
- The availability of such liquid concentrates could expand the potential uses of N coming from animal systems into arable systems. An issue tends to be that the N in animal systems in Ireland where grazing is practiced tends to be a limitation. A shift towards more clover swards may change this with time.

Adoption challenges for this technology:

- Low availability of solid-liquid separators in Ireland
- Ammonium stripping using sulphur is uncommon and thus the experience and equipment to do so needs development
- The economic case may not always be present but restrictions on concentrated units such as pigs means that innovative solutions are needed
- Farmers typically use granular fertilisers in Ireland and may not have the equipment or skillset to apply liquid without some training etc

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL24: Adapted stable construction for manure processing (Belgium), TRL9 (Housing manure separation (BE))

Evaluator: Patrick Forrestal and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- The return of P to areas of the farm which are further away is often a challenge due to the transport costs of unseparated manure. The higher concentration of P in the separated manure could address this issue.
- Ireland is challenged to meet its ammonia reduction targets, animal housing is a significant source of ammonia emissions this technology has scope to reduce this issue.
- The loss of ammonia-N from animal manures is one of the key factors making the recycling of the N nutrient inefficient, hampering efforts for N circularity in agricultural production systems. Hence the reliance on supplemental fertiliser N to replace N losses. This technology could contribute to reduced dependence on chemical N if coupled to best practice in the manure management chain.

Adoption challenges for this technology:

- The cost of these stables is large
- It is not clear if such construction methods are approved in the current national grant system for agricultural modernisation (TAMS)
- While the concentration of P in the solid fraction is certainly useful, frequently K is also need to be returned and the K tends to concentrate with the N in the liquid fraction. Using this liquid fraction on grazing paddocks could cause issues with grass teteny in cows
- Ready access to outlets for valorisation of the separated waste streams through bio-refineries or anaerobic digesters are currently limited in Ireland

Open questions for this technology:

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4 (Vacuum Evaporation (ES))

Evaluator: Patrick Forrestal and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- Concentrated pig operations that are importing feedstuffs in large quantities face challenges to export the nutrients and concerning ammonia loss. Recovering the majority of the N as a liquid concentrate opens potential for export of the N to crop growing farms at distance while the remainder of the manure nutrients are spread more locally.
- The availability of such liquid concentrates could expand the potential uses of N coming from animal systems into arable systems.

Adoption challenges for this technology:

- No availability of vacuum separators in Ireland
- Ammonium stripping using sulphur is uncommon and thus the experience and equipment to do so needs development
- The economic case may not always be present but restrictions on concentrated units such as pigs means that innovative solutions are needed
- Farmers typically use granular fertilisers in Ireland and may not have the equipment or skillset to apply liquid without some training etc

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL23 Pig manure refinery into mineral fertilisers (Italy), TRL 9 (Bio-based Fert from manure (IT))

Evaluator: Patrick Forrestal, Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- In Ireland, there are 1.6 million pigs, an average of 1,234 pigs per farm and produce over 2.4 million tonnes of pig manure annually mainly in the form of pig slurry (liquid form).
- The separation of solids and the concentration of nutrients in the solids decrease the livestock effluent volume and increases the economic value of the product.
- This solution allows farmers to have more livestock heads due to nutrient recovery and export. The obtained by-products can be reused in agriculture as fertilizers and close the present CNP loops in the agricultural systems in Ireland and soil quality enhancers.
- This technology can make substantial savings in fertiliser costs to replace much of the chemical fertiliser required to fertilise grassland and crops which is aligned with the government policy where Ireland targets to reduce the use of chemical fertiliser by 20% by 2030.
- In addition, this technology can contribute to environmental sustainability by treating the discharge liquid waste as clean water and reduction on carbon emissions.

Adoption challenges for this technology:

- If the farm size is not the limiting option for this technology, this technology can be useful for the pig/animal (dairy, beef)-crop production systems in Ireland.
- In Ireland, direct land spreading of raw pig manure is still the most economic method of utilising pig manure. Therefore the cost-effectiveness of this technology is in question.
- Farmers' willingness to invest in the sequential separation process and the availability of labour and the skillset to run and optimise the efficiency of this technology is lacking amongst farmers

Open questions for this technology:

- How does this technology deal with the ammonia–N loss or methane emission from the system?
- Is this technology also useful for smaller pig farms?

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL22 ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary), TRL 8-9 (Bone Char P (HU))

Evaluator: Patrick Forrestal, Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- ABC-BioPhoshate is a controlled release biofertiliser with a higher P supply (>30% P2O5) compare to triple super phosphate and crop yield increase more than 10% which make this technology very promising for Ireland.
- Farmers typically use granular P fertilisers in Ireland. The rock phosphate is mostly imported to Ireland and then it is used in the manufacture of various phosphate fertilisers.
- Currently, there is little use of animal bone in Ireland. Around 35,000 head of cattle are slaughtered every week in Ireland which can be a good source of bone to prepare animal bone char.
- There is a large meat processing sector in Ireland that can implement this technology.
- This technology can utilize unexploited animal bones and transform into phosphorus fertiliser products which can reduce the dependency of rock phosphate imported from abroad.
- ABC-BioPhoshate is a controlled release biofertiliser with no runoff and leaching, therefore can be a sustainable alternative nutrient source that is a food fit for Ireland.

Adoption challenges for this technology:

- The technical expertise to utilize animal bone using such technology is limited in Ireland.
- The preliminary cost of setting this technology is very high.
- Adoption of this technology mostly depends on the effectiveness and price of the Bio-NPK-C vs. traditional alternatives.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL41a Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6 (Floating Wetland (BE))**

Evaluator: Patrick Forrestal, Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- In Ireland, floating wetland plant like duckweed is still relatively rare and only recently arrived in Ireland. It is an invasive species that can negatively affect aquatic biodiversity.
- Pig wastewater in a big open pond is not common but this technology can be used in the wastewater treatment plant.
- Normally in Ireland, pig manure is used as organic fertiliser to replace part of the chemical fertilisers. Therefore, the availability of pic manure for such technology is limited.

Adoption challenges for this technology:

- Using this technique can lead to high emissions from the open pond with pig manure wastewater.
- Lower acceptability among farmers due to its bad odor from open wastewater pond.
- The cost of this technology seems to be very high.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL41b Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4 (Algae Protein (BE))

Evaluator: Patrick Forrestal, Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- Today, 70% of proteins in the European Union are imported. Production of protein-rich biomass using surplus nutrient-rich digestate could be an alternative pathway to land application of digestate. Utilising such nutrient sources to facilitate algal growth could be considered an alternative agricultural enterprise, especially where management practices are not currently in place.
- The challenge is to optimise the algae value chain, from local production to storage and handling, in such a way that it becomes a viable, economically relevant industry.
- In Ireland, digestate/slurry is used in the grassland or arable land as an alternative nutrient source. So, the availability of slurry/waste to grow the protein-rich microalgae biomass would be challenging for Ireland.

Adoption challenges for this technology:

- The potential problem with respect to using organic agricultural waste as a source of nutrients to grow algae i.e. the variations in nutrient content and P availability within and across agricultural waste types.
- The storage period for N is an important factor, as volatilisation will diminish nutrient contents (up to 30% in some cases). Similarly during the manure storage phase, P precipitates quite easily.
- For the production of algal biomass many things need to ensured e.g. water supply, suitable land topography, geology, favourable climatic conditions and easy access to nutrients and a carbon supply which will be challenging for most farmers.
- The preliminary cost of setting up this technology is very high.
- A dairy manure management strategy is already in place in Ireland (under the Nitrates Directive) and research now aims to maximise the nutrient utilisation of slurry. This means that dairy slurry is unlikely to be a viable source of nutrients for algal growth in Ireland.

Open questions for this technology:

- How to address the feasibility issues such as variable nutrient contents amongst and across source types, transparency issues, and sustained nutrient loss during the storage phase (N volatilisation and P precipitation)?
- What is the financial implication for the farmer for using this technology instead of applying directly in the grassland/arable land?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

Technology: LL13 Application of sensor technologies in plant cropping system (Hungary), TRL 9 (Sensor fert (HU))

Evaluator: Patrick Forrestal, Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- Smart and precision agriculture is one of the key goals of the government in Ireland which gives this technology potential environmental benefits.
- The adaptation of sensor technologies in (plant cropping system) in agriculture has the potential to improve precision farming practices and support economic and environmental sustainability in Ireland.
- A transition to smart farming can supplement and assist farmers in the multi-faceted day-to-day workings of the modern farm. This will help farmers make more environmentally sustainable decisions more quickly and with greater certainty.
- The current rapidly increasing mineral fertilizer prices might stimulate the uptake of this technology in order to use mineral fertilizer most efficiently and prevent over application of fertilizer in Ireland.

Adoption challenges for this technology:

- The instrument cost of the technology seems very high.
- Collaborations with farmers with Irish Govt and Technology Company can help to reduce the challenge.
- The willingness of the elderly farmers would be a challenge.
- The high technical knowledge required to operate this technology will be a barrier for non specilist farmers/ farmers with less IT knowledge.

Open questions for this technology:

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL15 Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7 (Bio-based Fert (FR))

Evaluator: Patrick Forrestal, Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- Ireland's National Planning Framework recognises the transition to a circular economy and bio-economy where the generation of waste is minimised and materials and resources are recycled facilitating the close of the nutrient cycles and increasing soil carbon sequestration. Therefore the use of manure and slurry to reduce the use of chemical fertilisers is aligned with the government policy in Ireland.
- There is a very small commercial wine production in Ireland and many of them are experimental or private vineyards however the integration of biobased fertilsiers into orchards and other agricultural systems has potential to displace mineral fertilsiers.
- The availability of goose slurry is limited. All geese produced in Ireland are termed free-range and commercial production is relatively small numbers compared with any of the other poultry meats. However, the manure of other fowl such as chickens is prevalent in concentrated areas.

Adoption challenges for this technology:

- As commercial vineyard and goose production is minimum in Ireland, the adaptation possibility of this technology in vineyards in Ireland is very limited however there is scope in other systems.

Open questions for this technology:

- Is it possible to adapt this technology to any other arable land use? It likely can be.
- The experiment is ongoing, it is unclear what the impact is.
- What is the cost-saving or benefit?

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL17 Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6 (Bio-based Fert (IE))**

Evaluator: Patrick Forrestal and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- Irish Agriculture is heavily dependent on imported mineral fertilisers and the direction of policy travel has been to reduce reliance on these imported fertilisers to reduce environmental losses. The war in Europe has exacerbated already high fertiliser prices with supply issues and complications. Also highlighted is the point that 20-25% of Ireland's fertiliser has been imported from Russia. The recycling of nutrients from animal farms and agricultural product processing can reduce this reliance and is therefore an increasingly good fit to need national challenges.
- Arable soils in Ireland are typically under conventional tillage over the long-term and the loss of organic matter over time is an issue. The use of mineral fertilisers containing no carbon return to soil does not help this issue. The use of manures and sludges returns carbon to the soil system and to feed soil microbial life which mediates nutrient cycling processes. Again this technology is a good fit.

Adoption challenges for this technology:

- Accurate nutrient content of the material
- Fertiliser equivalence values to determine replacement rate of mineral fertiliser are not always present, though more are becoming available
- Transport of bulky materials
- Spreading accuracy and consistency is very important in arable crops
- Bout width that material can be spread on many not match tramlines

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL66 Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9 (Bio-based Fert (PT))

Evaluator: Patrick Forrestal, Niharika Rahman and colleagues, Teagasc

Transferability to: Ireland

Fit of the technology in providing a solution to national challenges:

- There are 2.4 million tonnes of pig manure and 130,000 tonnes of poultry manure are produced in Ireland annually. Irish farmers have started using poultry manure as a fertiliser source.
- Ireland is aiming at reducing the use of chemical fertilizers and replace portion of chemical fertilisers with organic fertilisers like slurry and compost. This technology can replace up to 30% of the mineral N fertilizer and provide P to the soil.
- This technology can enrich the soil with organic matter which can increase Ireland's soil fertility and overall soil health.

Adoption challenges for this technology:

- Compost is not considered as efficient as synthetic fertilisers. The main issue with using manure/compost as a fertilizer is its unpredictability.
- Slurry spreading can be challenging.
- Labour cost also needs to be considered.

Open questions for this technology:

- What is the application rate for the poultry compost and the slurry in the crop field?
- What is the P recovery rate by this technology?
- What is the effect on crop yield?

Short-term transferability (to 2025): 3

Medium-term transferability (to 2030): 5

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

iii) Italy

Technology: LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9 (Anaerobic Digestion (BE))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- In general, Anaerobic Digestion (AD) technology has already proved to have a high transferability in Italy, thanks to the incentives policies since 2008, offering reasonable prices for biogas sources to the electricity of up to 0.28 €/kWh. In 2012, it followed another Decree on biogas electricity, introducing additional credits for projects capturing thermal energy, and reducing the nitrogen content of digestate. While in 2013, a Decree incentivized the refining of biogas to methane for feeding into the grid and use for transportation. And most recently, in 2018, a decree was introduced for connection to both the electrical grid and natural gas networks, quality standards for injection, and standards for operators to certify the environmental sustainability of the biomethane.[1]
- Because of the different incentives, Italian biogas plants are mainly devoted to electricity production. At the European level, Italy ranks second after Germany in electricity generation from biogas, with an electricity generation of 9368 GWh.
- As Italy fulfilled the National Renewable Energy Action Plan targets for 2020, new targets will be set for 2030. So, the sector needs further support, significantly to expand upon biogas (for electricity and heat generation) and biomethane (for injection in the natural gas network and fuel for transportation purposes) sub-sectors.[2]
- Moreover, the co-production of digestate as recovered fertilizer can help reduce dependence on synthetic sources.

Adoption challenges for this technology:

- Any required training skills that can need the operation and optimization of AD system for exploiting the maximum potential of its products (e.g. production of renewable energy from biogas).
- The use of digestate in the field could lead to emission N losses if it is not incorporated into the soil with the proper technique (injected) and used at the right time and according to crop requirements.

Short-term transferability (to 2025): 4

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Medium-term transferability (to 2030): 4

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9 (Digestate, Precision, NT (IT))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- This technology/local demonstration case is an excellent example of the transferability and advance of anaerobic digestion systems in Italy in the last decade. The efficient production and use of renewable energy from biogas generation that the technology produces while managing and transforming bio-waste into recovered fertilizers, besides integrating precision agriculture practices to give a better environmental performance of these recovered nutrients while used in the field. Make of it a very suitable technology to support some of the targets set in the National Energy and Climate Plan (INECP) for the next ten years (until 2030) to target goals such; 1) accelerating the transition from traditional fuels to renewable sources by promoting the gradual phasing out of coal for electricity generation in favour of an electricity mix based on a growing share of renewables; 2) to become less dependent on imports by increasing renewable sources and energy efficiency and to diversify sources of supply through the use of natural gas.
- This is aligned with other EU directives to address the N and P management in agriculture, for example, the Circular Economic Package, to reduce, for example, the import of phosphate per year and promote the use of bio-wastes as potential sources of fertilizers.

Adoption challenges for this technology:

- The high investment cost required for setting up an anaerobic digester, aside from the infrastructure needed to efficiently and adequately use the biogas produced as renewable energy.
- Italian agricultural biogas potential is based on efficient land use and changing farm practices to regenerate unusable agricultural land and integrate biomass as a double crop.[1]
- As the technology integrates different practices (e.g. precision agriculture), implying higher investment costs, it can be suitable only for large companies.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 4

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL[43+73] Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6 (Separated Pig Manure (NL+BE))**

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Often pig farms (especially extensive large units) are located in areas without nearby suitable cropland fields where slurry can be reused. Therefore, displacement of significant volumes of slurry at long transport distances is required implying higher economic cost because of its transportation and the environmental impact (e.g. GHG emissions). Separation into liquid and solid fractions form with further post-treatment to increase concentration and stability (e.g. ammonium sulphate). It's a solution that will facilitate the displacement of nutrients due to the reduced volume and a lower environmental impact.
- In general, potato represent a relatively large crop in Italy (60000 ha), representing a nutrient demand that should be covered to reach its yield potential. The access and reuse of recycling derived fertilizers is an alternative in producing potatoes that can go in line with actual directives to promote the use of organic wastes as fertilizer sources from the Circular Economic Package.
- Ammonium sulphate production can be a suitable candidate to enter within the RENURE (REcovered Nitrogen from manURE) frame,[3] to be safely used under the Nitrate Vulnerable Zones (Nitrates Directive), therefore, opening an accessible way into the commercial market.

Adoption challenges for this technology:

- The high costs of processing.
- In producing ammonium sulphate by an ammonium stripping system, besides the initial economic cost that can imply the system's setup, experience and technical skills are required for its operation and maintenance.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9 (Liquid N/ fractions (BE))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- In intensive livestock production systems, proper management of the excessive nutrient effluents is needed to be reused in cropland production. Especially in the cases where the importing of feedstock is still significant and requires large distances to return nutrients.
- The use of manure recycling derived fertilizers (RDFs) with predictable N release, and low P content can potentially apply in Italy as a potential substitute for synthetic fertilizers. However, the RDFs derived from animal manure are categorized as animal manure and as such, so they will need to comply with any legal application constraints for its use.
- The availability of these recovered nitrogen concentrates could expand the potential uses of N coming from livestock systems into cropland. Especially within the actual RENURE frame,[3] these recovered fertilizers can be a strong candidate for the top priority to be safely used under the Nitrate Vulnerable Zones (Nitrates Directive), opening a way into the fertilizer market and a potential substitute for synthetic N sources.

Adoption challenges for this technology:

- A better knowledge/training from operators on the importance of integrating proper techniques (e.g. precision agriculture) during the application in the field of recycling derived fertilizers are essential not only to minimize losses of ammoniacal N through volatilization but also to increase nutrient uptake efficiency.
- Possible high investment costs are required to adopt the technology for having different processed recovered fertilizers.
- Suitable farm size or district plants are needed due to the high complexity of the technological process and investment costs.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): 4

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: **LL24: Adapted stable construction for manure processing (Belgium), TRL9 (Housing manure separation (BE))**

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Intensive livestock farming has a high nutrient load of surpluses from the slurry that requires proper management to reduce its environmental impact, especially from N reactive losses and GHG emissions. Manure separation as a standard and simple practice has benefited by lowering emissions and giving better value/use to the separated fractions.
- As an immediate technology for the separation of liquid and solid fractions from manure, it can be very advantageous for reducing the emissions of ammonia and greenhouse gases from stables as less urine is in contact with urease, an enzyme that can be found in solid manure. Animal housing is challenged to meet its ammonia reduction targets in Italy and many other countries. Thus, this technology is suitable for tackling this problem. Besides, reducing ammonia losses from manure is essential for optimizing the recycling of N, increasing its nutrient circularity, and reducing the need for supplemental chemical sources to cover the N losses. Thus, this takes action in the frame of the Circular Economy Package.
- The immediate solid, liquid separation can be integrated with other post-treatment technologies to give a better value to the separated fractions; the solid fraction can be well valorized in an AD system to produce biogas (renewable energy), while the liquid fraction can be used as an N and K fertilizer. This, as a recovered fertilizer, can also help reduce the reliance on synthetic fertilizers sources.

Adoption challenges for this technology:

- Any policy regulations and incentives to comply for giving a commercial and safe use of recovered products.
- A possible need to integrate it with other post-treatment technologies to increase value and nutrient use efficiency in the separated fractions.

Short-term transferability (to 2025): **1**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

Technology: LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4 (Vacuum Evaporation (ES))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- In the pig sector industry, the recovery of ammonia from manure is very suitable for closing the Nitrogen loop by producing recovered fertilizers (e.g. ammonium sulphate). Its reduced volume can favour its storage and transportation to longer distances where arable cropland requires it. At the same time, the remainder of the manure nutrients can be used more in local crops.
- The specialized recovery of ammonia can help reduce or avoid its emission losses during further treatment/management of the recovered co-products generated.
- Within the actual RENURE frame,[3] this recovered fertilizer can be a strong candidate in the top priority to be safely used under the Nitrate Vulnerable Zones (Nitrates Directive), therefore, opening a freeway into the fertilizer market and being a potential substitute for synthetic N sources

Adoption challenges for this technology:

- Any related highly investments cost in the initial setting of the technology
- Operative costs might be a constraint.
- Specialized equipment for low-temperature vacuum evaporation is not a common practice, so it may require experience and/or training in its operation and maintenance.
- Possible integration of the post-treatment step in the processed manure remained has to be addressed to increase the value of the remaining nutrients (e.g., recovery of P).

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Nutri2Cycle
Nurturing the Circular Economy

Technology: LL23 Pig manure refinery into mineral fertilizers (Italy), TRL 9 (Bio-based Fert from manure (IT))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Aside from the large water consumption that the livestock industry has, the excessive slurry can cause several environmental problems when poor management does not integrate practices for the recovery and better allocation of these nutrient surpluses. Besides recognizing the growing challenge of water scarcity, wastewater management is identified in one of the 17 Sustainable Development Goals set by the United Nations, namely the SDG 6 (Safe wastewater treatment systems) and SDG 14 (managing excess nutrient flows causing eutrophication); they look to ensure sustainable withdrawals and supply of freshwater by 2030. Both targets are tackled with the excess of nutrient effluents that the technology seeks to manage while providing recovery of freshwater and concentrated nutrients.
- The constraint limitation that represents the use of manure by the Nitrate Directive Guidelines in Nitrate Vulnerable Zones (NVZ) can be overcome by the adoption of new Fertilizing Products Regulations (EC/2019/1009),[4] such as the recent RENURE (REcovered Nitrogen from manURE) criteria established by the EU Joint Research Centre to overcome the barriers in the safe use of recovered products over the limits in NVZ.[3] Therefore, this technology can be a vehicle to bring up recovered fertilizers products (mineral concentrates) complying with the standards set by the RENURE frame.

Adoption challenges for this technology:

- Relatively high energy consumption that carries membrane technology. Though input resources are minimal, chemicals for pH adjusting and membrane cleaning.
- Energy consumption is also a factor that could affect economic performance; profitability.
- Membrane fouling should be accompanied by prevention and mitigation practices (e.g. constantly monitoring, cleaning in place and others).
- Farm size and presence of skilled staff

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): 4

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: LL22 ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary), TRL 8-9 (Bone Char P (HU))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Although Italy is a large meat processing industry, there is little reuse of animal bones, so there is potential to implement this technology. Especially as the losses from 'mine to fork' for phosphorus (P) reach up to 80%.[5]
- Phosphorus is a critical raw material for Europe, showing an almost total dependence on imports from non-European countries and a shallow recycling rate from end-of-life products. EU imports >90% of its P, with only one active mine in Finland.[6] This is why the EU has put P-rock and white P on the list of Critical Raw Materials (https://ec.europa.eu/growth/ sectors/raw-materials/specific-interest/critical_en) to promote its recycling and increased resource efficiency. Thus this technology can utilize unexploited animal bones and transform them into phosphorus recovered fertilizer, reducing the reliance on limited natural imported sources such as rock phosphate.
- Animal Bone Char - BioPhoshate can be a sustainable and safe alternative to P as a nutrient source as a controlled release biofertilizer with no run-off and leaching.

Adoption challenges for this technology:

- The need for harmonized regulations (e.g. criteria limits for organic pollutants) that can open full market opportunity for all fertilizing products coming from organic materials streams, including biochar (e.g. Animal Bone Char - ABC).
- The investment cost for the setting of this technology can be very high, limiting its application to only a large scale.
- Application of this technology is scarce in Italy; therefore, high technical experienced support will be required in its implementation.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: **LL41a Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6 (Floating Wetland (BE))**

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- The growing of floating wetland plants such as duckweed has not developed so much application in Italy. Because it is more recognized as an invasive specie that can affect aquatic biodiversity rather than for its potential as a protein feed source. Besides, other alternative plants from the microalgae family with many industrial applications requiring similar minimum input for their production are receiving greater attention.
- Moreover, in Italy, swine manure waste streams are more commonly used as a fertilizer for inland crops and more recently explored as an alternative medium for growing microalgae in recirculated systems.
- Though, this technology could have some space of applicability because of the advantages and potential that it could have as a directly recovered feed source of protein with low heavy metal contents. Becoming a shorter way to recover and produce swine protein feed, reducing steps process and nutrient losses that take land crops (e.g. use of biofertilizers, crop management)

Adoption challenges for this technology:

- The management of the open ponds could lead to emissions and odours due to the reuse of pig manure streams.
- Any required post-treatment or management to the medium remained after nutrient removal from duckweed to recover clean water in the environment.
- A legal framework to use it as feed is not clear.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL41b Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4 (Algae Protein (BE))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Italy stands for one of the top three countries in the number of microalgae production industries in Europe. However, to produce 100 ton of microalgae biomass up to 200 of CO_2, 10 ton of N, and 1 ton of P are consumed, of which a minimum production cost around 0.5 €/kg is needed based on chemical fertilizers.
- The traditional use of agro-residues/livestock residues in Italy, especially south of Italy (soil fertilization and conditioning), has been increasingly discouraged by several factors, such as strict land spreading limits (concerning the risks of soil as well as surface and groundwater pollution), competition with higher-income uses (e.g., composting, energy conversion), low availability of receiving fields and so on.
- This technology allows better use of a nutrient-rich digestate in algae cultivation by providing a sustainable chain to produce protein-rich algae biomass with less production cost and energy and to recover nutrients from agro-residues.
- Moreover, this technology at a large scale contributes to the production of large amounts of valuable biomass, useful for animal feeding and agriculture uses, thus, enhancing the productivity and sustainability of food production.

Adoption challenges for this technology:

- High production cost and limited production capacity when using closed photobioreactors, the economic balance should be applied and assessed.
- Very low TRL by now
- High risk of contamination, including other algae species, bacteria or predators that could outcompete the desired target species cultivating with agro-residues without proper sterilization (since the bacterial community can be quickly and strongly influenced by cultivating medium). Thus, it leads to overloaded cleaning procedures.
- Multiple pre-tests are encouraged to perform in order to get the optimum biomass production and productivity considering the system installation to monitor light, temperature, gases exchange (O_2/CO_2), stirring and mixing system and so on.
- A legal framework to use the product is still not clear

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL13 Application of sensor technologies in plant cropping system (Hungary), TRL 9 (Sensor fert (HU))**

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- The use of precision agriculture tools can help mitigate the environmental impact of agriculture by reducing fertilizer use and irrigation while saving costs for the farmer. In this case, implementing a sensing Nitrogen tool to measure the plant uptake can give a more detailed view of the required by the crop and then provide better fertilizer use efficiency, with fewer N losses in the environment from run-off and leaching.
- Precision farming was the main target of the European Commission (EC) legislative proposal published in 2018 regarding the 2020 Common Agricultural Policy (CAP). Therefore, there is awareness and aim to integrate more precision agriculture technologies in the agriculture field, particularly where the information technologies sector is evolving and growing so fast, becoming part of our daily lives. Its inclusion in different industry sectors is essential in the current technology era.

Adoption challenges for this technology:

- Precision agriculture tools, in general, require a high initial investment of equipment, aside from sometimes the learning cost.
- Due to high investment costs and the need for an integrated approach to precision farming, the providers of services for farmers are more entitled to invest in this technology.
- A high level of capabilities and skills to manage a large amount of information collected also can be required.
- While economic support is useful and important for small-medium farms in the Italian context, other factors such as promoting agricultural policies that support creating information systems, innovation platforms, and networks involving small and large farms are also crucial. This can lead to greater levels of available information (more awareness and foster dissemination) among farmers helping to reduce the perception of complexity in the adoption process of integrating precision technologies.[7]

Short-term transferability (to 2025): 3-4

Medium-term transferability (to 2030): 5

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: LL15 Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7 (Bio-based Fert (FR))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Combining livestock, arable crops and agroforestry in a biological vineyard farm is a moving approach that can provide a better use of the different agricultural wastes by connecting the other sub-productive units and closing the nutrient cycles in a more systemic and sustainable way. This combination is in tune ideally with a more Circular Economy and sustainable production.
- Italy is the second-largest producer of grapes in the world. Though Italy's vineyard cultivation is commonly found under the slope, hilly conditions also give distinguished conditions to the land where it is cultivated, such as the risk of erosion and low soil depth. Therefore, incorporating organic matter in vineyards systems is essential in its crop management; in this way, the reuse of organic residues from oil production (sunflower, rapeseed, hemp and camelina) is worth for recovering organic matter to the soil.
- Besides the high organic matter (68%) that the processed recovered residues can bring, the low content of heavy metals in these biobased fertilizers is also a favourable characteristic in vineyard nutrient management.

Adoption challenges for this technology:

- There are short farms that integrate livestock systems with vineyard culture because of the slope conditions in which commonly grapevine is grown in Italy. This is mainly for the zones where is more extensive and applied the grapevine culture. And therefore, application in the case of manure derived fertilizers is limited for grapevine production.
- Therefore, geography and landscape could limit the integration of other productive units into the vineyard culture.
- Geographic areas suitable for integrating livestock, agroforestry and vineyard productive systems will require more intensive management than a monoculture. And thus, they can require more expertise, training in the different productive units, and more equipment tools for their management.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Short-term transferability (to 2025): 3

Medium-term transferability (to 2030): 4

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL17 Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6 (Bio-based Fert (IE))

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Italy is the eighth country in Europe with higher imports of chemical fertilizer, representing a trade value of $208M for 2020.[10] Synthetic fertilizers do not offer a stable price with a trend to increase in the future because of the limited use of no renewable resources used in their production. Moreover, the current war in Europe has impaired its prices, aside from limiting its supply, where for example, Italy imports the 6.29% from Russia.[10] Therefore, recycled-derived fertilizers are the way to create less reliance on importation from non-renewable sources and a better way to connect more with our environment by closing the nutrient loop.
- This demonstration solution will not only solve an actual problem concerning the excess manure produced. Still, it will also resolve the issue of low organic matter content in soils (SOM), which is considered low (<2%) or deficient (<1%) in many European soils.[8] Closing the loop in nutrients cycles like the C cycle, using organic materials such as manures, will result in the natural supply of nutrients to the soil, which will endure natural resources and increase the soil's health

Adoption challenges for this technology:

- Any difficulties in the transportation of organic wastes
- Aside from the initial characteristics of the infeed manure and how it is recovered and processed, it can change the nutrients ratio of recycled products. Thus, determining a mineral fertilizer replacement value is not always feasible.
- The risk of ammonia losses during the spreading and use of recovered fertilizers requires integrating proper techniques to reduce N losses.
- Regulations and incentive policies are necessary if circular nutrient practices are to be scaled up and will provide a commercial way to biobased fertilizers.

Short-term transferability (to 2025): 3

Medium-term transferability (to 2030): 5

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: **LL57 Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9 (Bio-based Fert (PT))**

Evaluator: Fabrizio Adani, Giuliana D'Imporzano, Axel Herrera

Transferability to: Italy

Fit of the technology in providing a solution to national challenges:

- Italy is the EU Country with the highest percentage of livestock manure treated (36.8% of production). Regarding volumes of treated farm manure, the technologies relating to separation and anaerobic treatment are the most frequently used in Italy. Though in Northern Italy, where animal breeding is highly intensive, other treatment techniques are also found, such as biological nitrogen removal and composting.[9]
- Areas with pig density farming come with an excess of slurry production that needs to be managed by selecting a technology accordingly to the farm size, manure characteristics, and available cropland.
- Compost and slurry contain a significant amount of organic matter that can restore in the soil. Increasing the quantity of organic matter in the soil will improve the soil's fertility and health and directly increase its carbon storage capacity. Besides, organic fertilizers are applied based on their total N content, which also provides some P to the soil, ensuring the closure of the slurry and compost P cycles and, therefore, the need for supplemental mineral P fertilizer.

Adoption challenges for this technology:

- Integrating practices for better use of biobased fertilizers during their application to avoid nutrient losses in the environment is essential.
- High transportation costs require allocating slurry surpluses to agricultural land available for its spreading.
- Clear criteria and better assessments for choosing the suitable technology for pig processing according to the conditions and needs of the farmer can be a restraint.

Short-term transferability (to 2025): 3

Medium-term transferability (to 2030): 5

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

iv) Spain

Technology: LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9 (Anerobic Digestion (BE))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- Anaerobic digestion is a well-known technology in Spain, although only around 150 plants have been established, 13 of them related to the agricultural and livestock sector.
- The Spanish Biogas Roadmap (2022) aims to identify the challenges and opportunities for the full development of biogas in Spain. It proposes a Vision for 2030 and 2050 in line with the Strategic Framework for Energy and Climate of the Government of Spain, establishing a minimum goal of biogas production of 10.41 TWh per year in 2030. This will make it possible to avoid the emission into the atmosphere of approximately 2.1 million tons of CO_2 equivalent per year.
- In the Biogas Roadmap it is considered in the medium term the possibility of establishing a mechanism to promote the use of biogas through the establishment of mandatory sales and consumption objectives. This support system for the development of biogas would be characterized by the legal imposition on consumers, suppliers or producers that a certain percentage or quota of their energy supply or production come from biogas, similar to the current mechanism for promoting the use of biofuels.
- The farm-scale Anaerobic Digestion could help to achieve the goals stablished in this Biogas Roadmap, related to biogas production, be a source of energy for farms and related activities, and avoid uncontrolled emissions of methane to the atmosphere in livestock manure storage pits.

Adoption challenges for this technology:

- The economic cost of this technology may not be affordable by a farmer, although the savings on energy consumption for example may help to achieve a fast return of the investment.
- The processing of this type of projects can become complex since they are subject to numerous regulations (waste, agriculture, livestock, animal and plant health, industrial, urban planning, gaseous emissions, liquid discharges, noise, odours, transport, SANDACH, gas and electricity, among others) and involves many organizations (General State Administration, Communities Autonomous and Municipalities).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

- The process is less efficient when operated with pig manure than with cattle manure. In Spain there are 6 million bovine animals, compared to 23.9 million of pig heads in 2016, so the technology has a wider market in the second kind of farms.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 4

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9 (Digestate, Precision, NT (IT))**

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- The Spanish Biogas Roadmap (2022) establishes a minimum goal of biogas production of 10.41 TWh per year in 2030.
- The use of the digestate as a fertilizer avoids the use of mineral fertilizers, which consume high amounts of fossil fuels for its manufacture.
- The Spanish Biogas Roadmap (2022) proposes to encourage the use of materials from anaerobic digestion from waste. For this, the agricultural application of the digestates will be facilitated, through technical advice to the agricultural sector, guaranteeing that the digestate applications are carried out following agronomic criteria.
- The use of the digestate is conditioned by the limits established in Royal Decree 47/2022, on the protection of waters against diffuse pollution produced by nitrates from agricultural sources, which restricts the application of nitrogen on land belonging to vulnerable areas, which can make it difficult for the digestate to be used in areas with a high supply of organic materials, such as those areas with many livestock farms. So, the possibility of removing nitrogen through stripping and absorption technology will allow to take profit of this digestate. However, this option would require an additional investment in the necessary equipment and would also lead to higher operating costs.

Adoption challenges for this technology:

- The overall cost of an anaerobic digester and a stripping and absorption system may be too high to be assumed by a farmer.
- Both technologies can be difficult to be operated by a farmer.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 4

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL[43+73] Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6 (Separated Pig Manure (NL+BE))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- In recent years we have witnessed a significant decrease in potato cultivation areas in Spain. In 1990, a cultivated area of 271,300 ha was registered in Spain and has been decreasing to the current 87,500 ha. However, this technology could be applied to other more extended crops in Spain.
- This technology stimulates the transition towards sustainable and resilient farming systems through circular agriculture because it aims to minimise external inputs and negative discharges to the environment, and to close nutrient cycles.
- On the one hand, biogas is produced from livestock manure treatment and emissions to the atmosphere are reduced. On the other hand, the digested liquid fraction obtained in a belt filter press system is used as a fertilizer for crops. The product can be further refined to produce ammonium sulphate and potassium concentrate by inducing ammonia volatilisation from de digested liquid fraction in a 4-stage thermal vacuum evaporation system during increased temperature regime. These products are easier and cheaper to transport to distant lands in case of nutrient surplus.

Adoption challenges for this technology:

- The obtaining of the three different kind of product depends on three different technologies: anaerobic digestion, belt filter and vacuum evaporation, that can be difficult to afford and operate by a farmer.
- Digestate application restrictions in vulnerable areas may limit the adoption of this technology if it is not further refined.
- In areas with a surplus of livestock manure in relation to the land available, the application of digestate to crops represents a cost for the farmer. On the contrary, in other areas with low farm density, digestate represents a source of income, so the cost of the technology will not be justified.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9 (Liquid N/ fractions (BE))**

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- The Spanish Royal Decree 47/2022, on the protection of waters against diffuse pollution produced by nitrates from agricultural sources, restricts the application of nitrogen on land belonging to vulnerable areas.
- On the other hand, the Spanish Biogas Roadmap (2022) proposes to encourage the use of materials from anaerobic digestion from waste. For this, the agricultural application of the digestates will be facilitated, through technical advice to the agricultural sector, guaranteeing that the digestate applications are carried out following agronomic criteria.
- The use of recycling-derived fertilizers can replace much of the chemical fertiliser used in the fields and make substantial savings in fertiliser.

Adoption challenges for this technology:

- Digestate and pig urine/slurry application restrictions in vulnerable areas in Spain may limit the adoption of this technology, since the transport cost can be high if land is far from the farm.
- It is important to determine the characteristics and effectivity of the different kind of recycling-derived fertilizers in each kind of crop to promote and expand their use.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL24: Adapted stable construction for manure processing (Belgium), TRL9 (Housing manure separation (BE))**

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- The Spanish national air pollution control program defines objectives and strategic actions from 2020. As of 2020, ammonia emissions must be reduced by -3%, compared to 2005, and, following a linear path. Global emissions must be limited by -16%, compared to 2005 emissions, as of year 2030.
- Ammonia emission from pig farms is one of the main problems of intensive farming, and farm owners must apply the Best Available Techniques (BAT) to minimize these emissions. The Spanish Royal Decree 306/2020 establishes basic regulations for the management of intensive pig farms and forces newly installed pig farms to adopt the BAT to reduce ammonia emissions into the atmosphere from each barn, as well as greenhouse gas emissions. A technique or a combination of techniques must be adopted that allows the reduction of ammonia emissions by at least 60% with respect to the reference technique.
- Spain is the second country in the European Union in pig production, after Germany, with a census of 23.9 million heads in 2016, which represents 20% of the total production of the European Union (EUROSTAT, 2016). In Catalonia and Aragon, 50% of the total census of Spain is concentrated. More than 50 million m^3 of slurry are generated annually, so it is necessary to find solutions aiming to reduce ammonia emissions.
- In situ separation of slurry into solid manure and urine can help to prevent emissions coming from the stable because urine is less in contact with urease, an enzyme that can be found in solid manure.
- Besides, separating urine will conserve its nitrogen content, thus being more valuable as a fertilizer.
- The application of this technology could help the farmers to achieve the objectives established in the Spanish Royal Decree.

Adoption challenges for this technology:

- Its implementation in new farms (under construction) are easy and affordable, but the cost of adapting the farm can be high, and technically challenging

Short-term transferability (to 2025): **1**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4 (Vacuum Evaporation (ES))**

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- In Spain there were 23.9 million pig heads in 2016, which represents 20% of the total production of the European Union (EUROSTAT, 2016). 50% of these heads are concentrated in certain areas of Catalonia and Aragon. More than 50 million m^3 of slurry are generated annually, so it is necessary to find solutions aiming to reduce ammonia emissions.
- Besides, the Spanish Royal Decree 47/2022, on the protection of waters against diffuse pollution produced by nitrates from agricultural sources, restricts the application of nitrogen on land belonging to vulnerable areas, making necessary to export pig slurry to distant land in areas with high concentration of farms.
- Low-temperature vacuum evaporation allows for ammonia recovery from livestock manure to obtain a salt solution that can be used as a fertiliser. The subproduct can be marketed, reduce mineral fertilizers consumption and, compared to raw pig slurry, it is easier to transport long distances in case of areas of nutrients surplus.
- Compared to conventional ammonia stripping and absorption, vacuum stripping operates at a lower temperature because of lower heating requirements, reducing operation cost.
- The plant is modular and adaptable to different livestock farm sizes and manure production.

Adoption challenges for this technology:

- Technical knowledge will be required by the farmer to operate the plant despite being an automated process.
- The cost of the plant will be only justified in high farm density areas, with low available land for pig slurry application.
- Operation parameters need to be well controlled to achieve high ammonia recovery.
- The processed slurry will end with a high pH that could promote the emission of the remaining ammonia, this should be controlled by further processing (e.g. acidification).
- It is important to determine the characteristics and effectivity of the by-products in each kind of crop to promote and expand their use.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 4

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: LL23 Pig manure refinery into mineral fertilisers (Italy), TRL 9 (Bio-based Fert from manure (IT))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- Organic residues such as pig slurry contribute significant amounts of nutrients to the soil. The use of these residues in agricultural soils will always be subject to compliance with current regulations and that their application is carried out with agronomic criteria.
- Spain is the second country in the European Union in pig production, after Germany, with a census of 23.9 million heads in 2016, which represents 20% of the total production of the European Union (EUROSTAT, 2016). In Catalonia and Aragon, 50% of the total census of Spain is concentrated. More than 50 million m^3 of slurry are generated annually (with an average content of 5 kgN/t, representing 250 million kg of nitrogen) which give rise to large surplus volumes in the areas with the highest concentration of farms.
- In general, Spain is a cereal country, since approximately 50% of the cultivated area is cereal. Cereals are crops that represent high nitrogen requirements (90 kg N/ha in average, despite large differences between rainfed cereals, such as barley or wheat, and those more suitable for irrigation, such as corn or rice).
- In the statistics of the Ministry of Agriculture, Fisheries and Food on the use of fertilizers in Spain in 2020, it is shown that of the 1.059.299 tons of elemental nitrogen used, 27% was in the form of complex fertilizers.
- Organic residues of livestock origin, well used, can replace or reduce the use of significant amounts of mineral fertilizers. In this way, the use of the different fractions obtained with this technology could represent savings for the farmer and a better environmental management.

Adoption challenges for this technology:

- The cost of the different equipment for the three-step separation can be high, and only in areas with a high density of farms will be justified such a cost. On the contrary, in other areas of Spain with low farm density, pig manure represents a source of income.
- The final permeate must meet the requirements for the final use, such as disposal in water bodies.
- The durability of reverse osmosis membranes must be assessed, since their replacement may increase the operation costs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL22 ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary), TRL 8-9 (Bone Char P (HU))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- In the statistics of the Ministry of Agriculture, Fisheries and Food on the use of fertilizers in Spain in 2020, it is shown that of the 486.673 tons of P_2O_5 used, only 5% was in the form of complex fertilizers. Compared to the 1.059.299 tons of elemental nitrogen used, phosphate is added to land in less amount.
- This technology helps to treat wastes of the meat industry, and to close the nutrients loops by replacing mineral phosphate fertilizer. Pyrolysis process is applied to cattle bones and a rich phosphorous char is obtained. In Spain there are 6 million bovine animals.

Adoption challenges for this technology:

- Due to the high temperatures required in the pyrolysis process, the energetic cost of ABC may be high.
- The adoption of this technology will require a high investment, only justified if the market price of the fertilizer is high enough, combined with the possible saving of the slaughterhouse in waste management.

Emission of the pyrolysis systems could be a concern of the neighbours and the society

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL41a Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6 (Floating Wetland (BE))**

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- Duckweed can effectively remove nutrients from agriculture wastewaters in a recirculated system while producing a feed source with a protein content of 35% DM, helping to close the nutrient loops.
- Besides, the use of pig slurries to grow floating wetland plants will reduce the land demand for application of livestock manure in areas with nitrogen surplus and high density of farms.
- Duckweed will be also a source of local protein, reducing importation of protein and the consumption of energy for animal feed transport.
- In Spain it is a technology that is being also assessed at pilot plant scale.

Adoption challenges for this technology:

- The investment cost for the pond can be high, depending on the surface. If the use of the wetland plants represents savings in animal feeding, the investment cost could be compensated.
- Operation of the floating wetland requires knowledge and dedication.
- Pig slurry is too concentrated for Duckweed grow and needs to be diluted, increasing the volume of the installation.
- The product used as animal feed has to guarantee its safety for the animals.
- Methods to assure the durability of the duckweed when storage have to be foreseen.
- Emissions of the open pond of greenhouse gasses and ammonia into the atmosphere have to be assessed.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL41b Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4 (Algae Protein (BE))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- The introduction of this technology in Spain, with around 2500 hours of sunlight per year, would be favourable since the requirements for lighting will be reduced compared to northern countries.
- Since the Spanish Royal Decree 47/2022, on the protection of waters against diffuse pollution produced by nitrates from agricultural sources, restricts the application of nitrogen on land belonging to vulnerable areas, algae growth will allow for an alternative use in areas with nitrogen surplus.
- Algae will be also a source of local protein, reducing protein importation and the consumption of energy for animal feed transport.

Adoption challenges for this technology:

- CO_2 supply is needed for algae growth, which can increase the operation cost. However, alternative sources of CO_2 could be found.
- Pig slurry is too concentrated for algae grown and needs to be diluted, increasing the volume of the installation and the number of pre-treatment steps.
- Operation of the algae reactor requires knowledge and dedication.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL13 Application of sensor technologies in plant cropping system (Hungary), TRL 9 (Sensor fert (HU))**

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- The Spanish Recovery, Transformation and Resilience Plan (PRTR) has enabled a line of 79 million euros for the acquisition of equipment in precision agriculture and 4.0 technologies, in order to increase the efficiency and sustainability of the sector.
- Using the N sensor tool the optimal fertilizer rate will be applied according to crop nutrition requirements, increasing fertilizer use efficiency and yields, reducing nitrogen residues in soils in post-harvest conditions and N run-off and leaching.
- This technology is especially useful in vulnerable areas with N restricted application, since fertilization could be adapted to the real necessity of the crops.
- The investment cost can be recovered in 4-5 years, due to the high cost of mineral fertilizers. However, in areas where the farmer pays for the application of livestock manure, the cost of the sensor for the land or crop owner may not be justified.

Adoption challenges for this technology:

- Specialized knowledge on information technologies may difficult the adoption of this technology for less experimented farmers.
- Implementation of tractors should increase the cost

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL15 Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7 (Bio-based Fert (FR))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- The Spanish Circular Economy Strategy, Spain Circular 2030, lays the foundations for promoting a new production and consumption model in which the value of products, materials and resources are maintained in the economy for as long as possible, in which the generation of waste is minimized and those that cannot be avoided are used as far as possible. The Strategy thus contributes to Spain's efforts to achieve a sustainable, decarbonised, resource-efficient and competitive economy.
- In Spain, according to the study "Heavy metals, organic matter and other parameters of agricultural soils and pastures in Spain. MMARM and INIA (MEC)", 50% of the soils have a content of less than 1.70% organic matter, that is, they are soils with a real risk of desertification.
- This solution will help to make a change from only recycling of the organic residues produced within the farms to a real agronomic use, with a CNP controlled flow from livestock to arable crop with agroforestry, or from arable crop to vine plant.

Adoption challenges for this technology:

- In some areas with nutrient surplus due to high density of farms, transport cost of these organic materials may reduce the adoption of this solution.
- Nutrients (N and P) content of these products may limit its use in vulnerable zones with high animal density.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL17 Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6 (Bio-based Fert (IE))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- The Spanish Circular Economy Strategy, Spain Circular 2030, lays the foundations for promoting a new production and consumption model in which the value of products, materials and resources are maintained in the economy for as long as possible, in which the generation of waste is minimized and those that cannot be avoided are used as far as possible. The Strategy thus contributes to Spain's efforts to achieve a sustainable, decarbonised, resource-efficient and competitive economy.
- In Spain there are 6 million bovine animals, and the food and beverage industry is the leading branch of the industrial sector, according to the latest Structural Business Statistics from the Spanish National Institute of Statistics (INE), with €113,593.07 million in value of production, which represents 2.5 % of GDP (in G.A.B.), 24.8% of the industrial sector. The number of companies in the food and beverage industry amounts to 31,342, according to the latest data from the INE's Central Directory of Companies, which represents 15.1% of the entire manufacturing industry. The use of dairy manure or food industry waste provides an option for balanced application of bio-based and chemical fertilisers to meet the demand of required crop nutrients like N, P, K and S and thus, will facilitate farmers' understanding to use these options and to replace chemical fertilisers.
- The use of this organic fertilizers will allow for a reduction in costs (453 €/ha with 100% chemical fertiliser compared to 285–349 €/ha with a combination of organic and chemical fertiliser options), with no effect on crop yield.

Adoption challenges for this technology:

- In some areas with nutrient surplus due to high density of farms, transport cost of these organic materials may reduce the adoption of this solution.
- Nutrients (N and P) content of these products may limit its use in vulnerable zones with high animal density.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Rank: 1-5 (1= low, 5= high)

Technology: LL57 Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9 (Bio-based Fert (PT))

Evaluator: August Bonmatí and Míriam Cerrillo

Transferability to: Spain

Fit of the technology in providing a solution to national challenges:

- Spain is the second country in the European Union in pig production, after Germany, with a census of 23.9 million heads in 2016, which represents 20% of the total production of the European Union (EUROSTAT, 2016). In Catalonia and Aragon, 50% of the total census of Spain is concentrated. More than 50 million m^3 of slurry are generated annually, so it is necessary to find solutions aiming to reduce ammonia emissions.
- This solution will help farmers to know the benefits and limitations related with the use of organic fertilizers for maize fertilization.
- The use of compost and pig slurry for fertilization will contribute to close the N, C, P loops, by replacing mineral fertilisers and producing cereals for animal fed.
- The use of pig slurry or compost is conditioned by the limits established in Royal Decree 47/2022, on the protection of waters against diffuse pollution produced by nitrates from agricultural sources, which restricts the application of nitrogen on land belonging to vulnerable areas, which can make it difficult to apply high amounts of pig slurry in areas with a surplus.

Adoption challenges for this technology:

- The main challenge of this solution is the surplus of this kind of organic substrates in some parts of Spain, that will need to consider long distance transport to nitrogen deficient areas.
- Nutrients (N and P) content of these products may limit its use in vulnerable zones with high animal density.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 4

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

v) Portugal

Technology: LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9 (Anerobic Digestion (BE))

Evaluator: David Fangueiro

Transferability to: Portugal

Fit of the technology in providing a solution to national challenges:

Will not solve the problem of slurry management and application to soil since need to apply the digestate.

Only bring some added value due to biogas production

Adoption challenges for this technology:

Use of digestate

Ibestment

Short-term transferability (to 2025):

1

Medium-term transferability (to 2030):

3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9 (Digestate, Precision, NT (IT))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Relies on AD adoption but still a good solution to be considered

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL[43+73] Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6 (Separated Pig Manure (NL+BE))

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Good way to find some new users for manures

Adoption challenges for this technology:

Short-term transferability (to 2025): 3

Medium-term transferability (to 2030): 5

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9 (Liquid N/ fractions (BE))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Relies on AD adoption and some new processes to be installed but still a good solution to be considered

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL24: Adapted stable construction for manure processing (Belgium), TRL9 (Housing manure separation (BE))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Reduction of ammonia emissions

Adoption challenges for this technology:

Only for new stables

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4 (Vacuum Evaporation (ES))

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Complexe and expesnive technology

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL23 Pig manure refinery into mineral fertilisers (Italy), TRL 9 (Bio-based Fert from manure (IT))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Complexe and expesnive technology

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL22 ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary), TRL 8-9 (Bone Char P (HU))

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Complexe and expesnive technology

Legal constraints

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030):**1**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL41a Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6 (Floating Wetland (BE))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Complex and expensive technology

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **1**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL41b Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4 (Algae Protein (BE))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Complex and expensive technology

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **1**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL13 Application of sensor technologies in plant cropping system (Hungary), TRL 9 (Sensor fert (HU))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Expensive and other solutions available

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL15 Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7 (Bio-based Fert (FR))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL17 Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6 (Bio-based Fert (IE))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL57 Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9 (Bio-based Fert (PT))**

Evaluator:

Transferability to:

Fit of the technology in providing a solution to national challenges:

Adoption challenges for this technology:

Short-term transferability (to 2025): 3

Medium-term transferability (to 2030): 5

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

vi) Hungary

Technology: **LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9**

Evaluator: Edward Someus_3R

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- The anaerobic digestion is an important element of the HU Climate Action Plan (2030) for better and more climate friendly utilisation of biomethane production from manure.
- As majority of farmers are SMEs the farm scale digestion technology is a good fit to the market.
- As there is an ongoing energy crisis, due to the Russian gas supply, it is expected that resilient and long term sustainable solution need to be adapted to replace N mineral fertilisers (which require large amount of natural gas supply).
- This technology could contribute to the EU goal of a 20% reduction in N fertiliser usage.

Adoption challenges for this technology:

- The production scale is not economical to run under market competitive commercial conditions.
- The CAPEX AND OPEX cost of a pocket digester is very substantial for most farmers they can not afford.
- If the installation/operations are based on subsidies, it will not be sustainable for long term.
- Qualified labour is a bottleneck on all SME farms and extra workload will function as disincentive.
- If the biogas plant is not operated correctly there will be less or no emission savings than possible.
- In comparison to an installation of larger biogas plants, there will be much more investment costs and training required for the same amount of kW produced.
- Beyond 2023 the EON will not pay anything for the grid uploaded green electricity daytime, but only at peak hours, so the utilisation of the electricity onsite will be challenging beyond 2023.

Open questions for this technology:

- What is different in this pocket digester to the already established small scale manure digestion plants?
- What are the emission savings of this technology (and what are the costs for these savings)?
- How will the storage be arranged?
- Can the technological standard be transferred (CE-standard)?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9

Evaluator: Edward Someus_3R

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- The use of sewage in Hungary is highly regulated. The trend in Hungary is a rapidly reduced use of sewage sludge in agriculture. The market is also supporting the ban of sludge use in agriculture, as those products that are grown on sludge cultivated soil are difficult to sell or only cheap priced.
- As Hungary is the Carpathians basin that is a large scale sensitive water base, the sewage sludge user risks are high, such as dangerous pathogens and chemicals could be transported into drinking water reservoirs, food, soil and groundwater through the use of sewage sludge as fertilizer or soil conditioner.

Adoption challenges for this technology:

- High restrictions for the use of sewage sludge in Hungary in the sensitive water base areas (that the majority of Hungary)
- The biogas production for heat and electric energy is a considerations, however this interrelation in most cases not resulting commercially market competitive outputs, while the continuous subsidy support in not possible.
- High costs for the technology and possibly a very high skill level required.
- Transfer of gas or electricity to the national grid from microgeneration is not viable in Hungary.

Open questions for this technology:

- The product of digestion tends to be labile carbon, therefore may not build soil organic carbon.
- Many technologies are combined here, e.g. digested, no-till, precision agriculture. The question remains which technologies have more benefits or are there any synergies between them.
- There is a contradiction between no-till and precision agriculture and how can these can be addressed?

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9**

Evaluator: Edward Someus_3R

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- For ammonium nitrate fertilizers there are special requirements regarding the safety of their use, to avoid that those fertilizers will be used outside of their intended purposes, for example as an explosive. Special requirements regarding their explosiveness and tracing should be established.
- The availability of such liquid concentrates could expand the potential uses of N coming from animal systems into arable systems.
- It is important that the product is storable and hygienically safe. That it does not change it characteristics during the storage process or change its qualities through storage.
- The product has to be homogeneous quality if it should be used in the field by farmers.

Adoption challenges for this technology:

- Need rather TRL9 for technology transfer than TRL7 (that is not enough for transferr.
- IRL + CRL + Authority permits need to be clarified and verified.
- Ammonium stripping using sulphur is uncommon and thus the experience and equipment to do so needs development
- Farmers typically use granular fertilisers in Hungary. P is also needed. However this can be managed if LL 1+2+9 are integrated to LL22 – P fertiliser.

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **L41: Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6**

Technology: **LL41b: Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4**

Evaluator: Edward Someus

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- It is rather difficult to get permit for such solutions in the CE area.

Adoption challenges for this technology:

- Below TRL7 is still low maturity for correct tech transfer evaluation.
- Pollutants and hygienic properties are to be considered.
- Costs might be a limiting factor.

Open questions for this technology:

- IRL + CRL + Authority permits need to be clarified and verified.
- What type of waste water or effluent from pig manure treatment facility is used?

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL24: Adapted stable construction for manure processing (Belgium), TRL9

Evaluator: Edward Someus_3R

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- The Hungarian phosphate import dependency is 100%.
- Majority of agricultural soils are Phosphorus depleted. Despite very large amount of rapid solution mineral Phosphate fertilisers used since 1950's, majority (>80%) of the P used is fixed into the soil Ca content structure, and not plant available for long term. It has been realised, that the Phosphorus content evaluation case in soil is controversial: P content in soil is measured in laboratory and extracted artificially, that analytics show large amount of P content in soil, versus the real field conditions where the situation is that this P content is fixed and not plant available for long term. As a result, the P surplus in EU soils is an inappropriate assumption in the majority of agri soil cases.
- Since 1950's the Russian Kola mineral phosphates imported in very large industrial scale, which was cheap and used in multiple doses. The Russian Kola mineral phosphates are magmatic origin, with lower cadmium content around 30 mg/kg but lower P2O5 content as well. (The SubSahara mineral phosphates are sediment origin, with much higher cadmium content (60-210 mg/kg) but higher P2O5 content). Now there is full stop for the Russian phosphate import to the EU. This EU import opportunity will not come back for long term, as the Russians already redirected its production for domestic use and export to China and India.
- As the Russian gas supply is at risk, also the very high gas prices, the two mega scale N fertiliser factory producers recently stopped its operations and closed down.
- This technology could contribute to reduced dependence on chemical N if coupled to best practice in the manure management chain.

Adoption challenges for this technology:

- Although the higher concentration of P in the separated manure, this is still not enough to make it economically high nutrient density above 30% P2O5 content to decrease the dose/ha use and save operational costs while increase efficiency.
- The cost of these stables is large and SME farmers unlikely to invest, at least not in short term.
- This construction methods is not approved in the current national grant system for agricultural modernisation.

Open questions for this technology:

- How are urine and solid manure transported and stored out of the stable? Is this included in the price calculations?
- Which measures are taken to prevent emissions outside the stable?
- IRL + CRL + Authority permits need to be clarified and verified.

Short-term transferability (to 2025): **1**
Medium-term transferability (to 2030): **3**
Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4**

Evaluator: Edward Someus_3R

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- Nitrogen fertiliser industrial producers are closing as of problematics around Russian gas supply.
- The availability of such liquid concentrates could expand the potential uses of N coming from animal systems into arable systems.
- Integration to LL22 is a good opportunity.

Adoption challenges for this technology:

- TRL4 is too low maturity to make any consideration for technology transfer.
- IRL + CRL + Authority permits need to be clarified and verified.
- In economical scale large industrial operations required that have it's logistical challenges.
- Ammonium stripping using sulphur is uncommon and thus the experience and equipment to do so needs development
- Farmers typically use granular fertilisers in Hungary. P is also needed. However this can be managed if LL 1+2+9 are integrated to LL22 – P fertiliser.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL15: Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7**

Evaluator: Edward Someus_3R

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- Aspects same as LL24

Adoption challenges for this technology:

- TRL6-7 is too low maturity to make any consideration for technology transfer.
- IRL + CRL + Authority permits need to be clarified and verified.
- Adaptation for MS regulation need to be clarified.

Open questions for this technology:

- Is it possible to adapt this technology to any other arable land use it likely can be
- The experiment is ongoing, it is unclear what the impact is
- What is the cost-saving or benefit?

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL17: Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6

Technology: LL57: Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9

Technology: LL23: Pig manure refinery into mineral fertilisers (Italy), TRL 9

Technology: LL[43+73] Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6

Evaluator: Edward Someus_3R

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

- Aspects same as LL24
- Arable soils in Hungary are usually under conventional tillage over the long-term and the loss of organic matter over time is an issue. The trend is to replace the use of mineral fertilisers use of agro by-products in large extent. The use of manures to the soil system is already applied traditionally since long time.

Adoption challenges for this technology:

- BelowTRL7 is too low maturity to make any consideration for technology transfer.
- IRL + CRL + Authority permits need to be clarified and verified.
- The solutions are challenging for the over-high PTEs (Zn/Cu) for which continuous inspection needed.
- Low nutrient density = high doses, that is resulting higher inputs for PTEs, pharma residuals, potential pathogens, hormones per ha while increasing adaptation cost/ha.
- Logistics, transport and lawfully storage of bulky materials.
- Spreading accuracy and consistency is very important in arable crops

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL13 Application of sensor technologies in plant cropping system (Hungary), TRL 9 (Sensor fert (HU)

Evaluator: Zoltán Hajdu, SOLTUB Ltd.

Transferability to: Hungary

Fit of the technology in providing a solution to national challenges:

Site-specific fertilization is one of the main objectives in the precision agriculture. Chemical fertilizers variable rate application requires accurate and efficient tools to determine the actual nutrient demand. The tractor mounted Yara N sensor and the Green Seeker by remote sensing offer the opportunity to deliver the required information quickly, precisely and cost-efficiently about the crop N supply to farmers. The sensors determine the crop N status by measuring the light reflectance properties of crops, by using the normalized difference vegetation index (NDVI). The use of the N sensor has several advantages in plant nutrition as the fertilizer rate is place on the right place and in the right amount, increase the fertilizer efficiency, decrease fertilizer losses by leaching and run-offs, the crop quality is more homogeneous and is a reduced cost for fertilizers. After several years soil is becoming more homogeneous. The provided fertilization maps can be used also in plant protection and for the variable rate of seeding. Recently the UAV (unmanned aerial vehicles) or drones are introduced in the plant cropping systems mostly used for liquid fertilizers and pesticides spraying. The drone sensors use the same NDVI as the tractor sensor, but are more precise that the satellite driven tractor sensors. Mostly the DJI Agras T30 drones are used with 6 propellers and 16 spraying nozzles which can carry 30 L fertilizer allowing a cloud based farming.

On the project website a video is available on the tractor mounted sensor technology. The second video with the drones is under preparation.

Adoption challenges for this technology:

- The cost of the tractor mounted and drone sensor technology is becoming more and more acceptable for crop farmers, mostly due to the subsidy systems for digital agriculture. There are HU farmers who use both sensor systems or are planning to introduce the drones.
- Yara and Green seeker sensors can be purchased as new one (approx. 35000 €) or on second hand price (approx.15000€).
- Drones allow large perspectives in fertilisation and pesticide spraying. In the future with automatic tractor driven systems is possible that the drones to communicate directly with the tractor software.
- In Hungary from 2021. only drones certified by the National Food Chain Safety Offices can be used in agriculture.

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vii) Belgium

Technology: Farm-scale AD, TRL 7-9
Evaluator: Sam Tessens (Biogas-E)

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- **Reducing GHG-emissions:** A farm-scale AD can result in a 50% reduction of the GHG-emissions of a livestock farm, making it one of the most cost-effective measurements to lower the climate impact.
- **Producing renewable energy:** A farm-scale AD can provide in a clean and stable energy production, enough to make a farm self-sustaining. At larger scale the biogas could be upgraded to transport fuel quality and used in farm vehicles.
- **Producing organic fertilizers:** Digestate, the remaining organic fraction after digestion, can be used as an organic fertilizer. An advantage is the higher nutrient-availability of digestate compared to raw manure.
- **Reducing N-emissions**: Agriculture is the main contributor to N-emissions in Flanders. Case studies prove that a stripping-scrubbing installation on the digestate can significantly reduce the N-emissions.

Adoption challenges for this technology:

- Adaptation to different types of feedstock: Currently mainly dairy manure is used as a feedstock. There are promising developments on the use of solid pig manure, but the use of other agricultural waste streams (produced on-farm) is still limited. This lowers the further growth potential of the technology.
- Efficient energy valorisation: The installation should be dimensioned on the local energy demand. The useful valorisation of the produced energy is not always easy on a farm with different energy needs throughout the year.
- Expertise and information requirements: The operation of a biogas reactor requires some attention and knowledge on the process of anaerobic digestion. Training and basic information has to be available for the farmers.

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- Trade-off between price and quality: AD at this scale are not the most cost-efficient compared to large-scale installations. Nevertheless, experiences learn that investing in some overcapacity, gas treatment etc pays off on the longer term.

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

Technology: **LL24: Adapted stable construction for manure processing (Belgium), TRL9**

Evaluator: Anne Adriaens, UGent

Transferability to: Belgium

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- In view of the realization of the Natura 2000 goals, nitrogen emissions have to decrease. Since the agricultural sector is the largest contributor to emissions of nitrogen oxides and ammonia, Programmative Approach to Nitrogen establishes measures to reduce the nitrogen emissions of that sector. By separating the pig urine and excreta at the source, the formation of urease and the subsequent emission of NH_3 is avoided. The VEDOWs system is certified as "ammonia-emitting stall system".
- Reduced reliance on high cost fertiliser N: pig urine is a ready-to-use mineral nitrogen fertilizer
- The separation at the source dry fraction of the manure yields 350 $Nm^3.t^{-1}$ biogas with a 65% CH_4 content, thus improving both quantity and quality of the produced biogas compared to normal manure. It thus contributes to realize the transition towards renewable energy sources.

Adoption challenges for this technology:

- The investment in a stable system is a long-term investment decision and a substantial cost for farmers. It will be implied only in case of newly constructed stables or thorough renovations

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- Investment will be achieve the best return if it is combined with on-site anaerobic digestion
- N-content of pig urine is significant lower than N-content of other fertilizers, thus rather to be used for additional fertilizing on top of the basic fertilisation
- As long as the urine doesn't acquire 'product'-status, it suffers a commercial disadvantage compared to chemical fertilizers

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

Technology: **Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9**
Evaluator: Lies Bamelis (United Experts)

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- In regions with a high nutrient pressure, using biobased fertilizers could help to decrease costs and increase nutrient recycling. Flanders is one of the largest users of fertilizers while being at the same time one of the European regions with the highest environmental nutrient pressure.
- At multiple locations in Flanders the recovery of nutrients from wastewater and agro-waste through digesetion is already performed, though often in co-digestion with manure. This latter makes that the overall recovered nutrients will not be considered as biobased fertilizer but as manure, what limits the application.
- The combination of the use of digestate as a soil enhancer in combination with precision agriculture will have a positive effect on the amount of fertilizers applied on arable land without jeopardizing the harvest of the farmers.

Adoption challenges for this technology:

- Because of the Nitrates Directive, the amount of manure that can be applied on the field is limited to 170 kg N ha^{-1} yr^{-1}. This might be a drawback to valorise all the available

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biowaste. As long as the product doesn't acquire the same status as chemical fertilisers, it suffers a commercial disadvantage.

- Using biobased fertilizers requires (in some cases) a different application method.
- Investing in the technology for precision farming needs to be done.
- The main issue with using waste as a fertilizer is its unpredictability. Hence, they are not considered as efficient or stable (in composition) as synthetic fertilisers.
- The composition of the fertilisers should always meet the end users' and crops' requirements.

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

Technology: Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility, TRL 6
Evaluator: Sander Vandendriessche, Inagro

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- In regions with a high nutrient pressure, using biobased fertilizers could help to decrease costs and increase nutrient recycling. Flanders is one of the largest users of fertilizers while being at the same time one of the European regions with the highest environmental nutrient pressure. Intensive animal husbandry is common in Flanders. Hence, manure and dairy processing sludge is available in large quantities.
- Similar research is being done within several field trials in Flanders, to assess the agronomic and environmental value of biobased fertilizers (for example LL (1+2+9) of Nutri2Cycle, Interreg NWE ReNu2Farm, OG RENURE, …).
- The main issue with using manure as a fertilizer is its unpredictability. A balanced application of biobased and chemical fertilizers – as proposed in this solution – could help to overcome this problem and generate tailor made fertilizers following end users' and crops' requirements.

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- This solution will reduce costs significantly: on the one hand, farmers will have less manure processing costs; on the other hand farmers will have a reduced need to purchase (often expensive) chemical fertilizers.

Adoption challenges for this technology:

- Because of the Nitrates Directive, the amount of manure that can be applied on the field is limited to 170 kg N ha^{-1} yr^{-1}. This might be a drawback to valorise all the available manure and dairy processing sludge. As long as the product doesn't acquire the same status as chemical fertilisers, it suffers a commercial disadvantage.
- Using biobased fertilizers requires (in some cases) a different application method.
- The composition of the fertilisers should always meet the end users' and crops' requirements. In other words, the nutrients should become available at the right timing.

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

Technology: Application of sensor technologies in plant cropping system (Hungary), TRL 9

Evaluator: Lies Bamelis (United Experts)

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The amount of nutrients (fertilisers) that can be applied on arable land are strictly governed by the MAP-framework (= Manure Action Plan) in Flanders. This legal framework is regularly updated and adjusted. The amount of fertilizers that can be applied depends on the location of the field, the type of crops grown and the type of fertilizers used.
- The quality of the ground water and the quality of surface water is continuously monitored as the historic overdosing of fertilizers have resulted in a significant loss in water quality in both watersources. The management and follow-up of the quality of ground water bodies and surface water bodies is governed in the 6-annual Integrated Water Policy plans (stroomgebiedbeheerplannen). With the use of the proposed innovation there would be no more is of "over dosing" of nutrients, as the actual dosage of fertilizers (including liquid manure) would be adopted to the soil nutrient availability and the crops nutrition needs. This will limit risk is of leaching of nutrients to the ground- and surface water.

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- Lowering the amount of fertilizers used will reduce the costs for the farmers (purchasing less fertilizers) as the crop yield will remain equal.

Adoption challenges for this technology:

- The system should be fit for handling different types of fertilizers, and with a variable composition when the aim is for use on recovered nutrients as well. The composition of the recovered nutrients can vary (slightly), even between different loads of the same type of fertilizer. This might put the use of the sensor technologies at risk as the benefit of the precise application might get lost.
- If only mineral fertilizers and liquid manure are to be used in combination with the technology there is a risk that the remaining fertilizers used on arable land (thick fraction, digestate, …) still cause a risk of overdosing (and therefore leaching of nutrients to the ground- and surface water.

Short-term transferability (to 2025): **3**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

Technology: Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling, TRL 6-7

Evaluator: Sander Vandendriessche, Inagro

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- In regions with a high nutrient pressure, using biobased fertilizers could help to decrease costs and increase nutrient recycling. Flanders is one of the largest users of fertilizers while being at the same time one of the European regions with the highest environmental nutrient pressure.
- Similar research is being done within several field trials in Flanders, to assess the agronomic and environmental value of biobased fertilizers (for example LL (1+2+9) of Nutri2Cycle, Interreg NWE ReNu2Farm, OG RENURE, …). Furthermore, soil care is very important. Therefore, carbon storage should be taken into account because a soil without

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sufficient organic carbon will have less productivity. In Flanders, there are also already several projects focussing on carbon storage in soil.

- This solution will reduce costs significantly: on the one hand, farmers will have less manure processing costs; on the other hand farmers will have a reduced need to purchase (often expensive) chemical fertilizers.

Adoption challenges for this technology:

- Because of the Nitrates Directive, the amount of manure that can be applied on the field is limited to 170 kg N ha^{-1} yr^{-1}. This might be a drawback to valorise all the available biowaste. As long as the product doesn't acquire the same status as chemical fertilisers, it suffers a commercial disadvantage.
- Using biobased fertilizers requires (in some cases) a different application method.
- The main issue with using manure as a fertilizer is its unpredictability. Hence, they are not considered as efficient as synthetic fertilisers.
- The composition of the fertilisers should always meet the end users' and crops' requirements. In other words, the nutrients should become available at the right timing.

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

Technology: **LL20 Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4**

Evaluator: Anne Adriaens, UGent

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- More specific with regard to nutrients, closing the cycle is an important challenge as Flanders is one of the largest users of fertilizers while being at the same time one of the European regions with the highest environmental nutrient pressure. In the past, most manure treatment facilities mainly focused on mitigation and invested in nitrification denitrification facilities for treatment of the thin fraction or digestate. As a consequence, nitrogen (N) was

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converted to inert N_2 that left the nutrient cycle. At present, new technologies are developed that aim to recuperate the N.

- The proposed solution can be applied directly to raw livestock manure or as a subsequent step of an anaerobic digestion process. Also, this technology can be used for other waste streams such as sewage sludge.
- The resulting ammonium salt, ammonium nitrate or ammonium sulphate, is similar to, but less concentrated than commercial fertilizers. The ammonium sulphate is similar to ammonium sulphate produced in chemical air strippers. However, at present, the ammonium salts resulting form stripping-scrubbing of air still maintain the status of "manure", which limits their application dose and the roll-out of the technology.
- In Flanders, Detricon developed a similar stripping/scrubbing technology. The difference is in the stripping step where NH_3 volatilisation is realised by increasing the pH and blowing air through the system. The availability of technology variants can accelerate the breakthrough.

Adoption challenges for this technology:

- The investment cost is very substantial for most farmers and the follow up of the installation requires skills and labour
- For the NH_3 scrubbing, a strong acid is required. The storage (and all associated handling such as filling up, pumping, …) of a strong acid requires safety measures and entails certain risks.
- As long as the product doesn't acquire 'product'-status, it suffers a commercial disadvantage compared to chemical fertilizers
- The ammonium salts are liquids. This has the benefit since it allows more a precise and effective application but might require adaptations for famers used to use solid fertilizers.

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

Technology: **ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary) TRL 8-9**
Evaluator: Lies Bamelis , Filip Raymaekers(United Experts)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- In regions with a high nutrient pressure, using biobased fertilizers could help to decrease costs and increase nutrient recycling. Flanders is one of the largest users of fertilizers while being at the same time one of the European regions with the highest environmental nutrient pressure.
- Animal Bone Char is covered by the EC 2019/1009 under CMC 14 (pyrolysis and gasification materials) under condition that the derived products have reached the end point in the manufacturing chain
- Phosphor from animal bones (cat II) is allowed in the national legislation by Royal Act (KB 28/01/2013 , annexe 1) under certain conditions.
- The Flemish legislation will ask for a specific derogation for ABC in fertilzers
- The EC142/2011 allows bone meal in fertilizers: art 22.3: The competent authority of the Member State where an organic fertiliser or a soil improver, which has been produced from meat-and-bone meal derived from Category 2 material or from processed animal protein, is to be applied to land, shall authorise one or more components which are to be mixed with those materials. But the member states should allow application (art 32.6)
- Despite animal rendering by-products (bone meal (BM) and meat and bone meal (MBM))are sterile products at the point of production at 133ºC 20 min 3 bars, there is a very high risk for cross and recontamination during applications. There are clear WHO reports on such disease trans-contamination routes related to Bone Meal in livestock feed and fertilizers, used in open ecological environment. ABC is a biochar mineral with no recontamination risk.

Adoption challenges for this technology:

- Because of the Nitrates Directive, the amount of Phosphorus that can be applied is very limited. Fertiliser with a high concentration in Phosphorus and with a high availability will be appreciated.
- The composition of the fertilisers should reach the conditions of the KB 28/01/2013

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Short-term transferability (to 2025): 4

Medium-term transferability (to 2030): 5

Rank: 1-5 (1= low, 5= high)

Technology: LL23 Pig manure refinery into mineral fertilisers (Italy), TRL 9

Evaluator: Anne Adriaens, UGent

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- More specific with regard to nutrients, closing the cycle is an important challenge as Flanders is one of the largest users of fertilizers while being at the same time one of the European regions with the highest environmental nutrient pressure. In the past, most manure treatment facilities mainly focused on mitigation and invested in nitrification denitrification facilities for treatment of the thin fraction or digestate. As a consequence, nitrogen (N) was converted to inert N_2 that left the nutrient cycle. At present, new technologies are developed that aim to recuperate the nutrients.
- The proposed technology offers an integrated solution since all fractions are recovered. The permeate (water) fraction meets the discharge limits to the water body but, depending on the system parameters, it might be suitable for re-use on the farm (cleaning water, …), thus contributes to the closure of the water cycle.
- The resulting mineral concentrate still maintains the status of “manure”, which limits its application rate and the roll-out of the technology.

Adoption challenges for this technology:

- The investment cost is very substantial for most farmers and the follow up of the installation requires skills and labour.
- The NPK-concentrations of the fertilizer are quite low. Therefore, this technology will only be implemented if possibilities of use in the immediate vicinity. Also, administration is more labour-intensive, as several applications might be required to achieve sufficient fertilization.

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- As long as the product doesn't acquire 'product'-status, it suffers a commercial disadvantage compared to chemical fertilizers

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

Technology: Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop, TRL 9

Evaluator: Sander Vandendriessche, Inagro

Transferability to: Belgium (Flanders)

Fit of the technology in providing a solution to national challenges:

- The Flemish Government Agreement 2019-2024 and several policy documents stress the importance of the transition to a circular economy[1]. This circular economy can be realised by reusing natural resources and (residual) biomass flows.
- In regions with a high nutrient pressure, using biobased fertilizers could help to decrease costs and increase nutrient recycling. Flanders is one of the largest users of fertilizers while being at the same time one of the European regions with the highest environmental nutrient pressure, so the use of biobased fertilizers is highly interesting in this region.
- Similar research is being done within several field trials in Flanders, to assess the agronomic and environmental value of biobased fertilizers (for example LL (1+2+9) of Nutri2Cycle, Interreg NWE ReNu2Farm, OG RENURE, …). In this sense, monitoring GHG emissions during the experiment is highly interesting.
- Furthermore, it is also of high importance to enrich the soil with organic matter (e.g. compost). Both compost and slurry can achieve this because they contain a significant amount of organic matter that will enrich the soil. This has a positive effect since increasing organic matter increases soil fertility and thus crop production.
- This solution will reduce costs significantly: on the one hand, farmers will have less manure processing costs; on the other hand farmers will have a reduced need to purchase (often expensive) chemical fertilizers.

[1] https://www.ewi-vlaanderen.be/sites/default/files/een_transversale_werking_voor_de_circulaire_economie_van_vlaanderen.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Adoption challenges for this technology:

- Because of the Nitrates Directive, the amount of manure that can be applied on the field is limited to 170 kg N ha^{-1} yr^{-1}. This might be a drawback to valorise all the available biowaste. As long as the product doesn't acquire the same status as chemical fertilisers, it suffers a commercial disadvantage.
- Using biobased fertilizers requires (in some cases) a different application method.
- The main issue with using manure as a fertilizer is its unpredictability. Hence, they are not considered as efficient as synthetic fertilisers. The timing of application is more important using manure instead of synthetic fertilisers.
- The composition of the fertilisers should always meet the end users' and crops' requirements. In other words, the nutrients should become available at the right timing.

Short-term transferability (to 2025): **4**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

viii) Germany

Technology: LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9 (Anerobic Digestion (BE))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- There are around 150 million tonnes of manure fresh matter[2] per year, only around one third is used for biogas production.
- In Germany there are currently around 800 small scale digesters of manure. In Germany small scale refers to 75kW or lower. 60 per cent of those would be able to produce more biogas.
- Only 10 percent of all dairy farms have more than 200 cows. 200 cows plus breeding is the required size to power a 75kW biogas plant. Hence there seems to be a market for smaller biogas plants.
- Under the new (2021) renewable Energy law (EEG) small biogas plants with at least 80 per cent manure use get 22 cents/kWh of electricity. The legislation and subsidy structure points towards small manure digesters.

Adoption challenges for this technology:

- The cost of a pocket digester is very substantial for most farmers
- The skillset to run and optimise the efficiency of the digester requires substantial training.
- If the biogas plant is not operated correctly there will be less emission savings than possible.
- In comparison to an installation of larger biogas plants, there will be more investment costs and training required for the same amount of kW produced.
- Labour is a bottleneck on many farms and extra workload will function as disincentive.

Open questions for this technology:

- What is different in this pocket digester to the already established small scale manure digestion plants?
- What are the emission savings of this technology (and what are the costs for these savings)?
- How will the storage be arranged?
- Can the technological standard be transferred (CE-standard)?

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

[2] Klages S, Heidecke C, Osterburg B (2020) The impact of agricultural production and policy on water quality during the dry year 2018, a case study from Germany. Water MDPI 12(6):1519, DOI:10.3390/w12061519

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL24: Adapted stable construction for manure processing (Belgium), TRL9 (Housing manure separation (BE))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- Pig production in Germany has decreased 9.4 percent in total animals produced and 7.8 percent in agricultural production units in 2021. There are now 23.6 million pigs in Germany, which is the lowest number since 1996. In the German sector each farm has an average number of 1,254 pigs per farm. Only 13 per cent[3] of pig farms are larger than 2000 pigs per farm (this is the number that was indicated for this technology)
- The separation of solid manure and urine would help prevent emissions inside the stable, which is also an additional animal welfare component.
- There is a similar stable construction designed/developed by the "Big Dutchman" which also focuses on the separation of solid manure and urine. They received a novelty award from the German agricultural society (DLG). Which indicates a high interest for this sort of product. (English press release)

Adoption challenges for this technology:

- The pig sector in Germany is currently undergoing a critical phase. The African swine fever (ASF) virus in combination with an ongoing animal welfare debate and a new government have led to a lot of insecurity in the sector.
- We believe that while this is a great technology it is not the right moment for German pig farmers to invest.

Open questions for this technology:

- How are urine and solid manure transported and stored out of the stable? Is this included in the price calculations?
- Which measures are taken to prevent emissions outside the stable?
- Are the 2000 pig places that are mentioned in the description of the technology, the favourable size for this technology, or can this technology also be (economically) useful in smaller pig stables?

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

[3] https://www.thuenen.de/media/ti-themenfelder/Nutztierhaltung_und_Aquakultur/Haltungsverfahren_in_Deutschland/Schweinehaltung/Steckbrief_Schweine.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9 (Digestate, Precision, NT (IT))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- The use of sewage in Germany[4] is highly regulated. In medium term (2032) the use of sewage from sewage plants with treatment capacities for more than 50,000 population equivalents is banned for direct agricultural use, but the recycling of phosphorus will be established instead for these larger plants. Sludge from smaller plants is accepted for agricultural use in case it meets the standards of fertilisation legislation (application standards and quality standards). These standards are higher than the application standards of the national sludge ordinance. Generally, the use of sludge in organic farming, forestry, gardens, fruit and vegetable planting, pasture and water and nature reserves is forbidden. This is due to hygienic properties, organic pollutants and heavy metals and the presence of other by-products, like microplastics.
- The trend in Germany is a falling use of sewage sludge in agriculture: only 35 % of 1.8 million tonnes of sewage dry matter was used in agriculture in 2016. The majority of sludge dry matter is burned. There is a strong belief that there are severe dangers related to the use of sewage sludge, as dangerous pathogens or chemicals could be transported into food, soil and groundwater through the use of sewage sludge as fertilizer or soil conditioner.
- However, the importance of sewage as a source for phosphorus is high, as Germany has no own p-mining sites for mineral P on its disposal, but more than half of the P fertilization demand can be met by manure[5].
- If all sewage sludge in Germany would be mono incinerated in combination with phosphorus recycling there could be theoretically 50.000 tonnes of phosphorus.
- Technology could be used for mono source sludges from industry. Possibly treatment would be less costly than treatment charge elsewhere.

[4] https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/2018_10_08_uba_fb_klaerschlamm_bf_low.pdf

[5] https://ojs.openagrar.de/volltexte/Kulturpflanzenjournal/2014/Heft08/XML/Webdaten/01_kratz_et_al/kratz_et_al.html

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

- Sanitation condition of 55°C has to be applied for sufficient length to ensure hygienic minimum standards (see new EU fertilizer standards)

Adoption challenges for this technology:

- High restrictions for the use of sewage sludge in Germany, but possible solution for single cases.
- High costs for the technology and possibly a very high skill level required.
- There is a very limited perspective for the use of this technology in Germany as treatment for municipal sewage, but a possibility for mono source sludges from the treatment of organic food wastes.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

Technology: LL17 Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6 (Bio-based Fert (IE))

Technology: LL57 Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9 (Bio-based Fert (PT))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- Generally using less mineral fertilizer and recycling waste sounds promising, especially if it is also cheaper than using purely chemical fertilizer.
- The German fertiliser ordinance regulates which substances can or cannot be used for fertilization in Germany and which restrictions are in place.
- If those alternative fertilizers are clearly labelled (according to national or EU-legislation) and are allowed to be used in Germany, we do not see a reason why it should not be done. Given it is also cheaper than pure mineral fertilizer.
- All named fertilizer substitutions are listed under the German fertilizer regulations. Which is in place parallel to the new EU Fertilizing Products Regulation (EU) 2019/1009.

Adoption challenges for this technology:

- Manure derived products are usually traded via manure exchange institutions. Generally, there is no (good) price for manure derived products.
- The skillset to mix the different fertilizers is needed to operate it correctly, not lose yield and – in particular – to stay within limits which secure no leaching of nitrates or accumulation of phosphorus: fertilizer planning and monitoring tool for fertilizer application is needed (FaST?)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Open questions for this technology:

- What is the future plan with this technology? Will there be a ready mixed product developed out of it? Or is the idea to develop guidelines or training sessions for farmers?

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

Technology: LL[43+73] Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6 (Separated Pig Manure (NL+BE))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- While field trials are a very important and necessary component, one needs to keep the practical components for the farmer also in mind. Soil situations vary from place to place. Nutrient components, plant availability, application technique and how to store the product are very important practical components.
- In Germany around 10.000 hectare[6] of potato are grown organically without the use of N mineral fertilizer.
- It seems to be a very specific case study were a potato grower, a pig farmer and a processor of pig manure collaborate. I am not sure about the number of eligible cases that this could be translated into the German context. I think that parts of this technology, using pig manure in potato production or using precision agriculture in potato production are already in place.

Adoption challenges for this technology:

- It is not clear to us what exactly is new in this technology. If it is the combination of things, it will be hard to estimate a possible transferability or uptake rate as it is very specific.

Open questions for this technology:

- What is the difference to organic potato growing?
- What is the advantage of using the refined pig slurry? In the overview it says that the refining did not influence the potato yield significantly.
- The refined pig slurry did decrease the N and P leaching compared to unrefined pig slurry, or was this decrease in leaching attributed to the precision technique?

[6] https://de.statista.com/statistik/daten/studie/378171/umfrage/anbauflaeche-von-kartoffeln-im-oekologischen-landbau-in-deutschland/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9 (Liquid N/ fractions (BE))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- As this is a field trial of different recycling derived fertilizers (RDFs) one has to keep the practicability and transferability to other local conditions in mind.
- For ammonium nitrate fertilizers there are special requirements regarding the safety of their use, to avoid that those fertilizers will be used outside of their intended purposes, for example as an explosive. Special requirements regarding their explosiveness and tracing should be established. (EU 2019/1009)
- It is not to be expected that the product derived always has exactly the same qualities. As manure varies greatly due to feeding and other factors. However, for this product to be used it would need to be always of the same quality.
- It is important that the product is storable and hygienically safe. That it does not change it characteristics during the storage process or change its qualities through storage.
- The product has to be homogeneous if it should be used in the field by farmers. This will be easier established for a dry than for a wet product.
- The purity of the product has to be kept in mind. If there is a high rate of outside products the spreading onto the field might be tricky, which will minder the usability for the farmer.

Adoption challenges for this technology:

- As this is a field trial to test whether recycle derived fertilizer can replace mineral fertilizer and the results indicate that at least for N fertilizers this could be the case, I would say this is an interesting solution. However, as we do not have any information (in this sheet) on how the fertilizer is derived and how it is used, it is hard to estimate.
- Pricewise this solutions seems to be very interesting with a price of 65 to 75 cents per kg of N.

Open questions for this technology:

What is happening with the P fertilizer?

Short-term transferability (to 2025): **2**

Medium-term transferability (to 2030): **4**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL15 Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7 (Bio-based Fert (FR))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- On German vineyards it is not uncommon to use the own oil cake. As the other bio-based products are not listed it is not possible to make a statement about those. Germany has around 100.000 hectare of vine.
- In Germany 109 agroforestry areas are reported to the German Association of Agroforestry.

Adoption challenges for this technology:

- As oilcakes are already in use in vineyards and agroforestry is rather small in Germany I see not a lot of potential for this technology.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **3**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Nutri2Cycle
Nurturing the Circular Economy

Technology: LL22 ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary), TRL 8-9 (Bone Char P (HU))

Evaluator: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- This is an approved P fertilizer in Germany, one of the oldest next to Guano and raw phosphate. In 2010 around 540.000 tons of animal bones meal were used as a P fertilizer in Germany (estimates[7]).
- The pyrolysis of animal bone seems also be established.

Adoption challenges for this technology:

- This technology seems to be implemented in Germany.

Short-term transferability (to 2025): **5**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

[7] https://www.openagrar.de/servlets/MCRFileNodeServlet/Document_derivate_00011322/2014_0149.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4 (Vacuum Evaporation (ES))

Technology: LL23 Pig manure refinery into mineral fertilisers (Italy), TRL 9 (Bio-based Fert from manure (IT))

Evaluator: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- (LL#23) 13 per cent[8] of pig farms are larger than 2000 pigs per farm (as mentioned above). Only around 5000 farms in Germany have more than 5000 pigs on the farm.
- If with both technologies the processed pig manure could replace mineral fertilizer I would assume that there is a lot of value in it. However, it is questionable for which size of farms these technologies make sense. If it is mainly targeting very large-scale farms, like LL 23, then the potential in Germany is limited, as the number of large-scale pig farms with over 5.000 pigs is limited.

Adoption challenges for this technology:

- (LL#23) If this technology is especially for large scale farms with 10.000 animals and more this technology does not have a large market in Germany as we do not have that many pig farms in that size.

Open questions for this technology:

- (LL#23) Is this technology also useful for smaller pig farms (less than 10.000 pigs)?
- (LL#20) For which size of pig farms does this technology make sense?
- Are there any by-products in those technologies and what happens to those?

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2-3**

Rank: 1-5 (1= low, 5= high)

[8] https://www.thuenen.de/media/ti-themenfelder/Nutztierhaltung_und_Aquakultur/Haltungsverfahren_in_Deutschland/Schweinehaltung/Steckbrief_Schweine.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: L41: Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6

Evaluator: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- We could envision this technology for waste water treatment for places were water is not able to directly go back into the ground water, like purification ponds at larger farmsteads.
- At the moment this seems to be quite specifically connected to a pig manure treatment facility. Depending on the flexibility of the source material/waste water it could have a larger or smaller potential usefulness in Germany.

Adoption challenges for this technology:

- The costs seem to be extremely high at this stage.
- The open storage of pig manure would lead to emission losses which would be undesirable.
- At the moment it seems to be a very specific and costly case, which would need a lot of further investigation to see potential in Germany. Generally, we see the open storage of manure as a big disadvantage as there would be a lot of emission losses there.
- This high cost of the technology needs to be compared to the alternative costs of this waste water that the farmer is occurring at the moment. For example: What are the current storage or disposal costs? Does it need to be treated to be used (at the moment)? If those costs are evaluated correctly one can rank the high cost of this technology better. (Maybe it is not as high as it seems if one compares it with the alternatives).

Open questions for this technology:

- It can only be operated 175 days per year during the vegetation period. What happens with the facility during the rest of the time and where is the waste stored then?
- What type of waste water or effluent from pig manure treatment facility is used?

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2**

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL41b Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4 (Algae Protein (BE))

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- It seems that algae as a feed for cattle are very desirable. It was reported that algae reduced methane emissions from cattle while increasing the feed conversion ratio[9].
- As this technology still is at an early stage it is hard to imagine the market potential and how the cost structure is going to change. At the moment the sales of the microalgae, which are 48kg per year at 12.000 euro per ton, are only equivalent to around 600 euros of algae sales. With operation costs of 3000 euros per year and costs of unit at 80.000 it seems to be very unprofitable. If I understand the numbers provided correctly.

Adoption challenges for this technology:

- In Germany, algae are produced for human consumption and the wellness sector. In this case, the prices are high, but manure as untreated raw material possibly would not be accepted. Further, pollutants and hygienic properties are to be considered.

Short-term transferability (to 2025): **1**

Medium-term transferability (to 2030): **2-3**

Rank: 1-5 (1= low, 5= high)

[9] https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0247820

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL13 Application of sensor technologies in plant cropping system (Hungary), TRL 9 (Sensor fert (HU))**

Evaluators: Bernhard Osterburg, Susanne Klages, Mareike Söder, Lena Behrendt Thünen Institut

Transferability to: Germany

Fit of the technology in providing a solution to national challenges:

- In Germany there are currently at least 6 different N sensor technologies in place. The most commonly distributed seems to be the Yara N sensor mentioned in this technology.
- The N sensor is since the end of the 1990s (Yara N Sensor 1) available in Germany. Since 2012 (Yara N Sensor 2) it seems to have been further developed and adapted. Additionally, there is a Active Light source Sensor since 2006 available.
- In 2014 there seem to have been already 700 N sensors in place for N specific fertilization[10] in Germany.
- Those sensors have the strong potential to optimise fertilization.
- Consultants for water conservation recommend among others also the N- Sensor, this in combination with the size of the company and its large presence in Germany it could explain the high implementation rate of the N-Sensor in Germany.

Adoption challenges for this technology:

- It seems that this technology is already in use in Germany.

Open questions for this technology:

- I am not entirely certain that I understand the novelty of the approach. With more information a better assessment could be made.

Short-term transferability (to 2025): **5**

Medium-term transferability (to 2030): **5**

Rank: 1-5 (1= low, 5= high)

[10]Sensoren für die Stickstoffdüngung –Erfahrungen in 12 Jahren praktischem Einsatz
JOURNALFÜR KULTURPFLANZEN, 66 (2). S. 42–47, 2014, ISSN 1867-0911, DOI: 10.5073/JFK.2014.02.02

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Viiii) The Netherlands

Technology: LL10: Farm-scale Anaerobic Digestion (Belgium), TRL 7-9 (Anerobic Digestion (BE))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The Netherlands has a very intensive livestock sector and large manure surplus. Currently about 3% of the manure is digested, so the potential for further uptake is still large.
- In the Dutch climate agreement an ambition of 2 billion m^3 biomethane by 2030 is included[11], whereas currently the production is about 0.23 billion m^3. With the current high gas prices and the need to become less dependent on the import of gas, the demand for biomethane will certainly increase.
- Currently about 150 digesters are using animal manure as feedstock. Most digesters are co-digesters using manure and other organic waste streams, often at central locations. However, the availability of other organic waste is limited, which means that growth in biogas production should mainly come from mono-digestion of manure.
- Dutch farmers are highly accustomed to using manures and slurries as fertilisers and also the use of digestate is common, although there is some concern by farmers whether there would be a negative impact on soil quality, due to the loss of part of the organic matter during digestion.
- Due to the strong increase in the use of solar panels, the capacity of the grid is becoming a problem in some regions. Therefore production of biomethane instead of electricity has more potential, but requires additional investments locations.

Adoption challenges for this technology:

- The cost of a farm-scale digester is substantial for most farmers. Good financial constructions are required to increase the uptake of this technology.
- Current support and subsidy schemes are mostly based on network energy-feed-in tariffs, but do not reward the prevented methane emissions from manure storages which disfavours smaller scale digesters.
- Procedures for permits can take a lot of time as and the public perception on digesters is often not positive, this can be a serious barrier for digesters, but for farm-scale digesters this is probably less a problem.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 2-4 depending on subsidy scheme

Rank: 1-5 (1= low, 5= high)

[11] https://groengas.nl/wp-content/uploads/2015/07/Routekaart-hernieuwbaar-gas.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL16: Using digestate, precision agriculture and no-tillage to improve soil organic matter (Italy), TRL 9 (Digestate, Precision, NT (IT))**

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- In the Netherlands anaerobic digestion is common process, but still only a small fraction of the manure is digested. However, most of the organic waste is either composted or digested.
- In many regions the applications limits for P determine the amount of organic fertilizers that can be applied. Although farmers appreciate the organic matter from these fertilizers, the fertilization strategy is still mainly based on N and P.
- In the Dutch climate agreement a target for carbon sequestration is included, which aims for an additional 0.4-0.6 Mton CO_2 that is annually sequestered by 2030. With the upcoming interest on carbon farming, the demand for organic inputs will increase, but the potential supply will be the limiting factor.
- Ammonium sulphate can now be used for replacing mineral fertilizer. The currently high fertilizer prices will stimulate its use.

Adoption challenges for this technology:

- Arable farmers now receive money for applying animal slurry. The question is whether farmers want to use the processed digestate products if they receive less money or even have to pay for it.
- Ammonium sulphate can only replace part of the mineral fertilizer as soils otherwise might become too acidified due to the sulphate.
- The amount of additional organic waste that can be processed is probably limiting the uptake of this solution.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 2

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL[43+73] Trial potato growing with refined pig manure fractions (The Netherlands and Belgium), TRL 5-6 (Separated Pig Manure (NL+BE))**

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- Potato-production in the Netherlands is a very important arable activity that occupies around 25% of the arable land area. Both manure and mineral fertilizer is used.
- The Netherlands has a manure surplus at national level due to the high livestock density. Especially pig farmers lack their own land to apply the manure and have to export this to other arable farmers in the Netherlands or even export it outside the Netherlands. Manure processing is therefore already quite common to reduce the volume of manure that has to be transported.
- Many agricultural soils are rich in P and the allowed amount of manure that can be applied is restricted. With processed manure with less P, more of the N and K from animal manure can be used, which can replace mineral fertilizer

Adoption challenges for this technology:

- The cost of processed manure is more expensive compared to unprocessed manure and farmers might therefore be hesitant to apply it, despite advantages in terms of nutrient composition.
- Only a part of the mineral fertilizer can be replaced, as part of the fertilization takes place during the growing season and machinery for application of the liquid processed manure cannot be used when the canopy is closed.
- The infrastructure, especially equipment for application of the liquid fraction, is not yet widely available.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL[1+2+9]: Using innovative recycling-derived fertilizers: ammonium nitrate, ammonium sulphate, (liquid fraction of) digestate, pig urine and pig slurry (Belgium), TRL 7-9 (Liquid N/ fractions (BE))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The Netherlands has a manure surplus at national level due to the high livestock density. Especially pig farmers lack their own land to apply the manure and have to export this to other arable farmers in the Netherlands or even export it outside the Netherlands. Manure processing is therefore already quite common to reduce the volume of manure that has to be transported.
- Many agricultural soils are rich in P and the allowed amount of manure that can be applied is restricted. With processed manure with less P, more of the N and K from animal manure can be used, which can replace mineral fertilizer, which fits well to the circular agriculture objectives that have been proposed by the ministry of agriculture.
- Surplus manures (exceeding N or P ceilings) are being transported to arable farms and in some case to centralised AD biogas plants. The number of AD plants was relatively stable last years, but currently new initiatives are being developed to increase the amount of biogas, which can be combined with stripping of NH_3.

Adoption challenges for this technology:

- The fertilizer replacement value of innovative recycling-derived fertilizers is often lower compared to mineral fertilizers, while in legislation the fertilizer replacement value has been set at 100% of mineral fertilizer.
- The cost of processed manure is more expensive compared to unprocessed manure and farmers might therefore be hesitant to apply it, despite advantages in terms of nutrient composition.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL24: Adapted stable construction for manure processing (Belgium), TRL9 (Housing manure separation (BE))**

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- In the Netherlands the intensive pig production and dairy farming are using slurry based manure systems. Traditional stables have slatted floors with manure storage below, which can have high ammonia and methane emissions.
- Due to regulations aimed at reducing ammonia emissions, a range of low emission stables have been developed. However, in practice these stables are often not reaching the promised emission reduction. Ongoing research to new stable constructions is ongoing, but results are showing variable effects on emissions.[12] Especially for dairy farming it is not clear yet which is the optimal stable adaptation to reduce emissions.
- Further reductions in ammonia emissions are required in Dutch agriculture and also methane emissions from manure storage systems have to be reduced, which offers perspective for adapted stable constructions.

Adoption challenges for this technology:

- The cost of reconfiguring the animal housing system to the in-house separation, considering the current large investment in slurry systems.
- The environmental performance of the adapted stable constructions very much depends on the frequency the manure is removed and how farmers maintain the system.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

[12] https://integraalaanpakken.nl/stalspoor

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL20: Ammonia recovery from raw pig slurry in a vacuum evaporation field plant (Spain), TRL 4 (Vacuum Evaporation (ES))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The Netherlands has a manure surplus at national level due to the high livestock density. Especially pig farmers lack their own land to apply the manure and have to export this to other arable farmers in the Netherlands or even export it outside the Netherlands. Manure processing is therefore already quite common to reduce the volume of manure that has to be transported.
- Many agricultural soils are rich in P and the allowed amount of manure that can be applied is restricted. With the ammonia recovery from manure more of the N from animal manure can be used, which can replace mineral N fertilizer, which fits well to the circular agriculture objectives that have been proposed by the ministry of agriculture.

Adoption challenges for this technology:

- Investment costs can be high, but with current high mineral fertilizer prices it becomes more attractive.
- Energy costs required for the evaporation might be a limitation.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL23 Pig manure refinery into mineral fertilisers (Italy), TRL 9 (Bio-based Fert from manure (IT))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The Netherlands has a manure surplus at national level due to the high livestock density. Especially pig farmers lack their own land to apply the manure and have to export this to other arable farmers in the Netherlands or even export it outside the Netherlands. Manure processing is therefore already quite common to reduce the volume of manure that has to be transported.
- If clean permeate can be created that can be discharged to the surface water, the volume of manure can be reduced, which will decrease transport cost.
- Many agricultural soils are rich in P and the allowed amount of manure that can be applied is restricted. With manure refinery new fertilizer products can be made with no or lower P content, which will result in more efficient use of N from pig manure, which can replace mineral N fertilizer. This fits well to the circular agriculture objectives that have been proposed by the ministry of agriculture.

Adoption challenges for this technology:

- Investment costs can be high, but with current high mineral fertilizer prices it becomes more attractive.
- The fertilizer replacement value of innovative recycling-derived fertilizers is often lower compared to mineral fertilizers, while in legislation the fertilizer replacement value has been set at 100% of mineral fertilizer.
- The cost of processed manure is more expensive compared to unprocessed manure and farmers might therefore be hesitant to apply it, despite advantages in terms of nutrient composition.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL22 ABC Animal Bone Char for Phosphorus recovery: Formulated Bio-Phosphate trials (Hungary), TRL 8-9 (Bone Char P (HU))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- Due to the high density animal farming sector in the Netherlands, slaughterhouses do have substantial amounts of animal bone waste which could potentially be utilised through this technology.
- Most agricultural soils are high in phosphate and with the high application rate of animal manure, there is no need for mineral P fertiliser, which is currently only used for specific horticulture crops.
- However, the ministry of agriculture has policies to promote circular agriculture, which would also stimulate the use of phosphate from waste streams.
- Bonemeal from pig and poultry residues are recently allowed again as animal feed under specific conditions, which means that this technology is mainly for cattle bones.

Adoption challenges for this technology:

- Currently, most slaughterhouse companies have already set up an efficient utilisation system for all animal-by-product and side-streams they produce, which could make it difficult to introduce the technology on the Dutch market, unless it can be proven either much more effective or economically for recycling P in animal bones than current technologies.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 2

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL41a Floating wetland plants grown on liquid agro-residues as a new source of proteins (Belgium), TRL 6 (Floating Wetland (BE))**

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The Netherlands has a high livestock density and high demand for protein for animal feed. Currently much of this demand is coming from imported soybean meal. As this can have negative effects on land use change and related GHG emissions, there is a need to reduce the dependency on imported protein sources.
- Some experiments with this technology have been done, which show that under natural conditions (outside) the yield is low, whereas in greenhouses the yield is much higher.

Adoption challenges for this technology:

- The potential area for implementation is limited given the high land prices.
- This technology will most likely remain a niche market, given the high demand for protein and the small amount that can be produced.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 1

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL41b Algae grown on liquid agro-residues as a new source of proteins (Belgium), TRL 4 (Algae Protein (BE))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The Netherlands has a high livestock density and high demand for protein for animal feed. Currently much of this demand is coming from imported soybean meal. As this can have negative effects on land use change and related GHG emissions, there is a need to reduce the dependency on imported protein sources.
- In the Netherlands experiments with this technology have been done as well (https://www.algaep-arc.com/), however, the results show that large scale production of algae for feed or fuel will likely not become cost-effective in the Netherlands, and only high value products might be produced from the algae.

Adoption challenges for this technology:

- The cost to grow algae for feed purposes will probably remain too high to compete with other protein feed sources.
- The growing season is in the Netherlands probably too short to make this solution cost-effective, as the light intensity during is too low to grow algae and using artificial light will be too expensive.
- This technology requires quite a lot of skill and maintenance and is not something that can be implemented by farmers directly.

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 1

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL13 Application of sensor technologies in plant cropping system (Hungary), TRL 9 (Sensor fert (HU))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- Nowadays GPS-controlled auto-steering tractors are widely available and used by many farmers. However, the use of variable rate application (VRA) is still limited, although machinery is available.
- The Yara N-sensor technology has been developed already more than 10 years ago and is being used already by quite some farmers. Although I don't have specific information for the Netherlands, it seems currently not yet widely implemented here.
- Precision agriculture is being promoted by the government given the potential environmental benefits
- The current rapidly increasing mineral fertilizer prices might stimulate the uptake of this technology in order to use mineral fertilizer most efficient and prevent overapplication of fertilizer

Adoption challenges for this technology:

- Farm and field size are relatively small in the Netherlands, which reduces the cost-effectiveness of this technology.
- The investment cost for the specific machinery is so far a barrier for farmers.
- There could be competition from alternative technologies using remote sensing and drones.
- The technical standards for communicating between the software of different brands of tractor GPS control, appliances etc. has been considered a barrier for non-specialist farmers.

Short-term transferability (to 2025): 3

Medium-term transferability (to 2030): 4

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL15 Using biobased fertilizers to optimize the organic carbon storage in soil and the NP cycling (France), TRL 6-7 (Bio-based Fert (FR))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- Agro-forestry production is very limited in the Netherlands, and therefore the case is not really applicable to Dutch conditions. Vineyard production exists in the Netherlands, but is area-wise a very small proportion of agricultural land and therefore not relevant.
- Due to the manure surplus, most agricultural soils receive manure and in most regions the soils have sufficient organic matter.
- From a policy perspective there is a need to reduce the mineral fertilizer use and stimulate circular agriculture, which can promote the use of biobased fertilizer products.

Adoption challenges for this technology:

- Application of organic fertilizers, especially in liquid form, can be difficult in agro-forestry or perennial systems
- Most perennial systems have grass cover between, which provides already a good amount of organic matter to the soil.
- The use of oil cake for fertilizer purposes seems not the best use, as this can be better used as animal feed and the manure as fertilizer

Short-term transferability (to 2025): 1

Medium-term transferability (to 2030): 1

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: **LL17 Crop farmer using a variety of manure and dairy processing sludge to recycle and build soil C, N, P fertility (Ireland), TRL 6 (Bio-based Fert (IE))**

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The Netherlands has a manure surplus at national level due to the high livestock density. Especially pig farmers, but also dairy farmers with insufficient land have to export the surplus manure to other arable farmers in the Netherlands or even export it outside the Netherlands. Manure processing is therefore already quite common to reduce the volume of manure that has to be transported.
- Many agricultural soils are rich in P and the allowed amount of manure that can be applied is restricted. With manure refinery new fertilizer products can be made with no or lower P content, which will result in more efficient use of N from pig manure, which can replace mineral N fertilizer. This fits well to the circular agriculture objectives of the government.
- Manure processing of surplus manure is in some regions an obligation

Adoption challenges for this technology:

- Biobased fertilizers rich in P, such as struvite, do not have large potential in the Netherlands because of the high soil P status and strict application limits. Mineral P fertilizer use is already very low in the Netherlands.
- The fertilizer replacement value of biobased fertilizers is often lower compared to mineral fertilizers, while in legislation the fertilizer replacement value has been set at 100% of mineral fertilizer.
- The cost of processed manure is often more expensive compared to unprocessed manure and farmers might therefore be hesitant to apply it, despite advantages in terms of nutrient composition.

Short-term transferability (to 2025): 2

Medium-term transferability (to 2030): 3

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Technology: LL57 Use of poultry compost and pig slurry to replace mineral fertilizers as basal fertilization in maize crop (Portugal), TRL 9 (Bio-based Fert (PT))

Evaluator: Jan Peter Lesschen, Wageningen Environmental Research.

Transferability to: Netherlands

Fit of the technology in providing a solution to national challenges:

- The efficient combined use of solid and liquid manures with mineral fertilisers has been common practice by Dutch farmers for many decades.
- Most of the poultry manure in the Netherlands is now being exported, processed or burned. The high P content and high dry matter content of poultry manure, makes this poultry manure the most suitable material for exporting P, given the high manure surplus in the Netherlands.
- In the Dutch climate agreement a target for additional soil carbon sequestration is included, which would stimulate the use of organic fertilizers, but availability of organic material and strict legislation, limit the potential for additional organic fertilizers.

Adoption challenges for this technology:

- The higher P content of these organic manures will limit the application, as most soils are high in P, and only a limited amount P can be applied.
- Solid fertilizers and compost are often much more expensive compared to slurries, for which arable farmers even receive money from the intensive livestock farmers.

Short-term transferability (to 2025): 2-5 (specifically for poultry manure will be low, but for other animal manure this is already common practice)

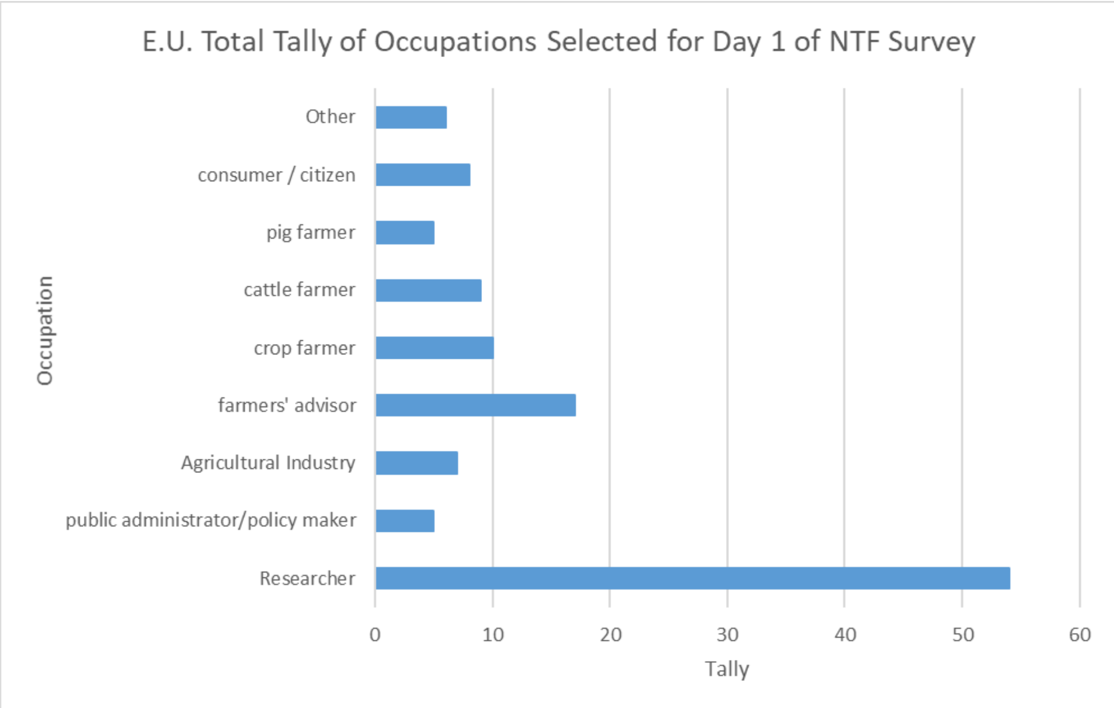
Medium-term transferability (to 2030): 2-5 (specifically for poultry manure will be low, but for other animal manure this is already common practice)

Rank: 1-5 (1= low, 5= high)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

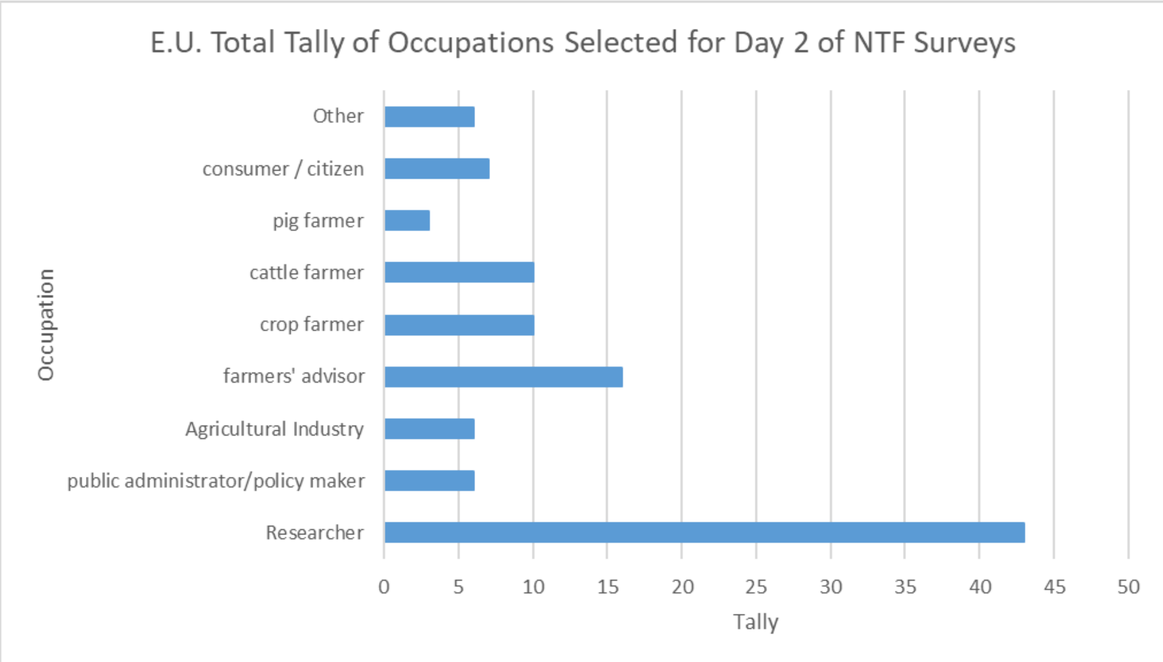
Annex 2 – National Task Force Participants Occupation Graphs

i) Occupation Selection Day 1 – NTF Survey

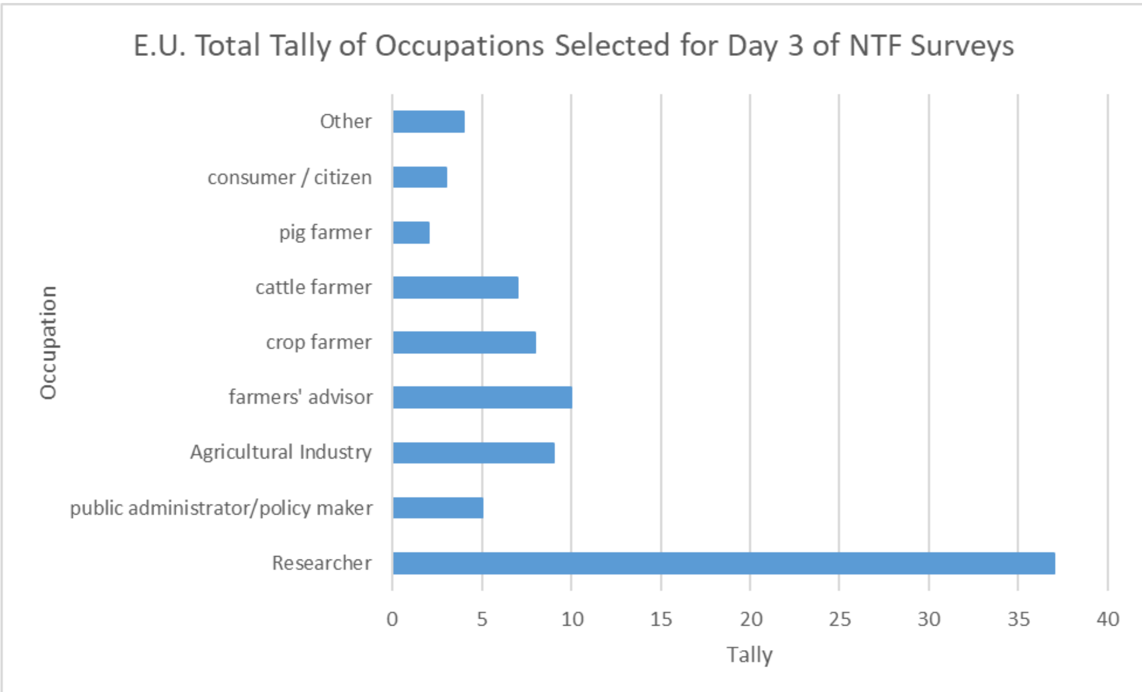


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

ii) Occupation Selection Day 2 – NTF Survey



iii) Occupation Selection Day 3 – NTF Survey



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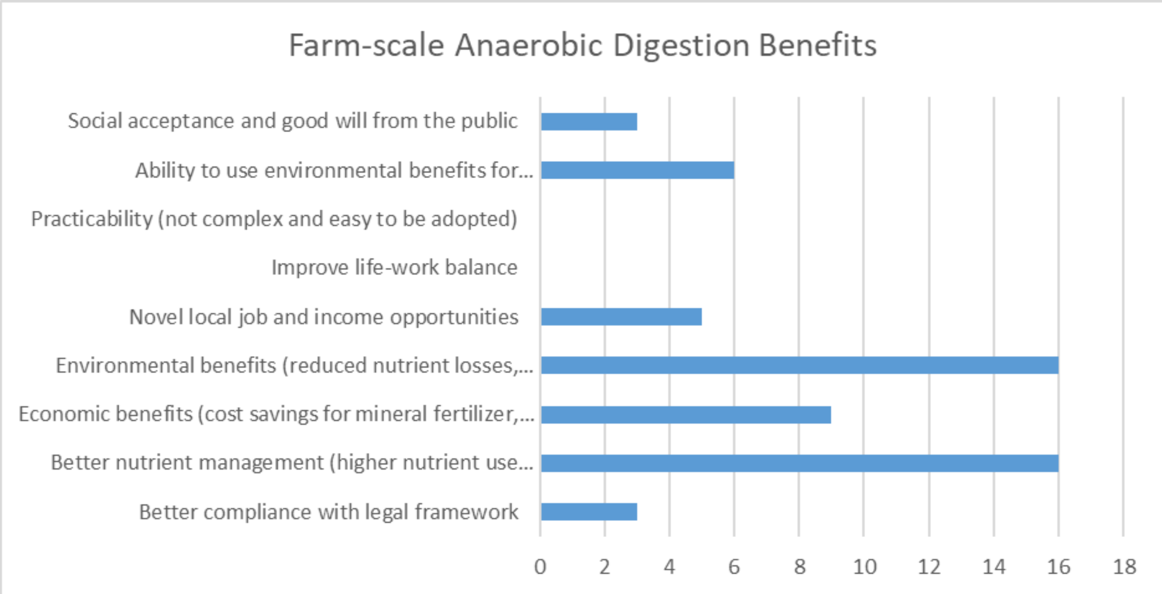
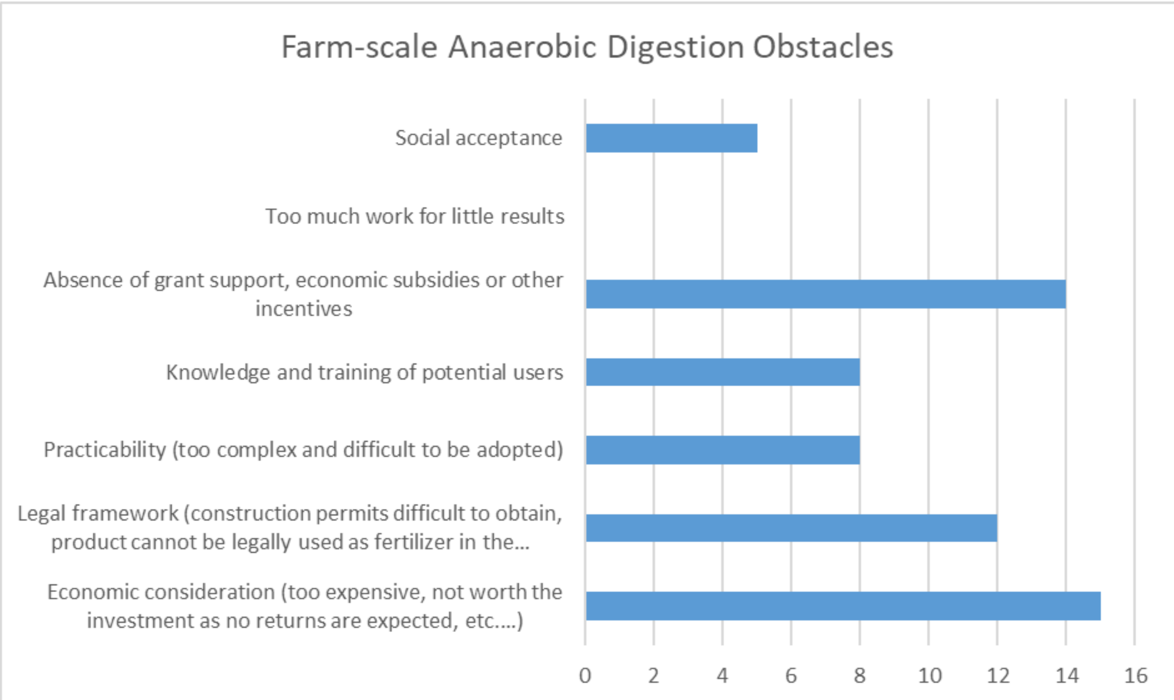
Annex 3 - National Task Force Participants Feedback Graphs

i) Northern Europe





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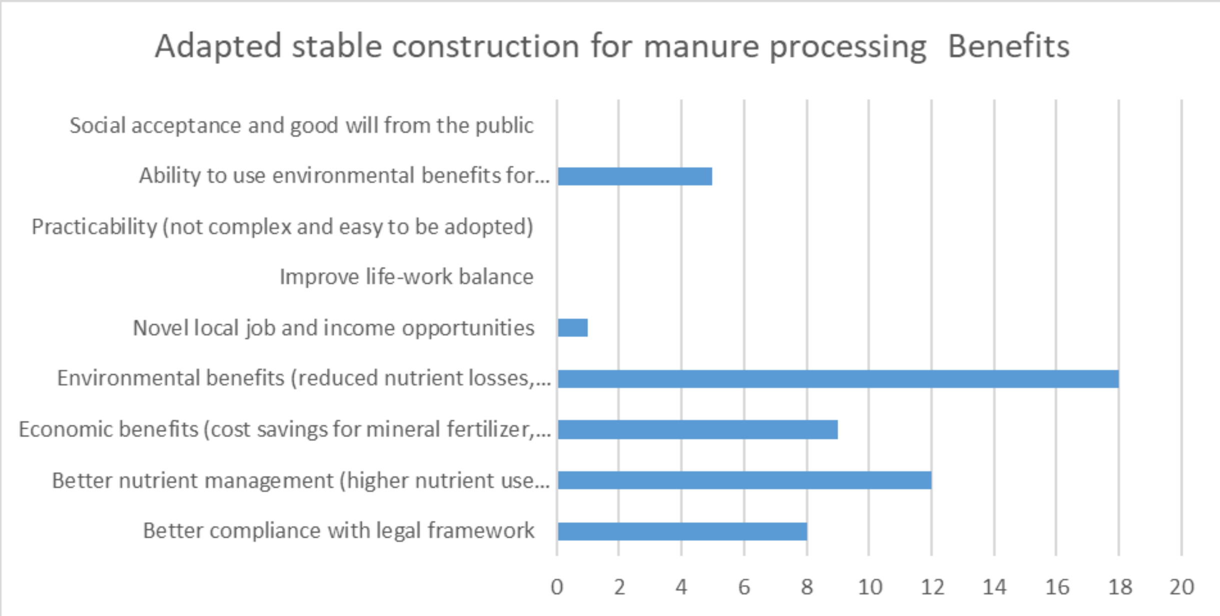

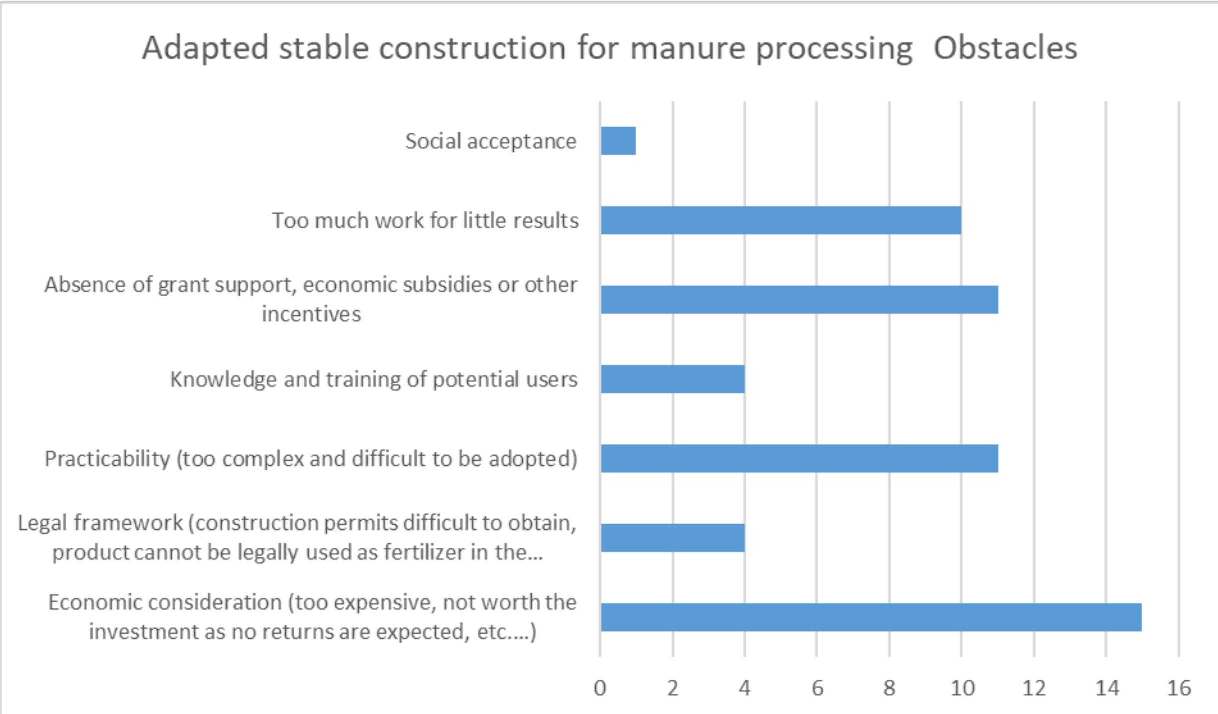

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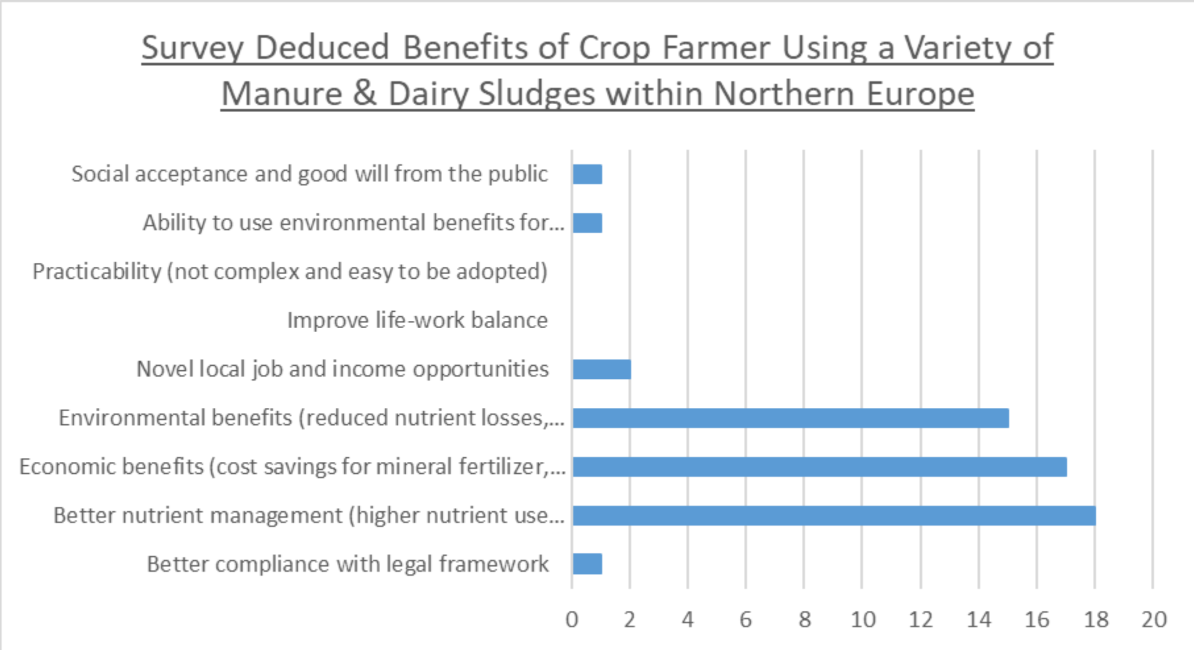

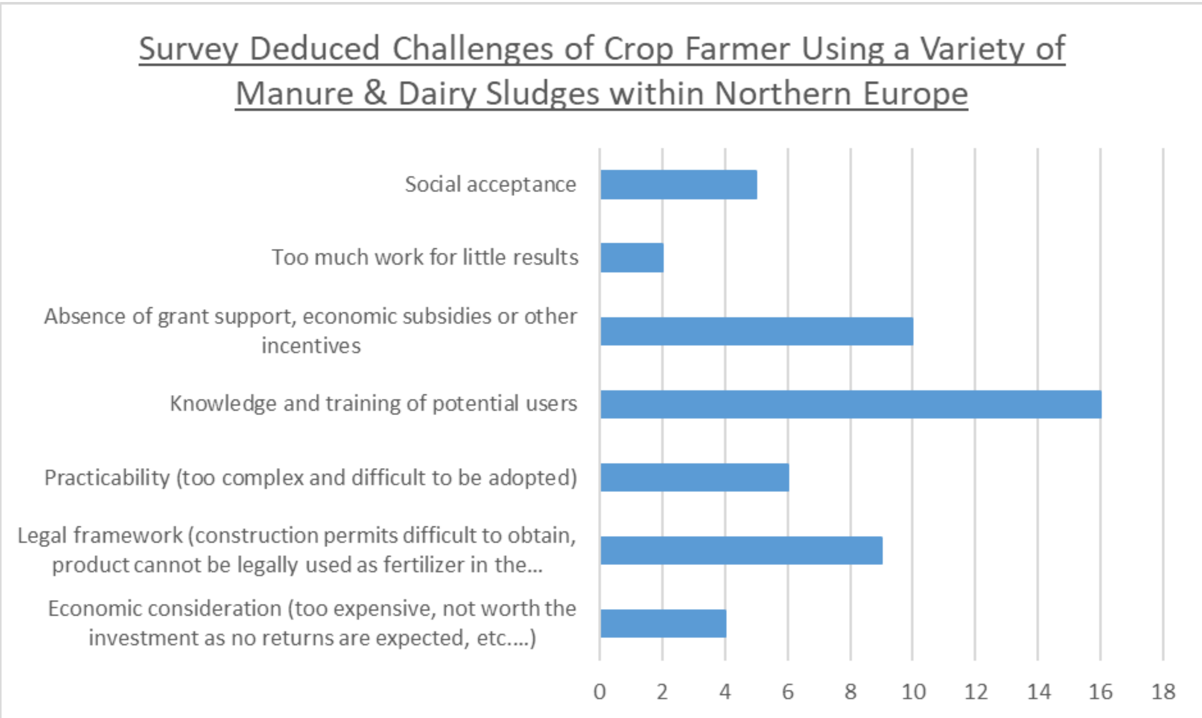

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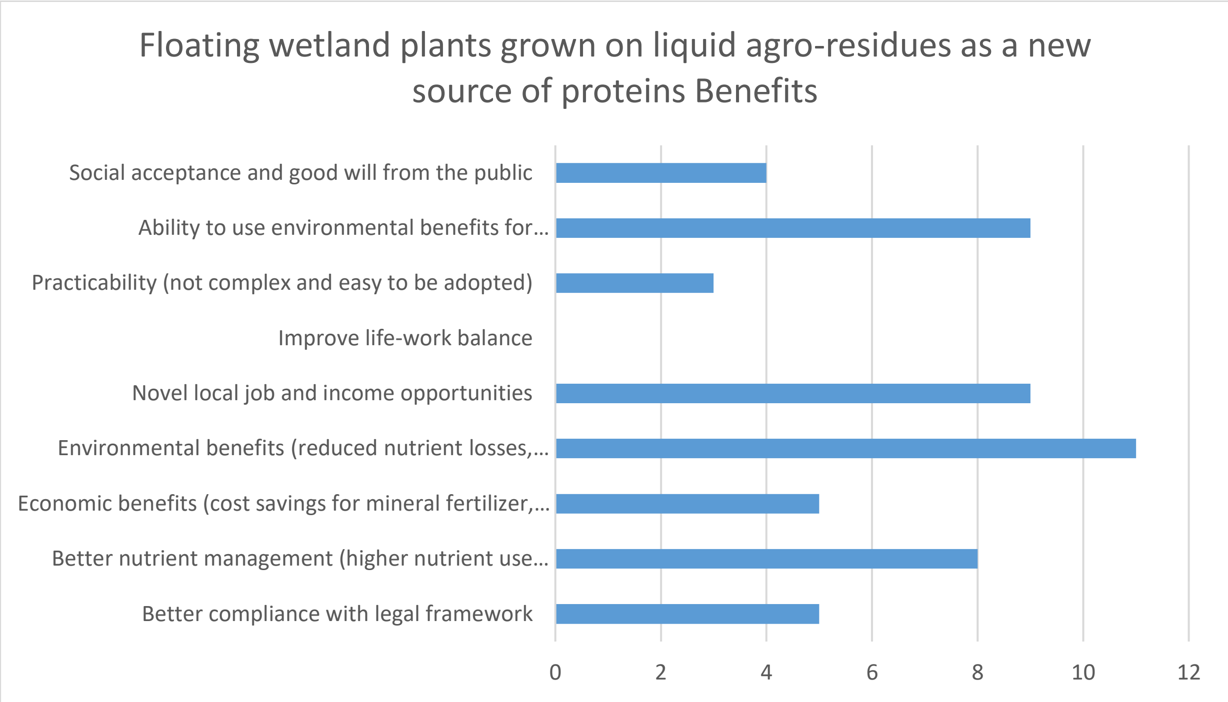

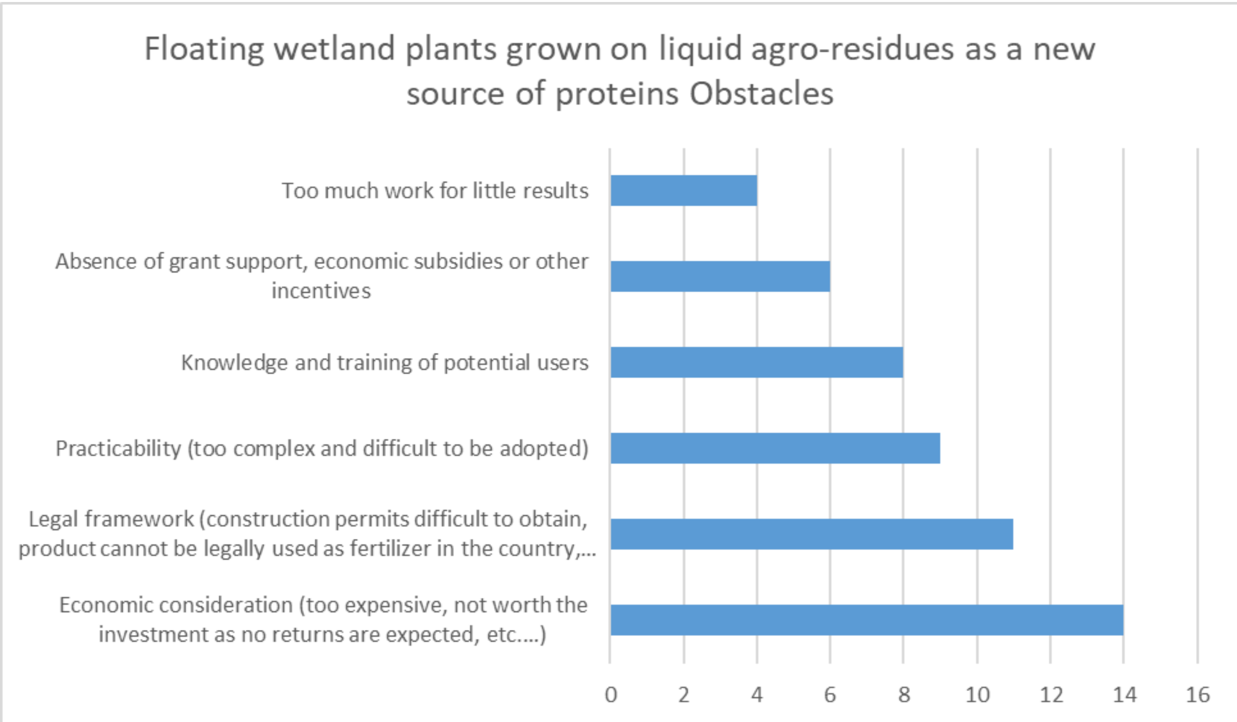

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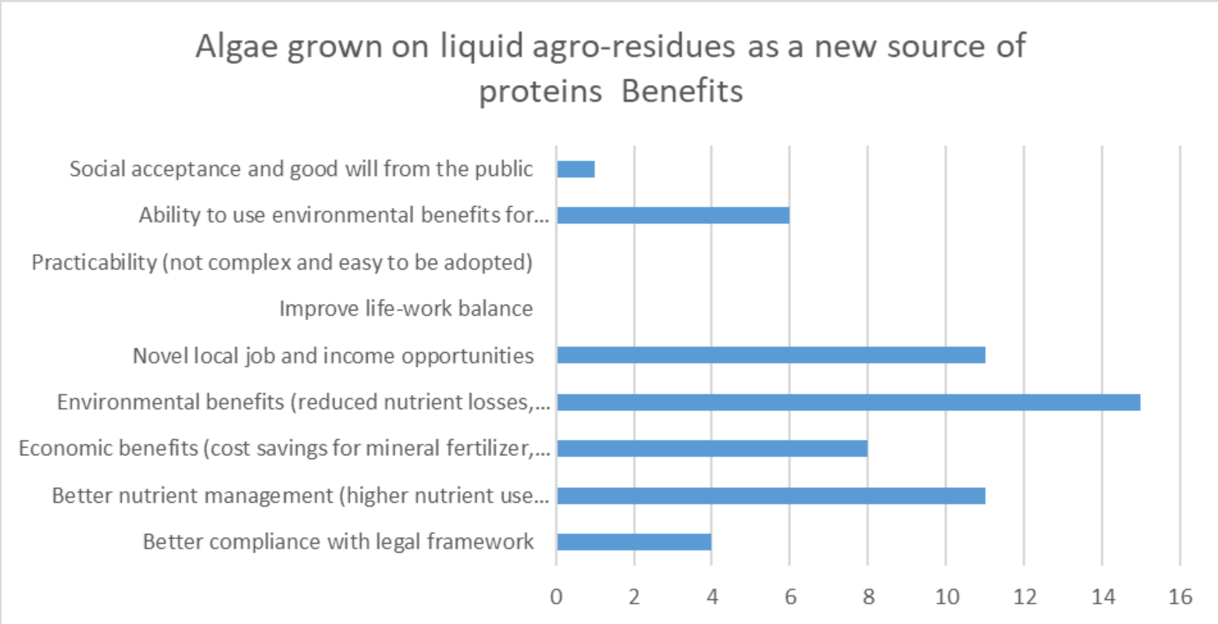

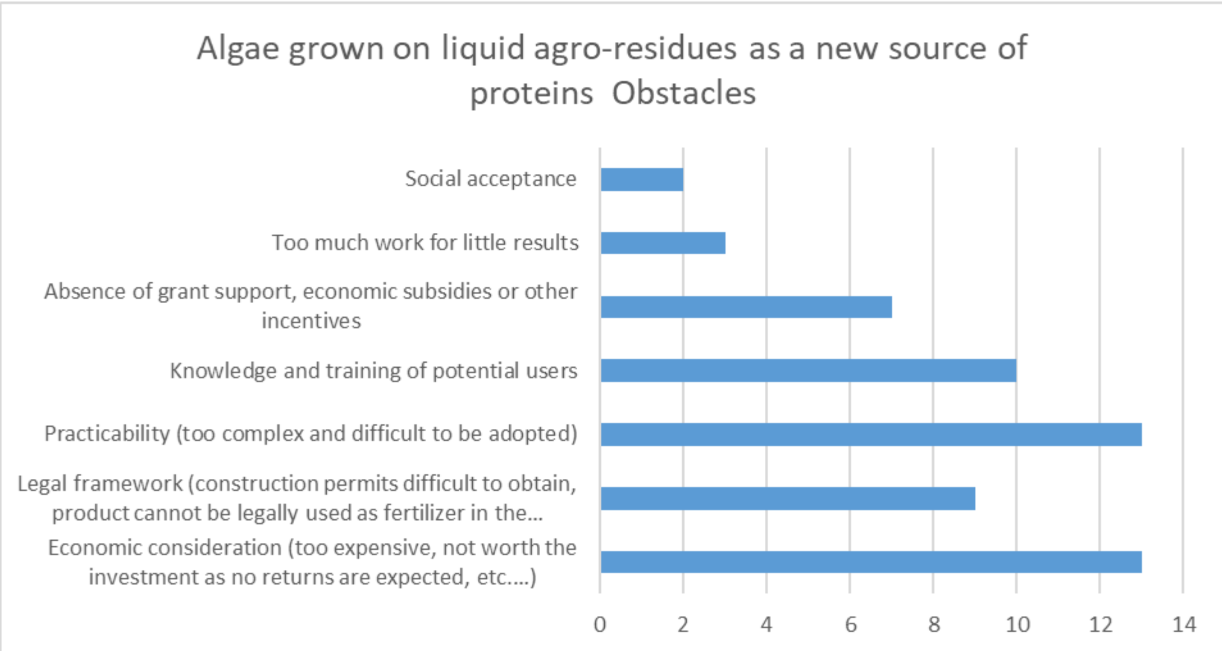

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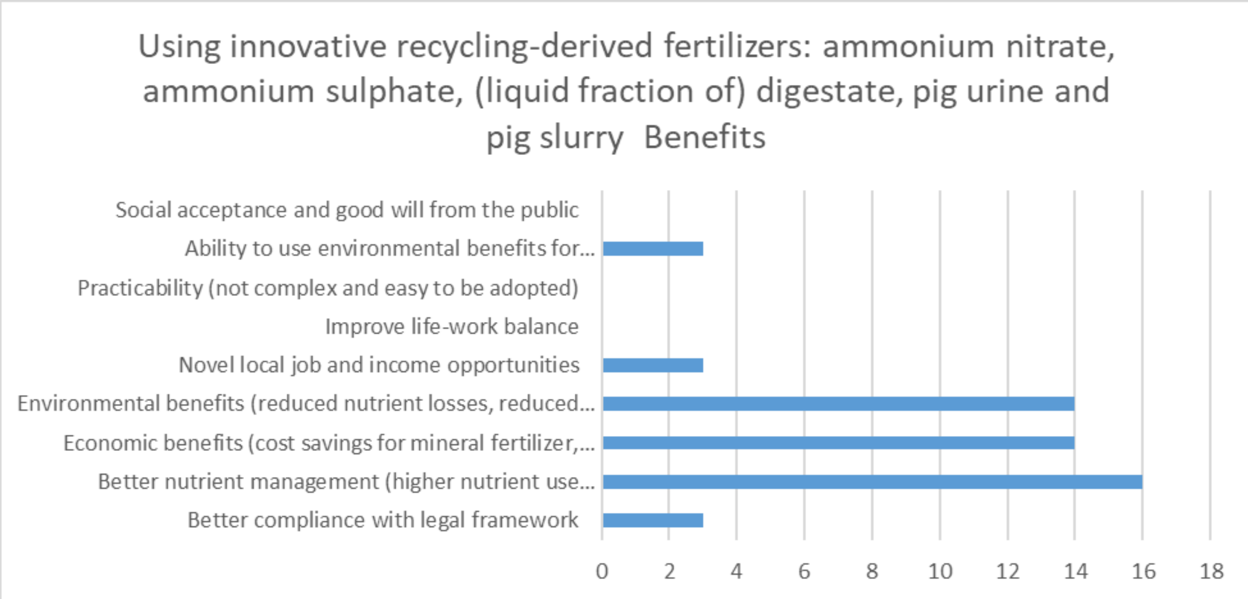

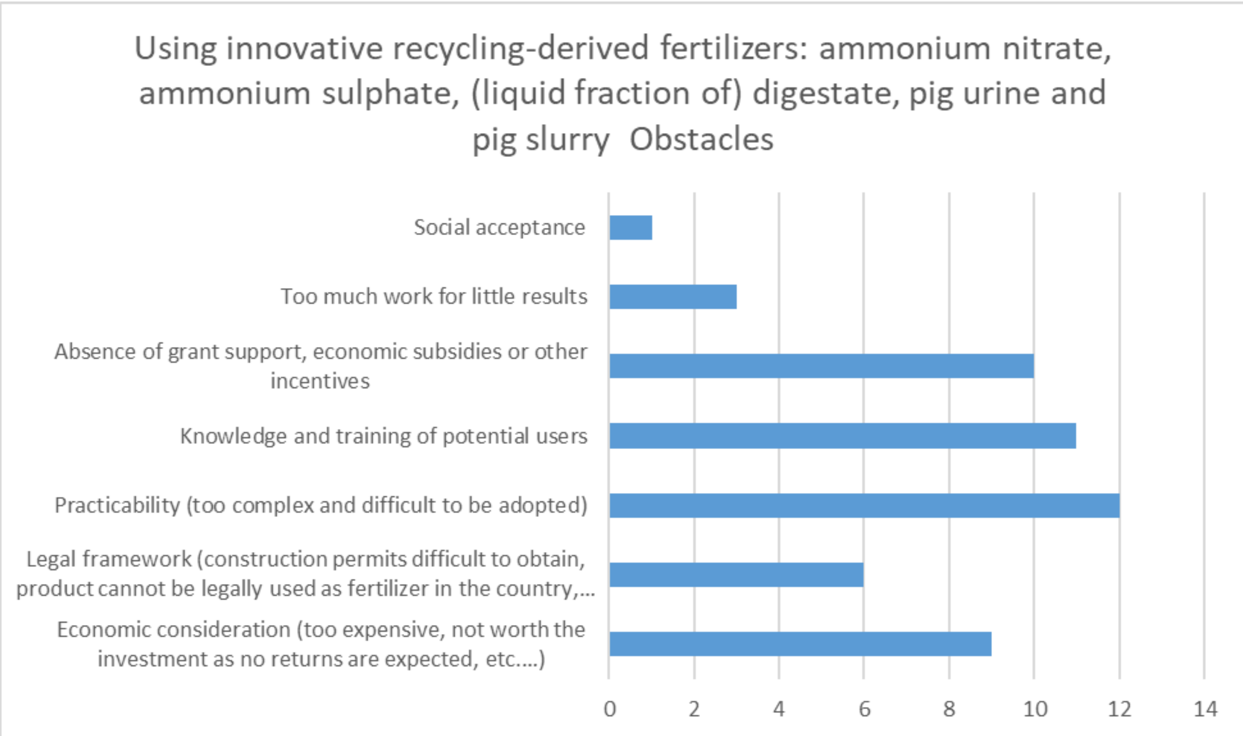

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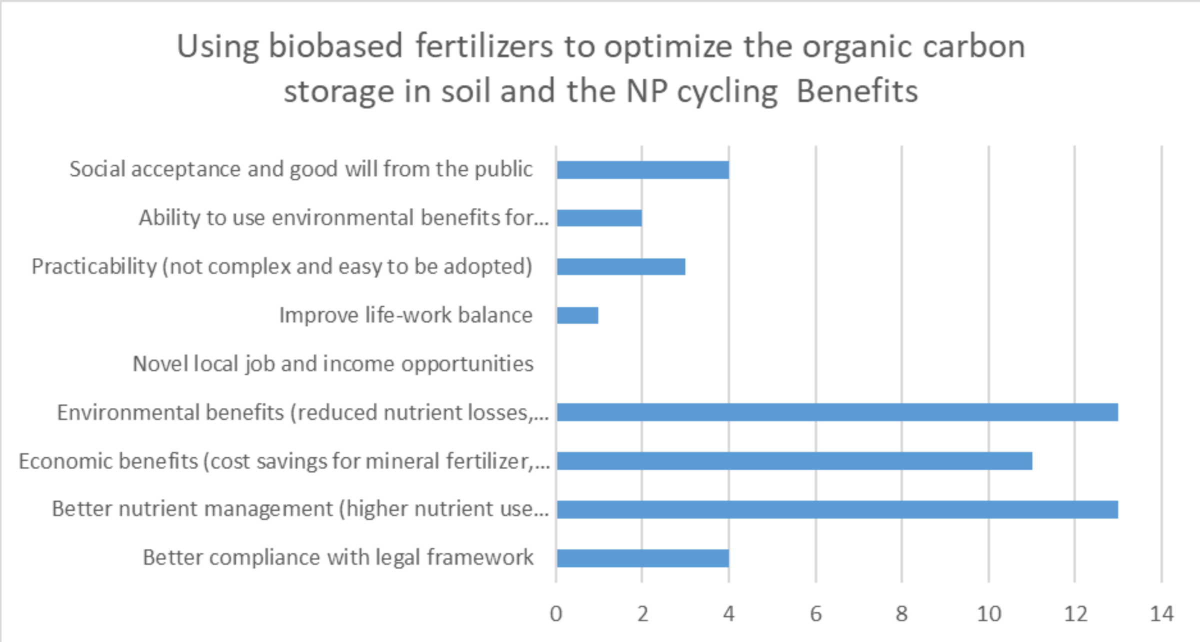

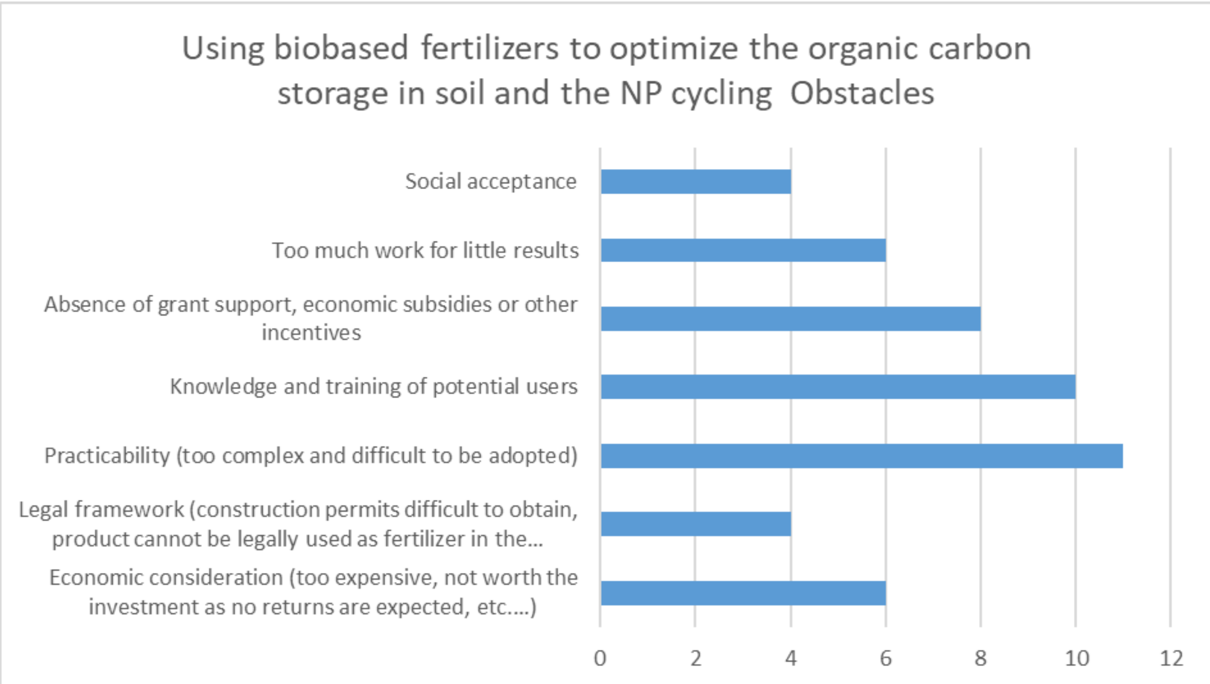

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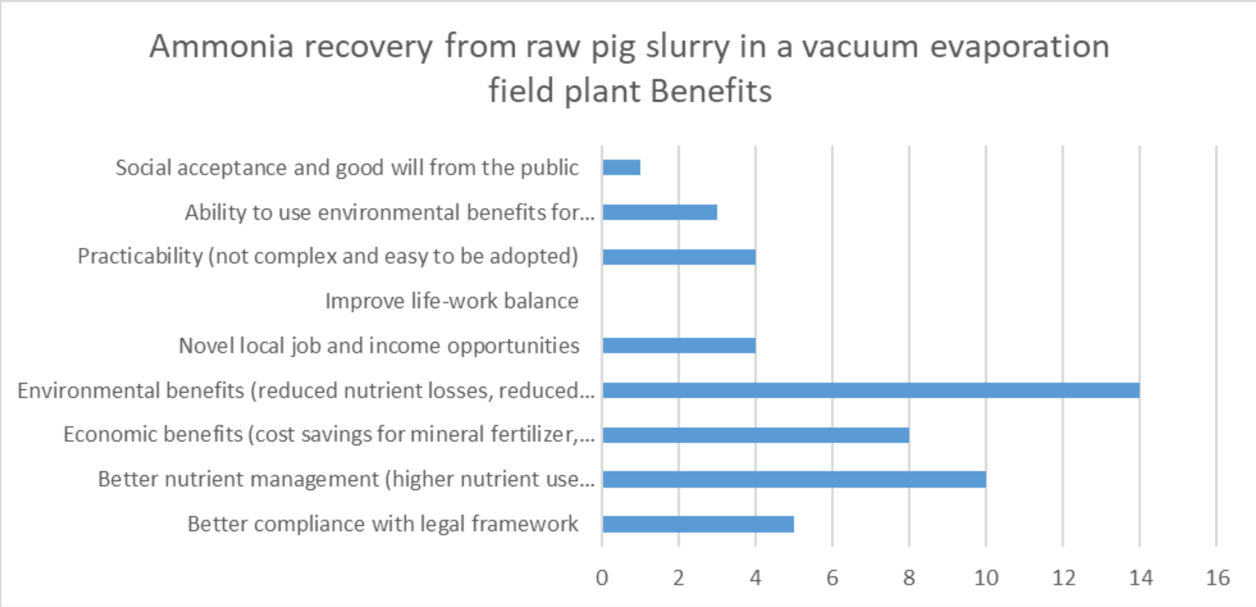

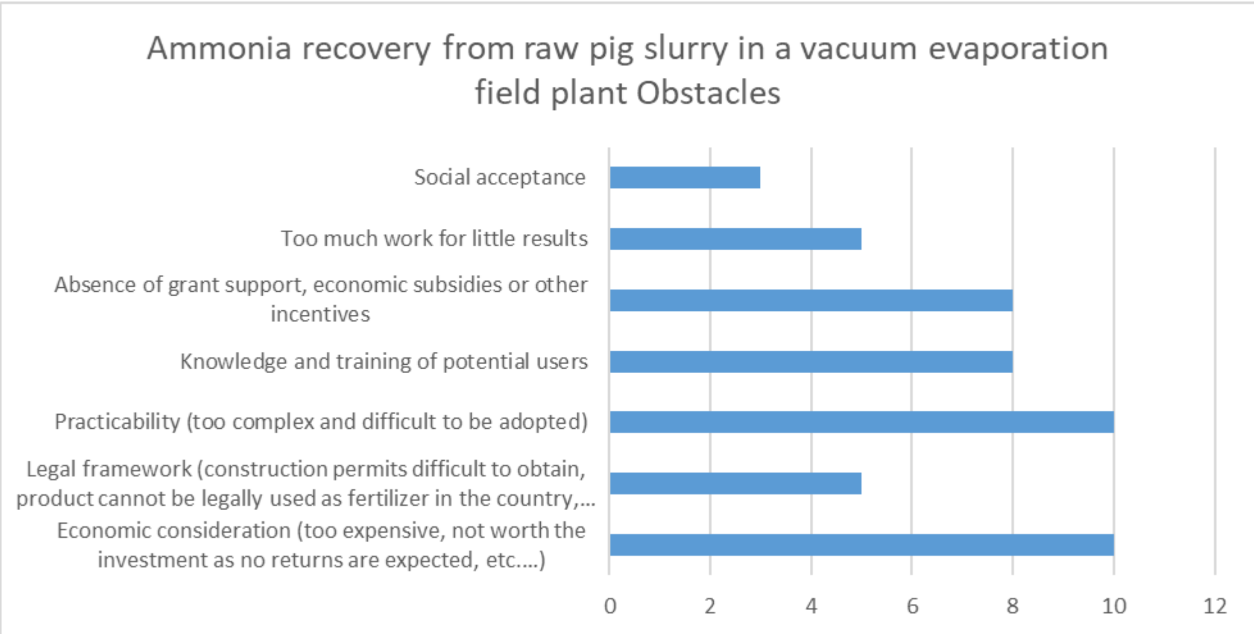

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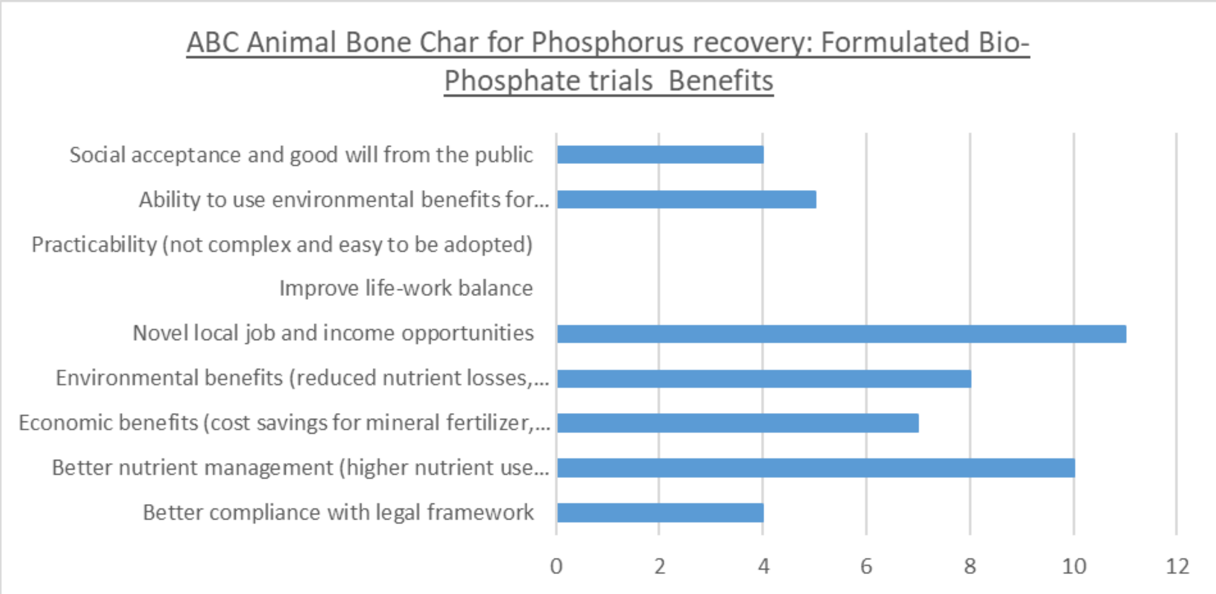

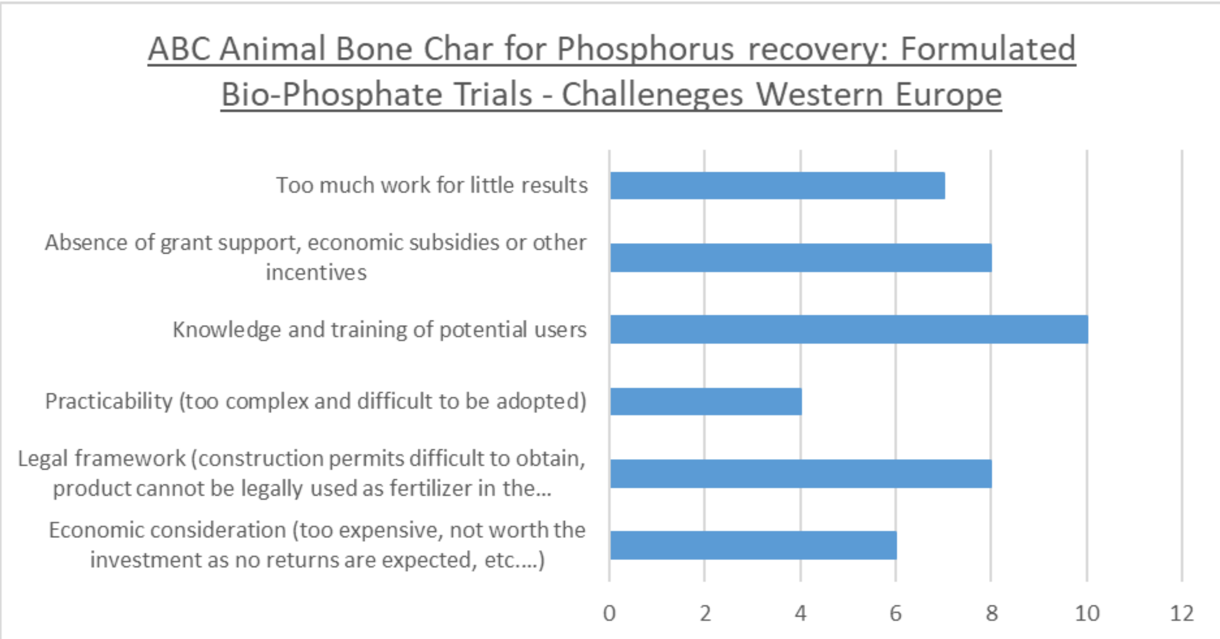

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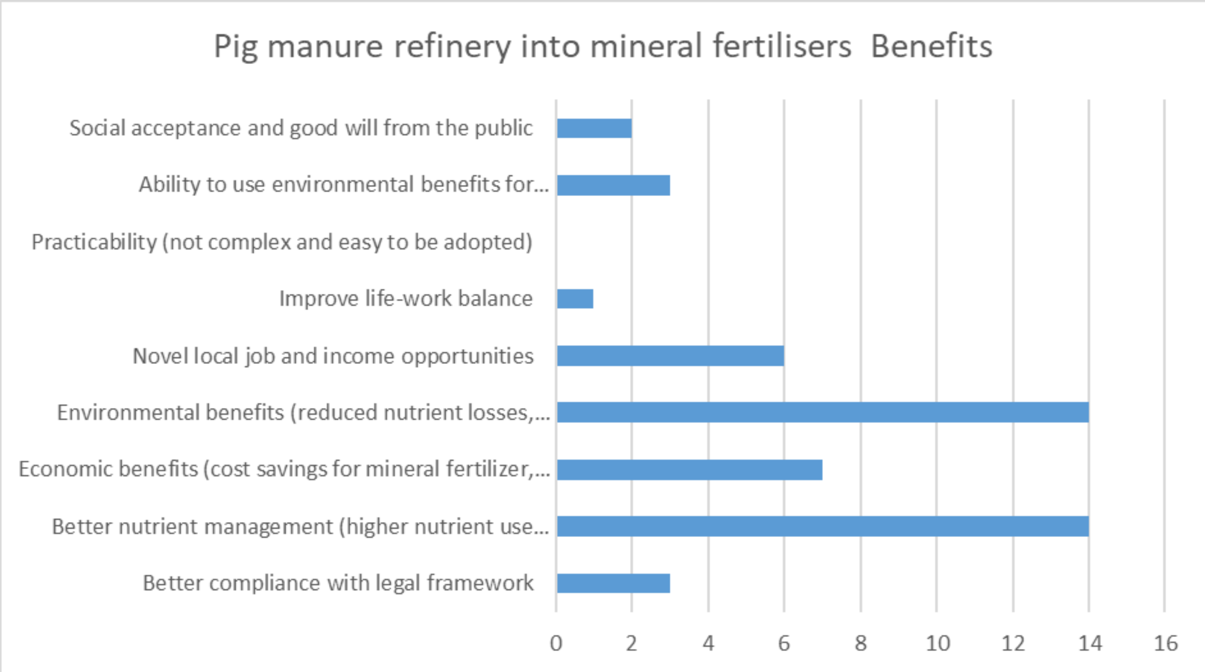

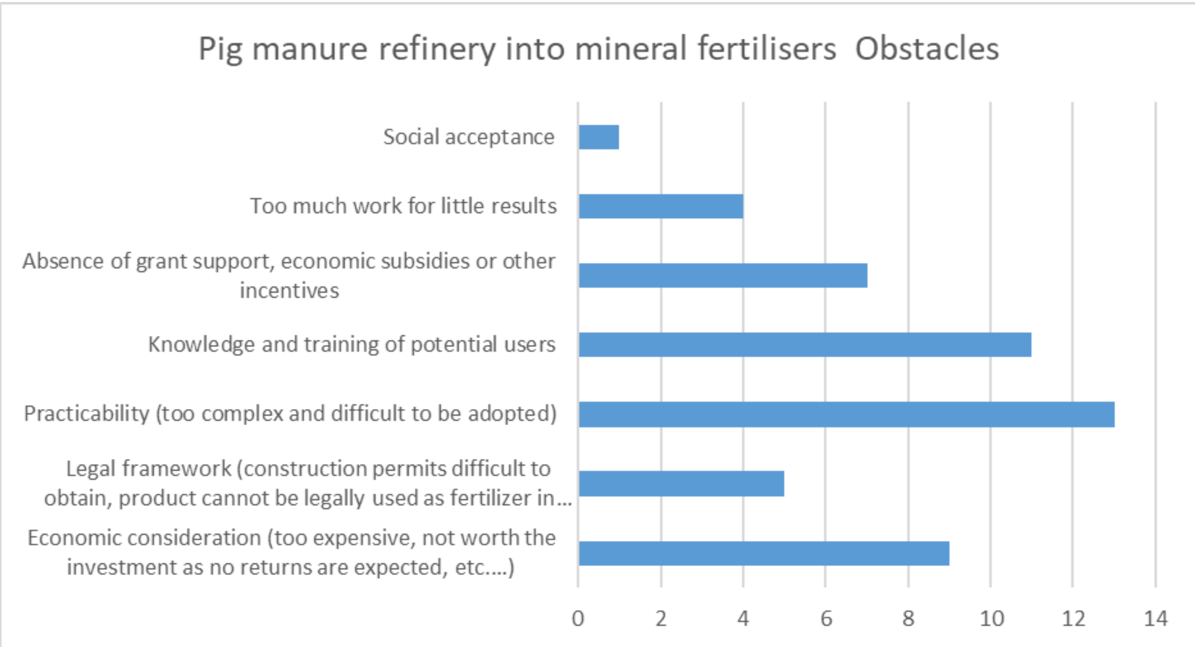

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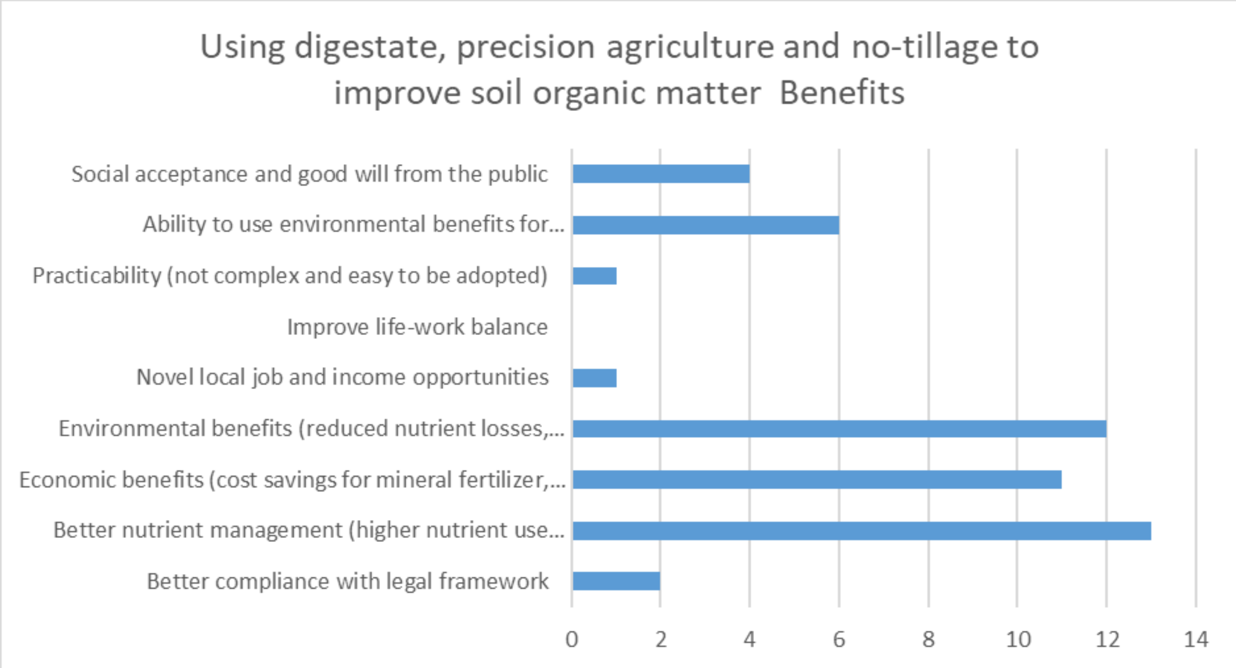

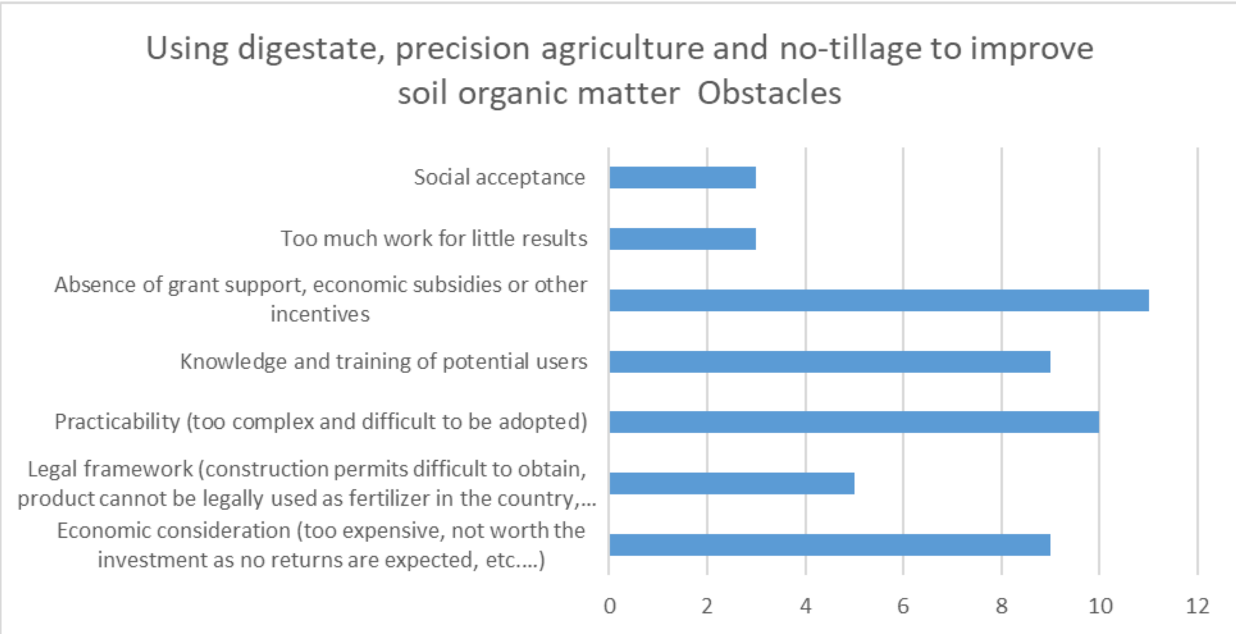

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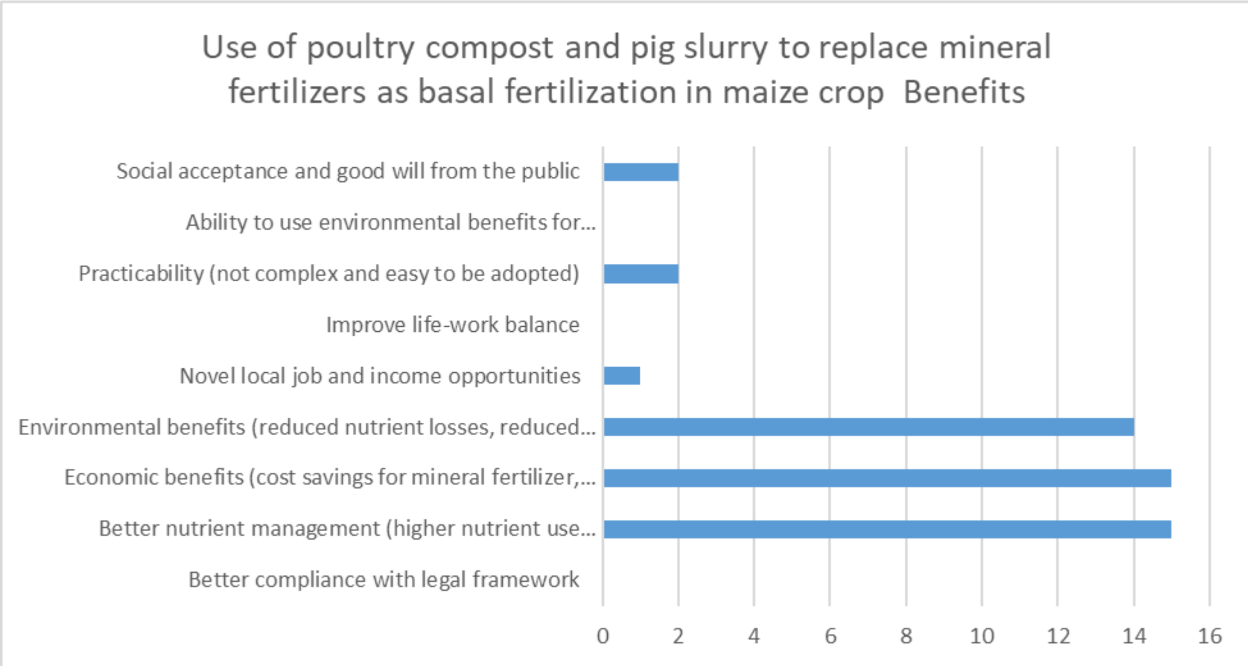

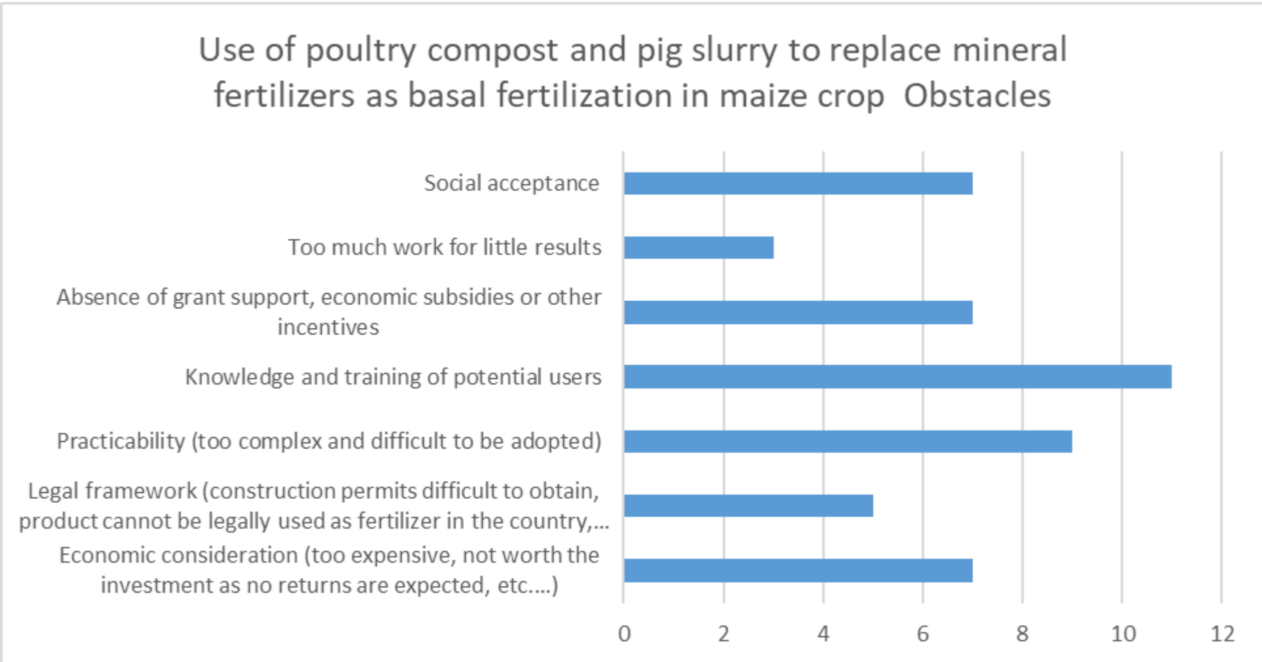

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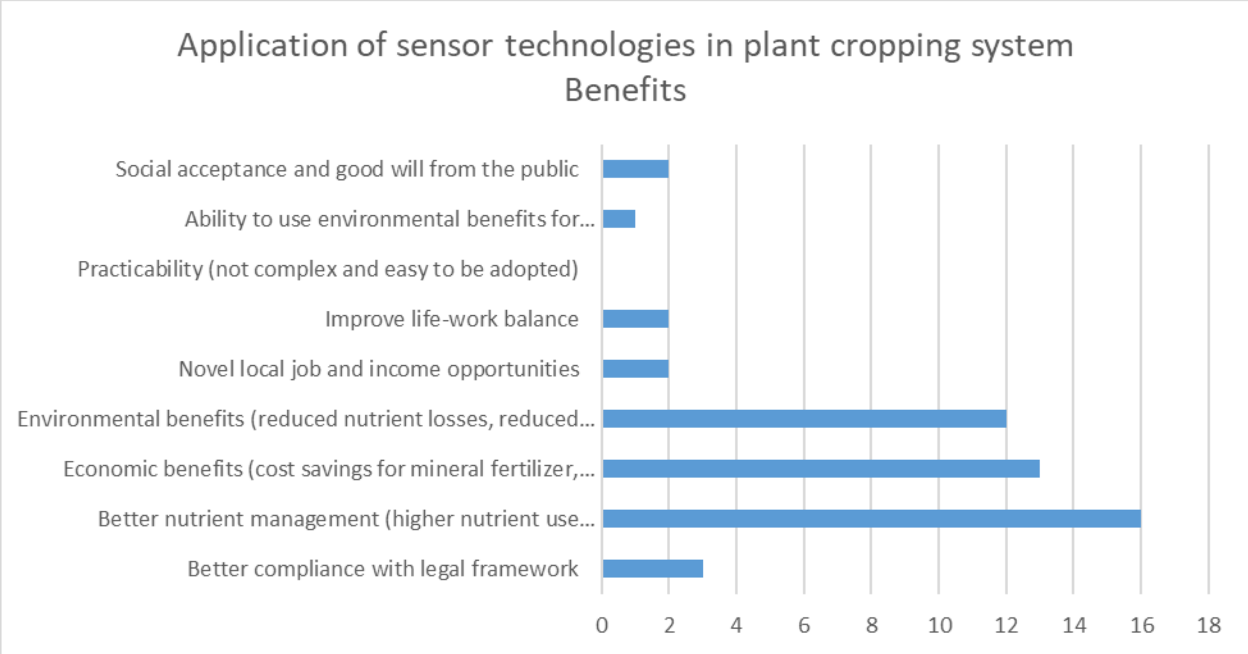

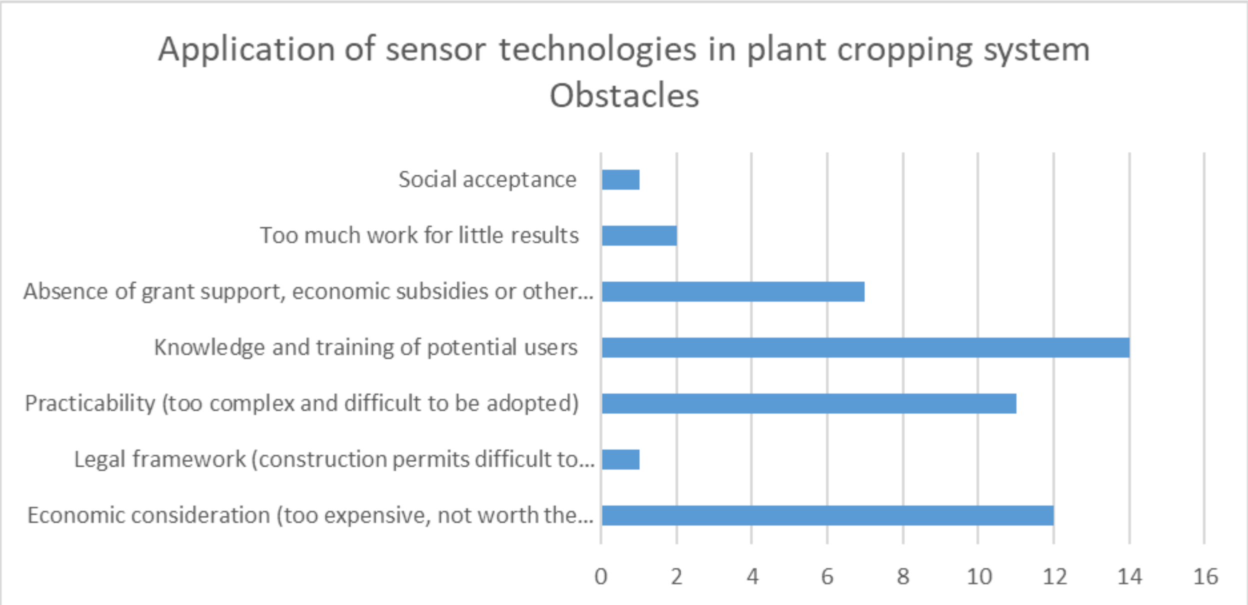

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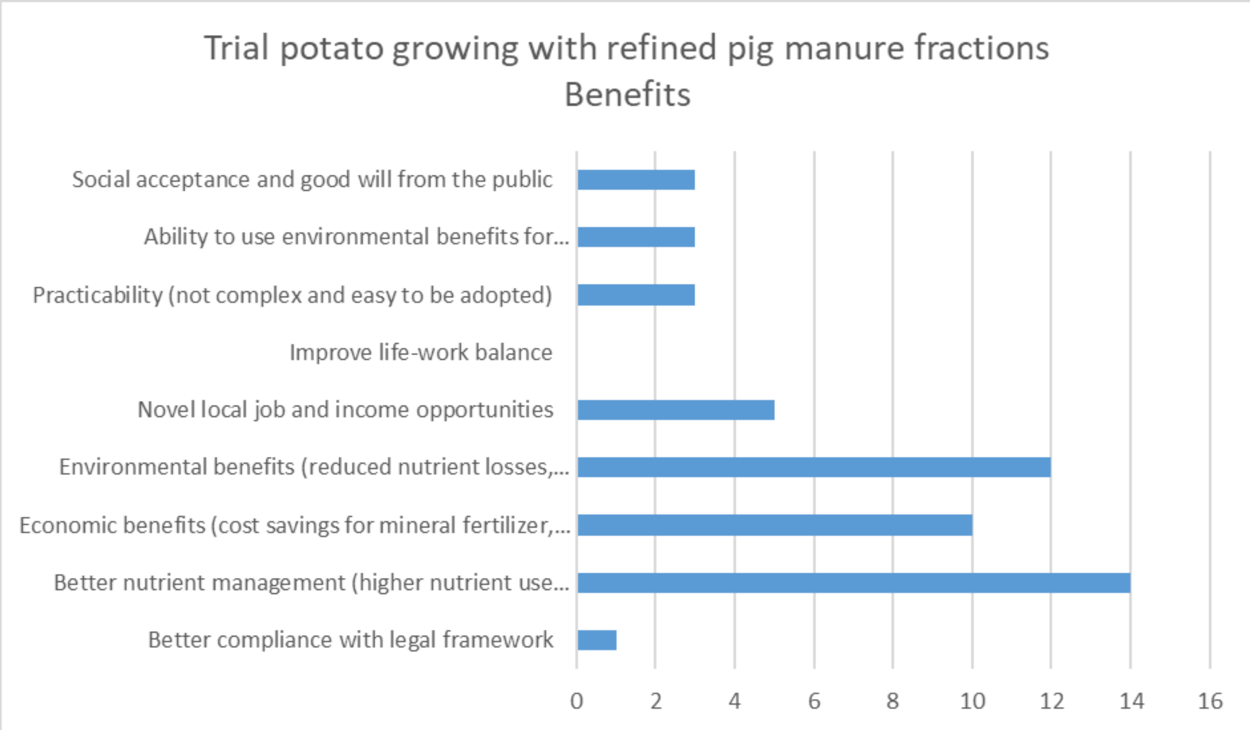

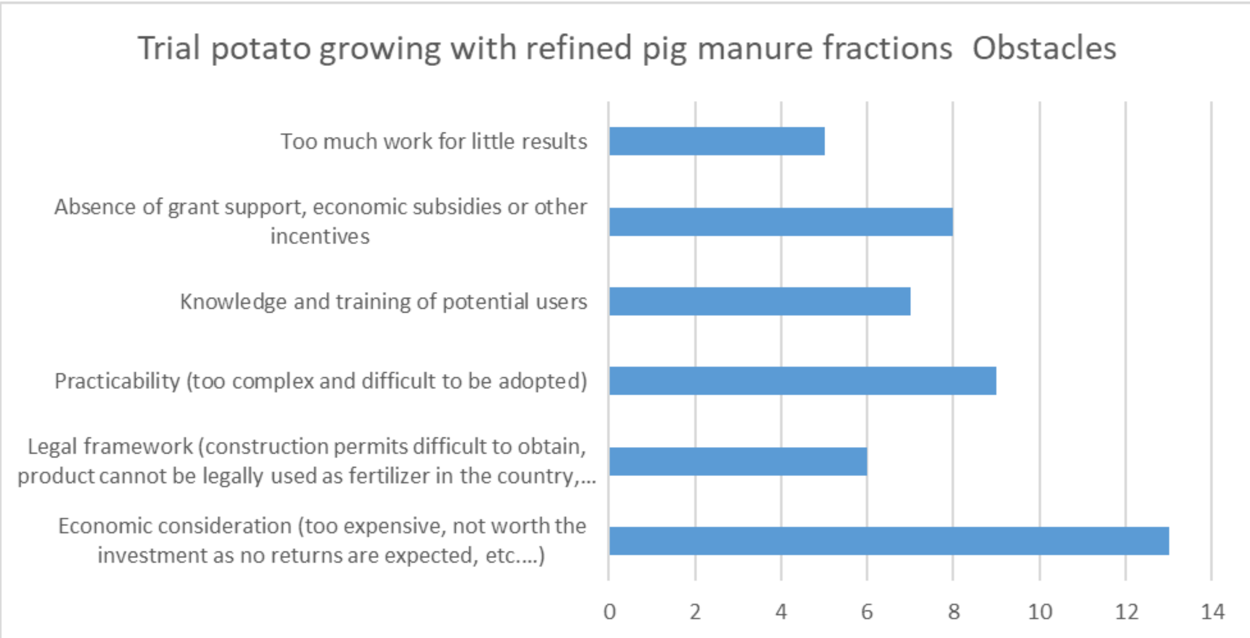

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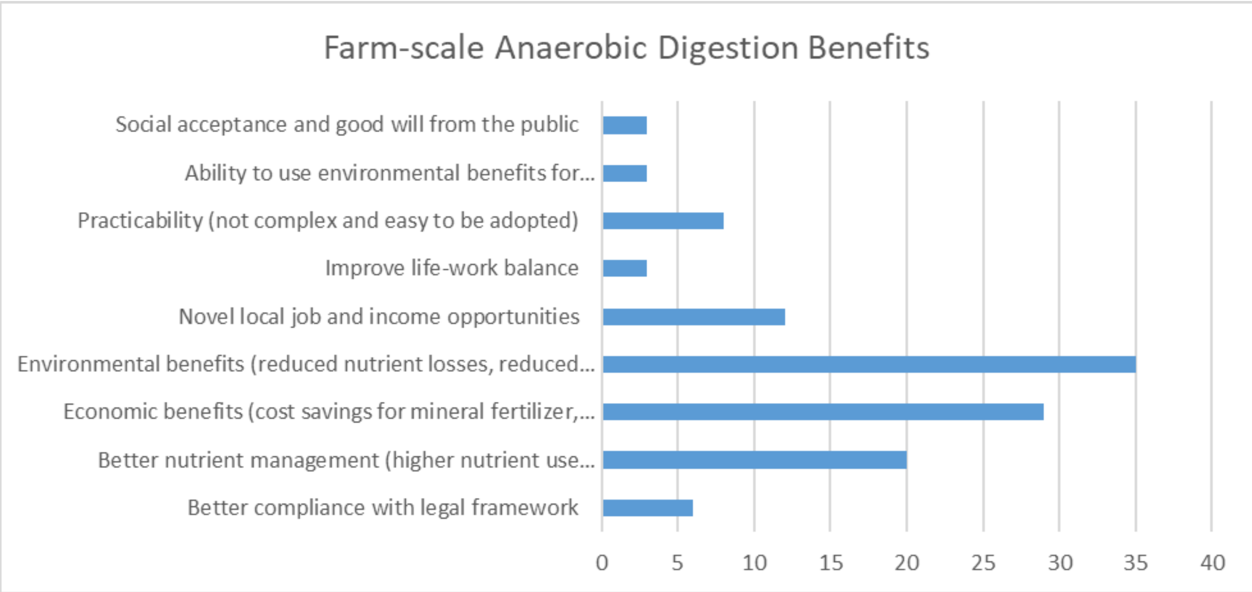
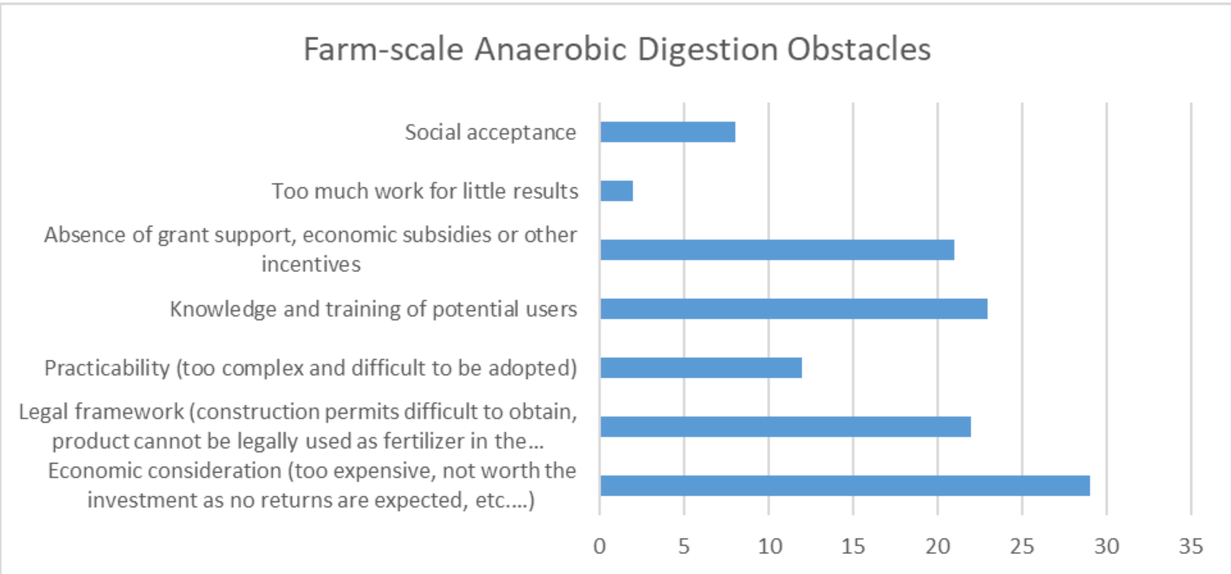
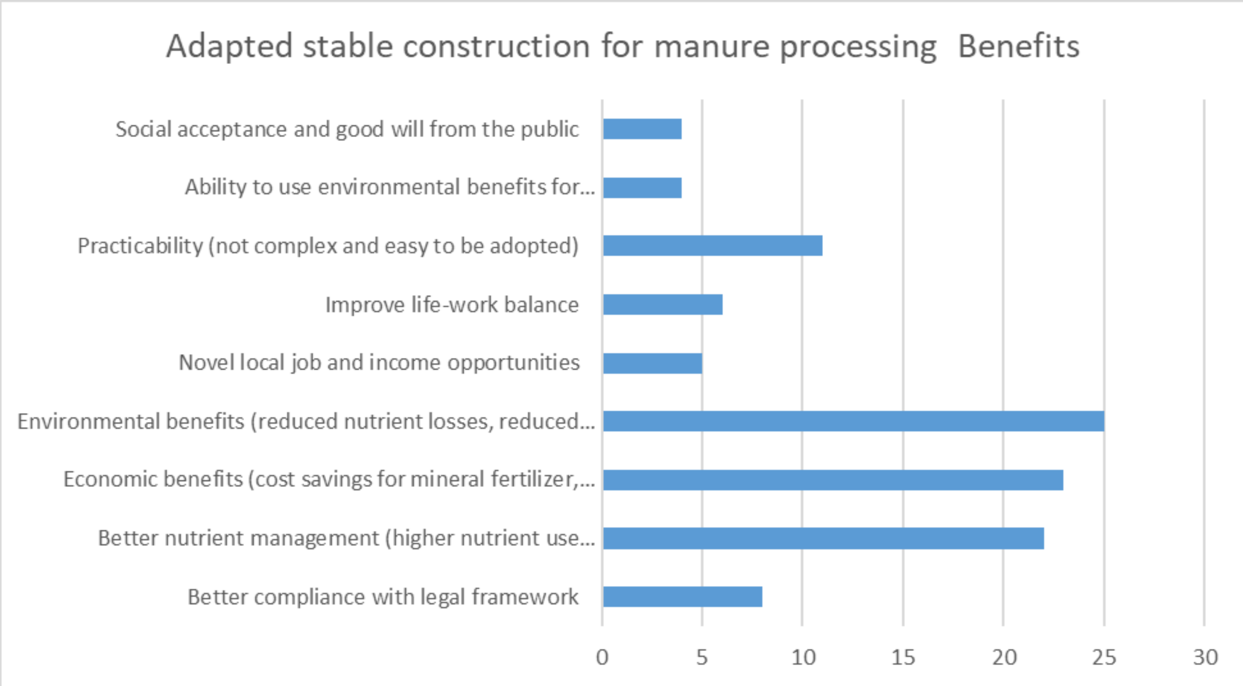
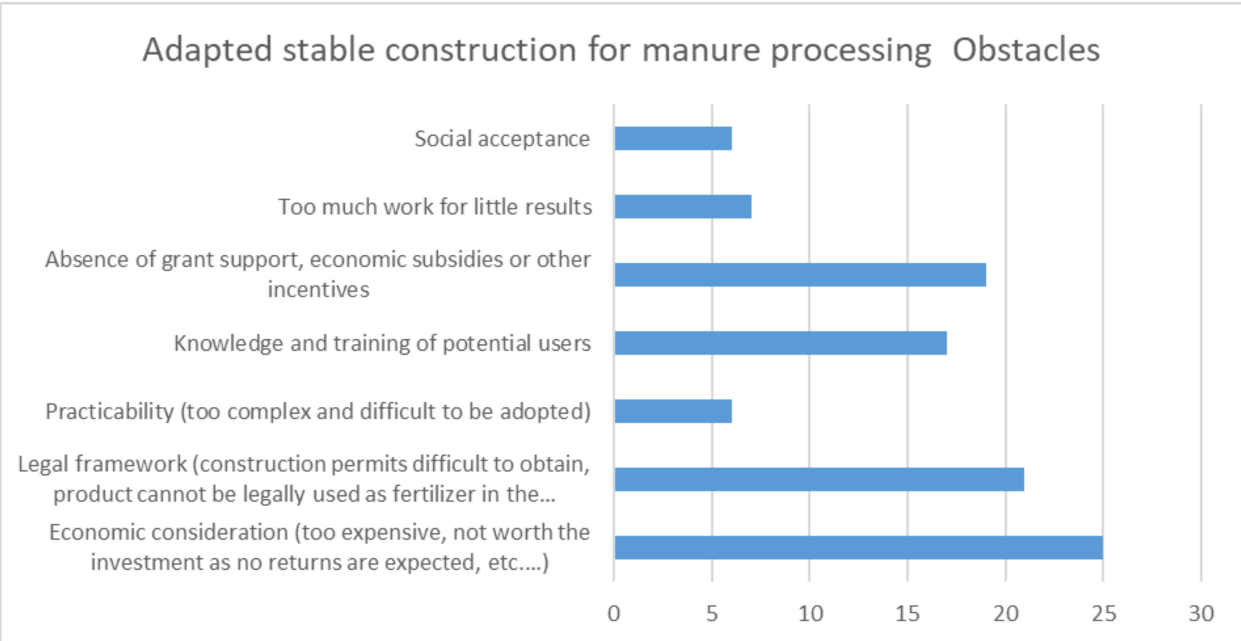
ii) Southern Europe





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.





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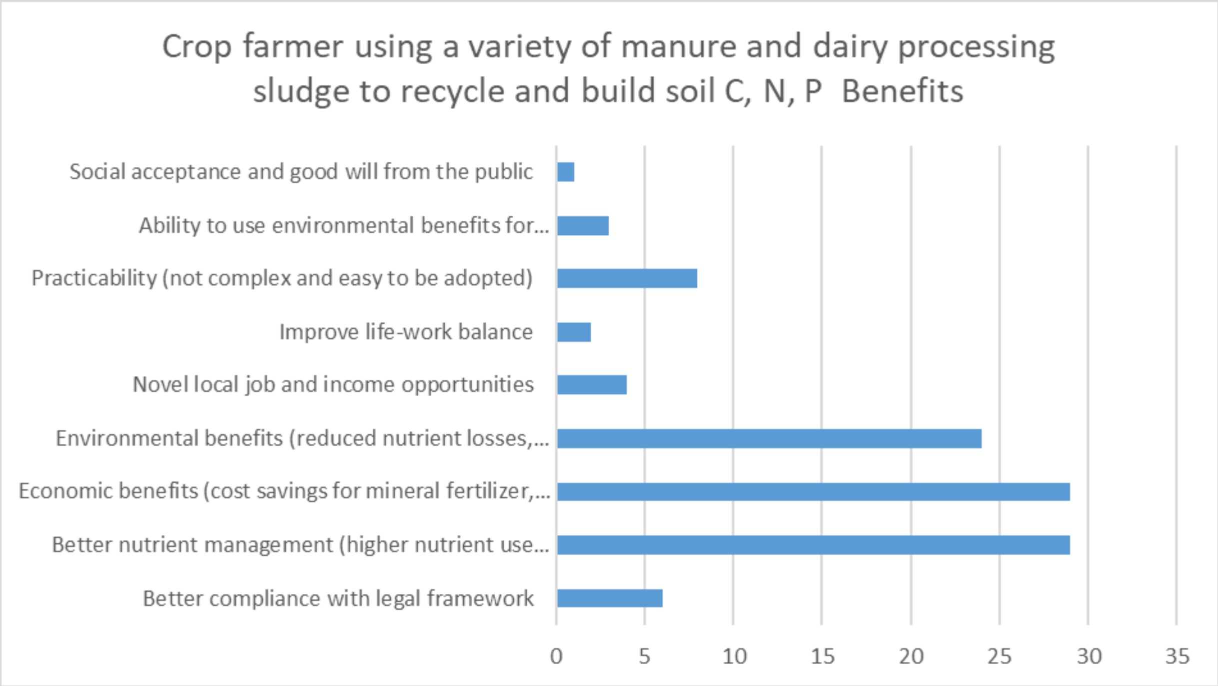

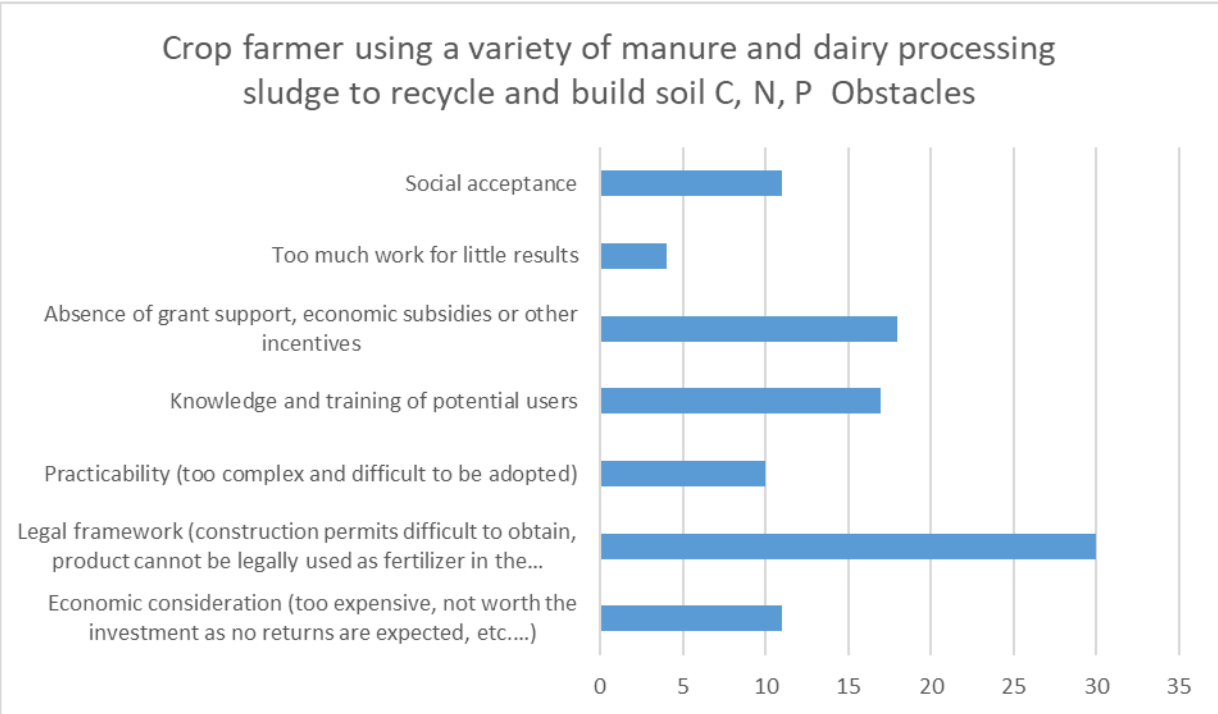

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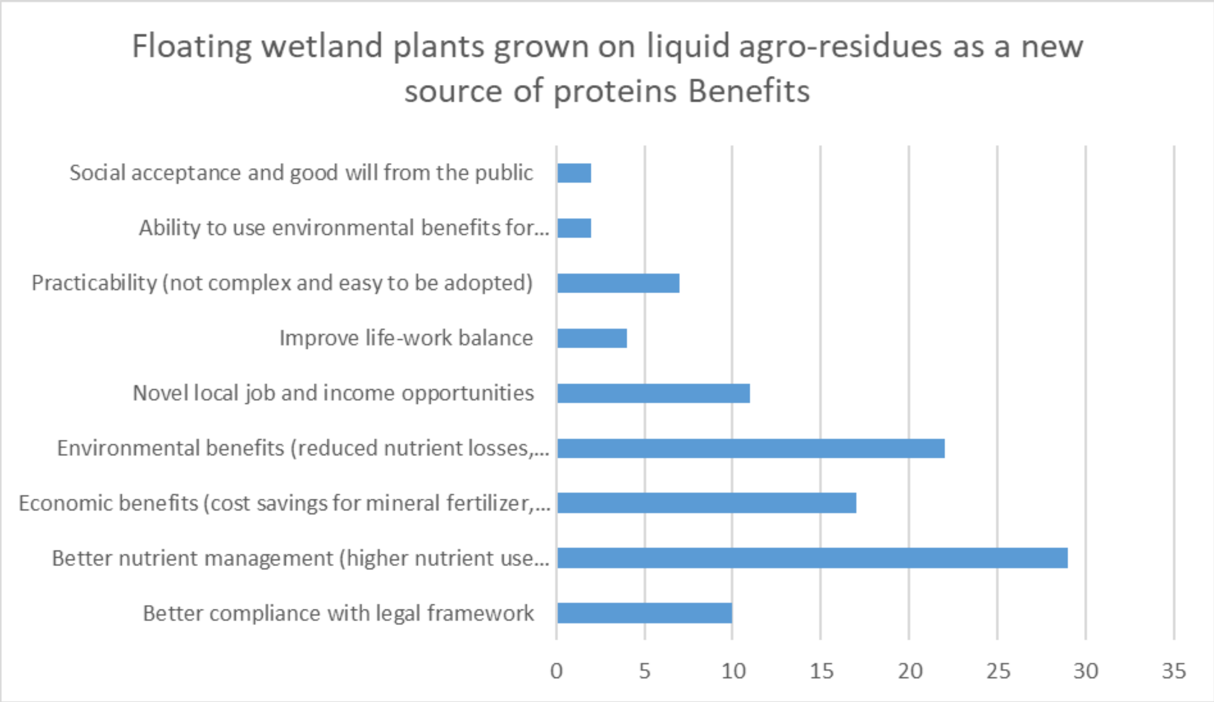

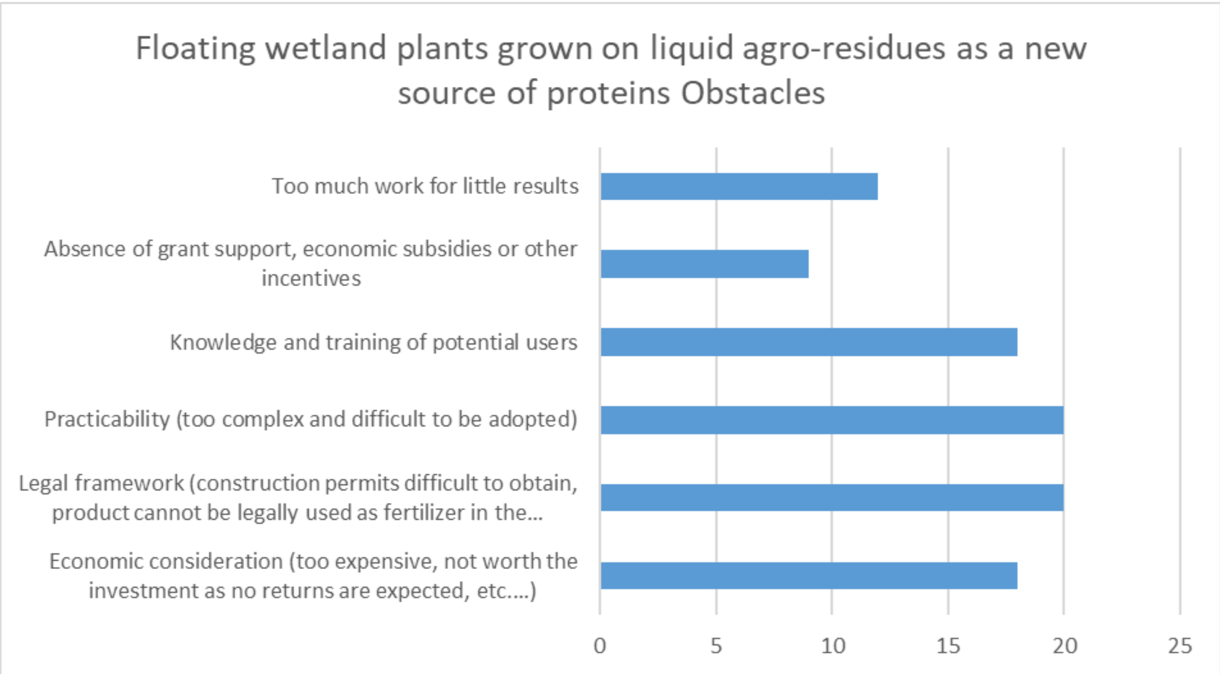

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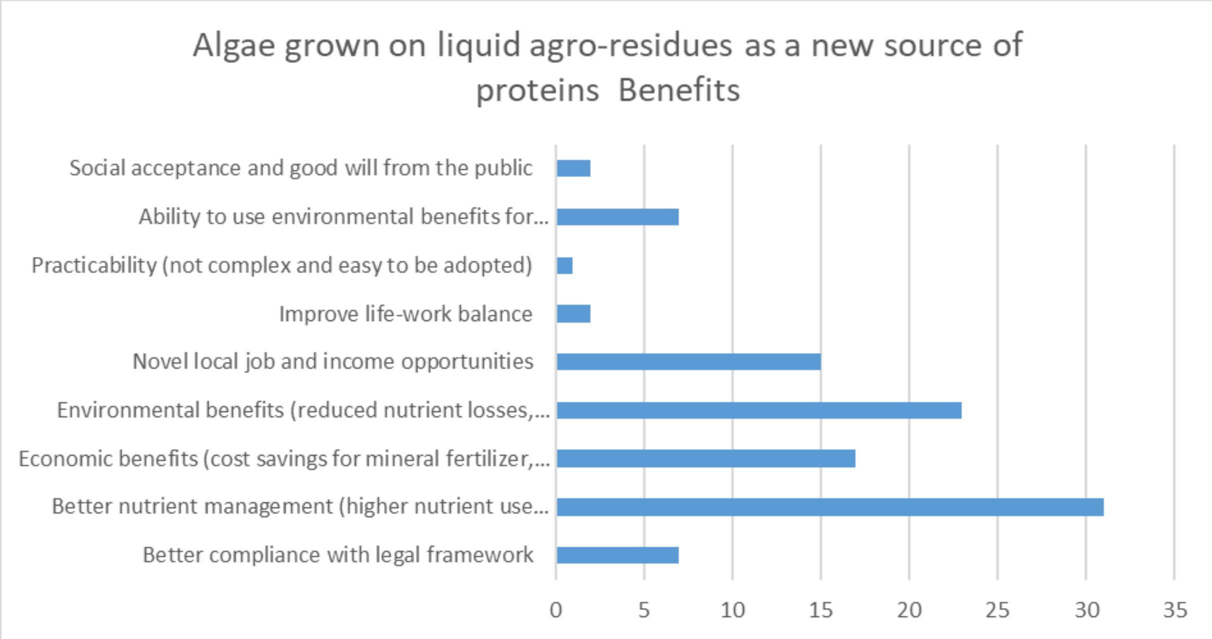

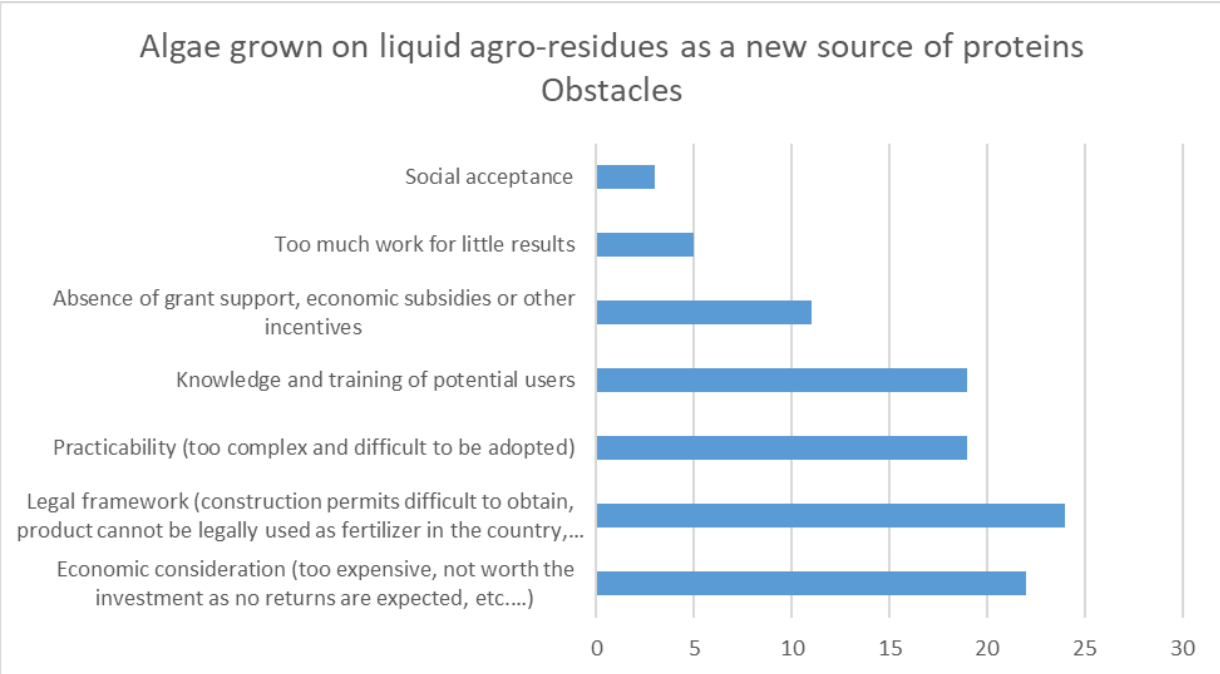

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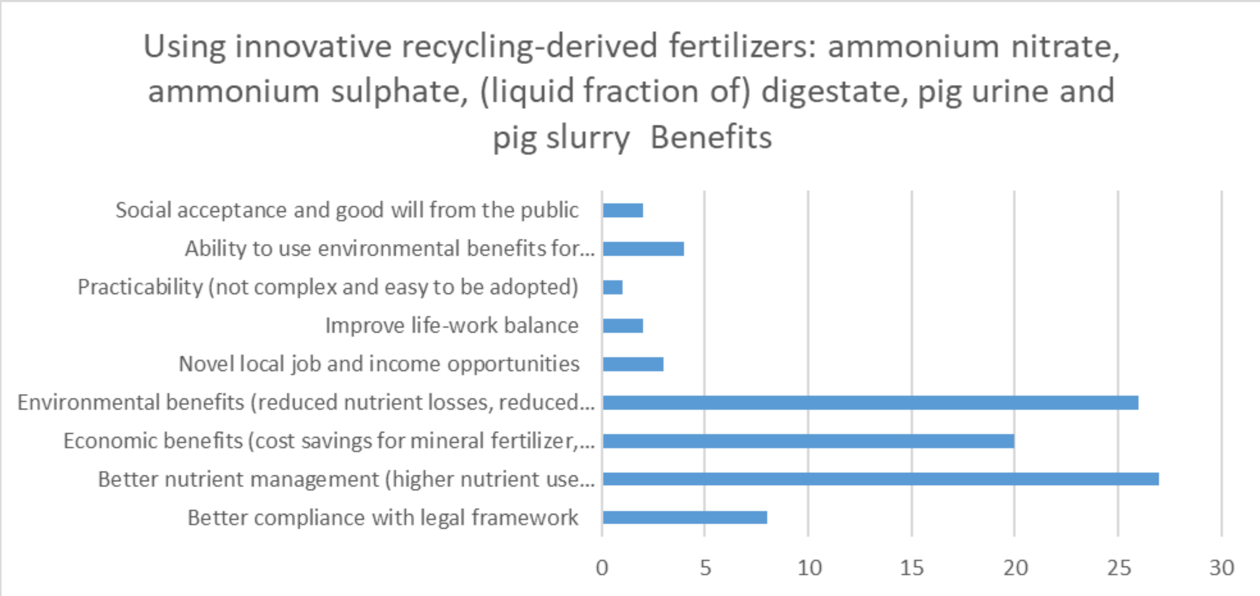

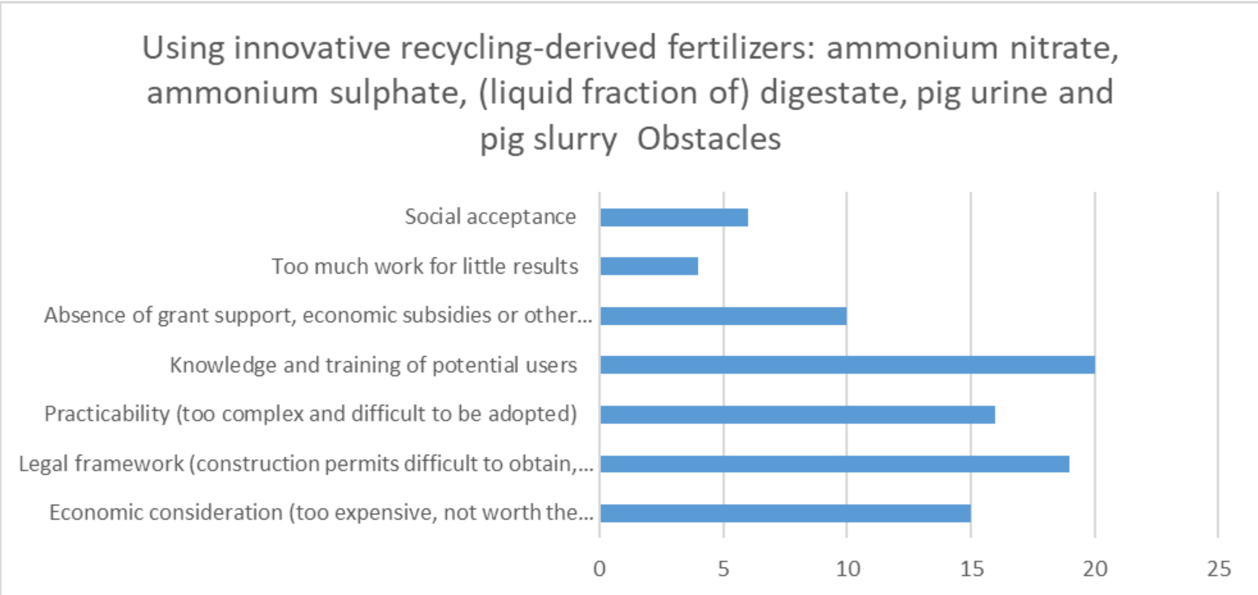

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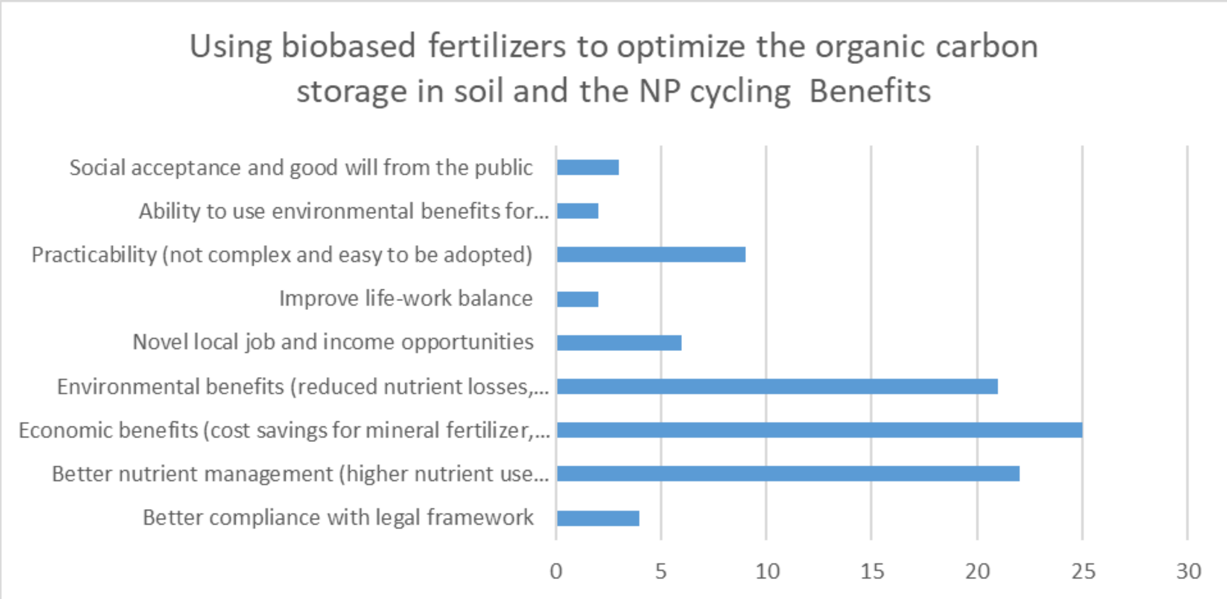

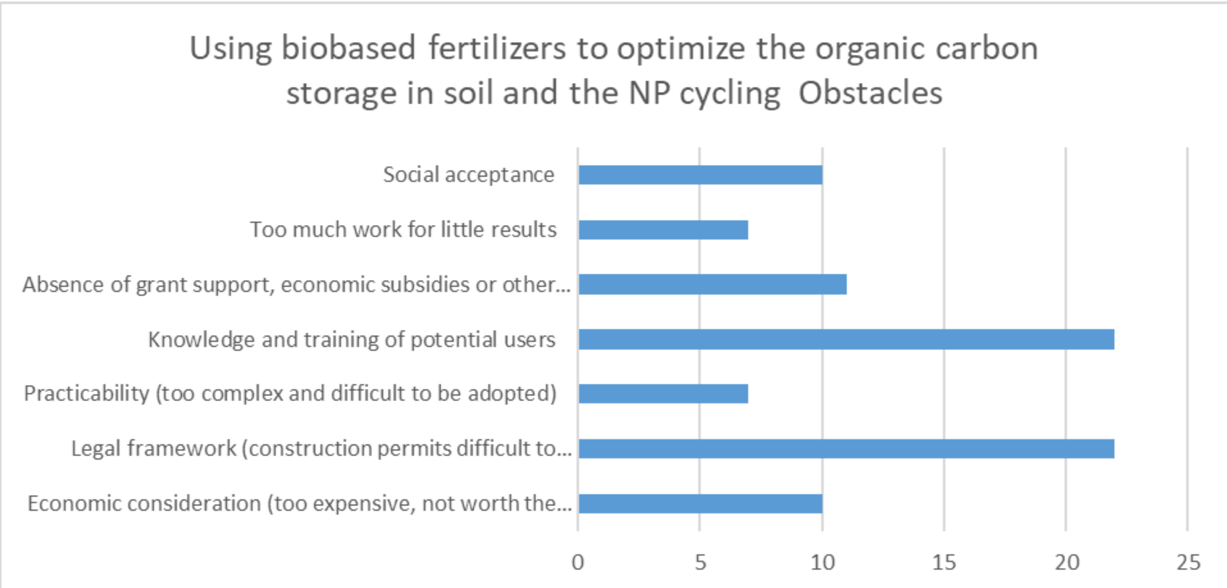

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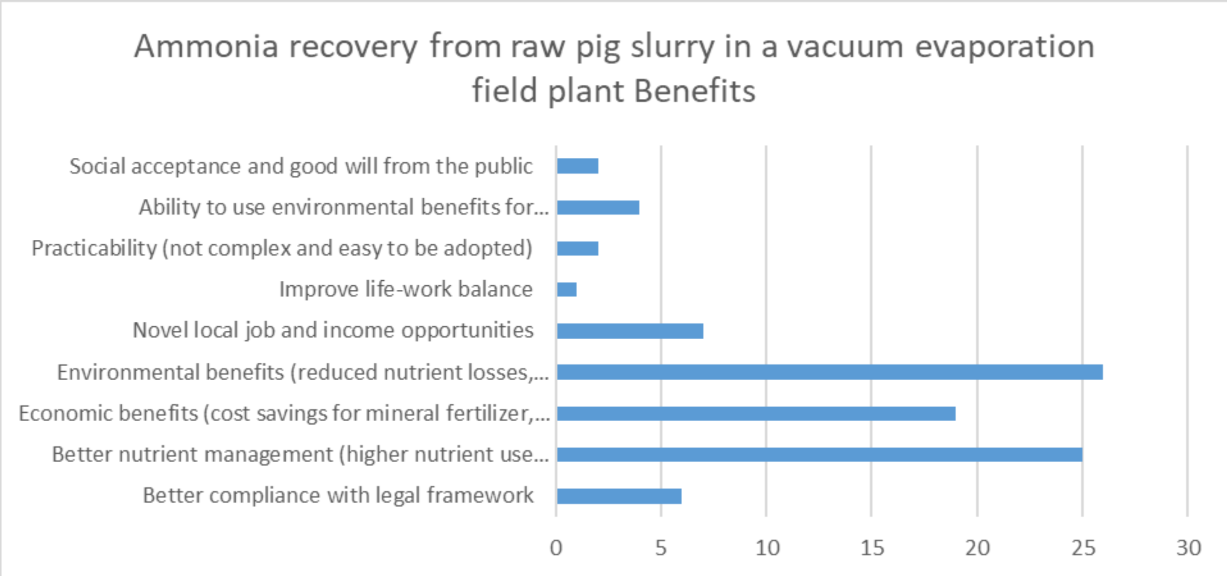

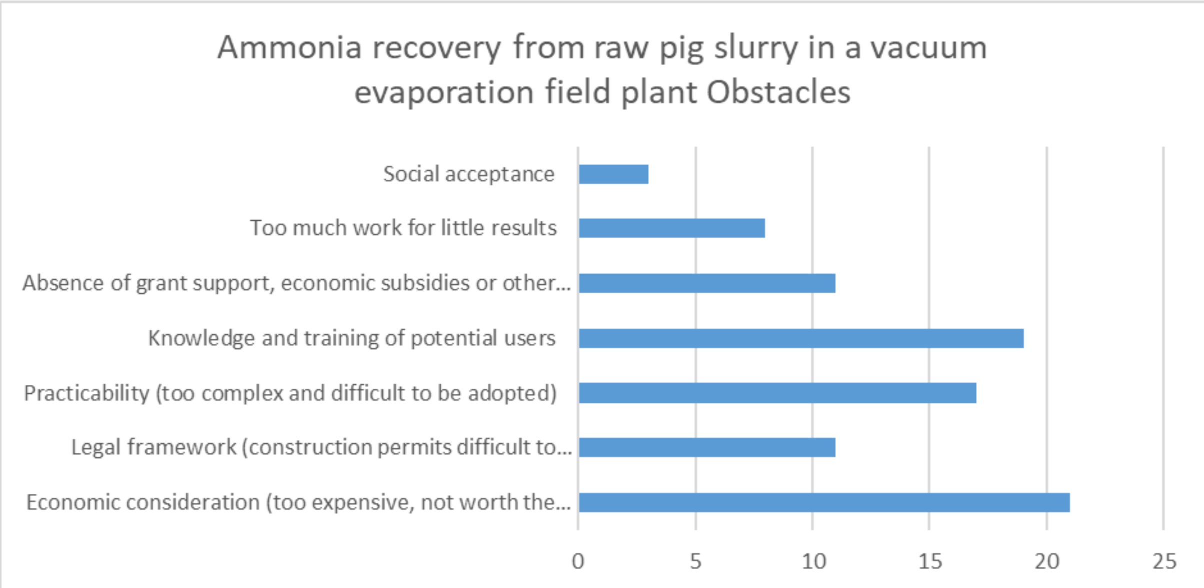

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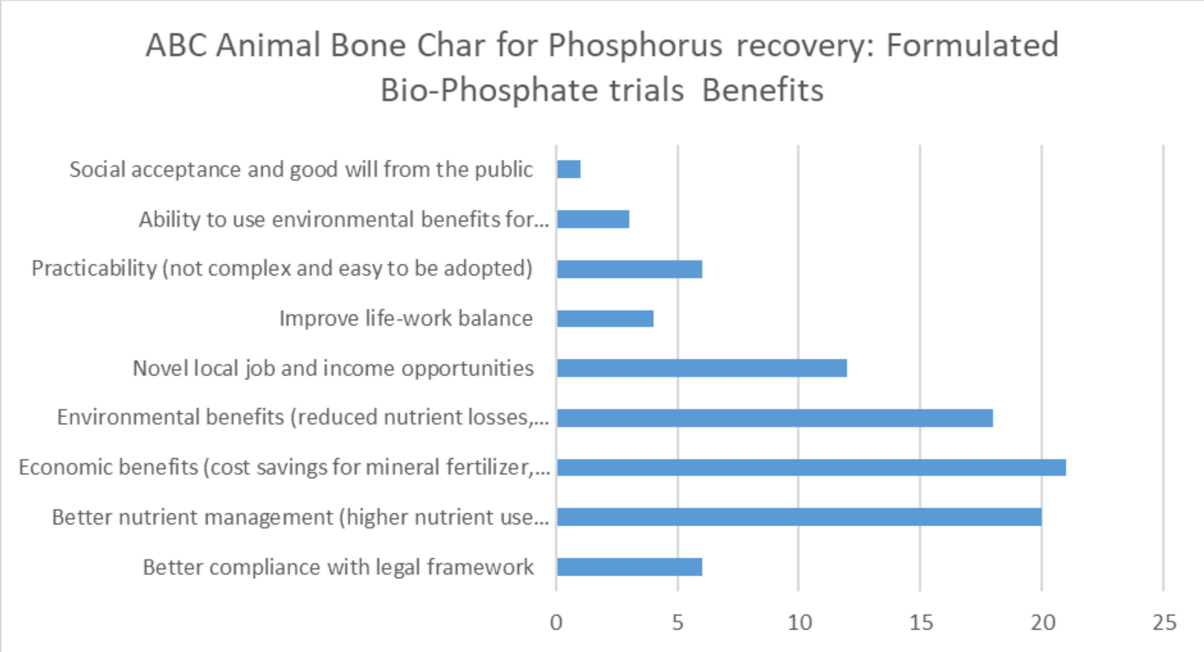

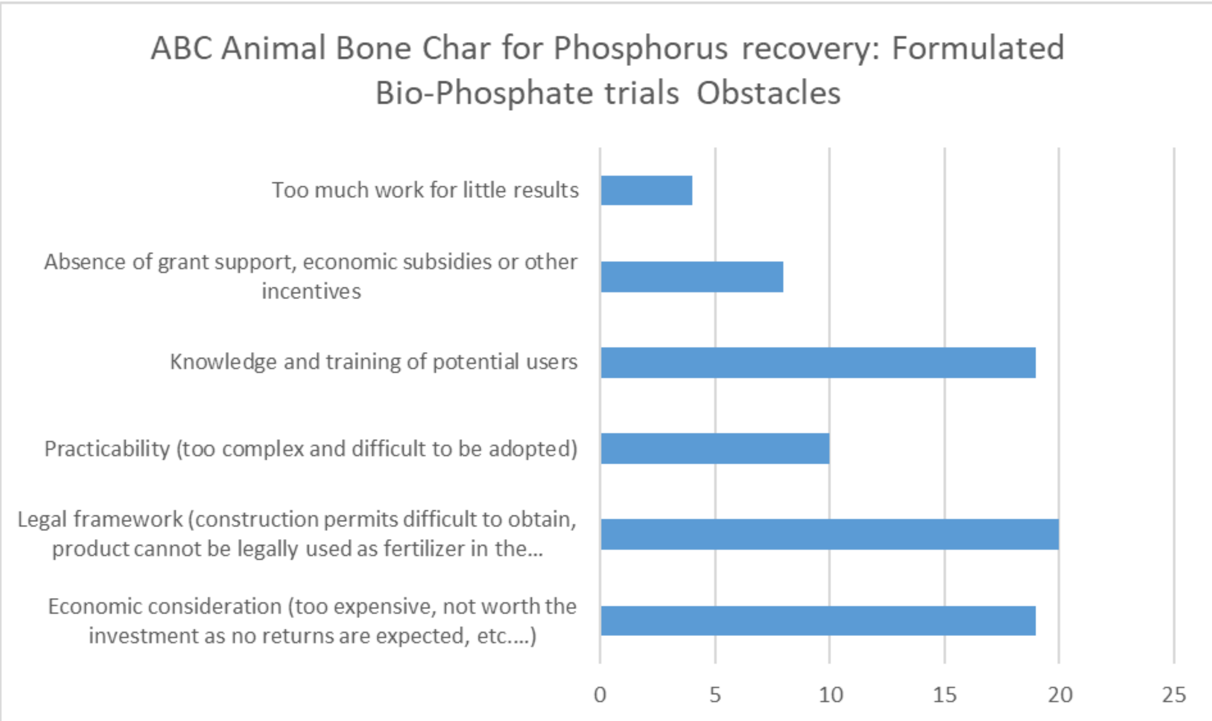

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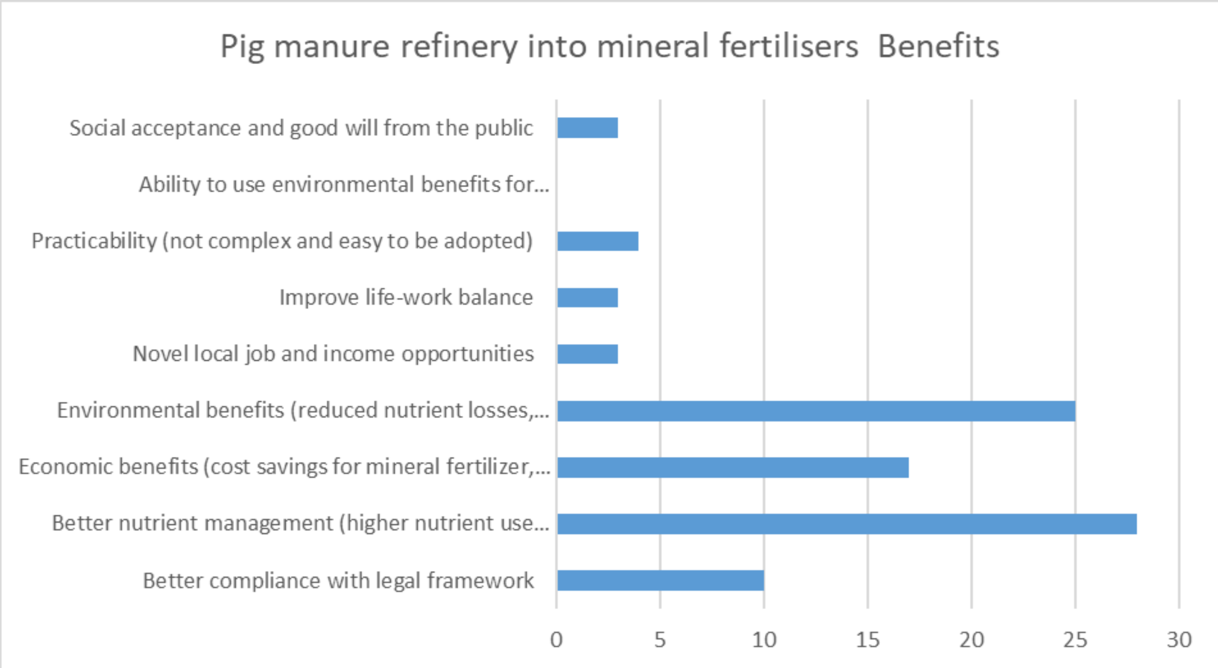

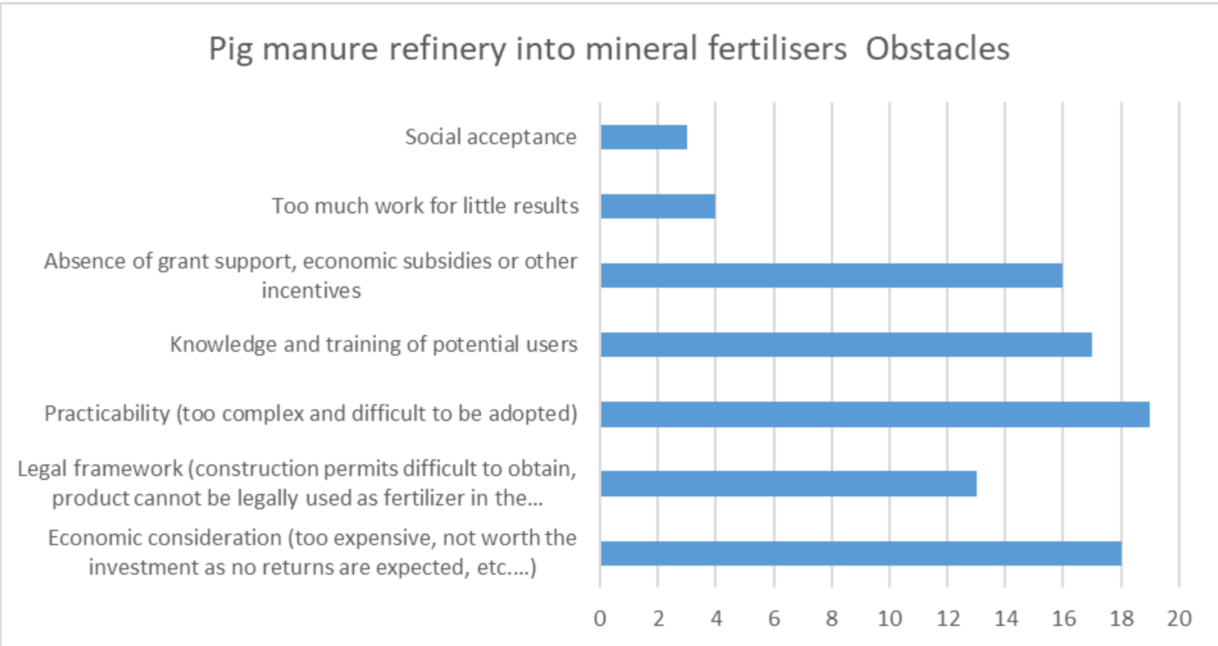

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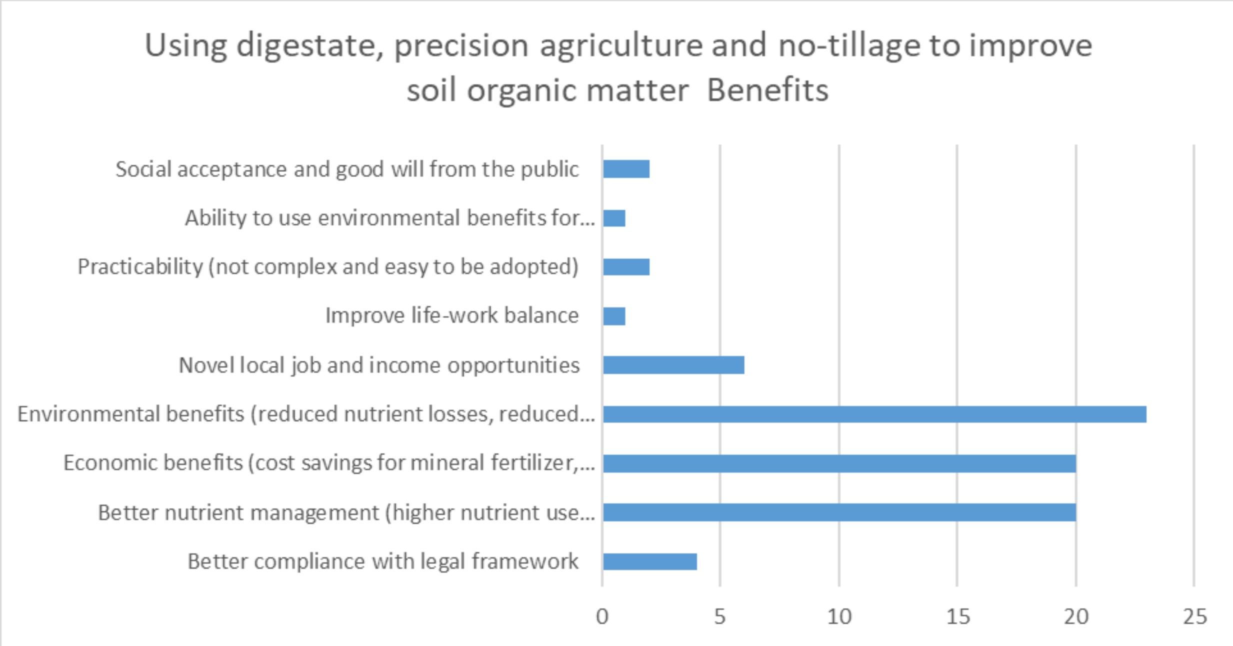

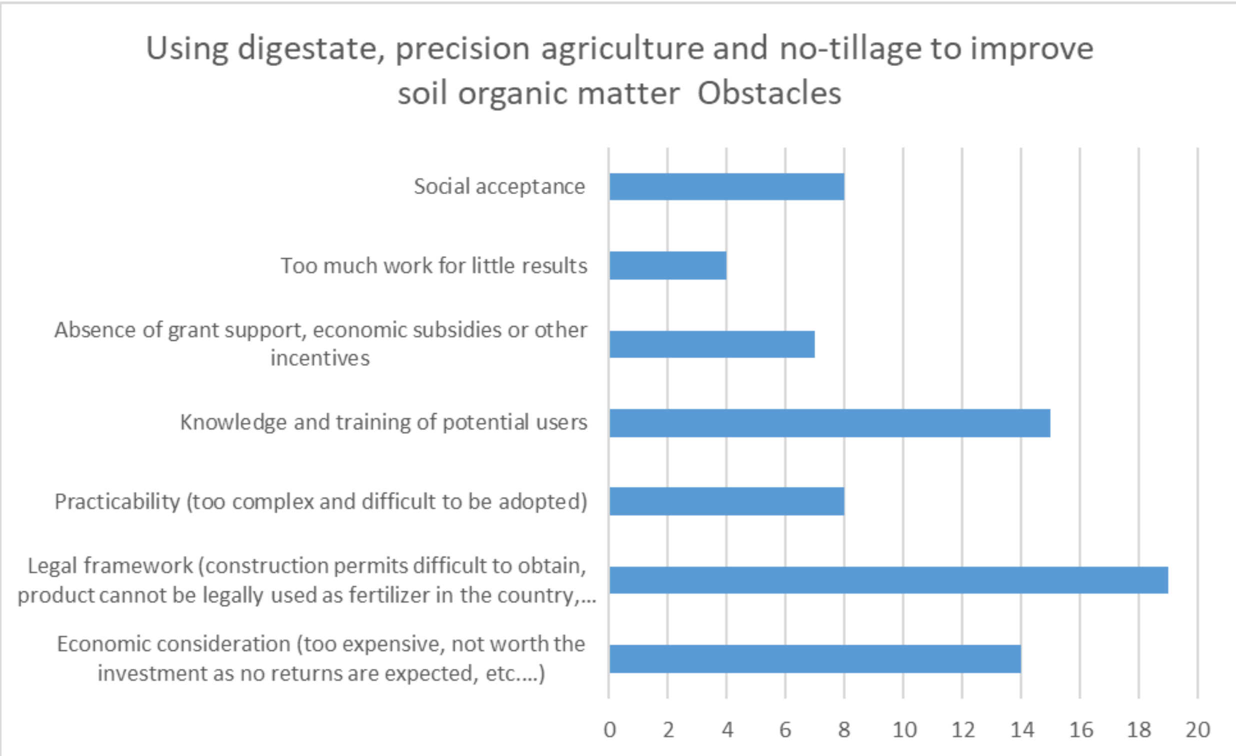

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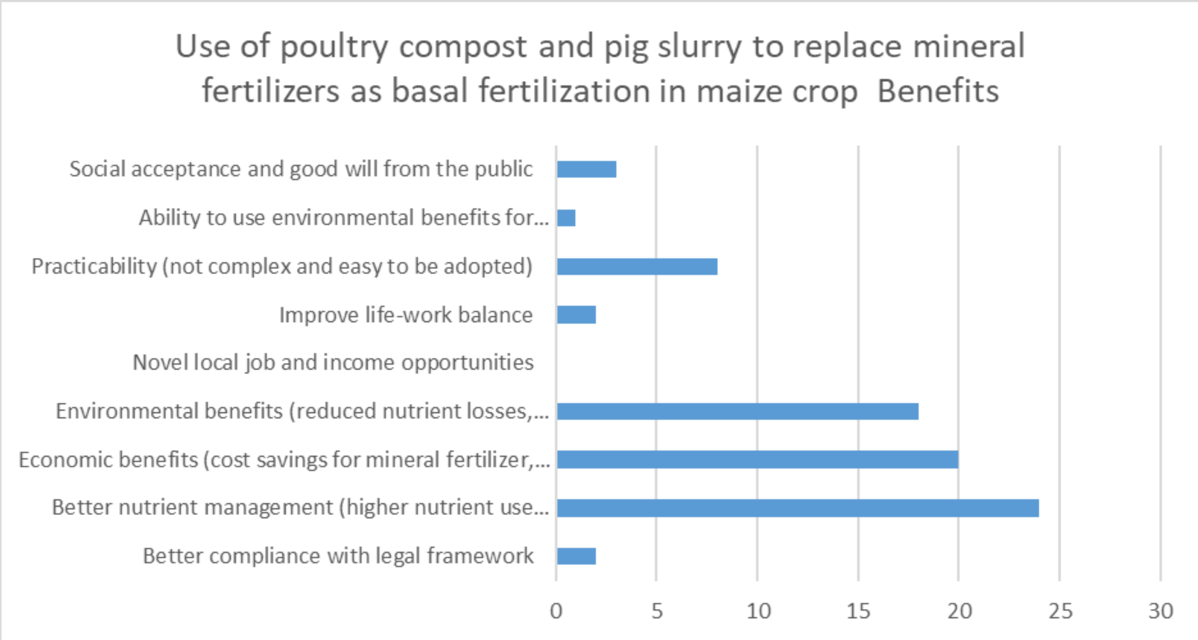

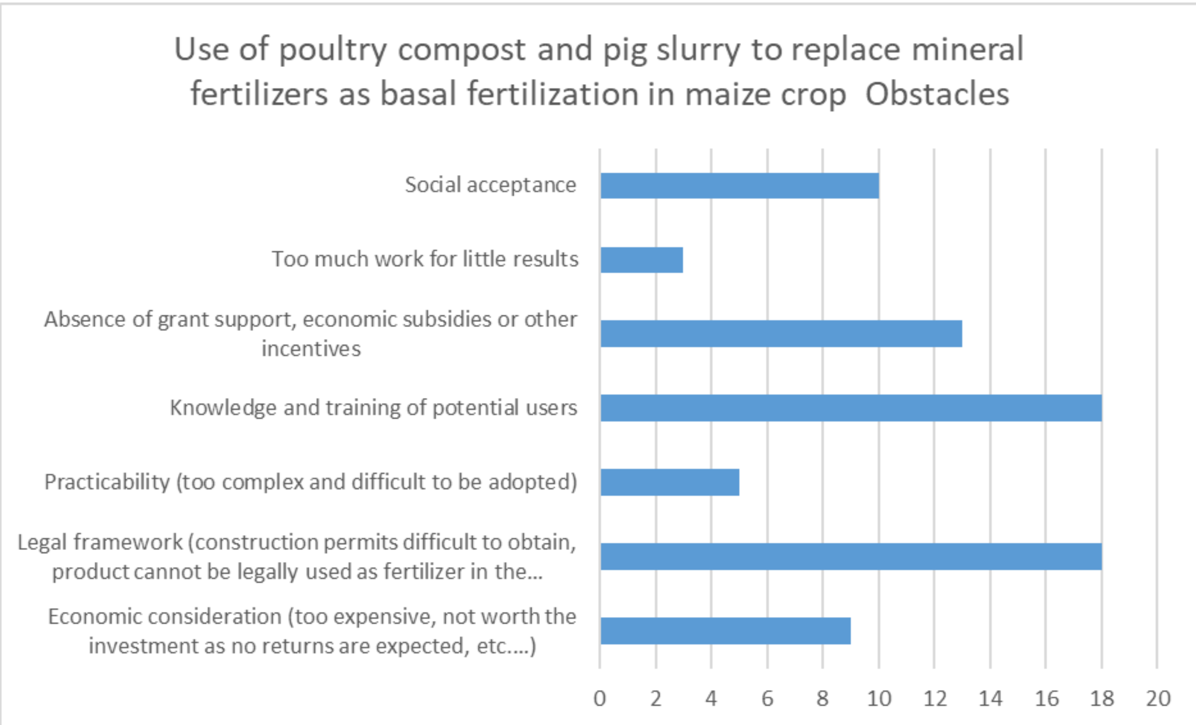

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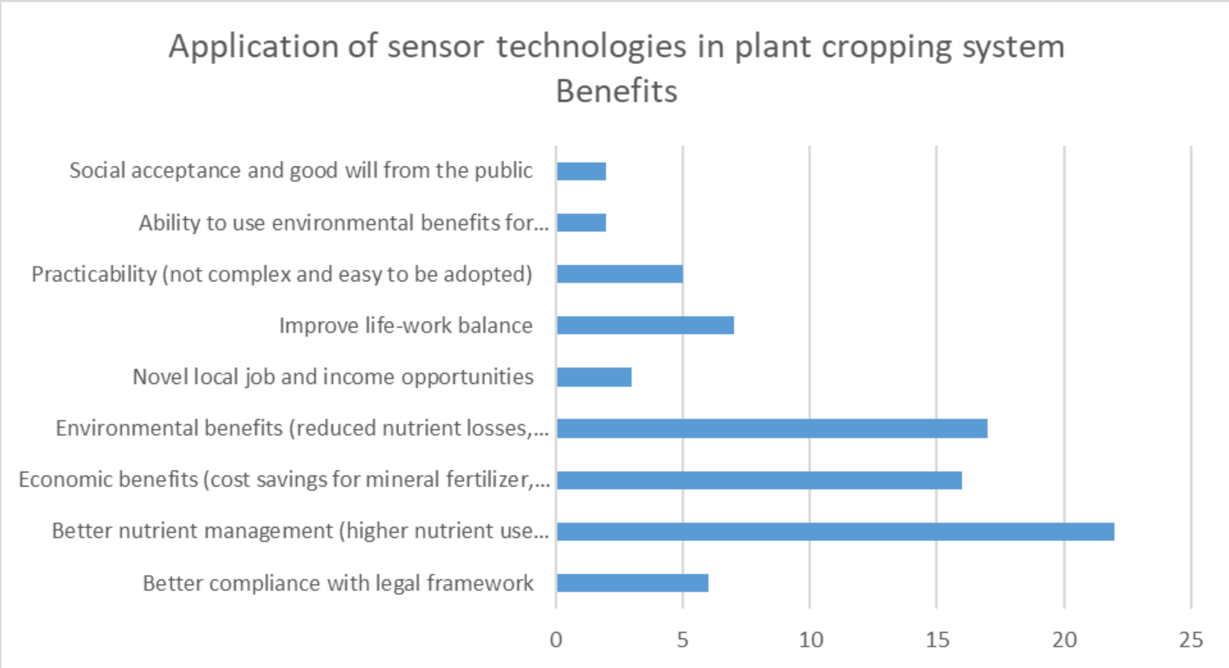

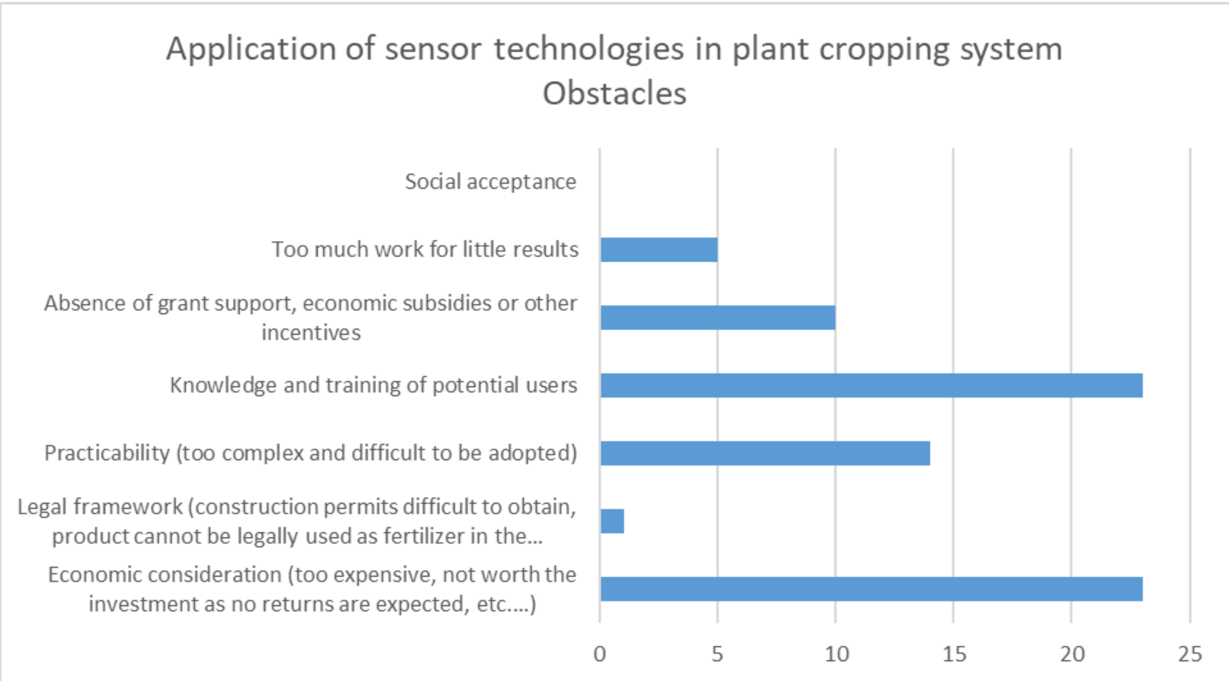

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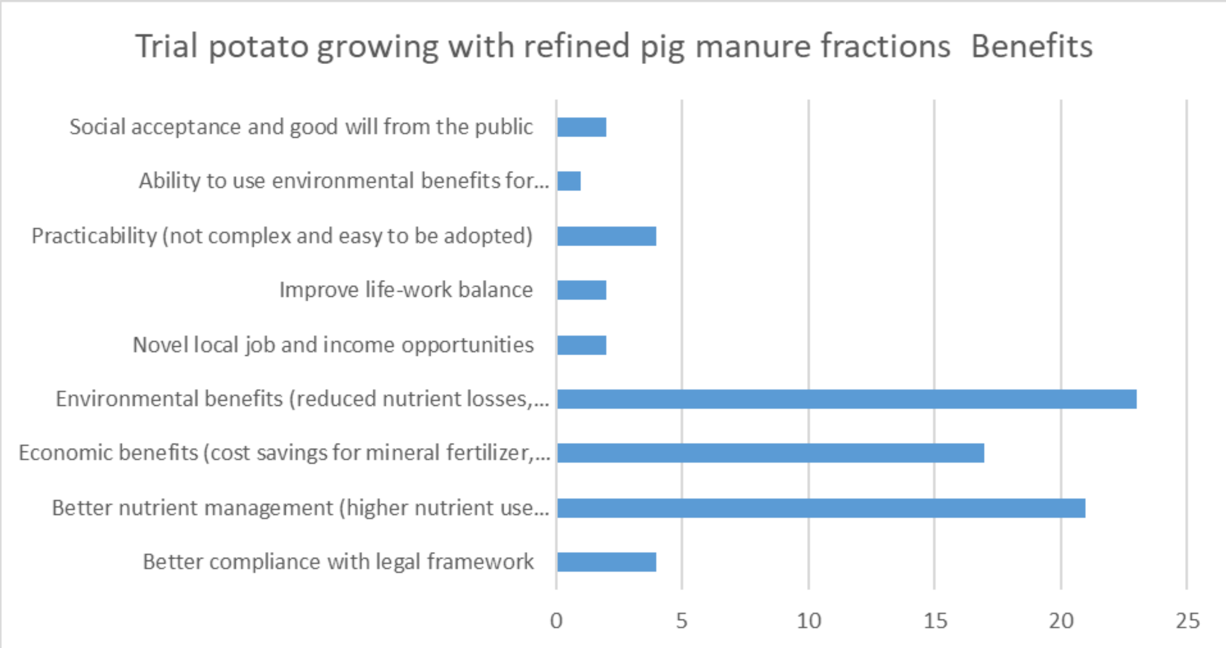

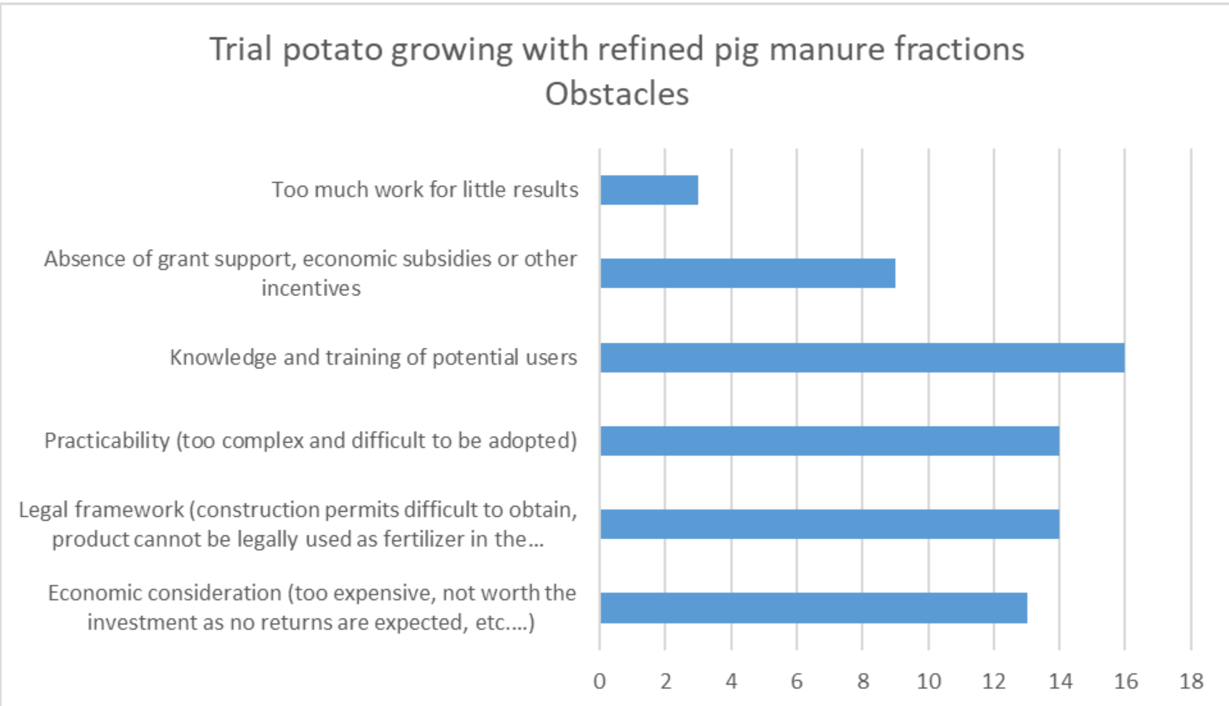

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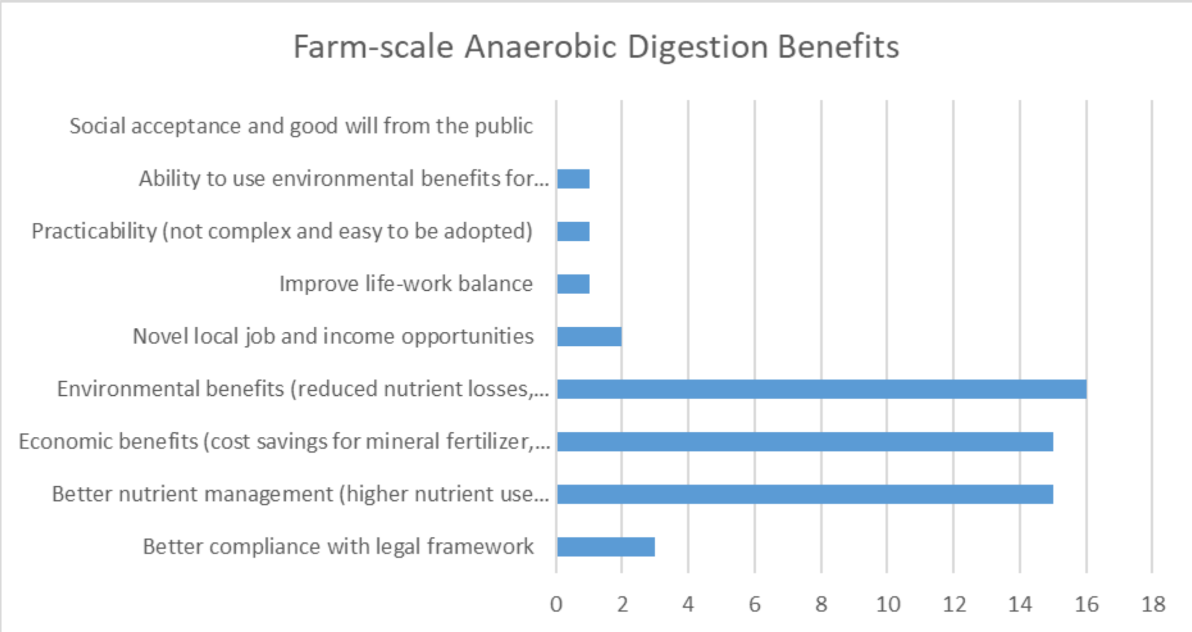
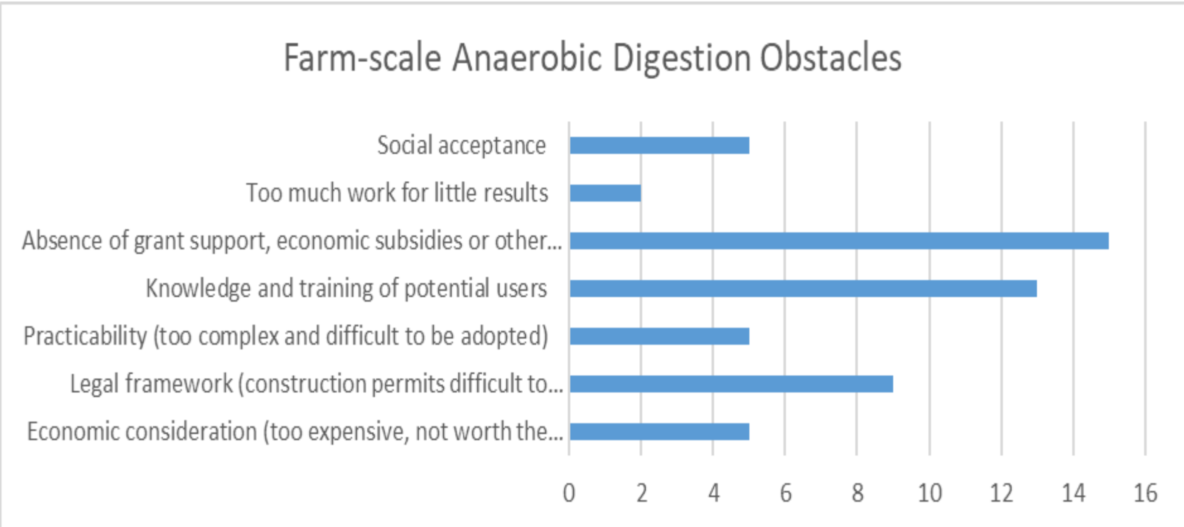
iii) Eastern Europe





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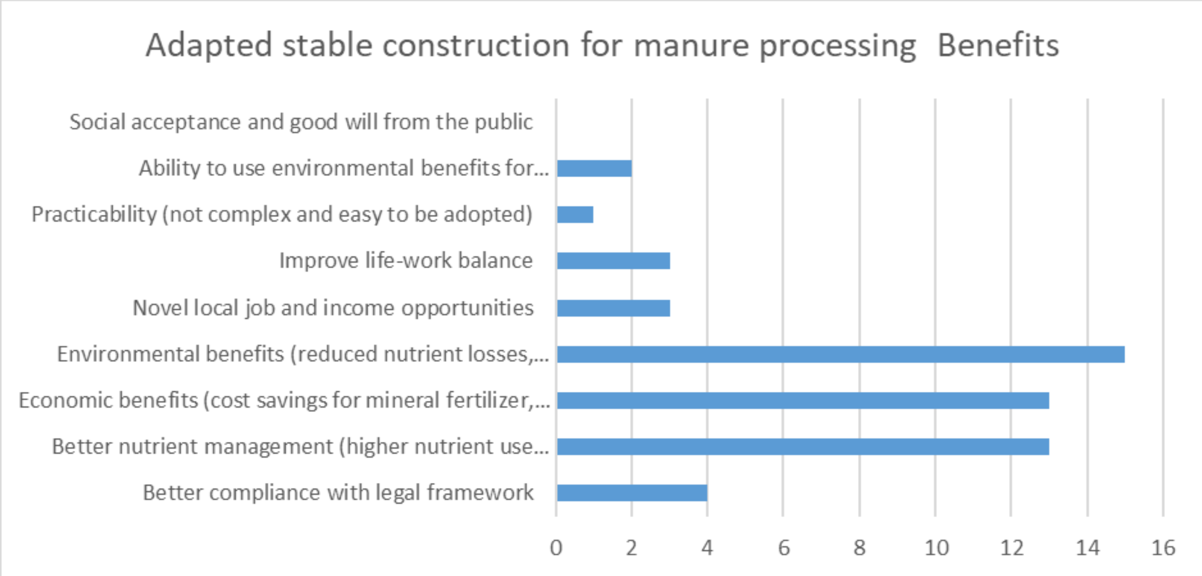

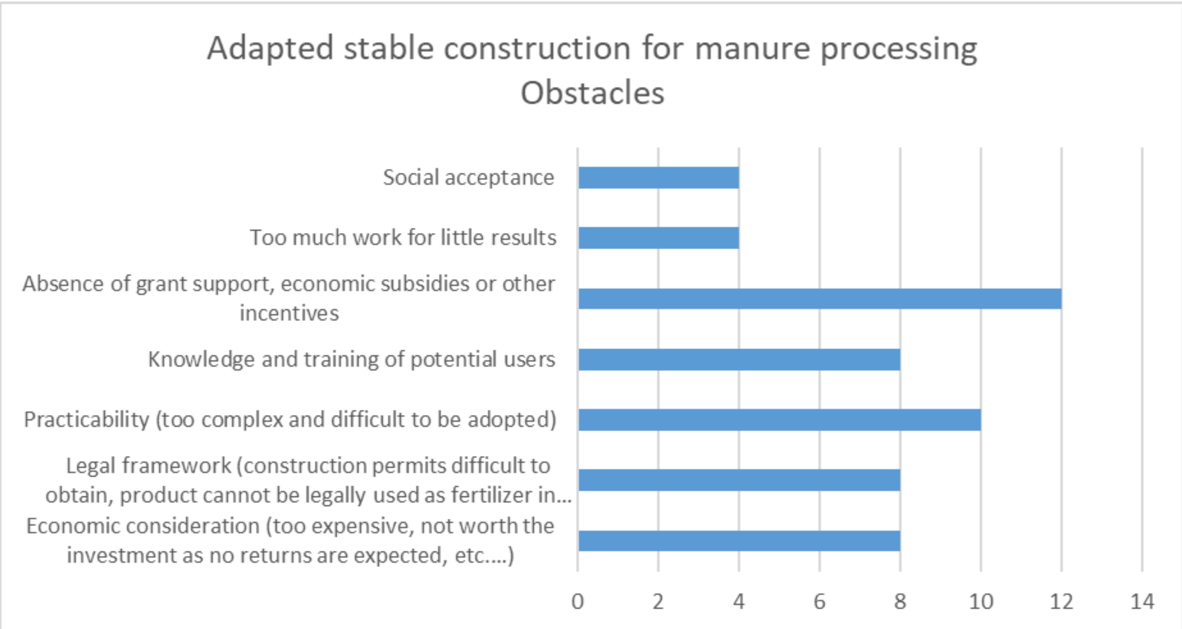

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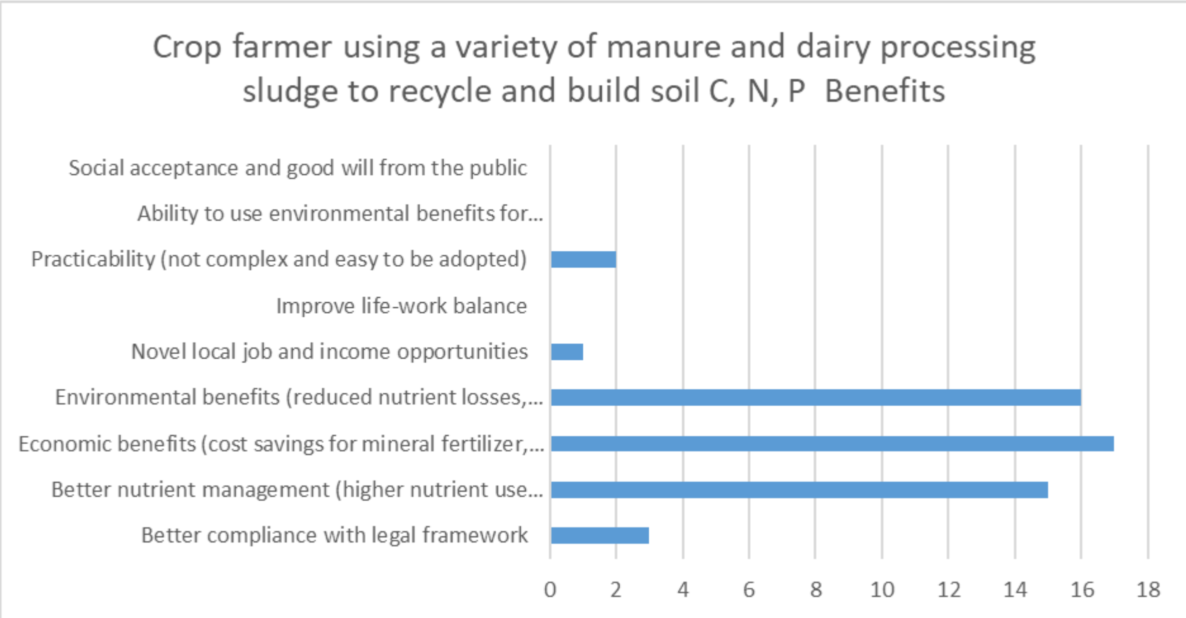

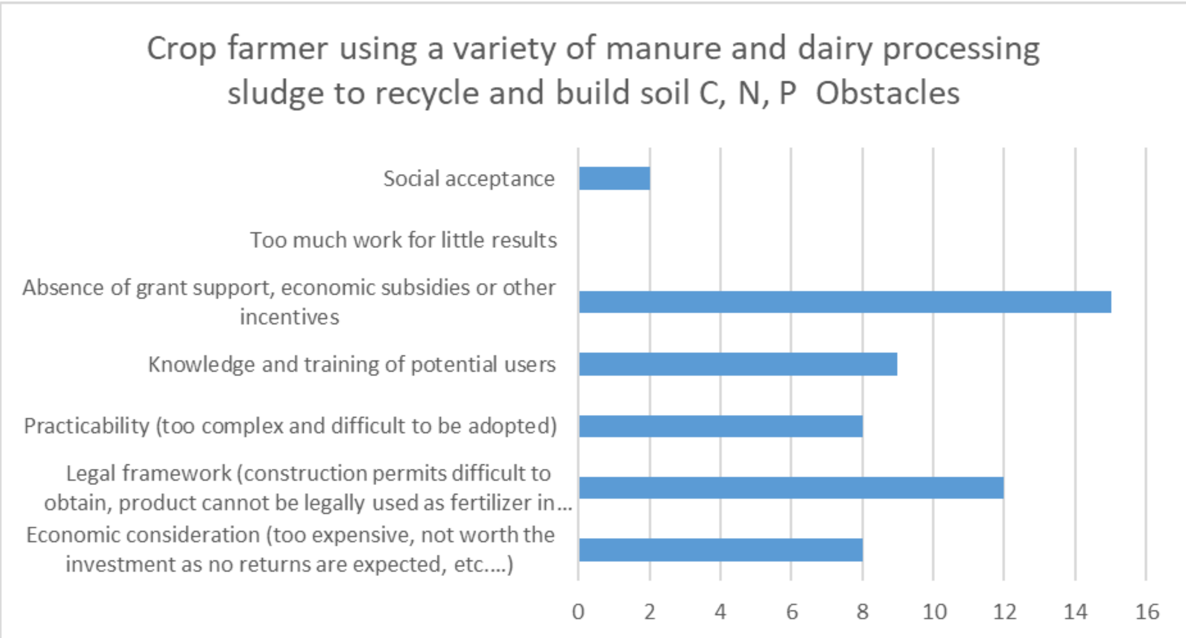

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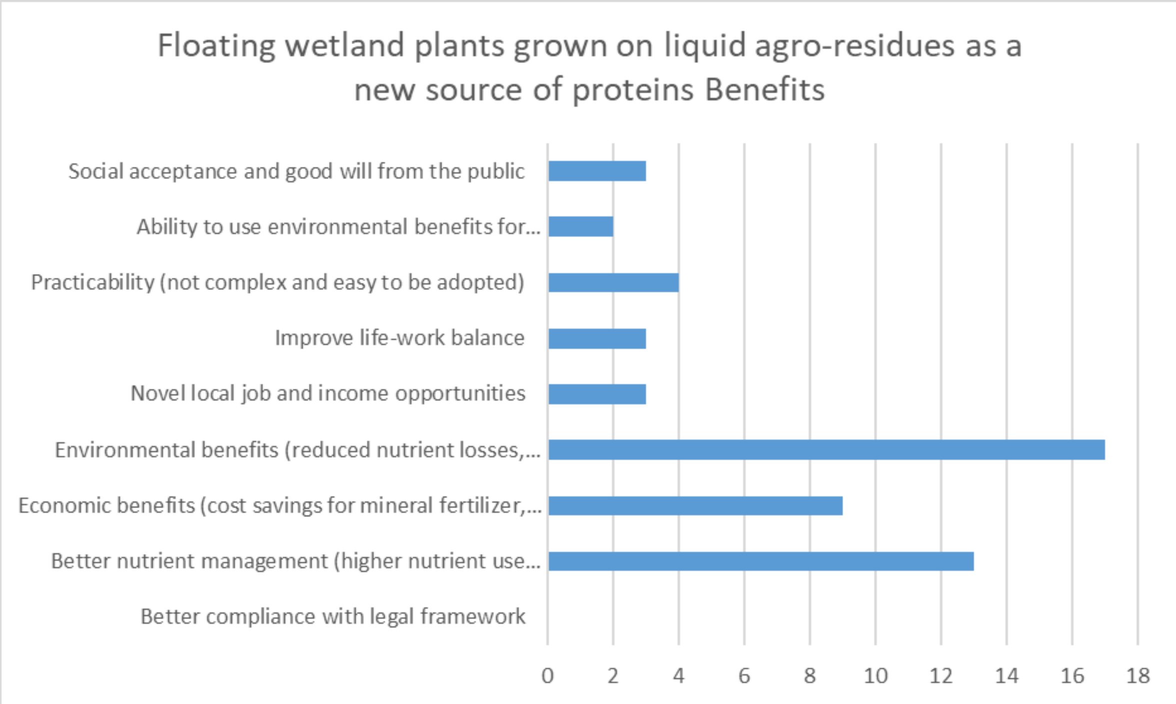

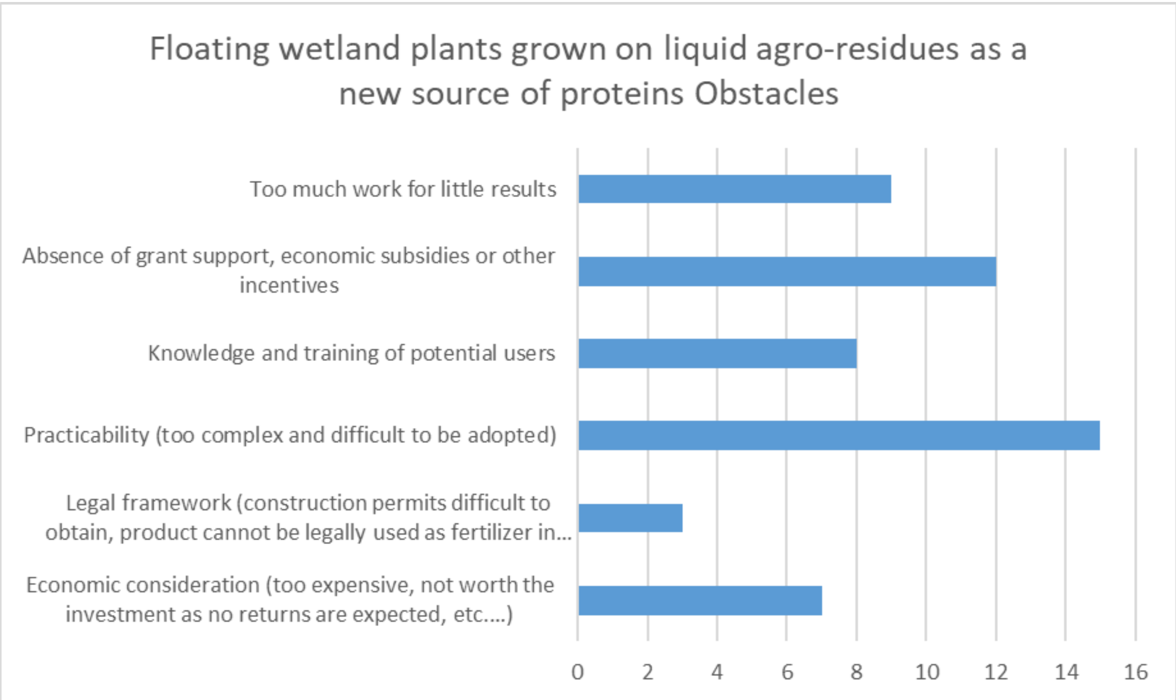

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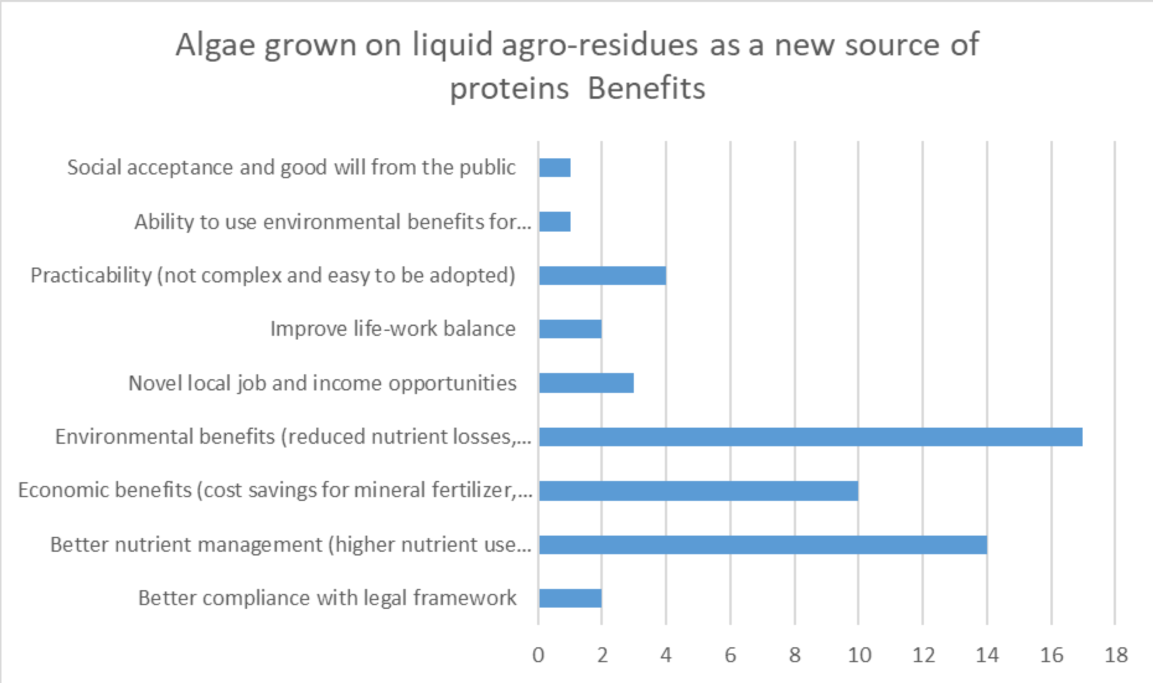

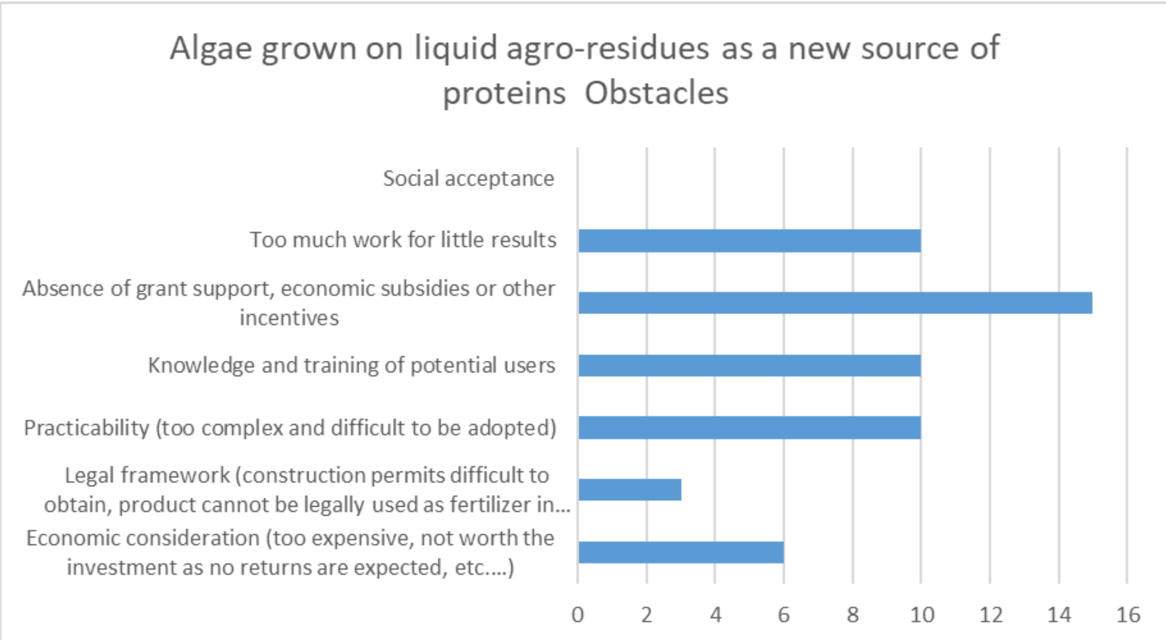

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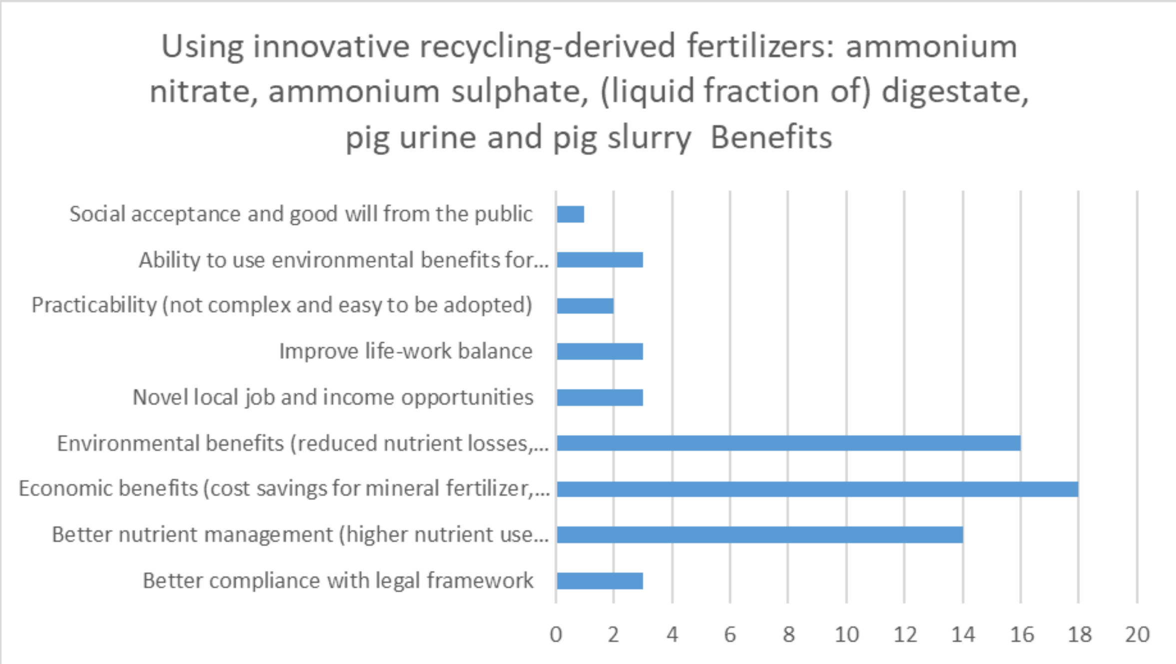

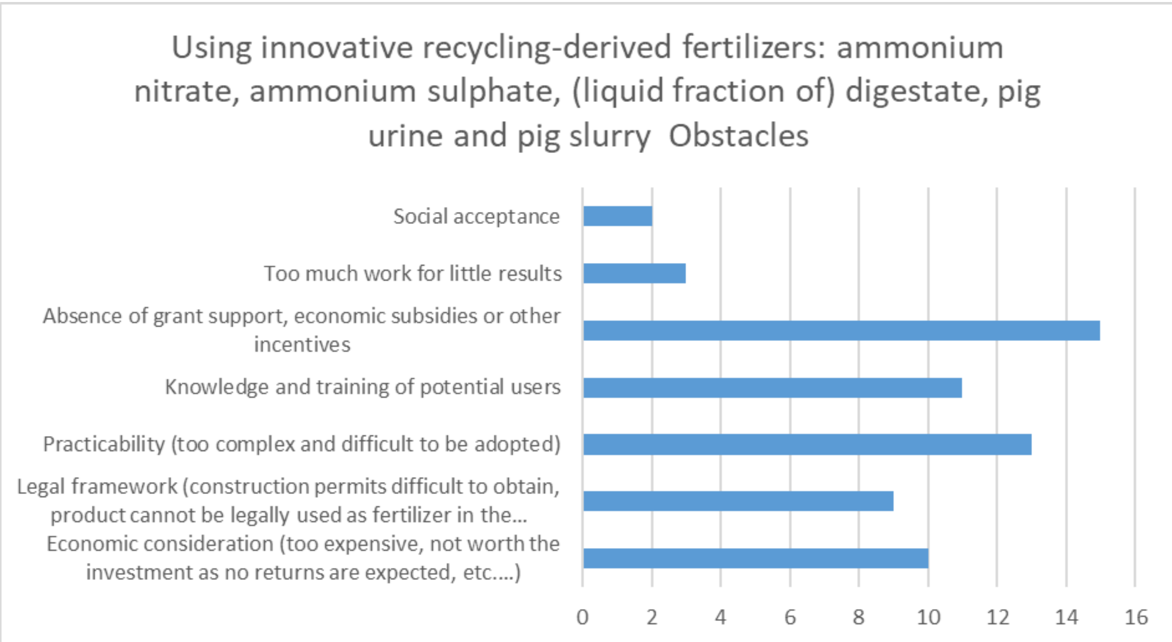

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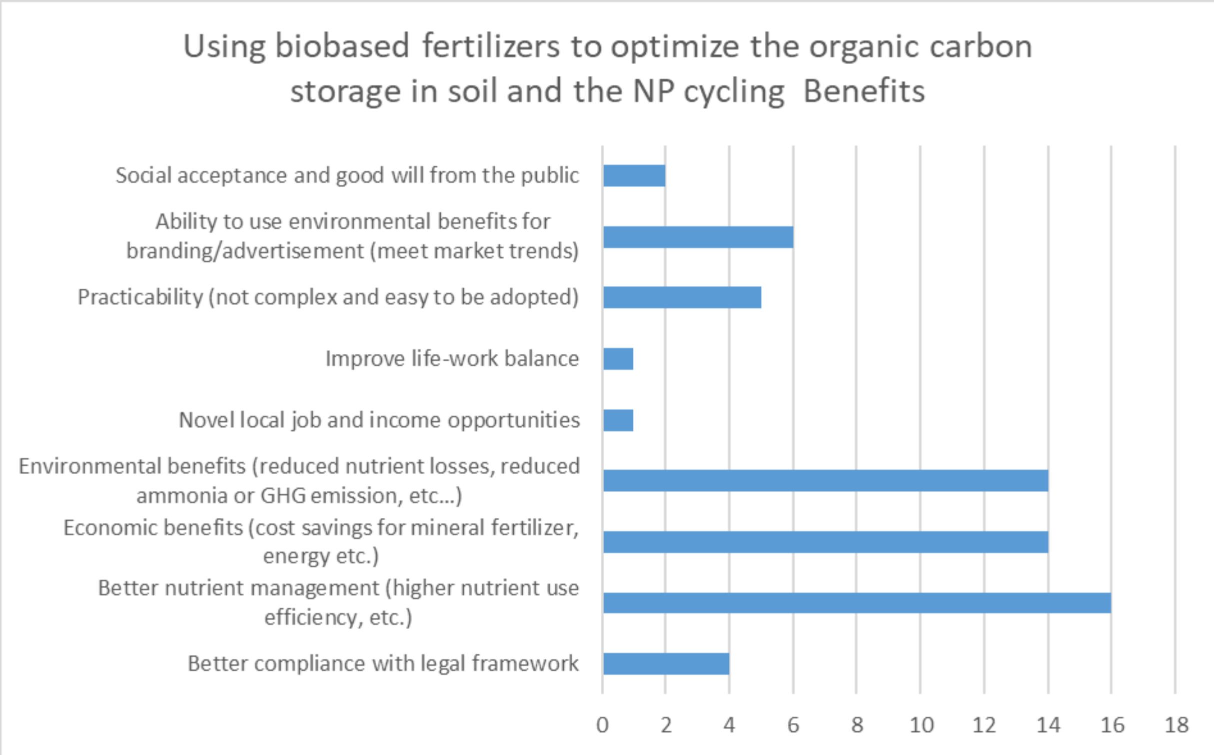

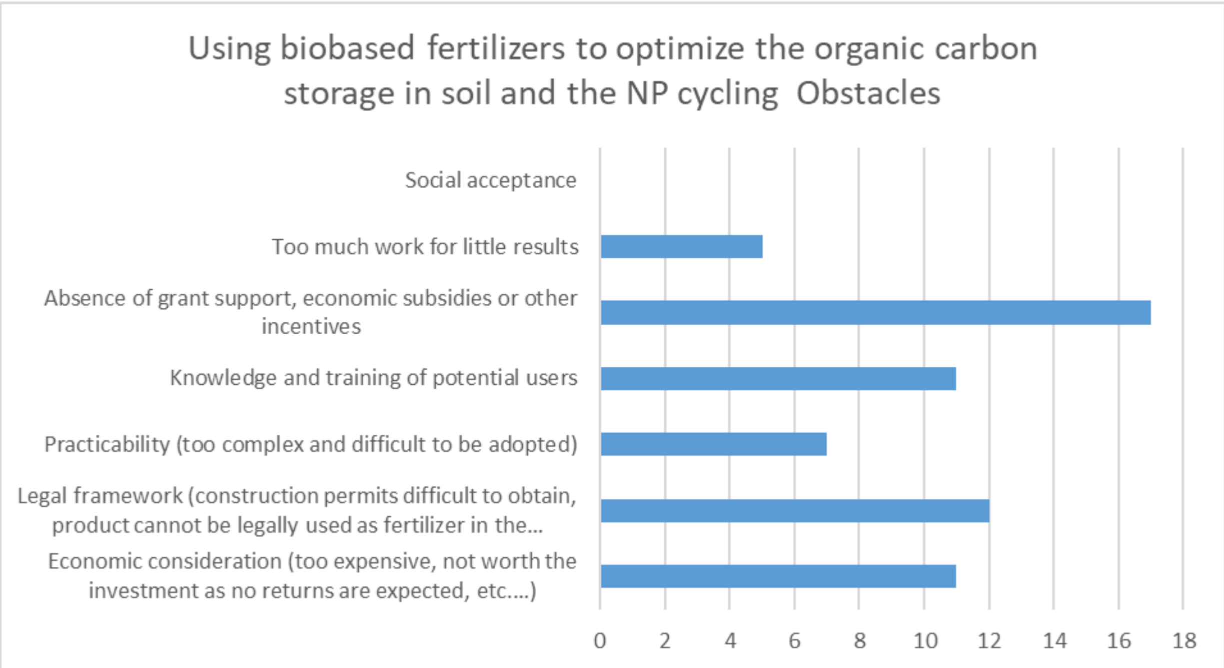

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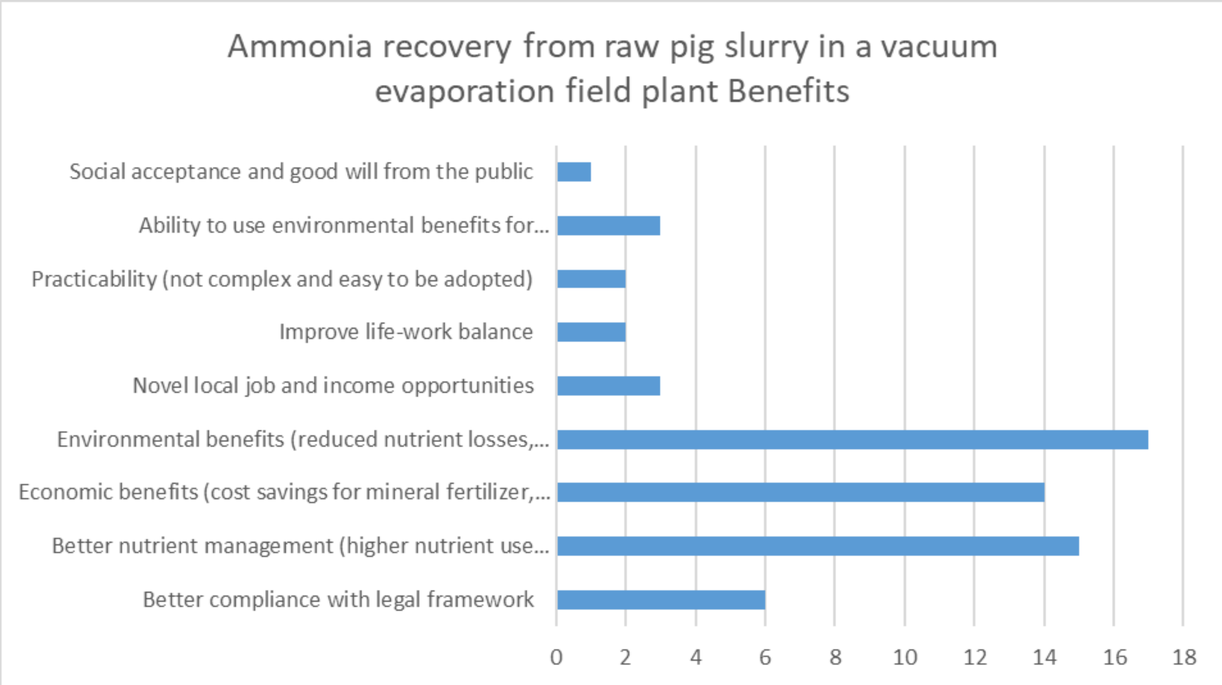

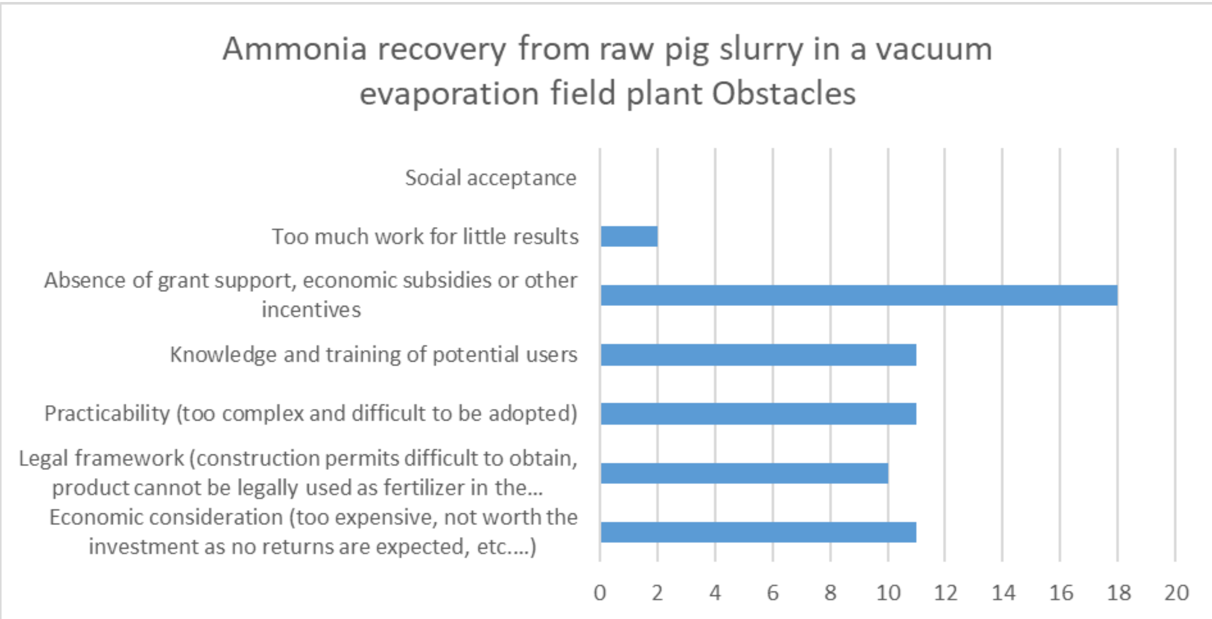

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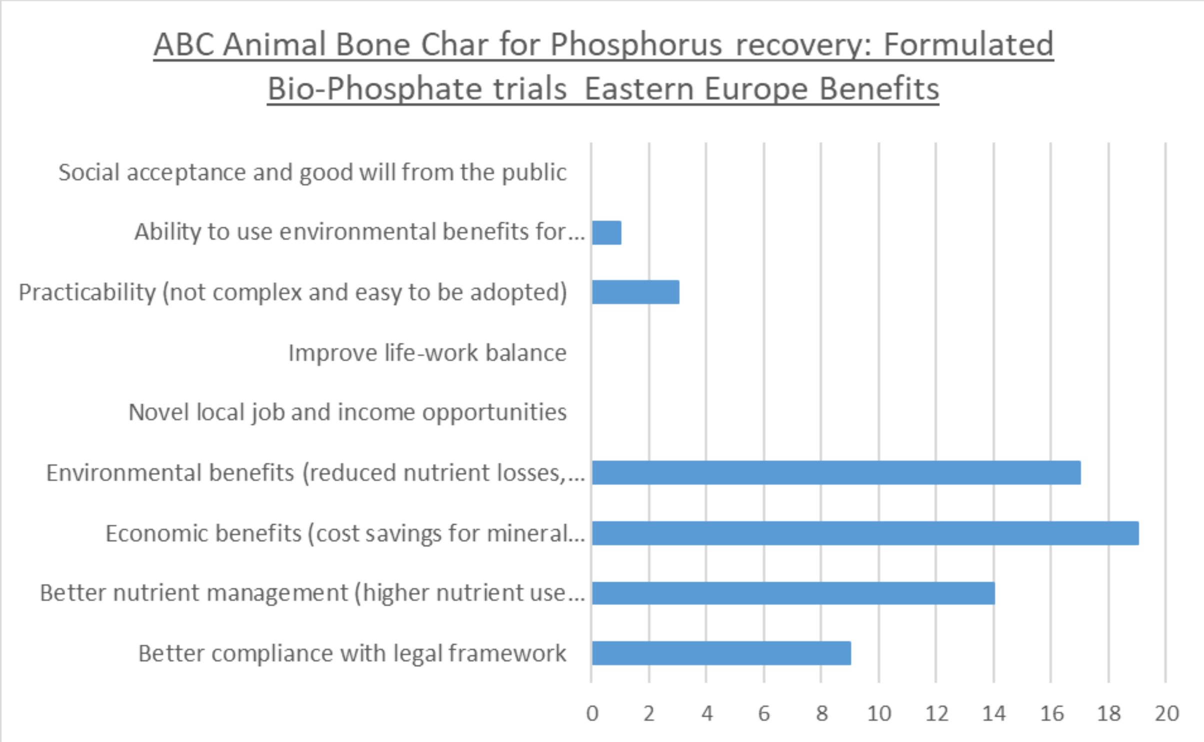

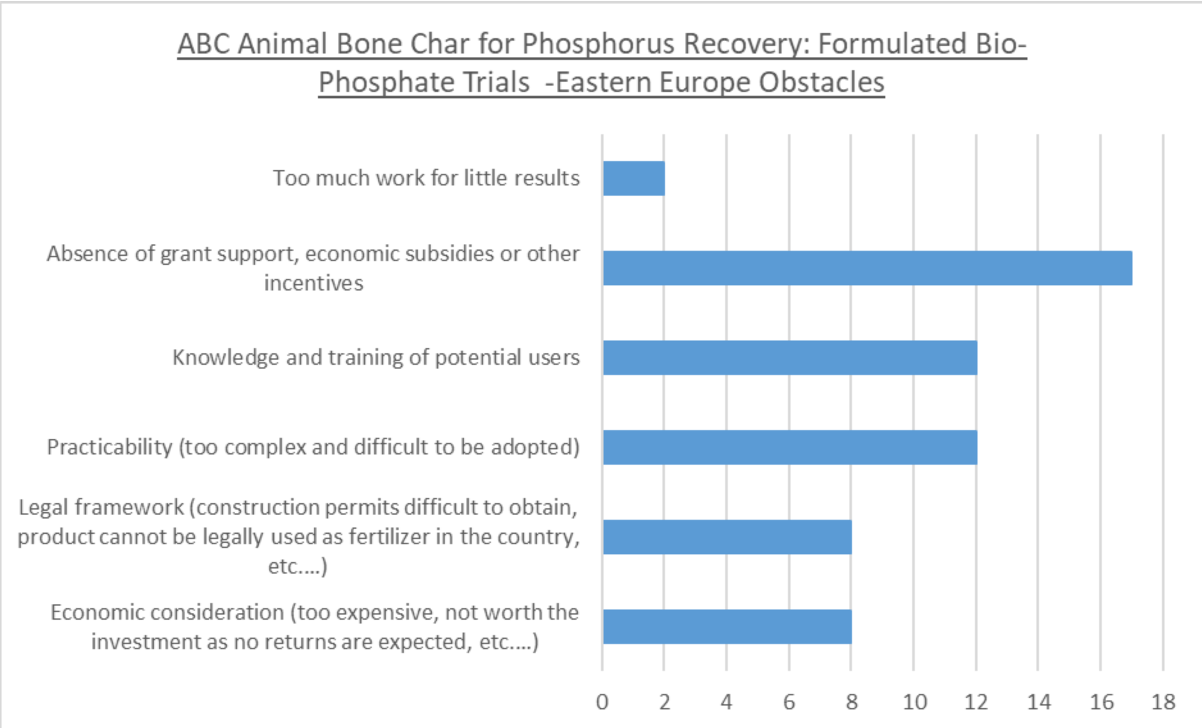

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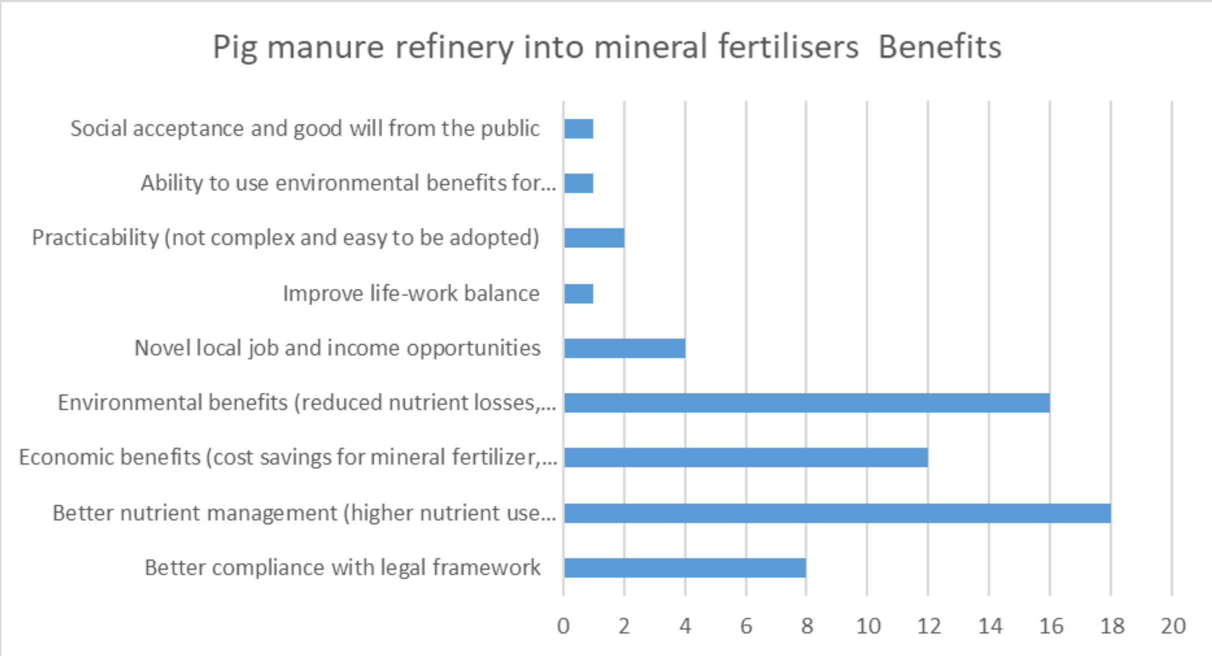

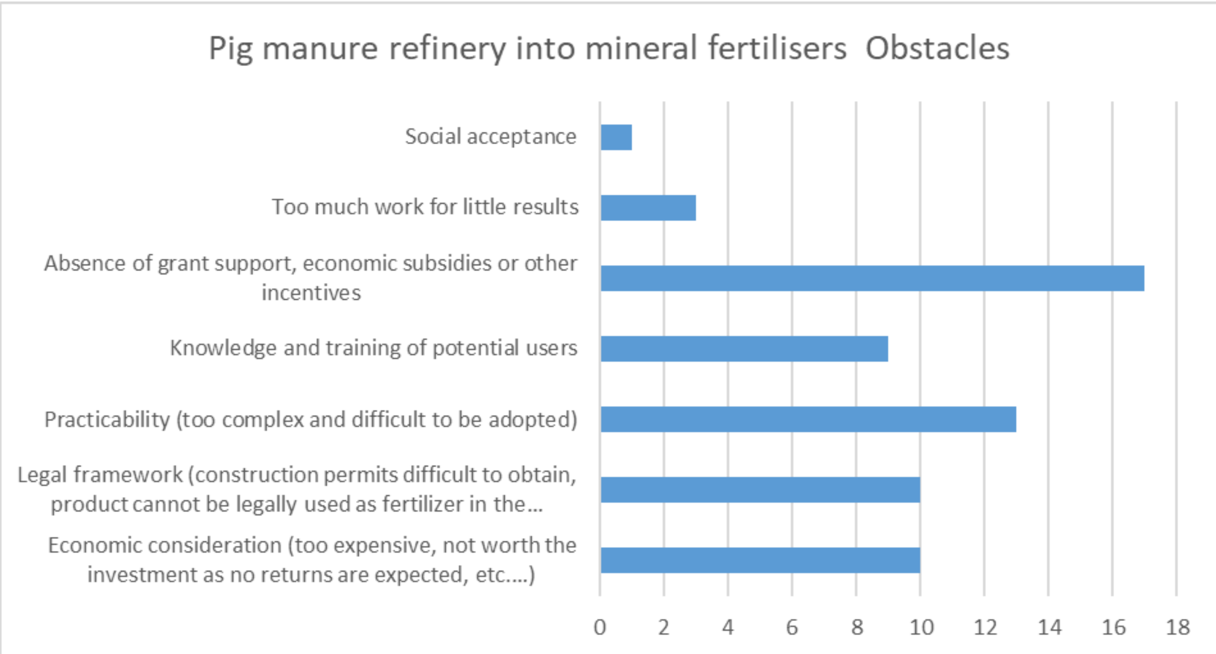

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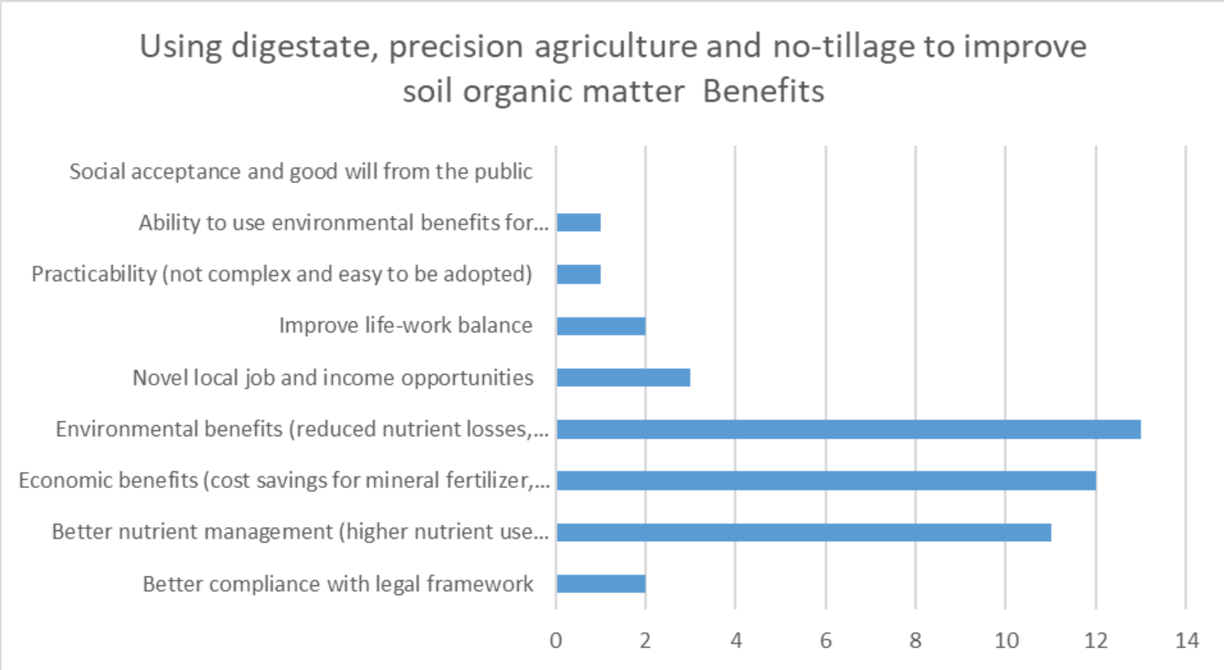

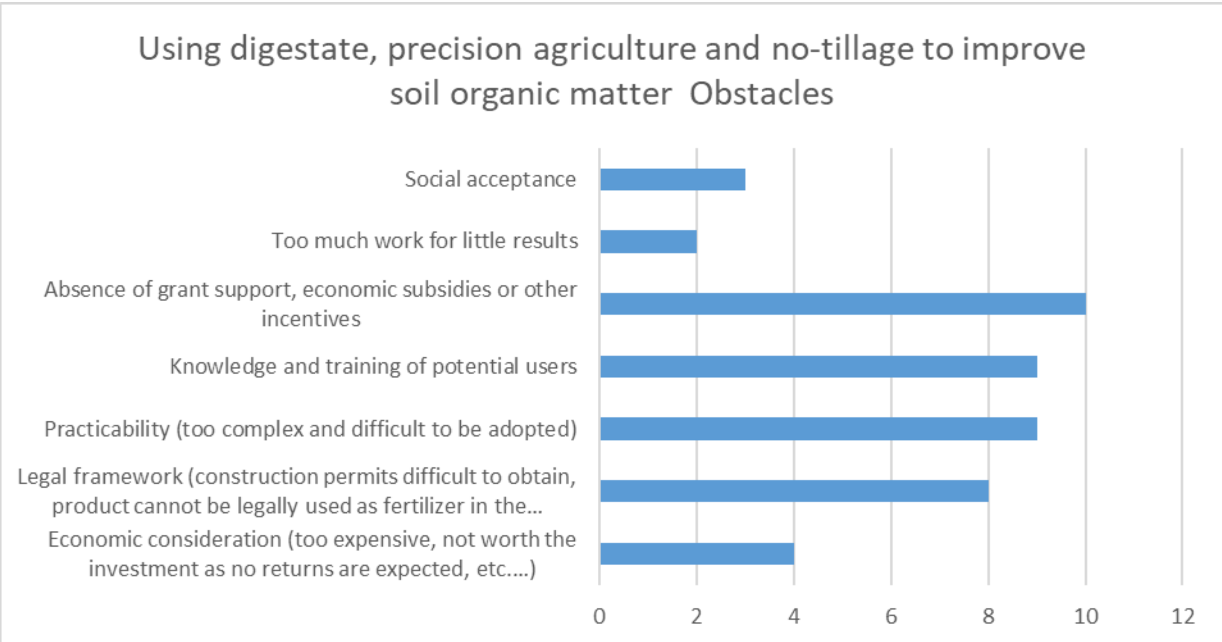

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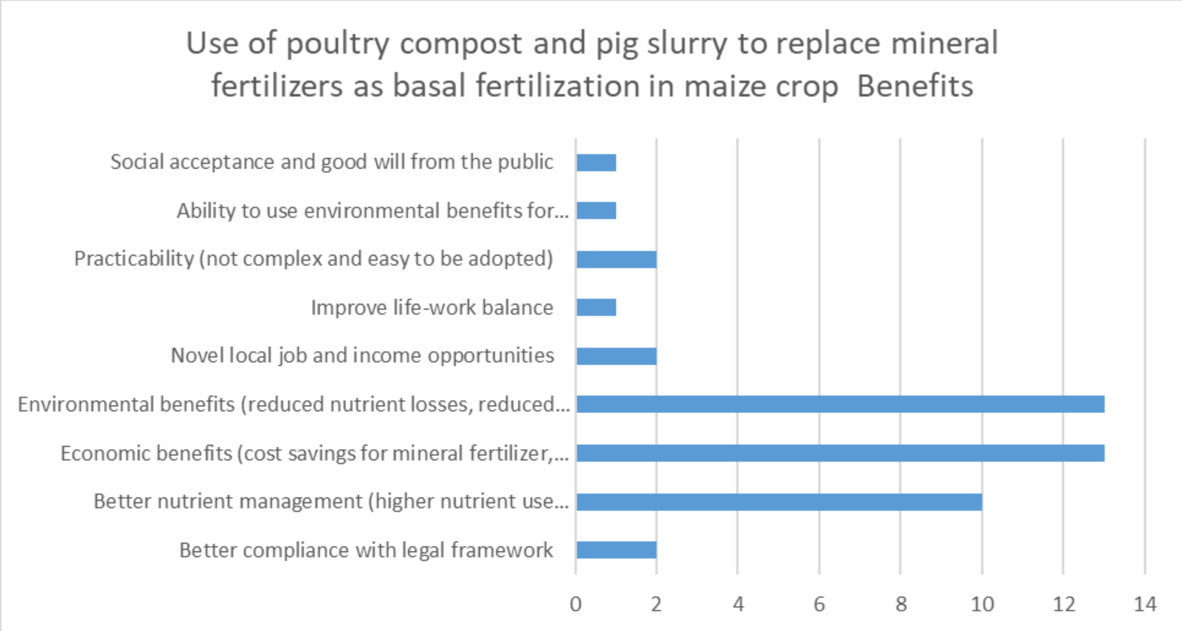

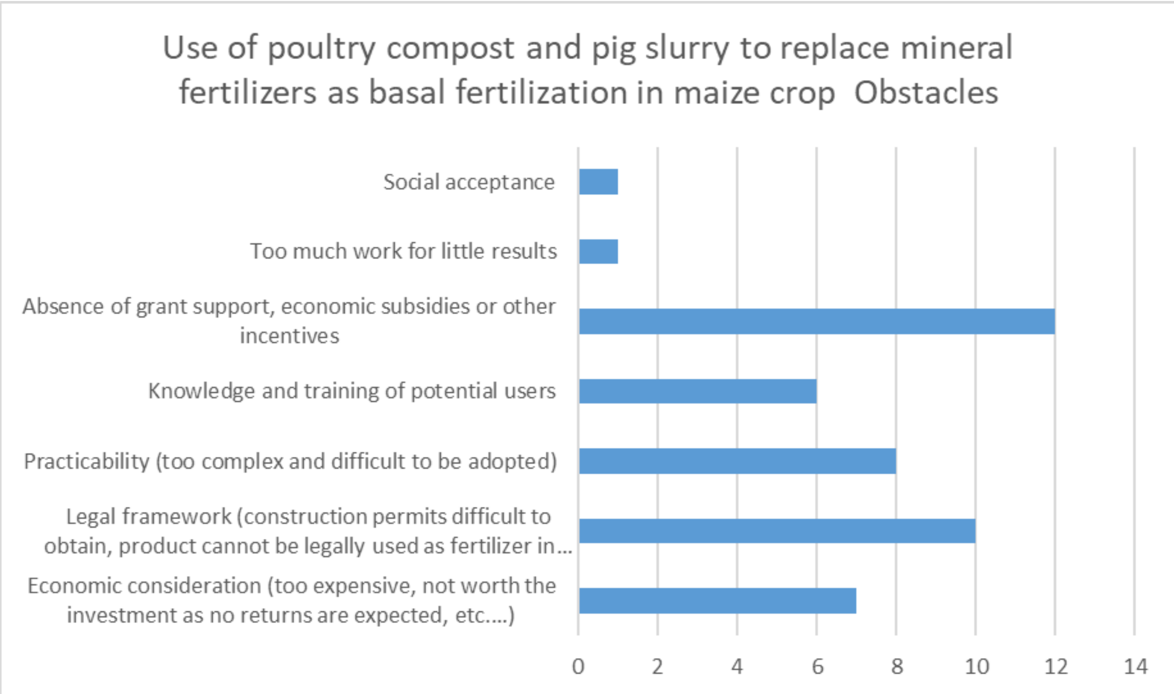

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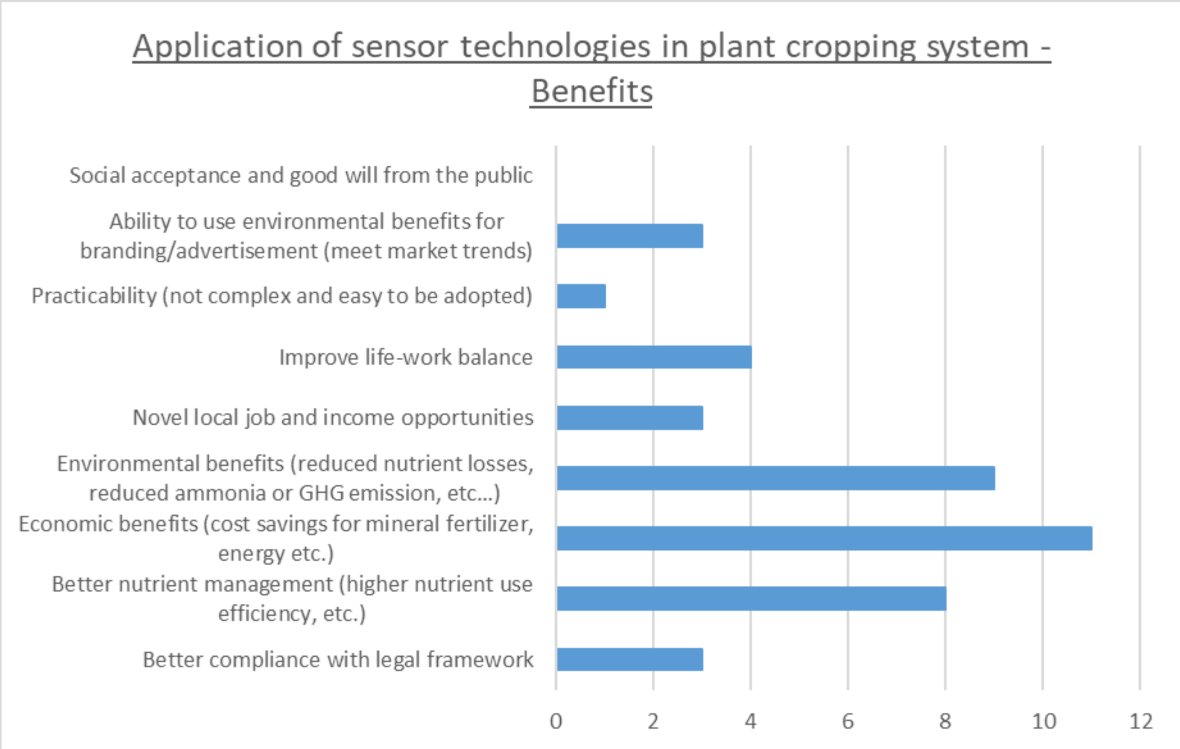

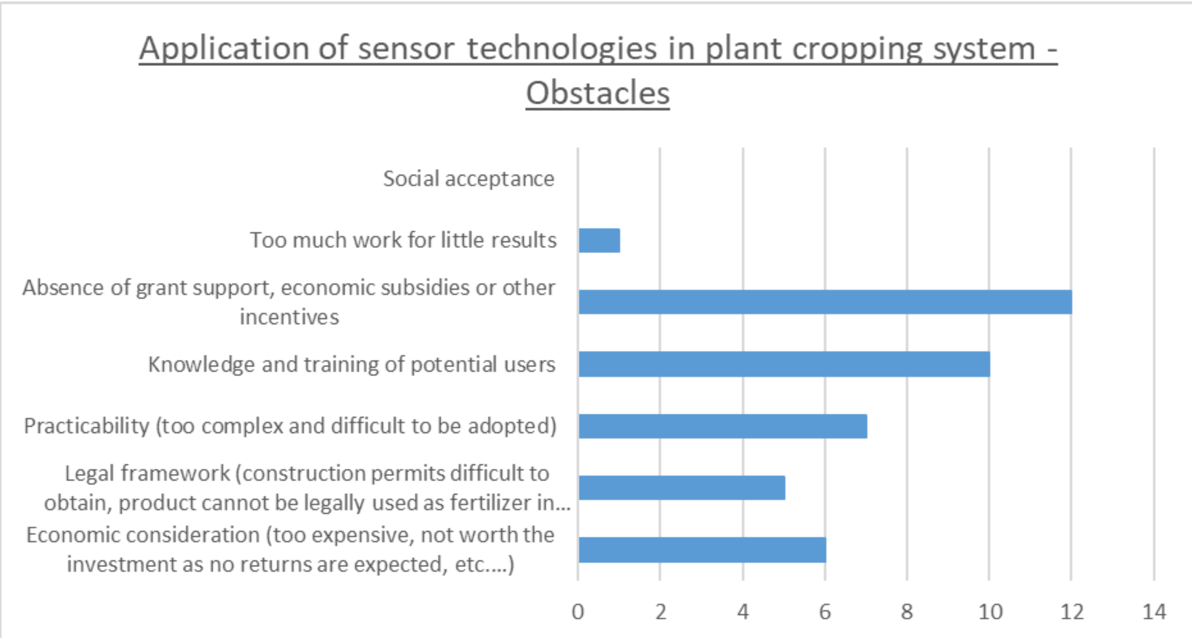

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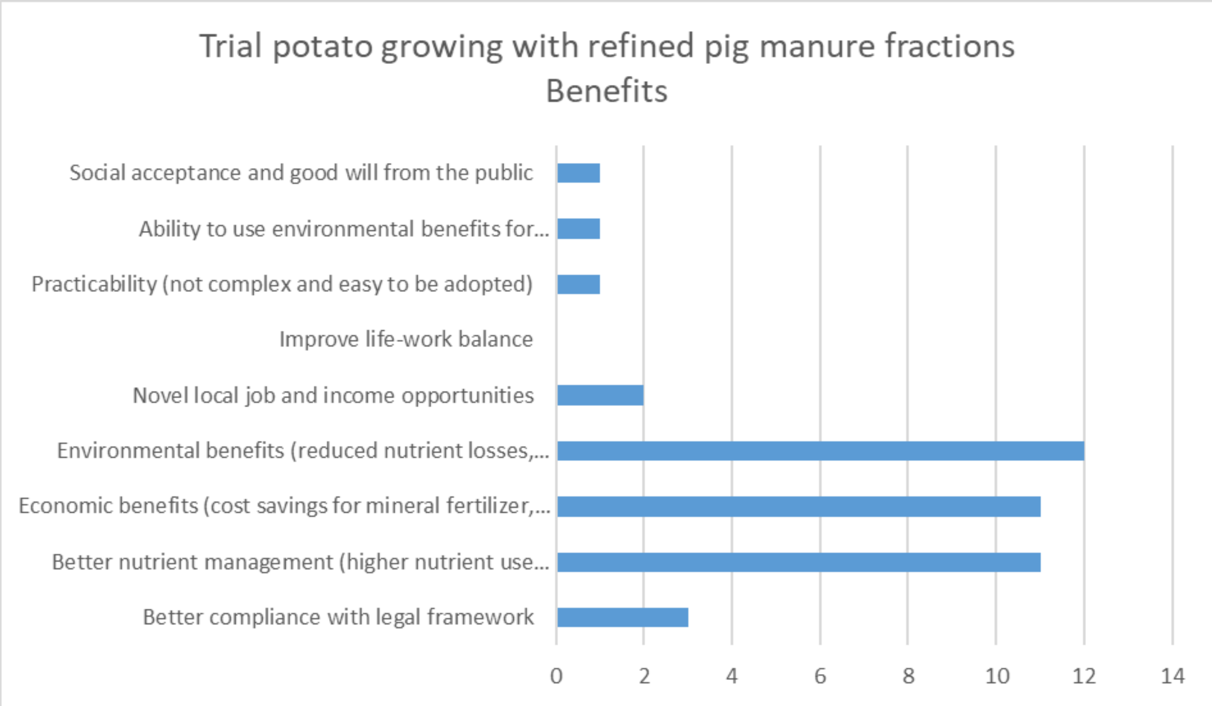

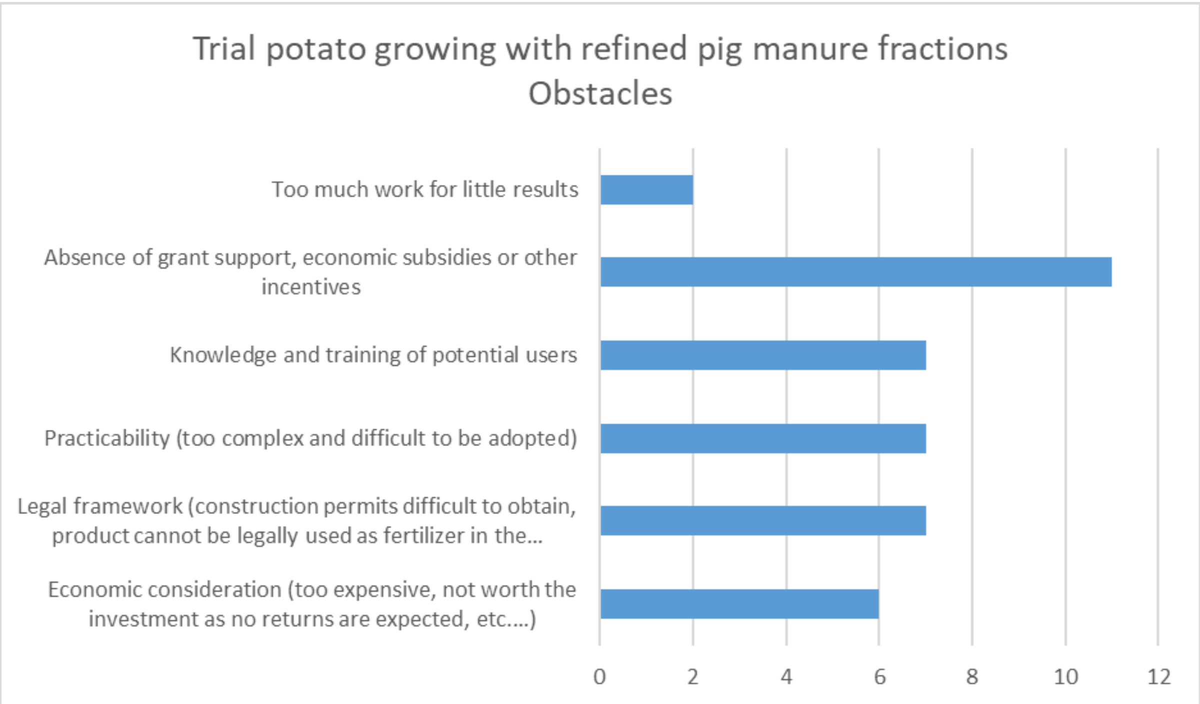

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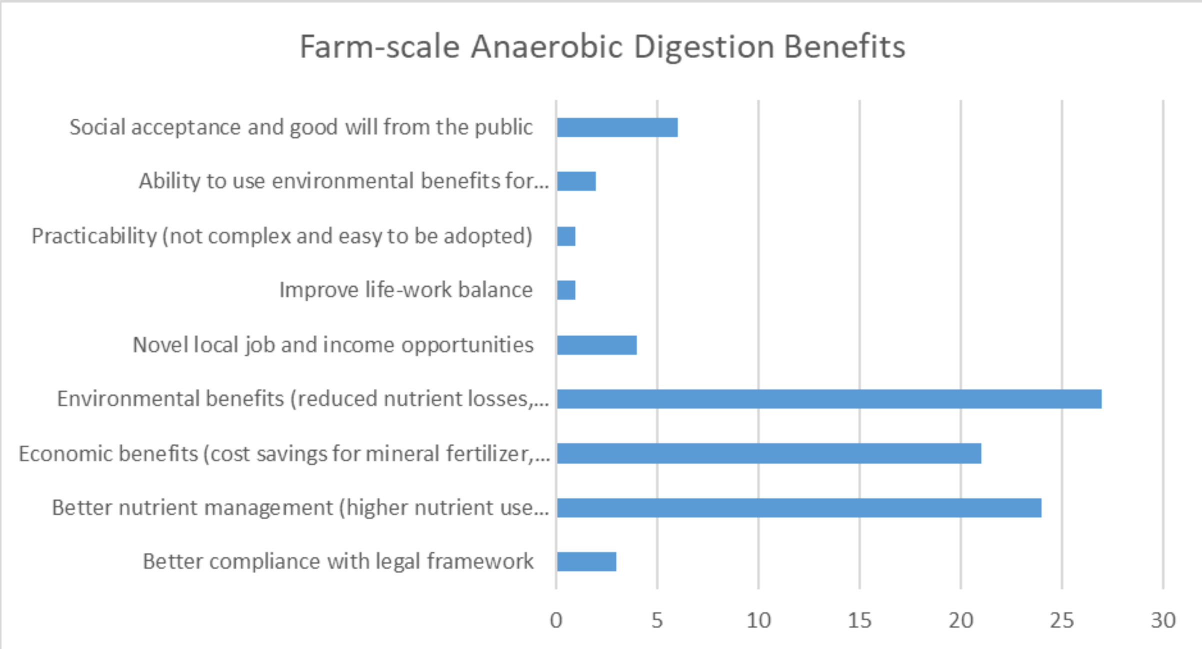
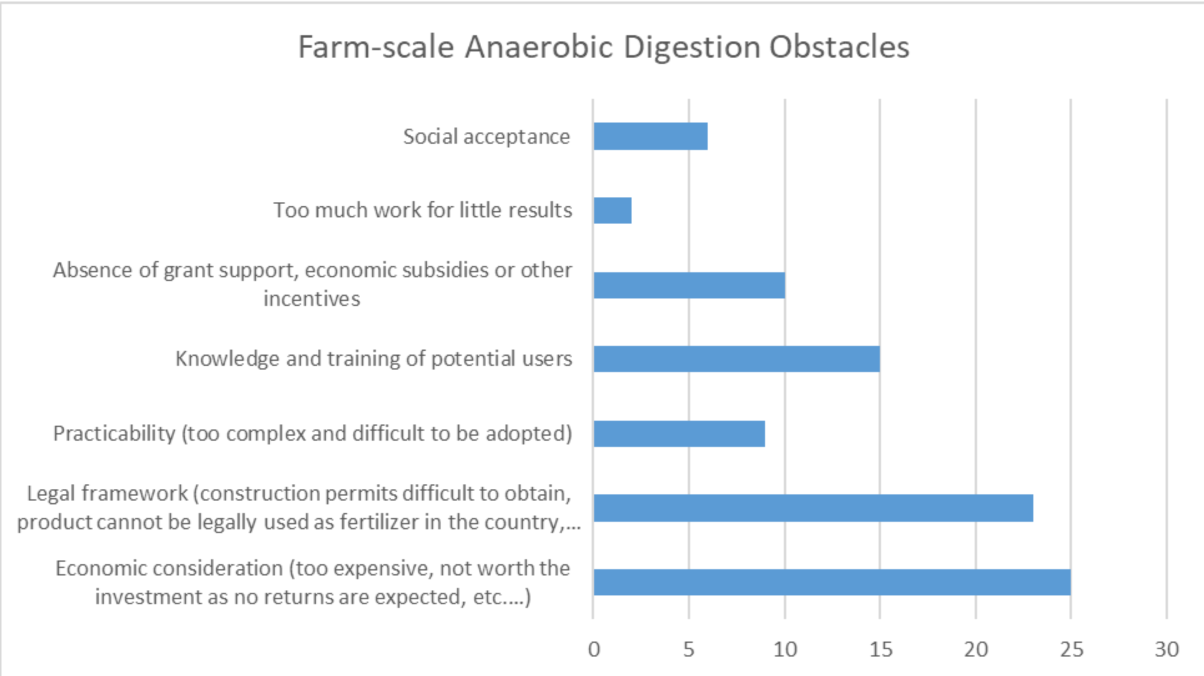
iv) Western Europe





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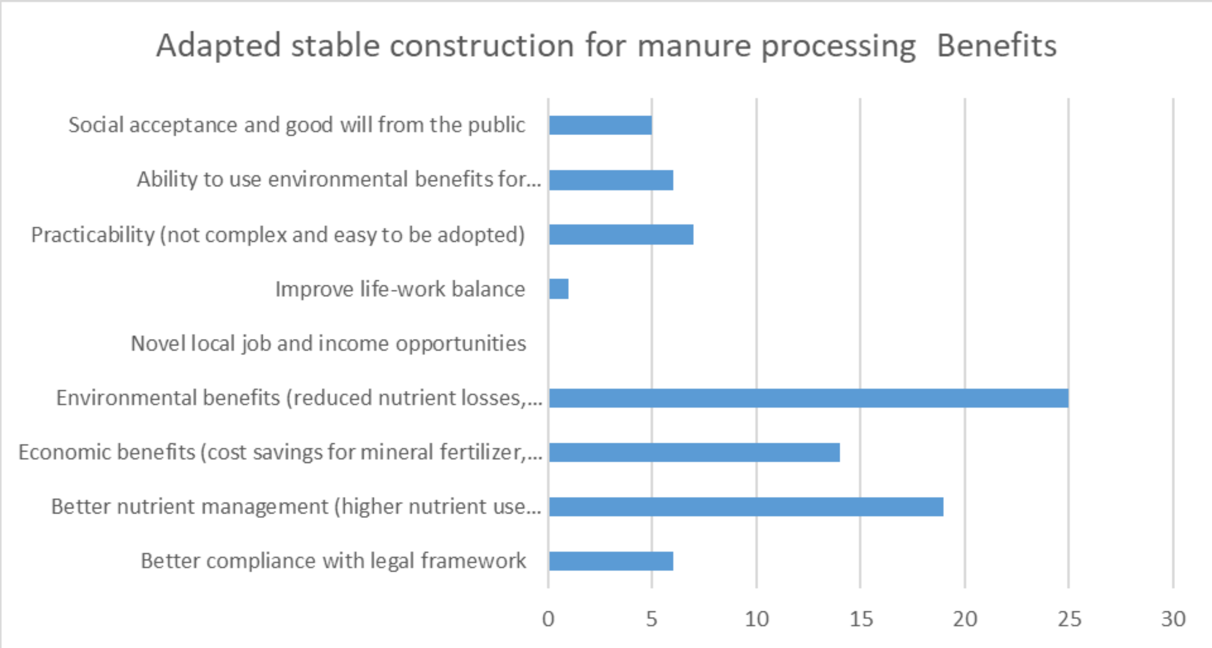

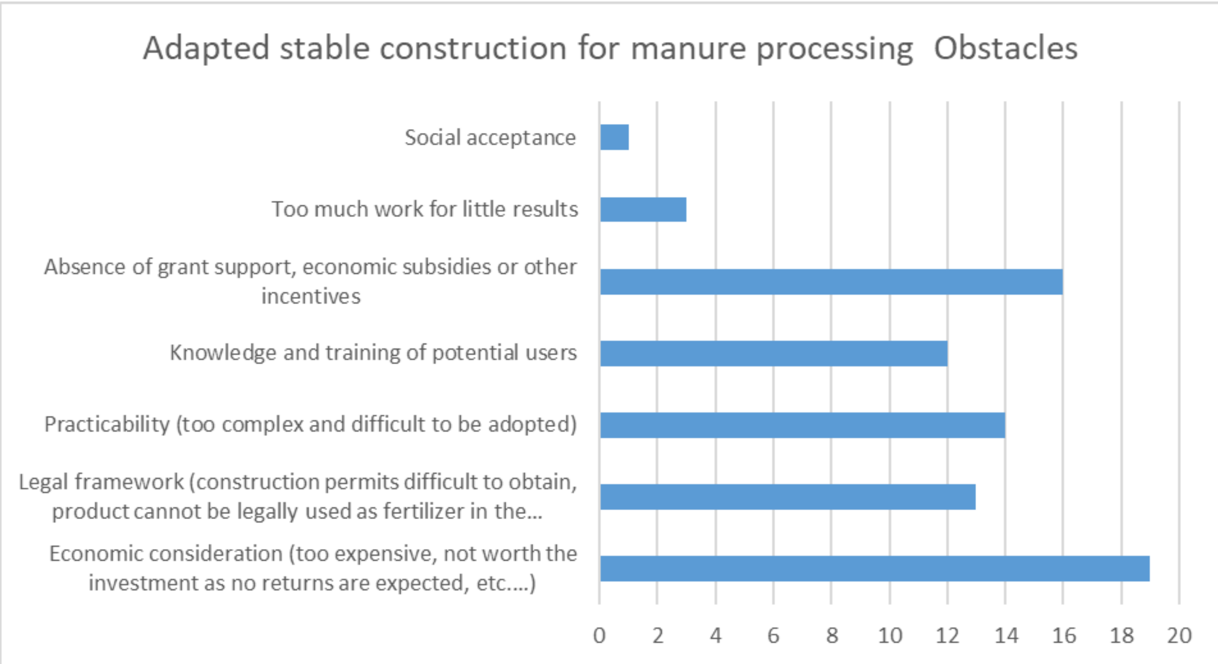

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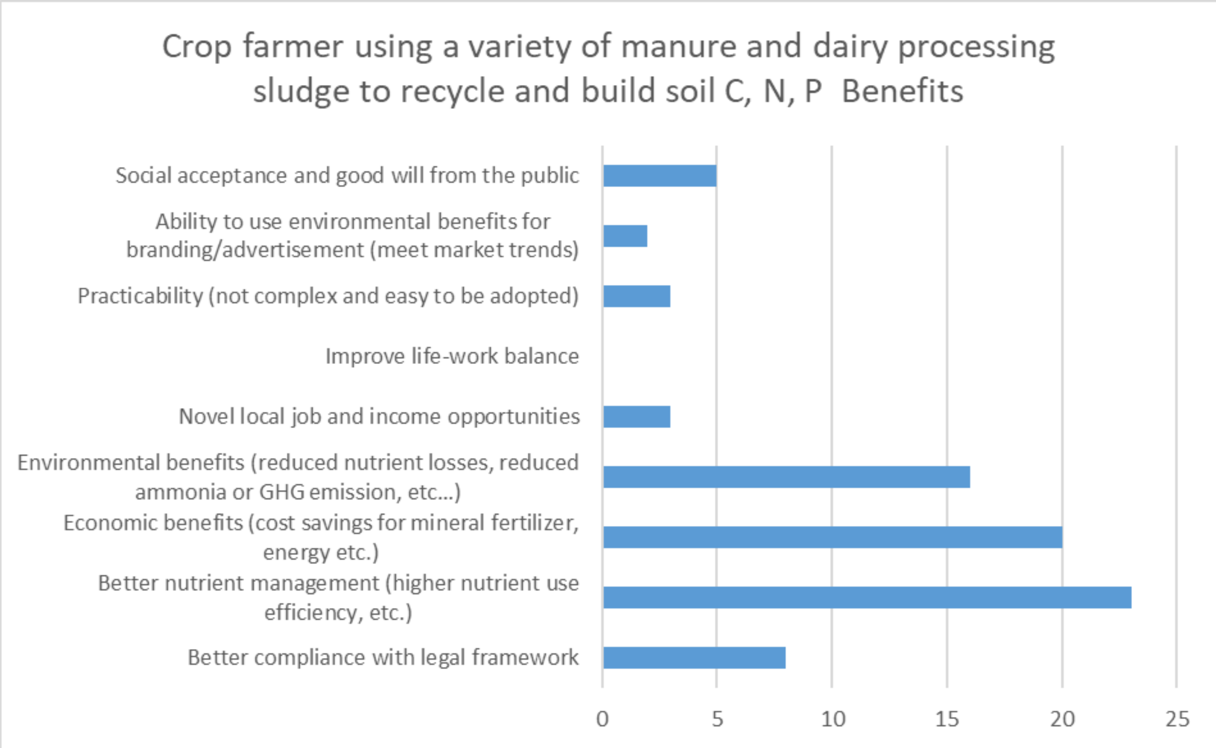

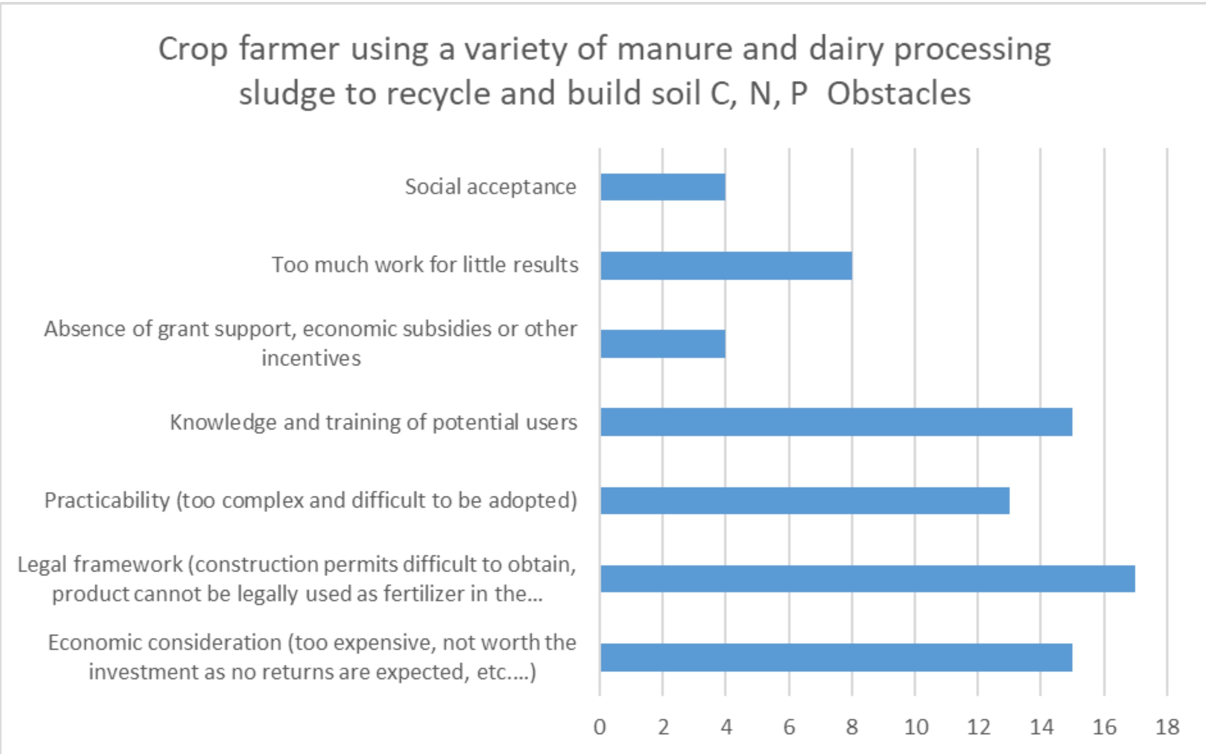

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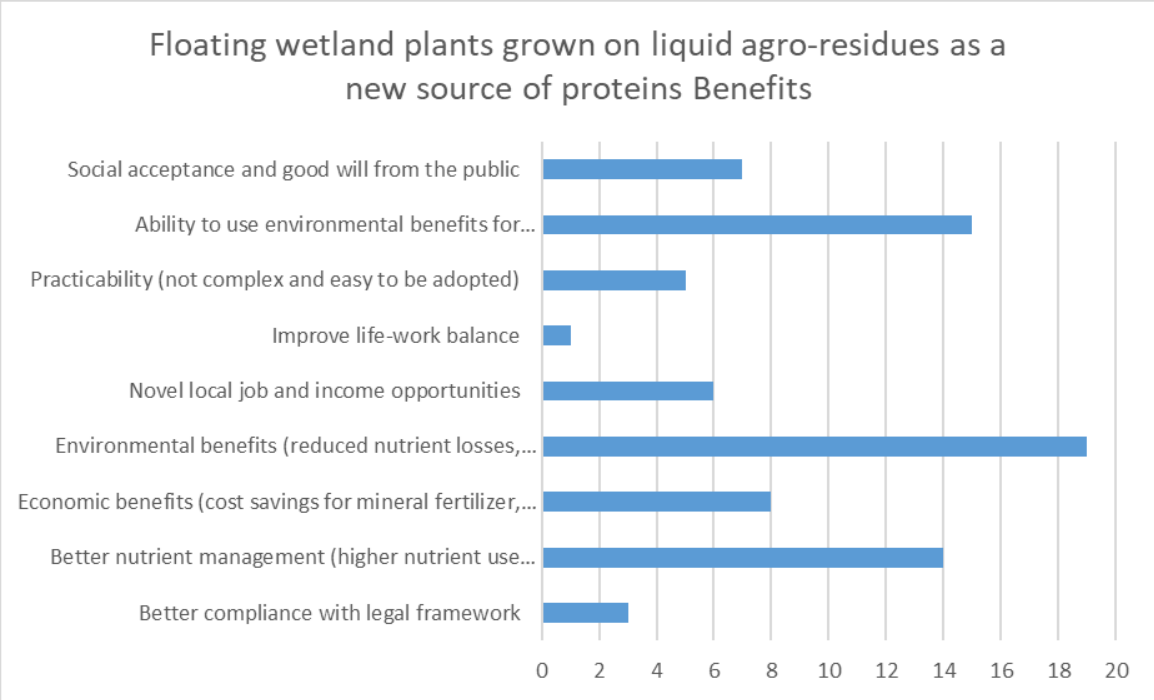

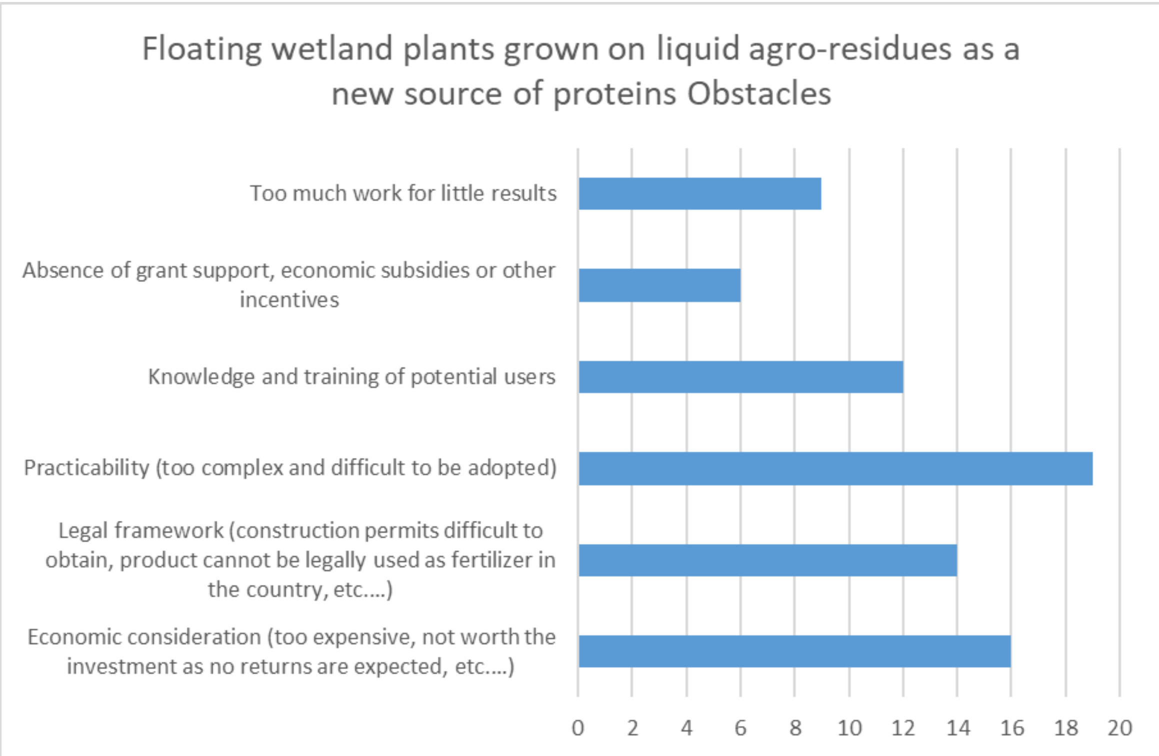

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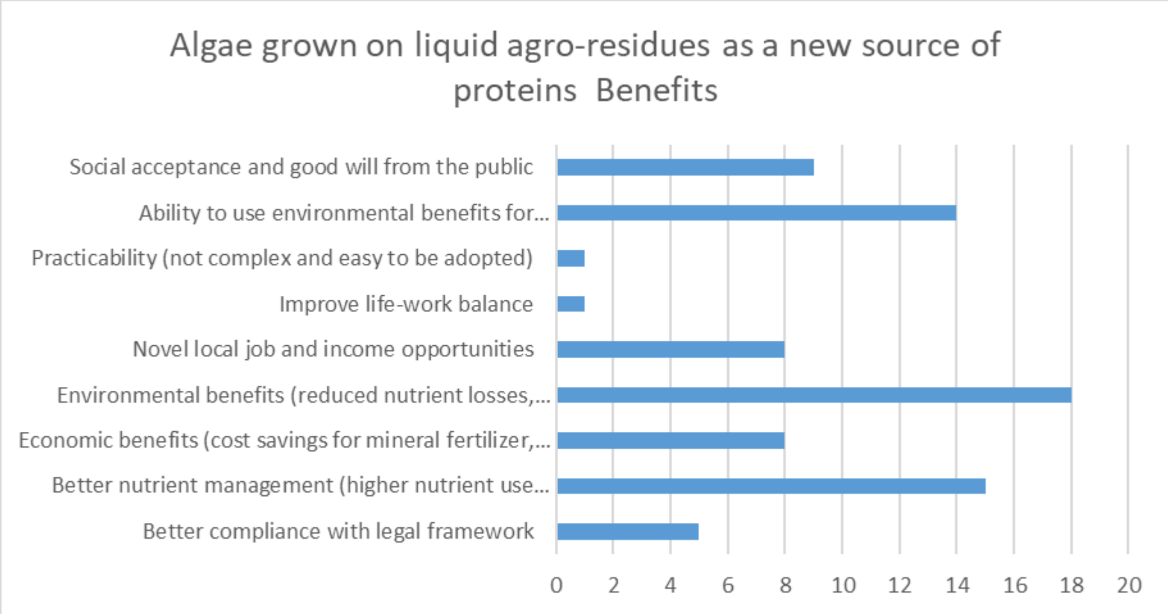

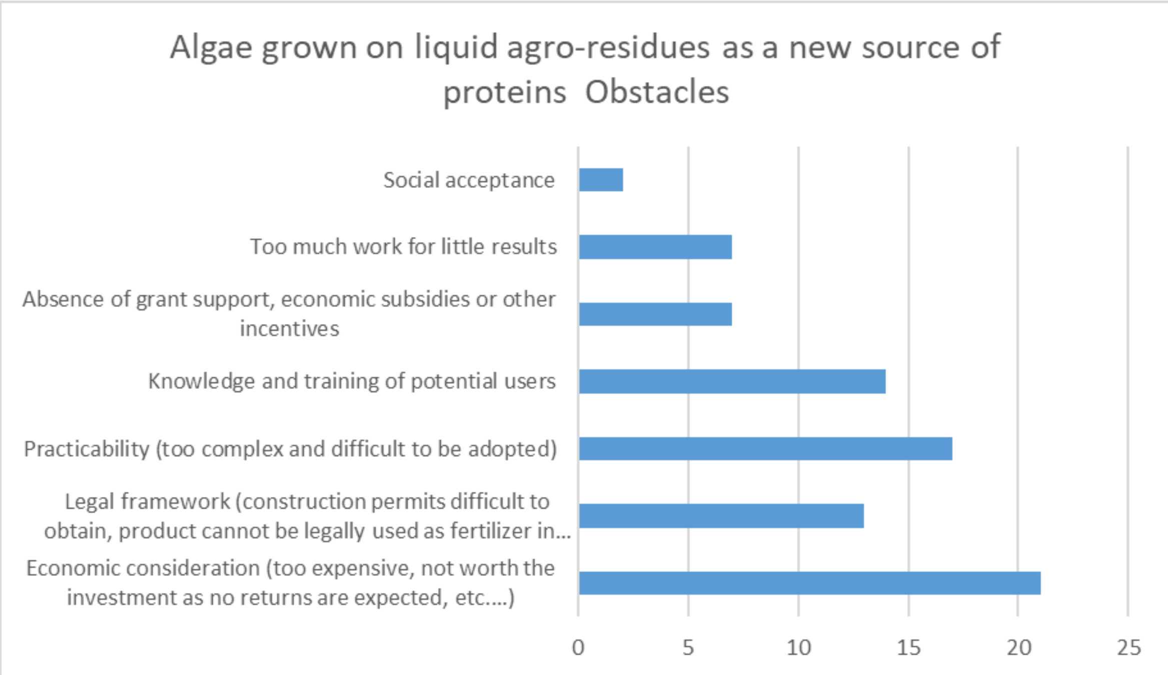

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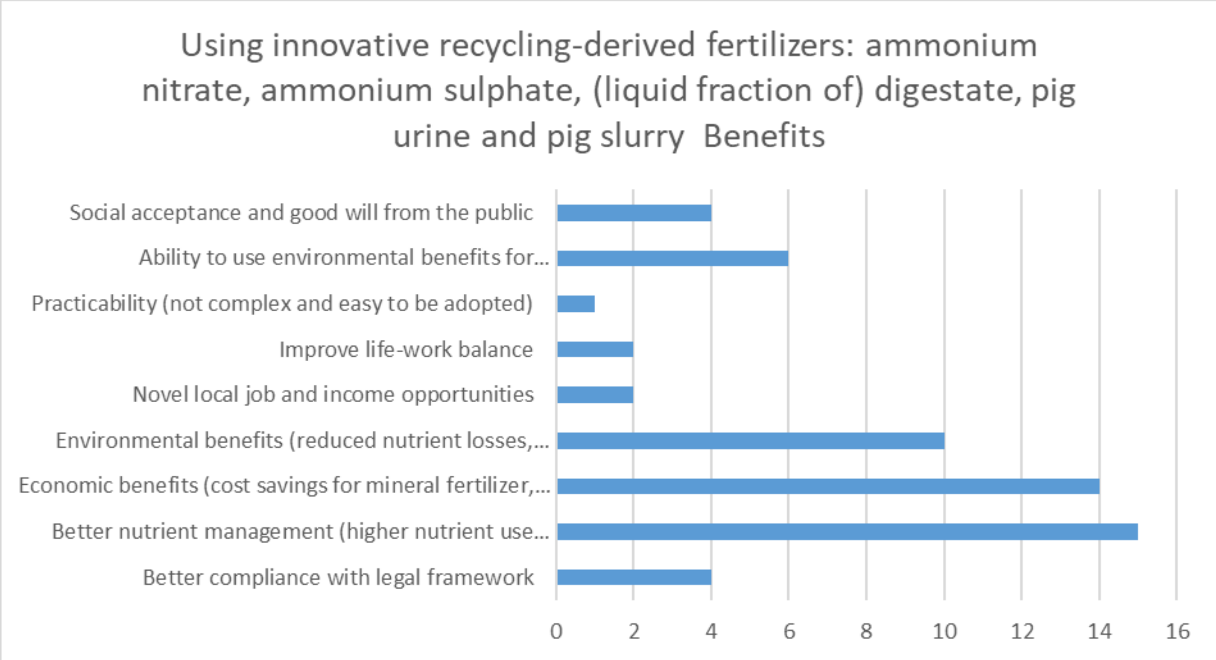

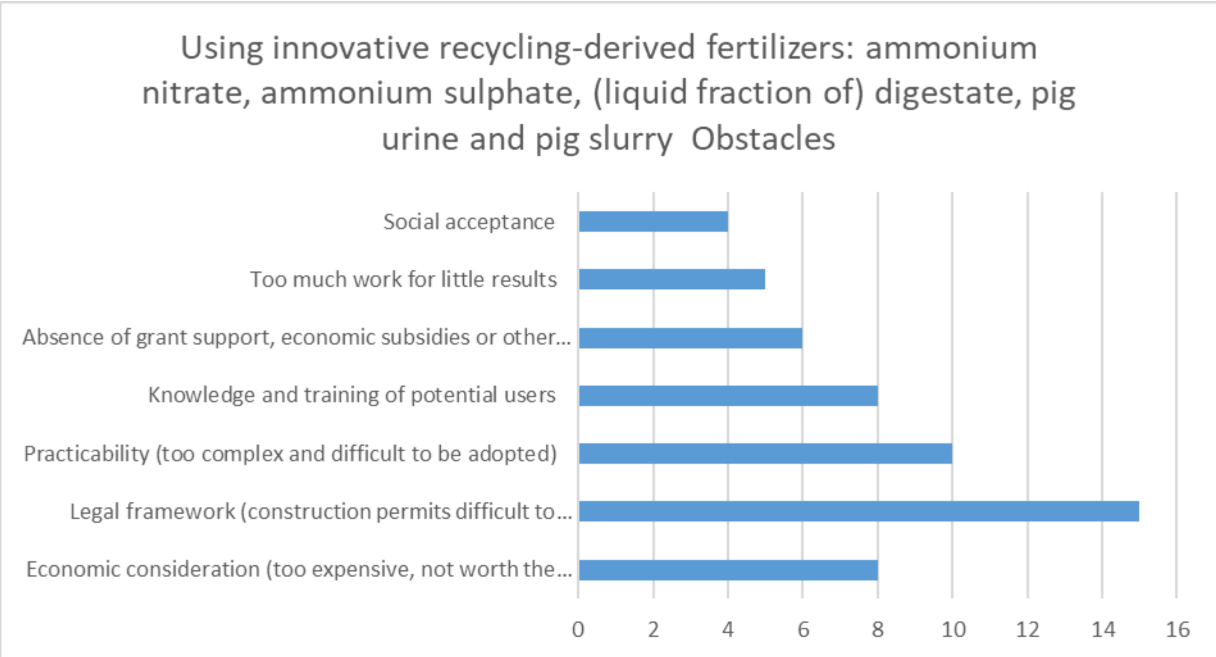

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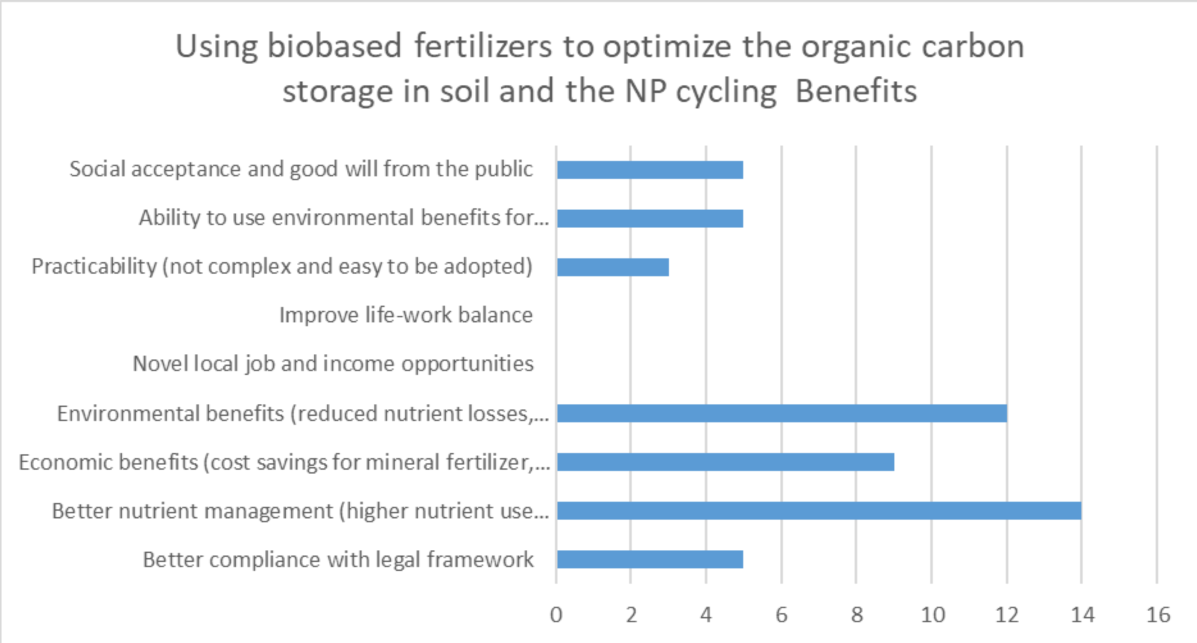

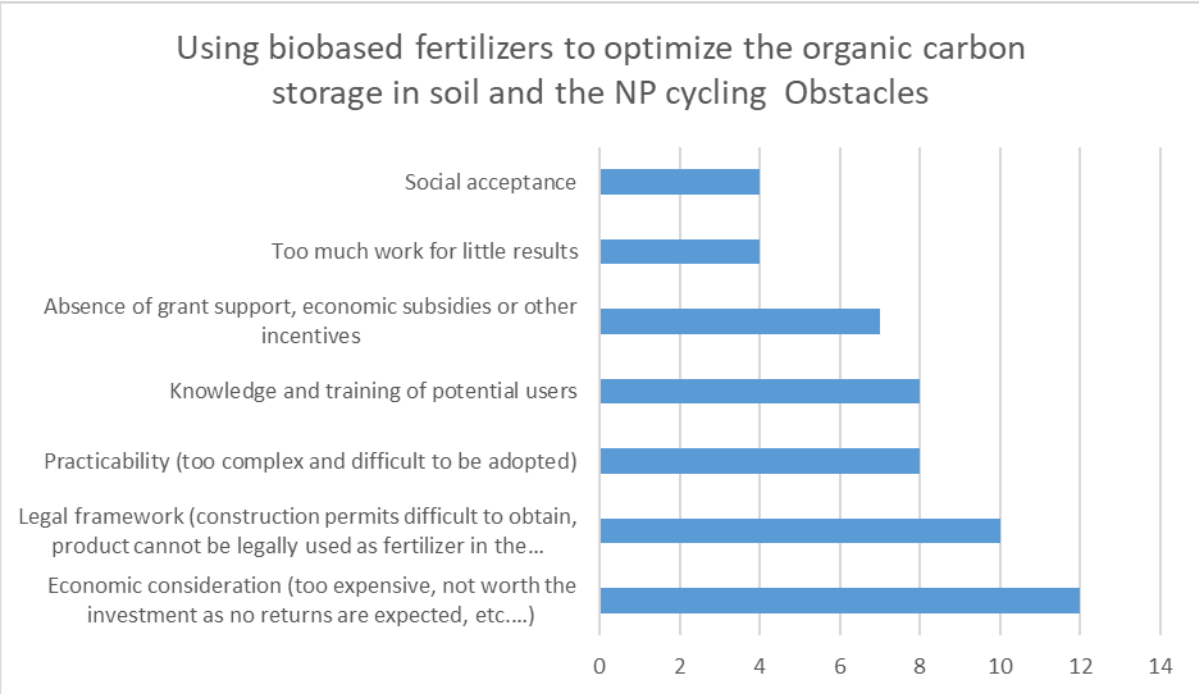

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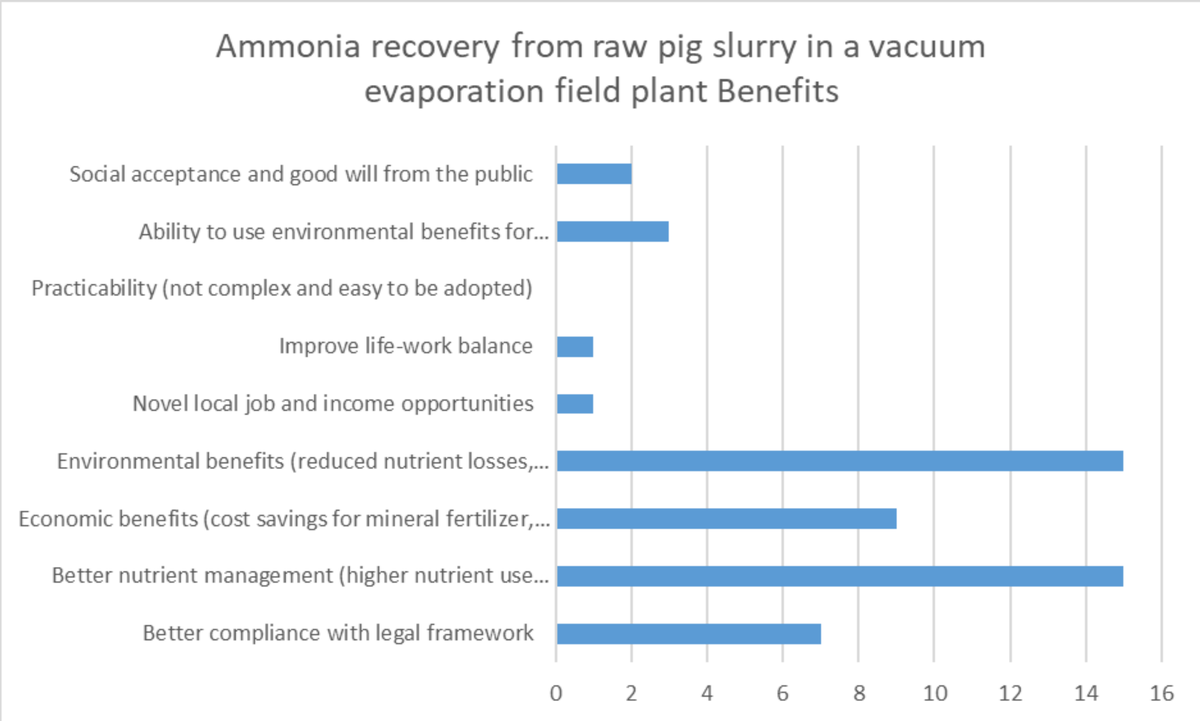

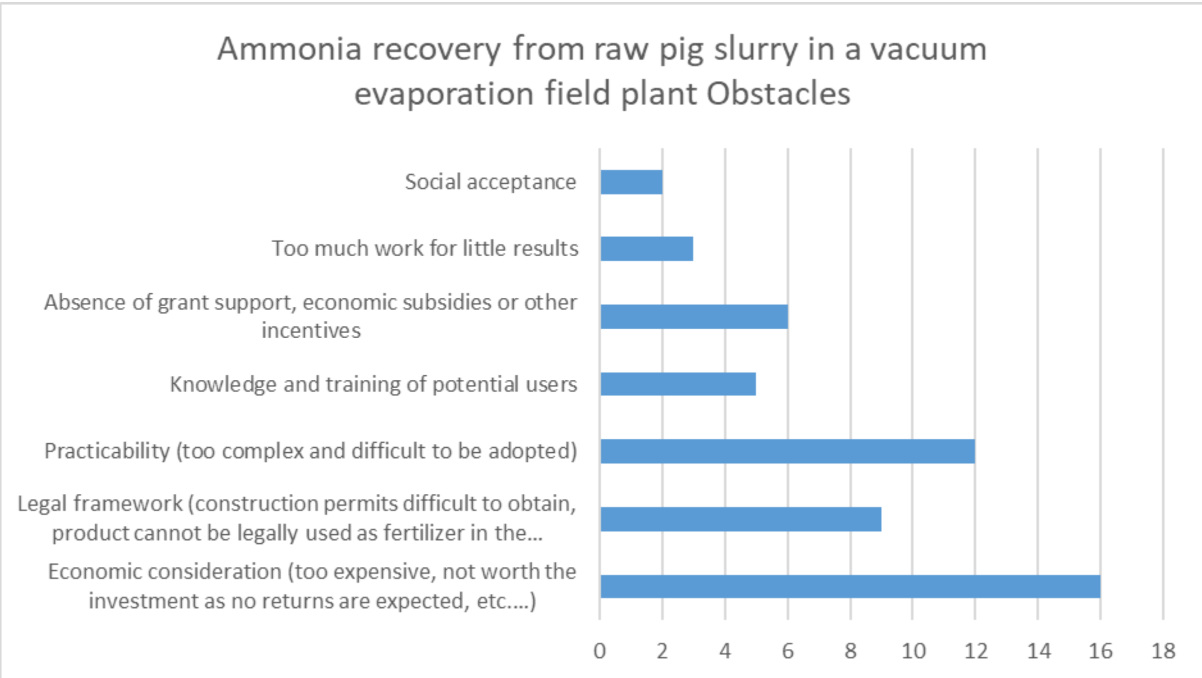

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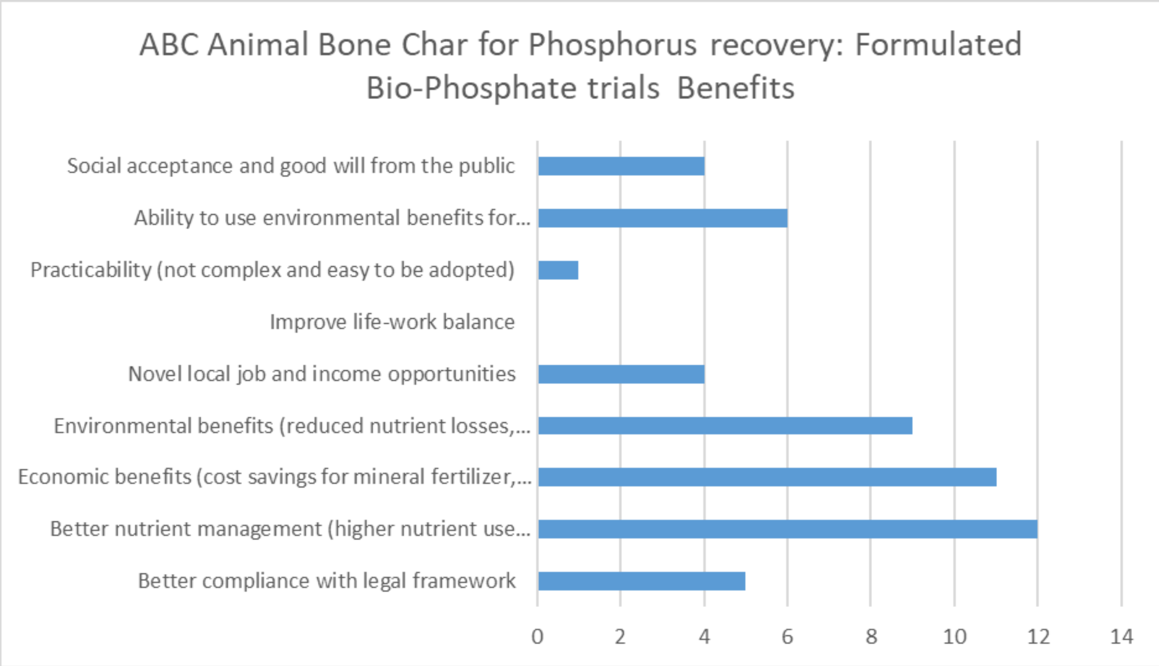

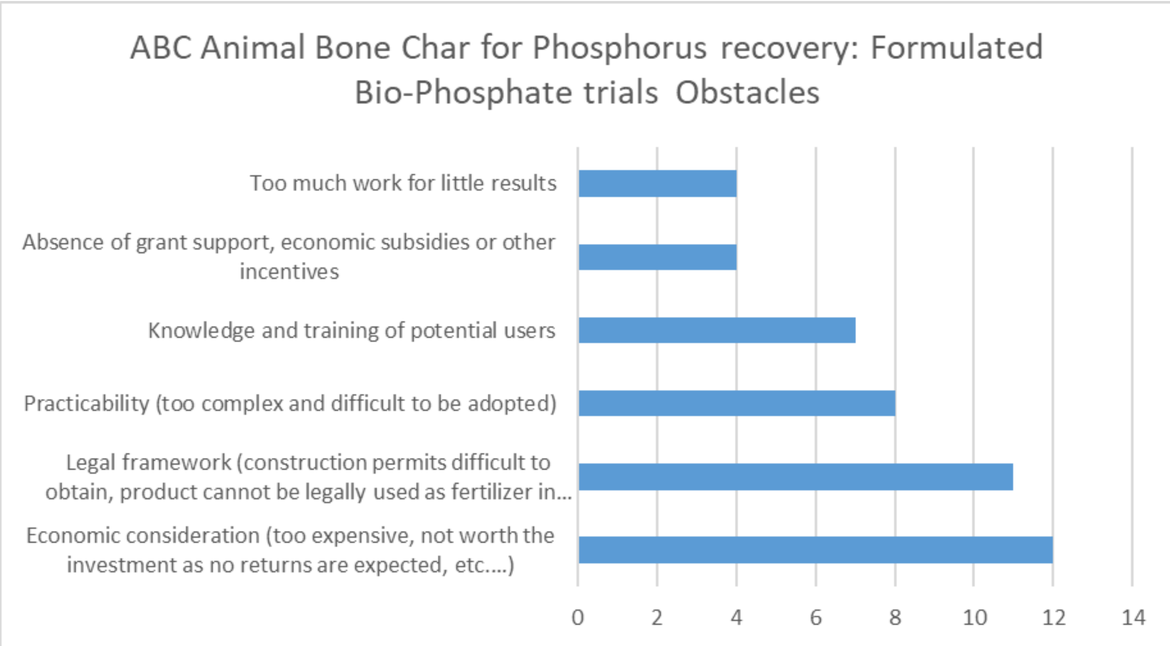

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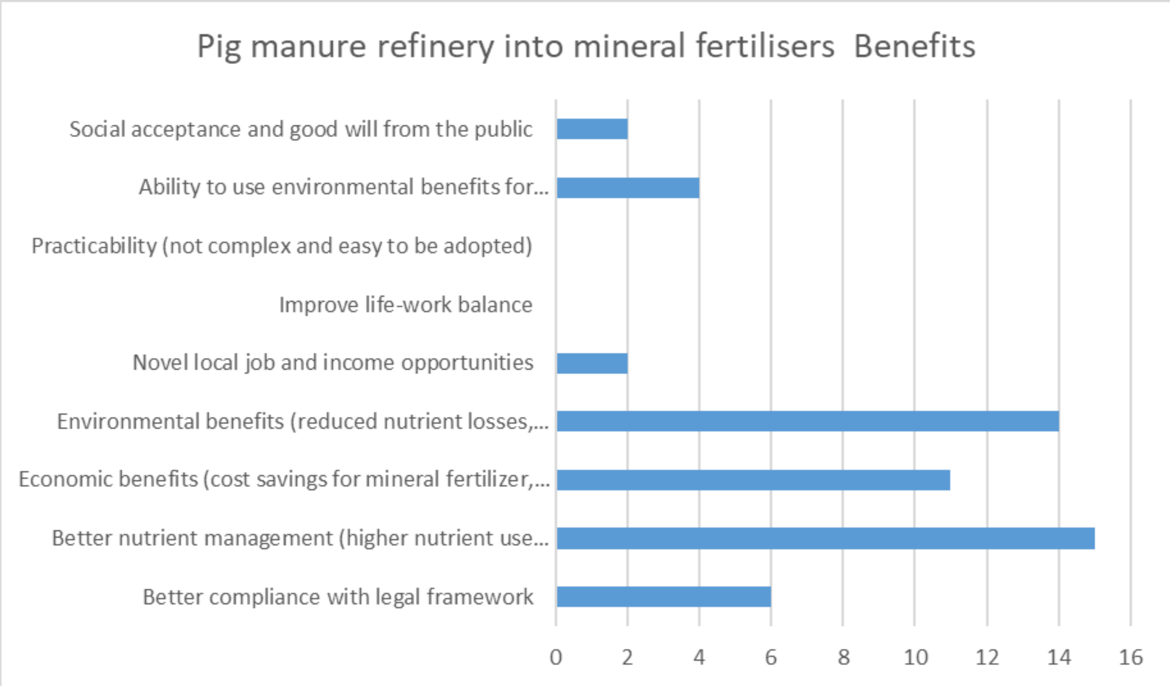

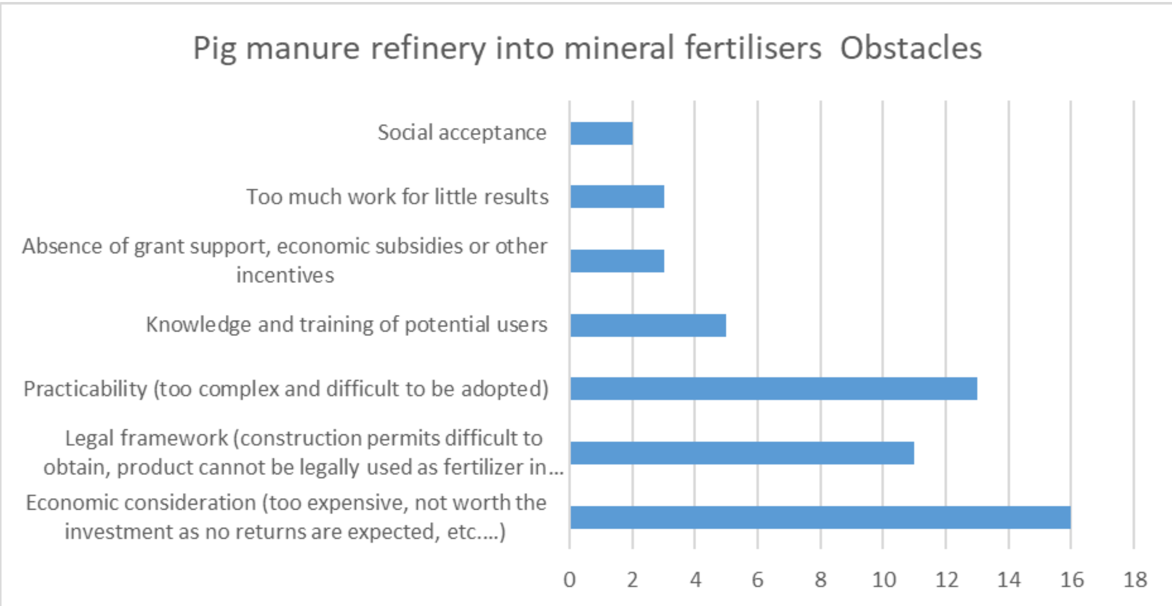

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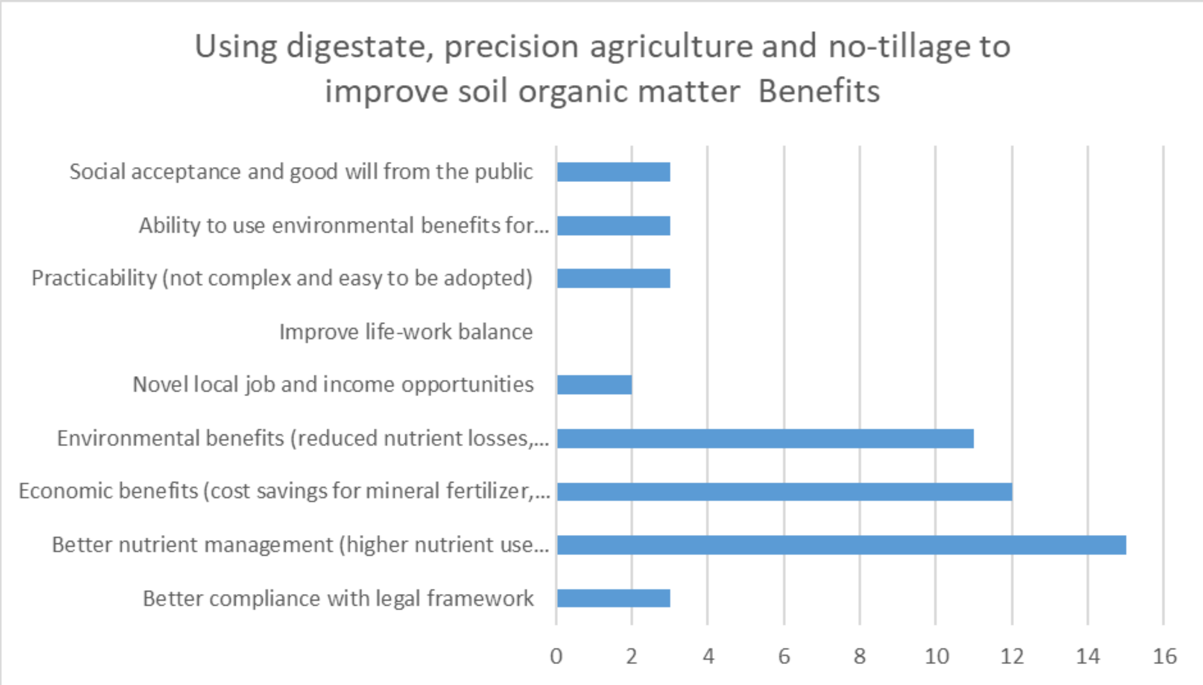

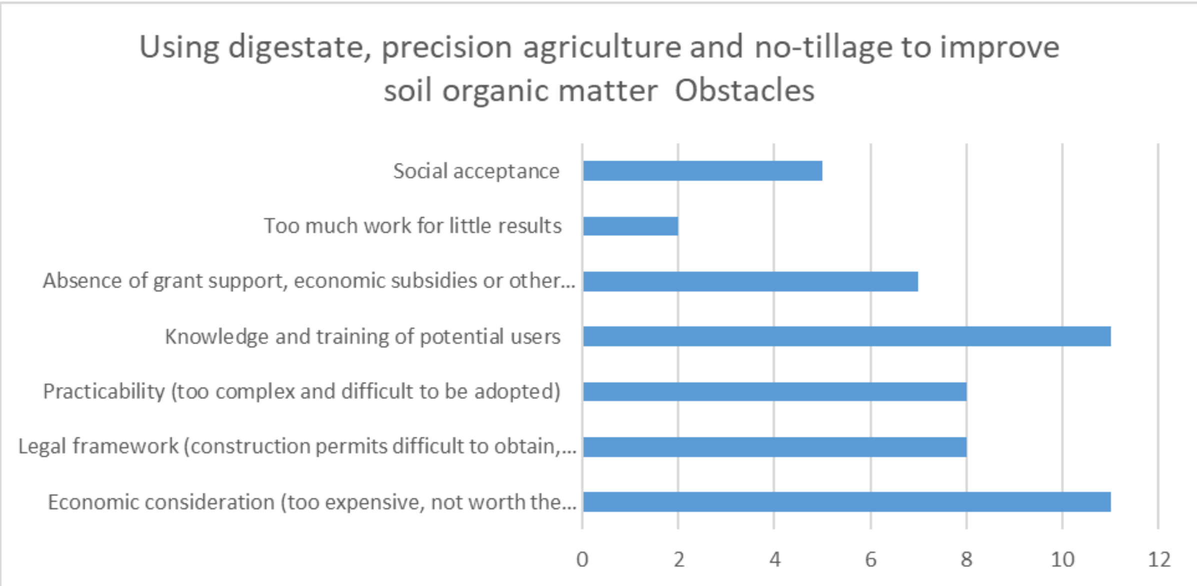

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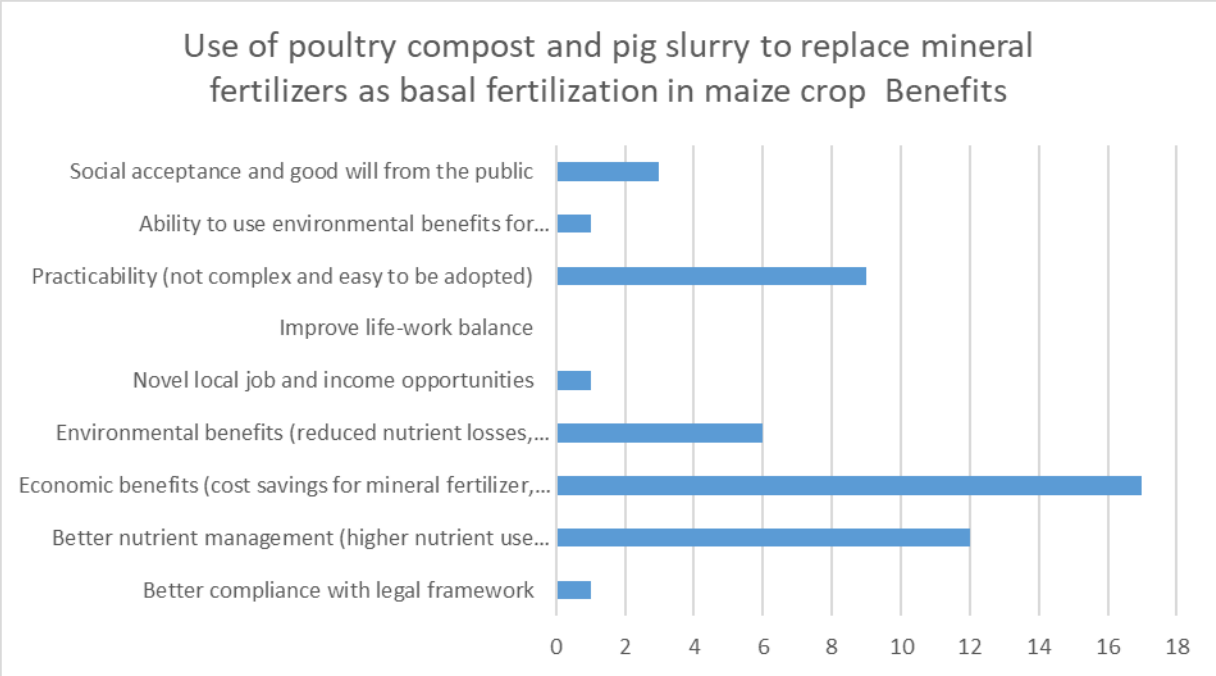

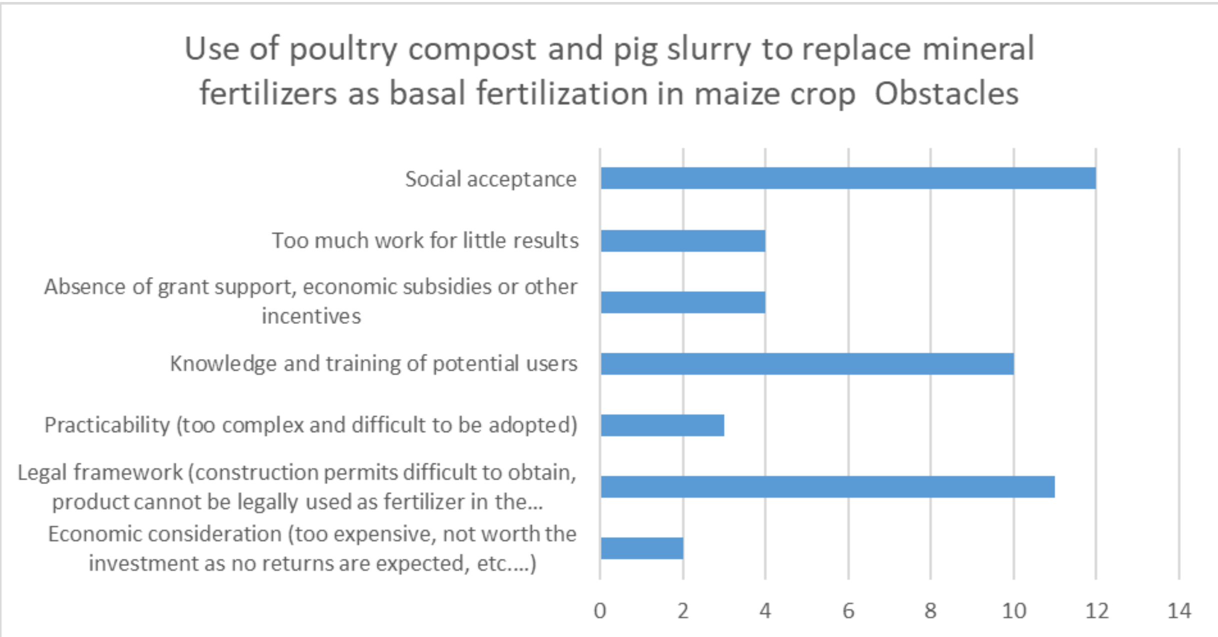

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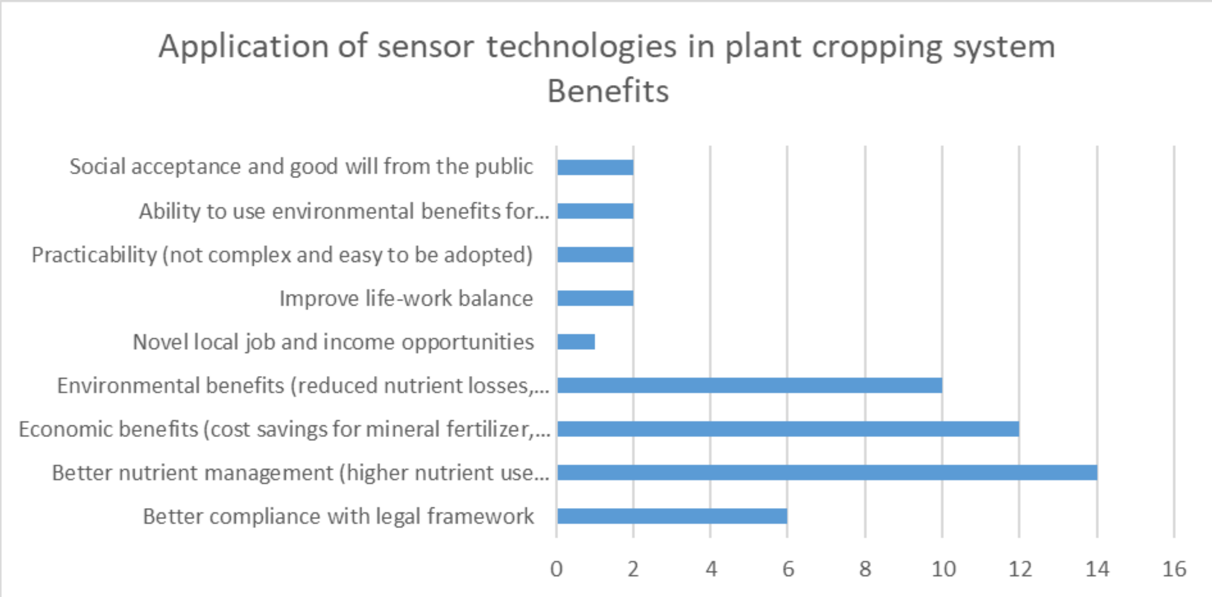

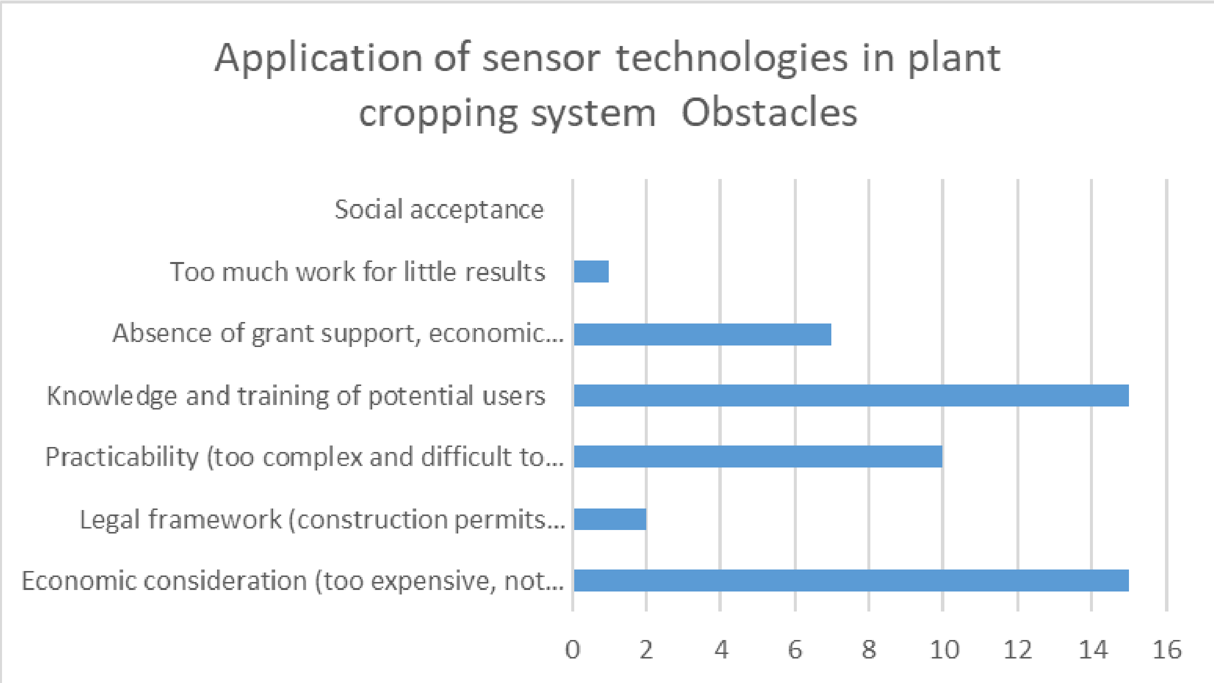

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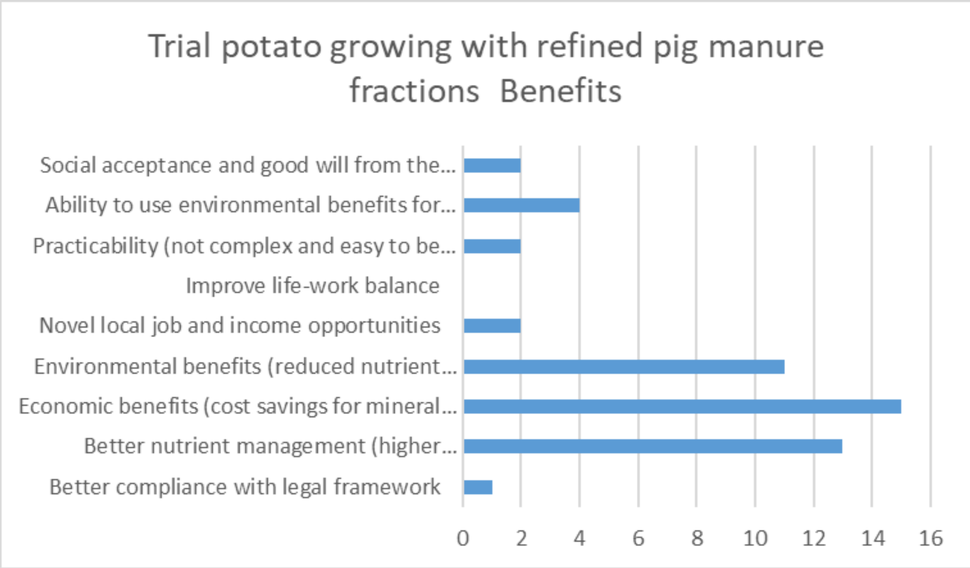

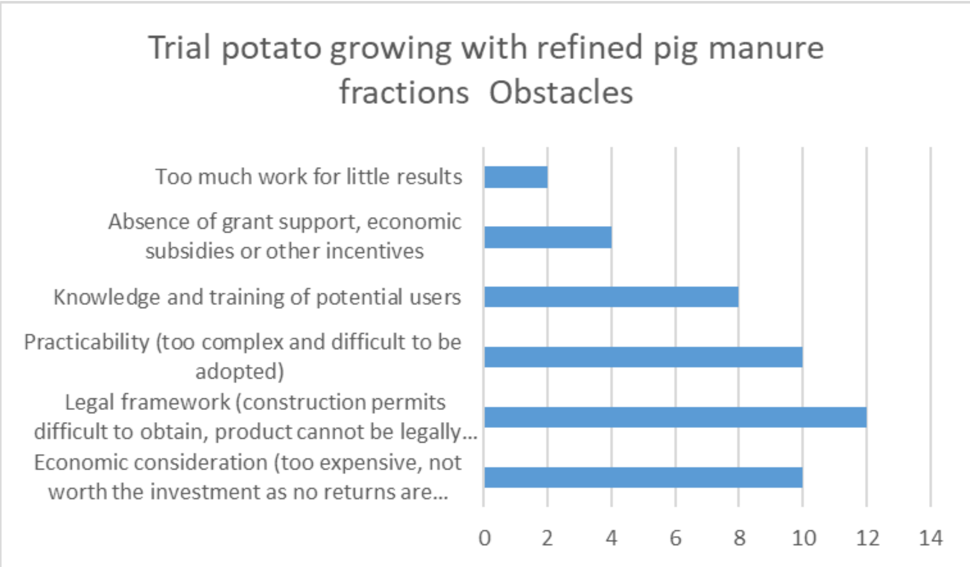

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