Novafert

D1.1 – Report on EU nutrient recovery technologies and derived products

Author(s):	*Dónal Kinsella, Patrick Forrestal (Teagasc, lead beneficiary) Ana Robles (UVIC), Nimisha Edayilam (UGent)*
Version:	*Final Version*
Quality review:	*Ana Robles (UVIC), Nimisha Edayilam (UGent), Katrien Windels (UGent)*
Date:	*31/05/2023*
Dissemination level:	*Public (PU)*
Grant Agreement N°:	*101060835*
Starting Date:	*01-09-2022*
Duration:	*36 months*
Coordinator:	*Prof. Erik Meers, Ghent University*
Contact details:	*erik.meers@ugent.be*

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Table of Contents

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

List of figures

List of Tables

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Abbreviations

Abbreviation	Meaning
ABG	AlgaeBioGas
D	Deliverable
DM	Dry Matter
EU	European Union
HRAP	High Rate Algae Pond system
K	Potassium
MAP	Monommonium Phosphate
N	Nitrogen
P	Phosphorus
RAS	Recirculating Aquaculture System
S	Sulphur
SBR	Sequencing Batch Reactor
T	Task
TRL	Technology Readiness Level
WP	Work package
WWAB	WasteWater-based Algae Bio-refinery
WWTP	WasteWater Treatment Plant

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Acknowledgements

This report satisfies the requirements for the first deliverable within WP1 on the NOVAFERT project led by Teagasc. All members within the NOVAFERT consortium contributed to this deliverable by collecting relevant information from their own resources.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Executive Summary

The present deliverable '*D1.1 report on EU nutrient recovery technologies and derived products*' compiles information on nutrient recovery technologies and products across Europe from regions own resources and from existing EU projects and nutrient recovery platforms. Information was collected by each partner within the consortium by using a template Teagasc created to collect available information. This deliverable will feed information for the rest of WP1 activities, creating an easily accessible online inventory and mapping nutrient orientated labs which a selected number will serve as lighthouse demos and will be strongly linked to dissemination activities in WP6.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1 Introduction

In line with the Zero Pollution action plan, the "Farm to Fork" strategy and the new Fertilising Products Regulation, NOVAFERT will demonstrate the technical, economic, and environmental feasibility and safe use of a wide portfolio of at least 25 alternative fertilising products, with the goal of facilitating the replacement of synthetic and mineral fertiliser's to reduce environmental impact and external nutrient dependency in Europe.

The objective of this deliverable is to build an inventory of current and promising alternative fertilising products across Europe (Fig 1). The inventory will be later available online allowing to easily access all the information (D1.2). Afterwards, at least 25 fertilising products will be selected and evaluated with regard to their environmental impact and safety, as well included in novel, circular and green business models in subsequent NOVAFERT studies.

The Alternative fertilising products are produced from different nutrient-rich side-streams. When treating nutrient riche side streams with the aim to recover nutrients, the technology chosen will vary depending mainly on the characteristics of the side stream, which will have a strong influence on the composition and properties of the resulting fertiliser/end-product. Therefore, NOVAFERT will promote the recovery and recycling of nutrients from 6 different nutrient rich side streams in Europe. The selected side streams are those leading to deterioration of the environment due to poor utilisation of their nutrients in representative countries of Eastern, Western, Northern, and Southern Europe, and that are responsible of creating nutrient hot spot areas. The selected regions and waste streams are:

- Biological by-products including i) Agricultural by-products (straw, green maize, grass, waste water) and animal by-products (bones, blood, and manure): in Ireland
- Municipal biodegradable waste streams (bio-waste and sewage sludge): in Andalusia
- Bio-waste, animal manure and digestate: in Croatia
- Animal manures and digestate: in Flanders
- Municipal biodegradable waste streams (sewage sludge) and digestate and animal manure: in Poland
- Manure, digestate and bio-waste: in Finland

The new Fertiliser Product Regulation (EU 2019/1009) implemented in the EU from July 2022 onwards sets criteria for CE-marked fertilisers, allowing free movement of alternative fertilising products across the EU and encouraging their use. However, there is still low awareness between the agricultural practitioners about these commercially "ready for practice" technologies drawn from high maturity research and the derived products. It is essential to spread the knowledge and information about the insufficiently exploited N/P recovery innovations. Thus, this deliverable aims to providing some general information about the regional distribution, characteristics, applications, availability and opportunities of the

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

technologies and products, and to serve as the basis for the environmental analyses that will be done in WP2.

There is a diverse range of technologies that can be applied for processing nutrient rich side streams. However, not all of them can be considered as nutrient recovery technology. We consider a nutrient recovery technology a process that creates an end-product with higher N or P concentrations than the untreated stream, or that separates the N and P from organic compounds, with the aim to produce an end-product that is fit for use in the chemical or fertiliser industry or as a chemical fertiliser substitute. Based on their fertiliser composition, we classified the current available recovered products as N&P, N or P products. For the purpose of this deliverable an alternative fertilising product is defined as any product that is not classified as a synthetic mineral fertiliser and is derived from a raw feedstock which has undergone a nutrient recovery process to further refine the product into a more stable form for land application. This can include by-products from technologies which main aim is not to recover nutrients (e.g., the digestate produce after anaerobic digestion). The by-products from non-specific nutrient recovery technologies (digestate, compost) would be also considered as alternative fertilising products as they are included in the new Fertiliser regulation. However, more concentrated fertilising products derived from nutrient recovery technologies (as define above) may serve as an economic benefit for transportation costs, application to land etc.

NOVAFERT will create an Atlas of the nutrient-oriented living labs (also known as sites in the new Soil mission lexicon) with the aim to support the development of sustainable local value chains and existing best practices (later analyse in task 1.4). By regionally contextualizing and interlinking all main recovering technologies and products, and technically connecting all value chains and key relevant stakeholders. Moreover, Novafert develops a portfolio of support policies and legislative instruments suitable for local deployment in the EU regions through 7 specific action plans and 4 policy briefs. Thereby Novafert brings together the necessary information for efficient and safe use of alternative fertilising products to help decision-making on valorisation employed in nutrient recovery.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

2 Methodology

Within the consortium, a variety of geo-climatological regions were represented. The map below (Fig 1) represents each region contributing to task 1.1 and the main side stream covered by each region. This report aims to satisfy the objective described in task 1.1: to map nutrient recycling technologies and products from the regions own resources, nutrient orientated EU-projects, thematic networks and EU nutrient platforms and associations (**Fout! Verwijzingsbron niet gevonden.**).

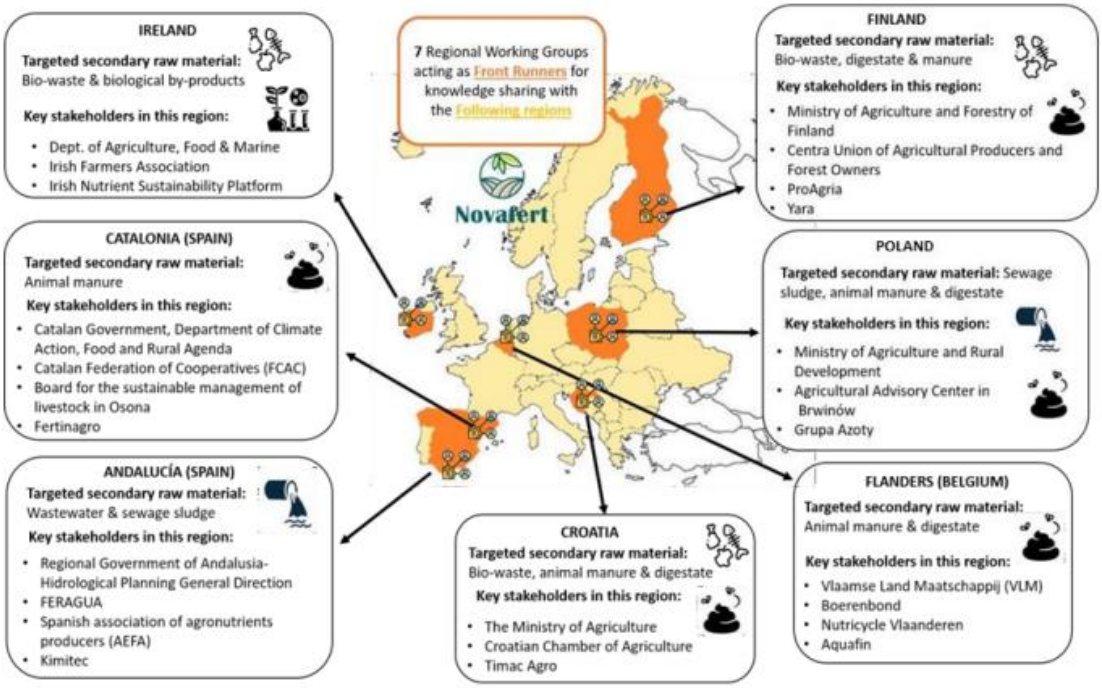

Figure 1 overview of the secondary raw materials covered by each region

A methodological approach for collecting different existing and novel alternative fertilising products was elaborated. The selection was based on following consecutive steps:

i) Teagasc created a first draft of a template to compile all available data from technologies and fertilising products. The purpose of the template was to gather information on technologies with a TRL of five and above. Type of information collected from these technologies included: Processing conditions, processing capacity, CAPEX & OPEX costs, Legal status, output & source material, country, product characteristics including: DM%, humidity%, N, P, K , S, pH, organic carbon%, form/state of the product, method of application, LCA reference, organic certification?, availability and any results of agronomic performance using the type of product.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

ii) Feedback meetings were organised with the consortium to discuss which missing information should be included in the template.

iii) Once the template was finalised in November 2022 with the agreed data to be collected, it was distributed amongst the partners to fill it in with the information from their own regions and from EU projects that covered the identified waste stream for their own areas (e.g. projects that dealt with nutrient recovery from wastewater were scrutinised by BIOAZUL)

iv) Monthly WP1 meetings were organised to help filling the template with the information each partner collected and solve doubts.

v) Data from nutrient related EU projects that covered several regions or waste streams (e.g., NUTRIMAN or FERTIMANURE) was added in the template by the partner who participated (or led) the project, i.e., data from Nutriman was added by UGENT and data from FERTIMANURE was added by BETA. Data was also added from other EU projects and sources including Yara Eco ltd, Sea2land, Systemic, Walnut, Nutri2cycle, ReNu2Farm, Lex4bio, Inagro, water2Return, RichWater, DESERT, SABANA, INCOVER, ALGAENAUTS, REUTIVAR and ENRICH.

vi) The JRC's STRUBIAS project and the SAFEMANURE project were also screened by Teagasc throughout the process for compiling data on suitable products & technologies.

vii) Furthermore, a Data Transfer Agreement was signed between the Novafert consortium and the Lex4Bio project which allowed Novafert to screen the products that they identified during their interviews.

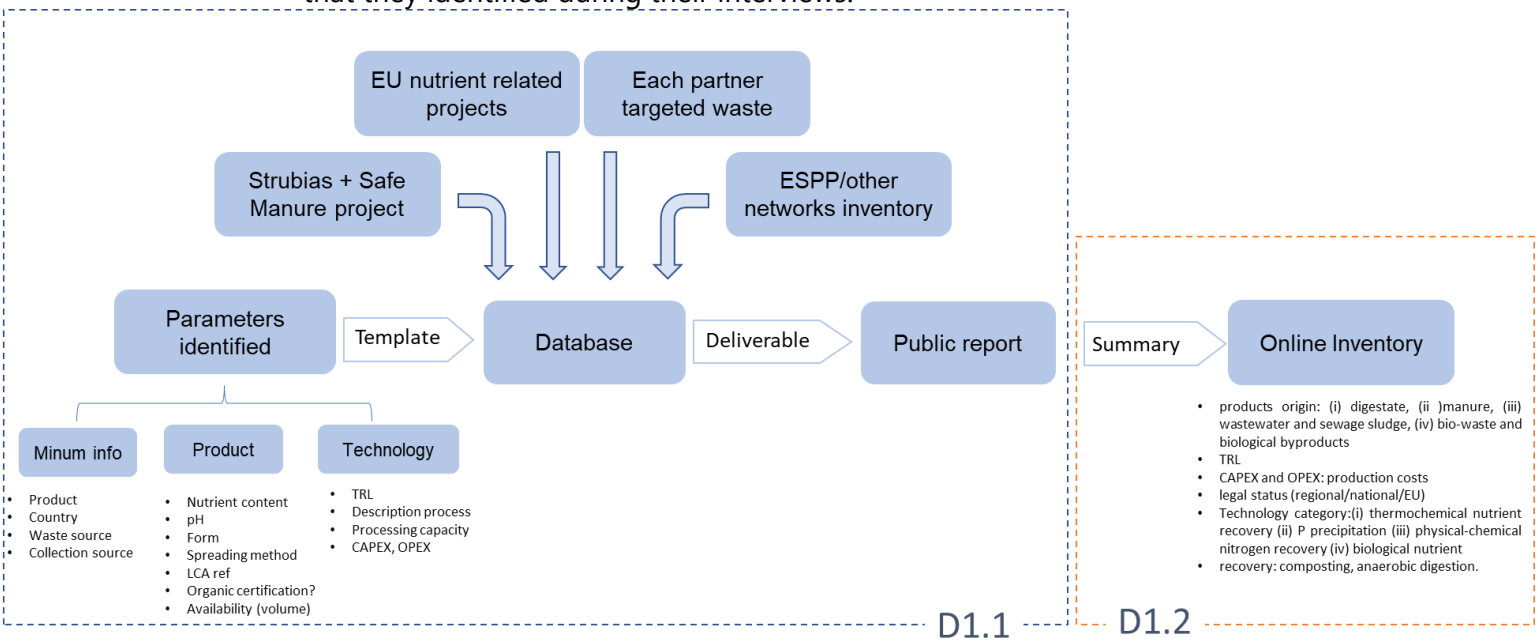

Figure 2 T1.1 Novafert methodology

Information on technologies and products were gathered from Technology Readiness Level (TRL) of 5 and above.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

The members of the consortium which participated in this task are as follows:

Table 1 Participating regions within the consortium

Region	Expert representative
Ireland	Agricultural research organisation Teagasc
Catalonia	Fundacio Universitaria Balmes
Andalucía	Biozul, SL
Finland	Luonnonvarakeskus
Poland	Instytut Gospodarki surowcami mineralnymi I Energia Pan
Flanders	Universiteit Gent
Croatia	IPS Konzalting Doo Za poslovne Usluge

Each region was tasked with compiling information on technologies and products from a targeted waste stream as described above. This is a guideline used within the project to focus on the waste streams which is more common in each region. However, when carrying out research for this task, members from each region did not use this as a limiting factor to include technologies and products from other waste streams also available within their region.

To consolidate the regional aspect of the task findings, the data compiled from each region was divided into the geographic regions of Northern Europe, Southern Europe, Eastern Europe and Western Europe, following the guidelines of the United Nations Statistics Division (United Nations statistics division, 1999), (fig 1). Taking this approach for representing the data allows to have both a European wide view and a European regional view and to include all technologies and products derived from different waste streams. This approach was taken by a consortium in another EU funded project "Nutri2cycle" which represented simplified and quality data by using this method. The regions were divided as follows:

Northern Europe – Ireland & Finland

Western Europe – Flanders

Southern Europe – Catalonia, Andalucía & Croatia

Eastern Europe – Poland

The map below (fig 3) visually represents each region involved in task 1.1 which are divided into geographic regions.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

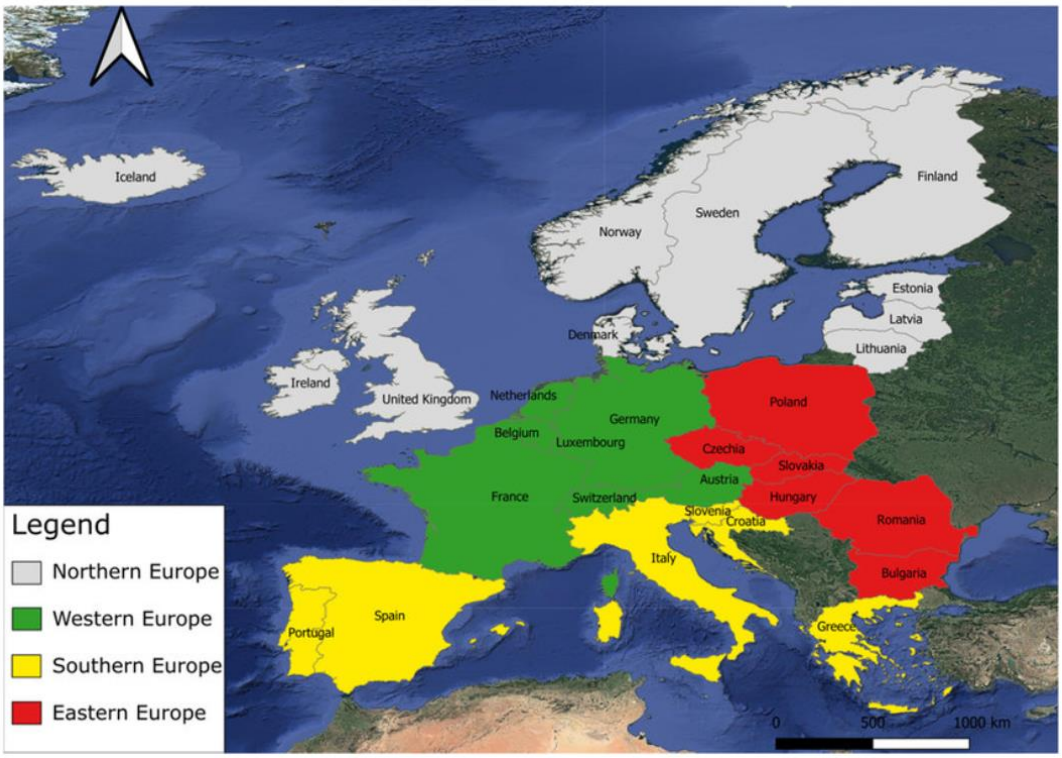

Figure 3 visual representation of the U.N geographic regions of Europe

The next section 3. Results & Discussion, summarises 47 technologies and 86 products compiled throughout the data collection in task 1.1.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

3 Results & Discussion

The consortium compiled information on 47 nutrient recovery technologies and 86 associated products which was provided to Teagasc, who screened it for any redundant or overlapping information. The below graph (fig 4) represents the number and type of nutrient recovery technologies which were found across Europe when carrying out this task.

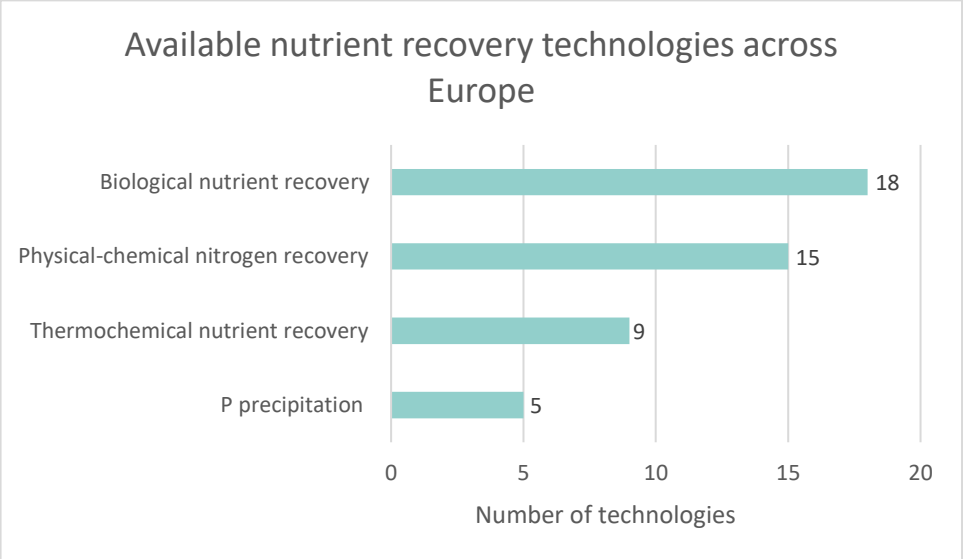

Figure 4. Available nutrient recovery technologies in Europe

The most common technologies such as composting, anaerobic digestion, mechanical separation were found in all regions. The readily available information on these technologies and products is presented in this report, while more detailed information can be found in the Annex. Below (fig 5) represents the total amount of the different types of products which were derived from the nutrient recovery technologies displayed above. Products which were derived from biological and physical-chemical nitrogen recovery were most commonly used across Europe especially in intensive agricultural areas in Ireland, Flanders and Finland.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

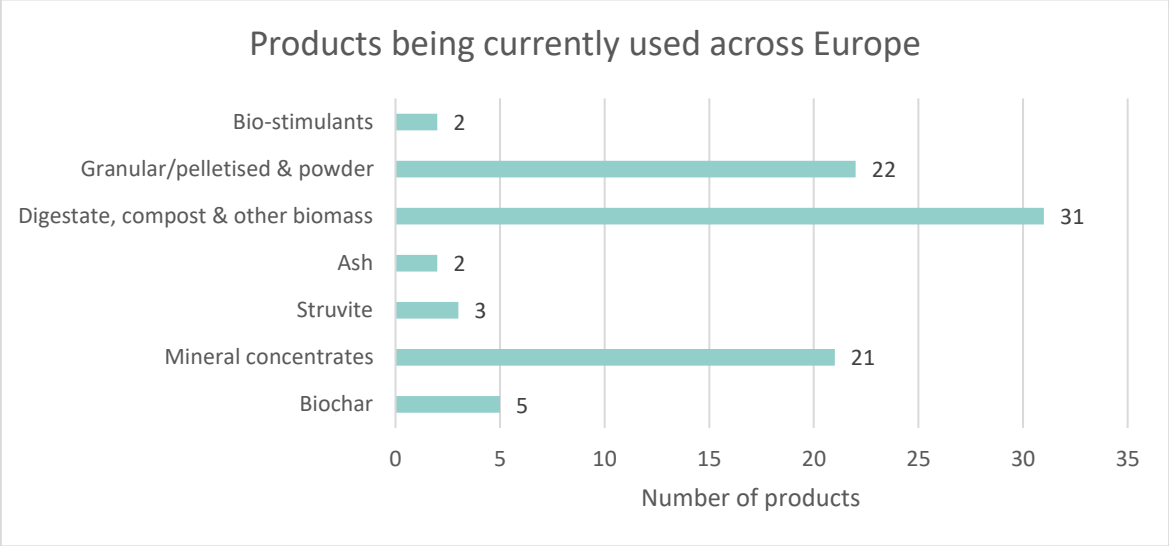

Figure 5. Products being currently used across Europe

The technologies and products were sorted by their respective regions, as described in section 2, and the most commonly compiled ones by the consortium from EU platforms and their own resources are documented in Tables 2, 3, 4 and 5.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

3.1 Northern Europe (Ireland and Finland)

The pre-identified waste sources for northern Europe were: Bio-waste and biological by-products, digestates and manure. After the screening in task 1.1, these sources were still identified as the most common to recover nutrients: Animal manure, digestate, green waste, agricultural by products and household bio-waste. The graphs below represents the total number and most common nutrient recovery technologies (Fig 6) and available products (fig 7) which are derived from the technologies in Northern Europe.

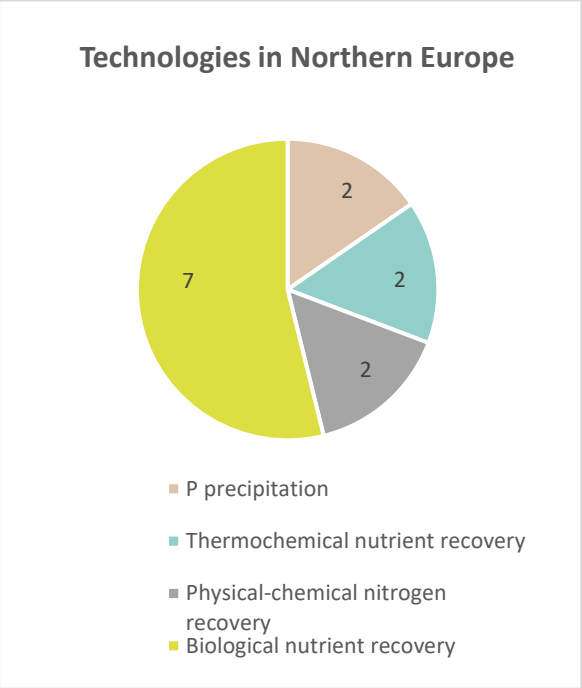

Figure 6. Types of technologies in Northern Europe

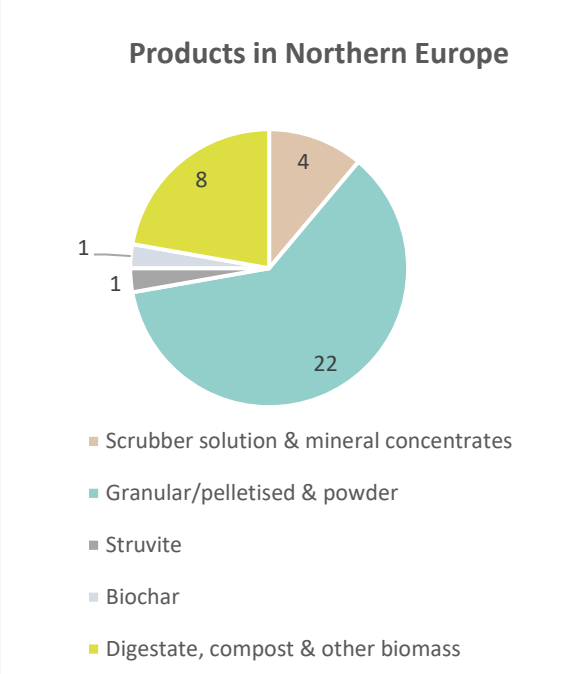

Figure 7. Types of products in Northern Europe

There are a wide range of nutrient recovery technologies and derived products available on the market across Northern Europe. The most common are: Drying & pelletising, composting, air scrubbing and P precipitation with TRL varying from 6-8.

1- Drying, mixing, pelletising and granulation of raw materials such as chicken/horse **manure**, **biowaste** such as seaweed, vinasse powder or potato starch, or **biological by-products** such as feather meal, meat and bone meal, or blood meal, mixing them with potassium sulphate, kieserite, or apatite. Each time a specific combination of ingredients to produce the alternative fertilizer is used. E.g. in Finland the following products are produced and available on the market and are manufactured for use in various land use applications: i) Biolan Ravinnepuikko is a high Dry Matter (DM) % granulated product that serves as a unique source of nitrogen (N), phosphorus (P), potassium (K), and sulphur (S).ii) Biolan Hevonkakkalannoite and Biolan kanankakka are granulated products that serves as sources of N, P, and K, but with different input

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

sources, iii) Biolon Havu-ja rodolannoite is a high DM% powder product that is a predominant source of N and K, with lower concentrations of P and S, iv) Biolan Marja-ja hedelmalannoite, and Biolan Peruna – ja juureslannoite are granulated products that serve as predominant sources of K with lower concentrations of N, P, and S, v) The Arvo series of fertilisers, including Arvo 11-1-2-1, Arvo 3-1-7-3, Arvo 3-1-15-5, Arvo 4-1-3-1, Arvo 4-1-6-2, Arvo 8-1-2-1 and Arvo 8-1-5-2, are granulated products with varying concentrations of N, P, K and S using chicken manure as a primary ingredient, with additional ingredients such as blood meal and potassium sulphate to add specific nutrient content.

2- Composting is a popular technology in Northern Europe E.g., i) in Ireland a TRL 9 processing plant is composting and pelletising **poultry manure**, processing it into a high DM% pelletised product which is a good source of N, P & K and can be easily transported and applied to land. This processing plant has also scope to produce a product for use in an organic system; ii) Composting of **household bio-waste** is carried out in Finland to produce a solid material known as bio compost which is a source of N, P, K and S; iii) the mushroom industry in Ireland also produces a biological by product known as spent mushroom compost. This product is used for mushroom production and is a mixture of **chopped wheaten straw, poultry manure, horse manure,** and **gypsum**. Once the mushroom compost leaves the facility as a by-product it is known as spent mushroom compost, which is a fine/crumbly mass material that is a source of N, P, K and S (Walsh, Grogan, Kelleger, Plunkett, & Lalor, 2013). Nutrient content in spent mushroom compost varies from different DM % and storage facilities.

3- Another common technology found in In Finland is gas scrubbing. The common practice is to convert ammonia gas that is released during **chicken manure** composting into a liquid form using lactic acid, potassium sulphate, and water. This technology produces products which are available on the market in Finland. These products are liquid fertilisers and are a predominant source of N and K, and in some cases S.

4- Precipitation of P by cations is a common technology used by milk processing plants in Ireland to recover P from **wastewater** produced from milk processing. The product from this recovery stream is a semi-desiccated sludge which is a predominant source of P and is spread on grassland and arable land. Recovering phosphorus and ammonium sulphate from waste water into easily transported forms such as struvite or pellets is also an increasing technology in Ireland and will be a significant source of nutrients to reduce the reliance on imported fertilisers in the near future.

5- Anaerobic digestion is also widely used across Northern Europe with a variety of different feedstock's being used within this process. In the South of Ireland organic

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

material from all sectors is used in anaerobic digestion to produce a by-product called digestate, a semi desiccated material which is applied on local land for crop production.

Refer to

Table 2 Technologies & products in Northern Europbelow for more information on the nutrient recovery technologies and products throughout Northern Europe.

Table 2 Technologies & products in Northern Europe

Technology	Country	*TRL*	Sources	Fertilising product	Nutrients[1] Nutrients ()[2]	Type	Other characteristics
Drying, mixing, pelletizing and granulation (Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletised and granulated)	Finland	9	Chicken manure, seaweed, potato starch	Biolan Ravinnepuikko	N, P, K, S	Granulated	High DM%
			Horse manure, feather meal, potassium sulphate	Biolan Hevonkakkalannoite	N, P, K	Granulated	High DM%
			Feather meal, meat and bone meal, potassium sulphate, vinasse powder	Biolan Havu- ja rodolannoite	N, P & K	Powder	High DM%
			Chicken manure, seaweed	Biolan Kanankakka	N, P & K	Granulated	High DM%
				Biolan Luonnonlannoite	N, P & K	Granulated	High DM%
			Meat and bone meal, potassium sulphate, kieserite, blood meal, seaweed	Biolan Parvekekasvilannoite	K & S (N & P)	Powder	High DM%
				Biolan Tomaatti- ja vihanneslannoite	K & S (N & P)	Powder	High DM%
			Meat and bone meal, blood meal,	Biolan Yrtti- ja taimilannoite	N & K (P & S)	Powder	High DM%

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

			potassium sulphate				
			Chicken manure, potassium sulphate	Biolan Kasvimaalannoite	K (N, P & S)	Granulated	High DM%
				Biolan Peruna- ja juureslannoite	K (N, P & S)	Granulated	High DM%
			Chicken manure, apatite, feather meal, potassium sulphate	Biolan Marja- ja hedelmälannoite	K (N, P & S)	Granulated	High DM%
			Chicken manure, blood meal, potassium sulphate	Arvo 11-1-2-1	N (P,K & S)	Granulated	High DM%
				Arvo 8-1-5-2	N & K (P &S)	Granulated	High DM%
			Chicken manure, potassium sulphate	Arvo 3-1-7-3	K (N, P & S)	Granulated	High DM%
				Arvo 3-1-15-5	K (N, P & S)	Granulated	High DM%
				Arvo 4-1-6-2	N & K (P & S)	Granulated	High DM%
			Chicken manure	Arvo 4-1-3-1	N & K (P & S)	Granulated	High DM%
			Chicken manure, blood meal	Arvo 8-1-2-1	N		
Gas scrubber (In the production of the fertiliser, the ammonia gas released during composting has been used by turning it into a liquid form with the help of lactic acid)	Finland	9	Ammonia from chicken manure composting, lactic acid, potassium sulphate, water potassium sorbate	Novarbo Aino 3-0-3	N & K	Liquid	Suitable for use in organic production.
				Novarbo Aino 1-0-3	N & K	Liquid	
				Novarbo Aino 5-0-0	N	Liquid	
			Ammonia from chicken manure composting, lactic acid, water,	Biolan Ravinneneste	N, K & S	Liquid	

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

			potassium sulphate, potassium sorbate, seaweed				
Precipitation of P by cations	Ireland	6	Wastewater from dairy processing plant	Dissolved air flotation sludge	P	Semi-desiccated material	
				Activated sludge	N & P	Semi-desiccated material	
Mechanical separation	Ireland	6	Cattle manure	Liquid and solid fraction of cattle manure	K (N, P & S)	Liquid and solid	
Composting	Ireland	6	Chopped wheaten straw, poultry manure, horse manure & gypsum	Spent mushroom compost	K (N & P)	Fine/crumbly mass material	
	Finland	9	Household bio-waste	Bio compost	N, P , K & S	Solid	
Small scale layers unit	Ireland	5	Manure	Poultry manure	N, P, K & S	Fine crumbly bulk material	
Drying, heating, cooling, pelletising, sieving and bagging	Ireland	9	Broiler manure, seaweed, Bone meal & blood meal	Dynamo	N, P, K (S)	Pelleted	High DM%
				PK plus	P & K (N & S)	Pelleted	High DM%
Anaerobic digestion	Ireland	9	Organic material & agricultural by-products from all sectors	Digestate & sometimes refined further into forms such as ammonium sulphate pellets	N, P & K	Semi desiccated material & often further refined into granules/pellets/liquid	
Grass bio-refinery	Ireland	6	Grass	Grass whey	N, P & K	liquid	Comparable to cattle slurry
Drying & granulating	Ireland	N/A	Industrial waste water	Pellets	N & S	Pelleted	
Ostara's Pearl phosphorus recovery	Ireland	7	Urban waste water	Struvite	P	Struvite	
Pyrolysis	Ireland	6	Rushes, bracken, hazel, furze	Biochar	N/A	Charcoal like substance	Can be added to other biomass such as manure, crop residues to improve the soils carbon store

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Ash2Phos process	Sweden	8	N/A	Sewage sludge	N/A	Granulated	Can also be used for animal feed

Key:
Nutrients[1] - Predominant source of nutrients
Nutrients ()[2] – Low concentrate of nutrients
N – Nitrogen
P – Phosphorus
K – Potassium
S – Sulphur
N/A – No answer

Raw data from the template created by Teagasc on nutrient recovery technologies and products throughout Northern Europe can be found in Annex 1.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

3.2 Southern Europe (Spain and Croatia)

The pre-identified waste sources for Southern Europe were: Bio-waste, animal manure, digestates and predominantly wastewater and sewage sludge. After the screening in task 1.1, these sources were still identified as the most common to recover nutrients within this region. The graphs below represents the number and most common nutrient recovery technologies (Fig. 8) and product (Fig. 9) derived from the technologies in Southern Europe.

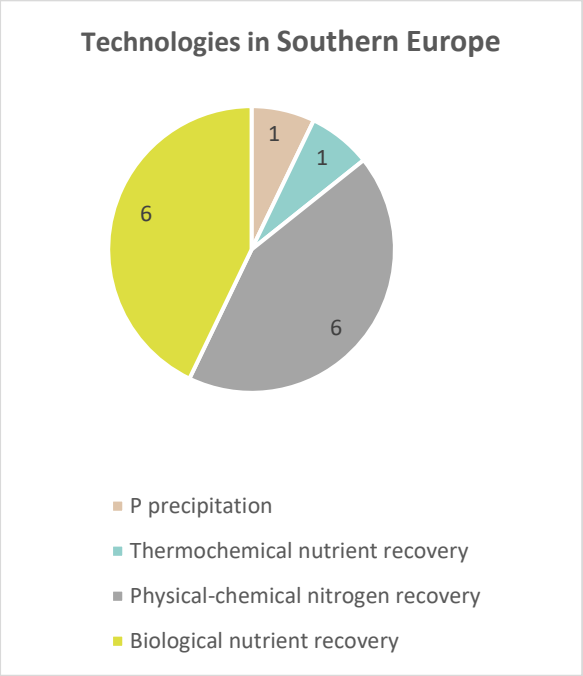

Figure 8. Types of technologies in Southern Europe

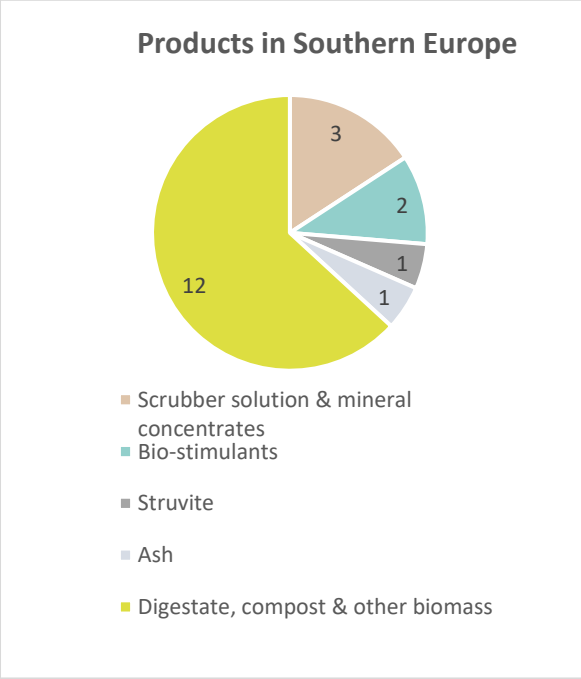

Figure 9. Types of products in Southern Europe

There are several nutrient recovery technologies available in regions across Southern Europe.

1. Anaerobic digestion is also commonly found in Croatia where the byproduct digestate is further refined into pellets which is a product that is a source of P and K. The product has a high TRL of 9, indicating that it has been fully demonstrated and tested in its intended environment.
2. Wastewater treatment In Spain (Andalusia region, Salteras municipality), the sequencing batch reactor (SBR) and nutrients recovery module produce an **enriched reclaimed water** that is a liquid fertilising product and a predominant source of N. The product also has a TRL of 9.There are two technologies for nutrient recovery from **sludge** by-product resulting from wastewater treatment via SBR from the **slaughtering industry** in Spain (Andalusia region, Salteras municipality). One technology is the fermentation process using Bacillus sp., which produces a liquid bio stimulant based on

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

hydrolysed sludge and is a predominant source of N. The product has a TRL of 6. The other technology is AlgaeBioGas (ABG) technology, which produces a liquid bio stimulant based on algal biomass and is a predominant source of N. Likewise, this technology is also at TRL 6. Technologies for nutrient recovery from **urban waste water** is common in the Andalusia region, Algarrobo municipality. One technology produces an enriched reclaimed water that is a liquid fertiliser product containing a source of N, P, and K with a TRL of 6. The second technology integrates different technologies for N and P recovery, such as struvite, ammonium nitrate, and sludge, in the Murcia Este waste water treatment plant. The technology produces a liquid product that is a potential source of N recovery up to 11% and P recovery up to 42% of input material. The product has a TRL of 6 and is located in the Murcia region, which borders Andalusia to the East. There are also two technologies located in the Andalusia region, America municipality that recovers nutrients from wastewater-based algae bio-refinery (WWAB) and High Rate Algae Pond system (HRAP). The WWAB technology produces a microalgae hydrolysate that is a source of nutrients. The HRAP system produces a product which is a predominant source of P from **urban wastewater**. Both technologies are at a TRL of 5 and 6, respectively.

3. Within Spain, there are four pilot technologies for nutrient recovery from **solid pig slurry fraction**, **poultry manure**, **solid fraction of fish sludge** from Recirculating Aquaculture System (RAS), and **solid fraction of fish sludge** collected in wastewater treatment plants (WWTP) in the fish industry. The bio drying technology produces a solid fertilising product that is a predominant source of K and S (for **solid pig slurry fraction**) and N (**for poultry manure** and **solid fraction of fish sludge** from RAS and WWTP.
4. Combustion technology produces an ash fertilising product that is a predominant source of P and K from **pig slurry** and **bio dried solid fractions**.
5. Membrane systems technology produces a liquid fertilising product from the liquid fraction of **pig slurry** that is a source of N, P, and K. Finally, a membrane contractor technology produces a liquid fertilising product that is a predominant source of N from the **solid fraction of pig slurry**.
6. In Italy two composting technologies produces granulated products **from green waste**, **digested mixed waste and food waste**. The products have a nutrient source of N, P, and K and are at a TRL of 9.

Below Table 3 Technologies & products in Southern Europe represents more detailed information on technologies and products that were collected in regions across Southern Europe.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Table 3 Technologies & products in Southern Europe

Technology	Country	*TRL*	Sources	Fertilising product	Nutrients[1] Nutrients ()[2]	Type	Other characteristics
Anaerobic digestion	Croatia	*9*	Digestate	Organic-mineral	P & K	Pelletised	
Sequencing batch reactor (SBR) + nutrients recovery module	Spain (Andalusia region, Salteras municipality**)**	*9*	Wastewater from the slaughtering industry	Enriched reclaimed water	N	Liquid	
Fermentation process using Bacillus sp. AlgaeBioGas (ABG) technology, (validated in the frame of Eco-innovation pilot and market replication project AlgaeBioGas	Spain (Andalusia region, Salteras municipality**)**	*6*	Sludge by-product resulting from wastewater treatment (via an SBR) from the slaughtering industry	Bio stimulant based on hydrolysed sludge	N	Liquid	
				Bio stimulant based on algal biomass	N		
Waste water treatment	Spain (Andalusia region, Algarrobo municipality)	*6*	Urban waste water	Enriched reclaimed water	N, P & K	Liquid	
Different technologies for N & P recovery are integrated in the existing Murcia Este WWTP.	Spain (Murcia region - borders Andalusia to the East - , Murcia municipality)	*6*	Urban waste water	Struvite, ammonium nitrate and sludge	N & P	Liquid & granular	N recovery up to 11% and P recovery up to 42% of input material
Wastewater-based algae bio-refinery (WWAB).	Spain (Andalusia region, Almeria municipality)	*5*	Wastewater (sewage, centrate and pig manure) + marine water	Microalgae hydrolysate	N/A	N/A	
Wastewater is treated by a 3000 m2 High Rate Algae Pond (HRAP) system.	Spain (Andalusia region, Almeria municipality)	*6*	Urban wastewater	N/A	P	N/A	
Thermal pre-treatment and anaerobic co-digestion	Spain (Andalusia region, Almeria municipality)	*6*	Urban wastewater	N/A	N/A		
Bio drying	Spain	*Pilot*	Solid pig slurry fraction	Bio dried solid fraction	K & S	Solid	
			Poultry manure	Bio dried solid fraction	N	Solid	
	Spain (Mediterranean case study)	*Pilot*	Solid fraction of fish sludge from RAS	Bio dried solid fraction	N & P	Solid	

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Spain (Fresh aquaculture case study)	*Pilot*	Solid fraction of fish sludge collected in WWTP in fish transformation industry	Bio dried solid fraction	N	Solid	
Membrane systems (Microfiltration coupled to Reverse Osmosis and freeze concentration)	Spain	*Pilot*	Liquid fraction of pig slurry	Nutrient-rich concentrate	N, P & K	Liquid	
	Spain (Mediterranean case study)	*Bench/lab*	Liquid fraction of Fish sludge from RAS	Nutrient-rich concentrate	N/A	Liquid	Low concentrations of nutrients
Combustion	Spain	*Pilot*	Pig slurry, bio dried solid fraction	Ash	P & K	Fine milled	
Membrane contractor	Spain	*Pilot*	Pig slurry, solid fraction	Ammonium salts	N	N/A	
ACEA pinerolese	Italy	*9*	Green waste and digested mixed waste	Compost	N, P & K	Granulated	
Biociclo	Italy	*9*	Green waste and food waste	Compost	N, P & K	Granulated	

Key:
Nutrients [1] - Predominant source of nutrients
Nutrients ()[2] – Low concentrate of nutrients
N – Nitrogen
P – Phosphorus
K – Potassium
S – Sulphur
N/A – No answer

A more detailed description of the products and technologies can be found in Annex 2.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

3.3 Eastern Europe (Poland)

The pre-identified waste sources for Eastern Europe were: Animal manure, digestates and sludge. After the screening in task 1.1, these sources were still identified as the most common to recover nutrients along with other biological by-products from the agricultural industry. The graph below (fig 10) represents the number of most commonly found nutrient recovery technologies and product (Fig. 11) derived from the technologies in Eastern Europe.

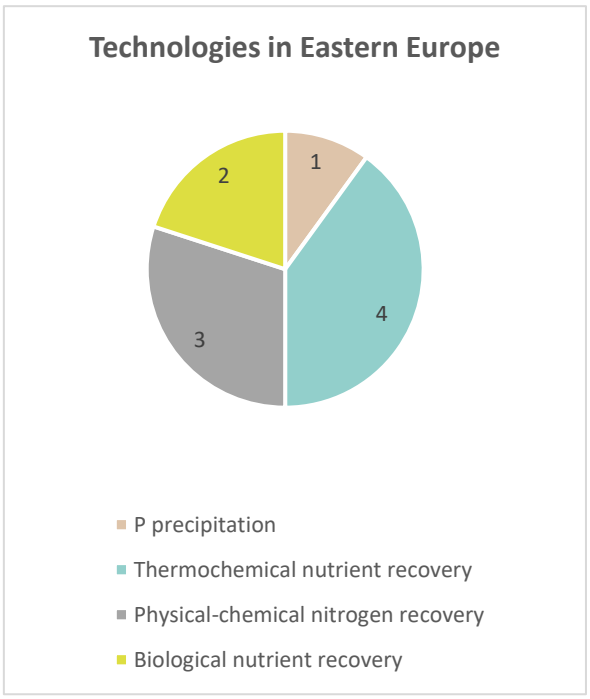

Figure 9. Types of technologies in Eastern Europe

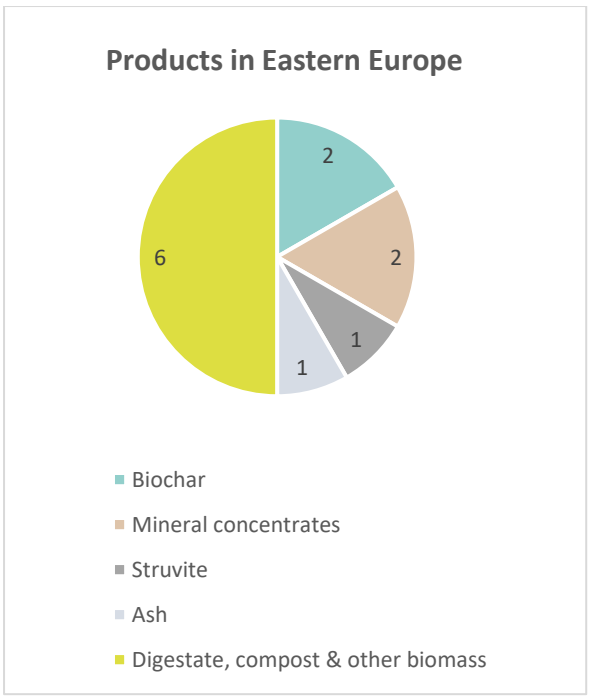

Figure 10 . Types of products in Eastern Europe

Below the nutrient recovery technologies and derived products along with identifying the feedstock is further explained.

1. PolFerAsh is a technology that used industrial **sewage sludge** to produce Monommonium Phosphate (MAP) that is a solid material with a pH of 5. The technology is at TRL 9 in Poland.
2. Another technology that has reached TRL 9 in Poland is FuelCAI® which uses **sewage sludge, biodegradable waste, and selected animal by products** to produce organo-mineral fertiliser, which is a powder product that has a high pH of 12.6 and is suitable for acidic soil.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

3. **Chicken manure** is used in two different technologies – composting and air drying – to produce organic fertilisers that are granulated products and a predominant source of N & K. This technology is also considered to be at TRL 9 in Poland.
4. Manure heating-dispersing technology is used with **cattle manure** to produce liquid fertilisers like AGROLINIJA-S, which is a liquid product with low concentrations of N, P & K, and has reached TRL 9 in Poland.
5. Incineration is also used in Poland to produce P as an ash product from the processing of **bones and fish bones**.
6. Pyrolysis technology in Hungary uses **food grade animal bone** to produce Bio-phosphate, which is a granulated product with a high source of calcium and biochar is also produced from **wood chip** following a Pyrolysis process.

Table 4 Technologies & products in Eastern Europe below provides additional information on nutrient recovery technologies and derived products that is being used or being developed in Eastern Europe. These products are being derived from various sources such as **sewage sludge, animal waste, biomass combustion, food grade animal bone, and wood chips**.

Table 4 Technologies & products in Eastern Europe

Technology	Country	*TRL*	Sources	Fertilising product	Nutrients[1] Nutrients()[2]	Type	Other characteristics
PolFerAsh - Polish Fertilizers form Ash	Poland	*9*	Industrial sewage sludge	Monoammonium phosphate (MAP)	N & P	Pulp, solid, material	pH 5
Stage I A technology for the production of potassium sulfate (IV) was developed Stage II Potassium thiosulfate was produced from potassium (IV) sulfate and sulphur from the Claus desulfurization process.	Poland	*9*	Sulphur dioxide from the installation for the production of sulphuric acid	Potassium thiosulfate	K	Liquid	
FuelCAl®	Poland	*9*	Sewage sludge, biodegradable waste, selected animal by-products	Organo-mineral fertilizer OrCal®	N, P & K	Powder	pH 12.6 suitable for acidic soil

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Composting and air drying	Poland	*9*	Chicken manure	BIOPOWER - organic fertiliser	P & K	Granulated	
				ROLPOWER - organic fertiliser	P & K	Granulated	
Wastewater Treatment	Poland	*9*	Sewage sludge	Granbial - organic fertiliser	N & K	Granulated	
Bioral technology	Poland	*9*	Sewage sludge, ashes from biomass combustion	BIOROL Natural Fertiliser	P & K	Granulated	
Manure heating-dispersing technology	Poland	*9*	Cattle manure	AGROLINIJA-S	Low concentrations of N, P & K	Liquid	
Incineration	Poland	*N/A*	Ashes from incinerated dried sludge from sewage treatment plants and products resulting from the processing of bones and fish bones	N/A	P	Ash	High source of P
N/A	Poland	*N/A*	Sewage sludge	Fertiliser from sewage sludge with the addition of dusty mineral materials	N/A	Granulated	
Pyrolysis	Hungary	*8*	Food grade animal bone	Bio-phosphate	N/A	Granulated	High source of calcium, application 0.2-2.5T/Ha, preformed in field trials in five different countries
			Wood chip	Biochar	N & P	Granulated	low concentrates of N & P, suitable for low input organic system

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Key:
Nutrients [1] - Predominant source of nutrients
Nutrients ()[2] – Low concentrate of nutrients
N – Nitrogen
P – Phosphorus
K – Potassium
S – Sulphur
N/A – No answer

Refer to Annex 3 for more detailed information on the above list of nutrient recovery technologies and derived products in Eastern Europe.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

3.4 Western Europe (Flanders, Belgium)

The pre-identified waste sources for Eastern Europe were: Animal manure and digestates. After the screening in task 1.1, these sources were still identified as the most common to recover nutrients along with bio-waste from the food industry. The graph below represents the types and number of technologies (Fig.12) most commonly found and product (Fig. 13) derived from the technologies in Western Europe.

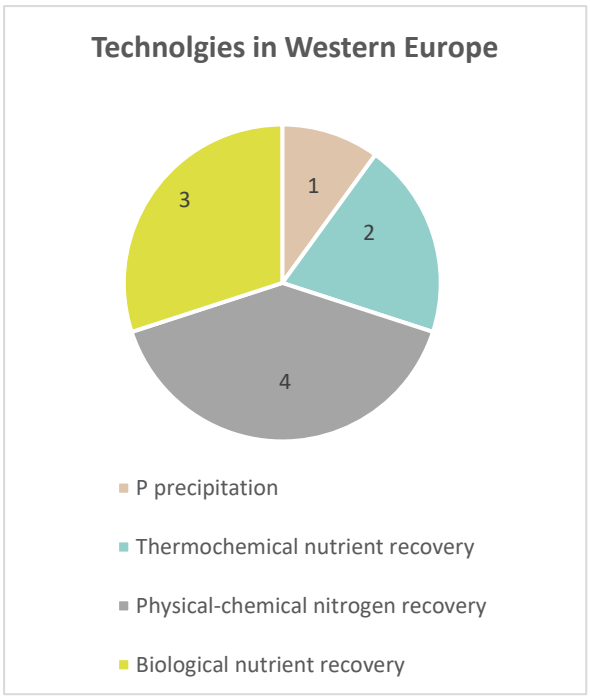

Figure 11. Types of technologies in Western Europe

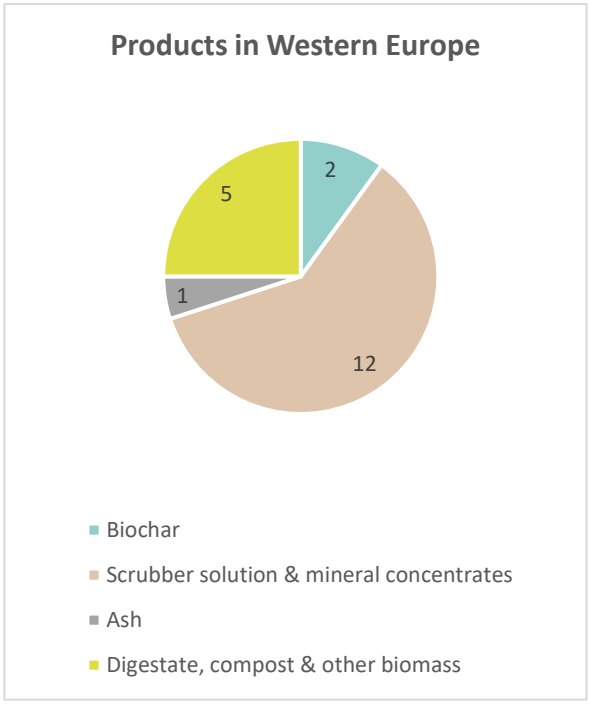

Figure 12. Types of products in Western Europe

There are a range of nutrient recovery technologies and derived products in regions across Western Europe. Commonly found technologies within these regions include:

1. Stripping and scrubbing; the ammonia stripping-scrubbing approach is applied on a digestate liquid fraction rich in nitrogen (N). Scrubbing and stripping of ammonia are performed in a closed system, so emissions are generally low. This method is now used in livestock operations to recover N from waste streams such as animal manure, digestate, and their liquid fraction. The operation of (stripping-)scrubbing is that ammonia (NH3) can be stripped by air, steam, or vacuum through an N-rich waste stream in an NH3 stripping reactor, resulting in NH3 transfer from the aqueous phase to the gas phase. The ammonia-saturated stripping gas is then brought into contact with an acidic solution (often sulfuric acid, H2SO4). Ammonium sulphate solution is generated when sulfuric acid is used for capturing ammonia. Optionally, nitric acid

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

(HNO3) can be used to capture ammonia, resulting in ammonium nitrate, which is more interesting for fertilising.

2. On-farm scrubbing; the product is a liquid fertiliser in the form of an ammonium sulphate solution collected from the air from pig stable using an on-farm scrubbing procedure. The NH3 emission from the pig stables is recovered by on-farm scrubbing with sulphuric acid. This approach minimizes GHG emissions from pig farms and helps to make agriculture more sustainable. Because ammonium sulphate contains more N than animal manure, a less amount is required for agricultural use.
3. P precipitation; This approach recovers soluble phosphate from manure or digestate by adding chemical solutions containing multivalent metal ions such as calcium, magnesium, and iron, etc
4. Pyrolysis. The pyrolysis product biochar has more significant P and K contents than the original manure or substrate. As a result, they're used as slow-release fertiliser to improve soil fertility and crop yields.
5. Separation; to mechanically separate the raw digestate into its liquid and solid forms. The screw press, centrifuge (decanter), and belt filter press are the most commonly used techniques. The phase separation produces a solid fraction (SF) rich in P and a liquid fraction (LF) rich in N and K. The SF has a high phosphorus and organic fraction content, which is beneficial to soil characteristics and humus development. It can then be dried, composted, granulated, or apply directly to the field as a soil amendment. With high levels of plant-available N and K, the LF is more suitable as a fertilizer applied by soil mixing (slurry cultivator), mechanical injection, drag hoses, or surface dressing.
6. Chemical nitrogen recovery; It uses sulphuric acid to reduce the pH since it is the most concentrated and efficient acid to lower the pH. When the slurry enters the soil, the ammonia is converted to ammonium and becomes readily available to the plants.

The raw input materials used by these technologies include, **digested cattle and pig slurry, poultry manure, raw solid and liquid fractions of animal manure and bio-waste** from the agro-food industry. The resulting products vary form and nutrient content, with some being liquid or semi-desiccated and providing a predominant source of N, P, or K, while others are fine or dried solids with a combination of P, K, and S. These technologies are being used and adapted across Western Europe in regions such as the Netherlands, Belgium, and France. A number of available technologies and products are listed from regions in Western Europe below in Table 5 Technologies & products in Western Europe

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Table 5 Technologies & products in Western Europe

Technology	Country	*TRL*	Sources	Fertilising product	Nutrients[1] Nutrients()[2]	Type	Other characteristics
Stripping & scrubbing	Netherlands	*Pilot*	Digested cattle slurry	Ammonium sulphate solution	N & S	Liquid	
				Potassium fertiliser	K	Liquid	
	Belgium	*Pilot*	Liquid fraction of pig slurry	Ammonium nitrate	N	Liquid	
	France	*Pilot*	Pig manure	Ammonium sulphate	N & S	Liquid	
	France	*Pilot*	Exhaust pig slurry (pig slurry after N stripping)	K fertiliser	K	Liquid	
	Netherlands	*9*	Digestate, liquid fraction, pre-treated manure	Ammonium nitrate/sulphate	K	Liquid	
	Belgium	*9*	Digestate or manure slurries	Ammonium sulphate	N & S	Liquid	
On-farm scrubbing	Belgium	*9*	Pig manure	Ammonium sulphate (recovered from NH3 emissions)	N	N/A	
P precipitation	Netherlands	*Pilot*	Digested cattle slurry	Wet organic phosphorus rich fertiliser	P	Liquid	
Pyrolysis	France	*Pilot*	Poultry manure	Biochar	K	Fine dry material	High DM%
			Solid fraction of digestate	Biochar	K	Fine dry material	High DM%
Separation	Belgium	*7*	Liquid fraction of digestate	N/A	N/A	Liquid	pH of 7.5 – 8.5
Thermochemical nutrient recovery	Netherlands	*9*	Poultry manure	Ash	P, K & S	Ash	
Composting	Netherlands	*9*	Mix of composted poultry manure and composted pig manure	Organic fertiliser +2:2	P	Semi-desiccated material	

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	France	*N/A*	Cattle manure (local composting process under aerobic conditions)	Compost	N, P & K	N/A
Physical chemical nitrogen recovery (VeDoWS adapted stable construction system)	Belgium	*9*	Raw pig manure	Urine from pig manure	K	Liquid
Reverse osmosis, evaporation	Netherlands	*9*	Raw pig manure	Mineral nitrogen concentrates	N	Liquid
	Belgium	*9*	Bio-waste from agro food industry	Evaporator concentrate, dried solid fraction of digestate	N, P & K	Solid
Farm scale anaerobic digestion	Belgium	*7-9*	Cattle slurry	Digestate	K (N & P)	Semi desiccated product
			Pig slurry	Digestate	N, P & K	Semi desiccated product

Key:
Nutrients [1] - Predominant source of nutrients
Nutrients ()[2] – Low concentrate of nutrients
N – Nitrogen
P – Phosphorus
K – Potassium
S – Sulphur
N/A – No answer

For more detailed information on the above nutrient recovery technologies and products refer to Annex 4.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

4 Conclusion

In conclusion, the compilation of information on nutrient recovery technologies and products across Europe reveals a growing trend towards sustainable and efficient use of resources in the agricultural sector. This document highlights the diversity of nutrient recovery technologies available, which can help extract valuable nutrients from different side streams (fig 14) and reuse them in crop production.

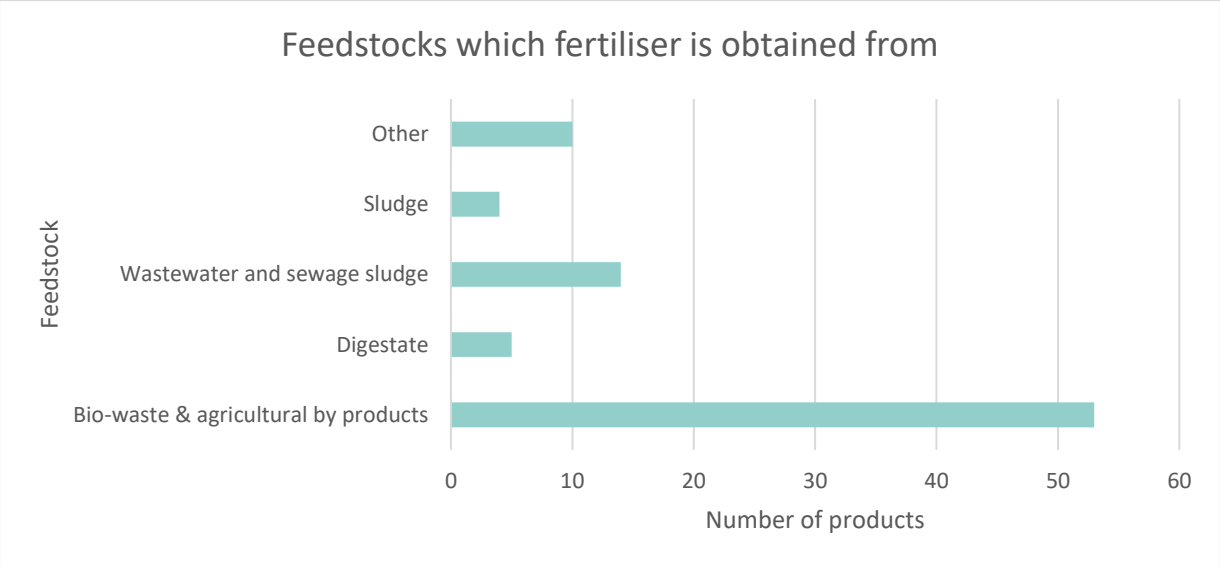

Figure 13 Most common feedstock's available in Europe

The technologies discussed vary in complexity, availability and scalability, offering opportunities for different agricultural operations to adopt nutrient recovery practices. Assessing the European wide distribution of technologies and products a total of 47 technologies and 86 alternative fertilising products was located across Europe including technologies such as composting, anaerobic digestion, P precipitation, thermochemical nutrient recovery and physical chemical nitrogen recovery ranging with a TRL from 5 up to 9. From analysing the above information it is clear that drying, mixing, pelletising and granulating raw materials from waste streams such as bio-waste, digestate and manure is a common technology used to produce nutrient rich products in Finland. When comparing this to other regions in Northern Europe this type of technology is not as well adapted. Recovering nutrients from raw materials through the use of gas scrubbers is also a well-adapted technology in Finland. A variety of nutrient recovery technologies are available in Ireland, predominately at pilot scale with some industrial scale anaerobic digesters, composting facilities and waste water treatment plants. In addition, across the four European regions certain technologies are more popular in certain regions. Anaerobic digestion, stripping and scrubbing, composting and pyrolysis are more commonly found in regions across Western Europe. Likewise, in Eastern Europe composting and pyrolysis were also common with Incineration.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Overall, the findings suggest that nutrient recovery technologies and products that are available have a promising role to play in creating a more sustainable and circular agricultural system across Europe.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Bibliography

Hackett, R. (2015). Spent mushroom compost as a nitrogen source for. *Nutrient cycle Agrosystem*, 253-263.

Jordan, S., Mullen, G., & Murphy, M. (2008). Compopsition variability of spent mushroom compost in Ireland. *Bioresource technology, 99*(2), 411-418.

Leong, Y. k., Ma, W. T., Chang, S. J., & Yang, F. C. (2022). Recent advances and future directions on the valorization of spent mushroom substrate (SMS): A review. *Bioresource technology, 344*.

Natural resources institute Finland. (n.d.). *Database for research results*. Retrieved from https://px.luke.fi/PxWeb/pxweb/en/maatalous/

Pace, M. G., Miller, E. B., & Farrell-Poe, K. L. (1995). The composting process. *UtahState UNIVERSITY EXTENSION*.

United Nations statistics division. (1999). *Statistics division methodology*. Retrieved from United Nations: https://unstats.un.org/unsd/methodology/m49/

Velusami, B., Jordan, S., Curran, T., & Grogan, H. (2022). Fertiliser characteristics of stored spent mushroom substrate as a sustainable source of nutrients and organic matter for tillage, grassland and agricultural soils. *Irish journal of agricultural and food research*, 1-11.

Walsh, G., Grogan, H., Kelleger, T., Plunkett, M., & Lalor, S. (2013). *Spent mushroom compost - nutrient content for application to agricultural crops.* Teagasc.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Annex 1 – Raw data from technology & product template Northern Europe

1	Alternative fertilsing product	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Project	Source	Country	Humidity %	Dry matter %	Kg/tonne of DM											Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
											N %	P %	P2O5	K %	K20	S %	SO3	Organic carbon	pH	Form	Availibility estimate				
2	Biolan Ravinneneste	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, water, potassium sulphate, potassium sorbate	Finland	86	14	1	0		2		1			6,8	liquid	available	Liquid injection systems			www.biolan.fi
3	Biolan Ravinnepuikko	Drying, mixing, pelletizing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized				Chicken manure, seaweed, potato starch	Finland	10	90	4	1		2,7		0,6			6,5	granular	available	Fertilizer spreader			www.biolan.fi
4	Biolan Kanankakka	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, seaweed	Finland	10	90	4	1		2,7		0,6			6,5	granular	available	Fertilizer spreader			www.biolan.fi
5	Biolan Luonnonlannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, seaweed	Finland	10	90	4	1		2,7		0,6			6,5	granular	available	Fertilizer spreader			www.biolan.fi
6	Biolan Hevonkakkalannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Horse manure, feather meal, potassium sulphate	Finland	10	90	3	1		4		2,6			5,1	granular	available	Fertilizer spreader			www.biolan.fi
7	Biolan Havu- ja rodolannoite	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Feather meal, meat and bone meal, potassium sulphate, vinasse powder	Finland	4	96	8,4	1,3		8,2		4,3			5,9	powder	available	Fertilizer spreader			www.biolan.fi
8	Biolan Parvekekasvilannoite	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Meat and bone meal, potassium sulphate, kiserite, blood meal, seaweed	Finland	4	96	6	2		9		7			6,2	powder	available	Fertilizer spreader			www.biolan.fi
9	Biolan Yrtti- ja taimilannoite	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Meat and bone meal, blood meal, potassium sulphate	Finland	3	97	9,4	2,7		4,7		2,2			6,1	powder	available	Fertilizer spreader			www.biolan.fi

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1	Alternative fertilsing product	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Project	Source	Country	Humidity %	Dry matter %	Kg/tonne of DM										Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
											N %	P %	P2O5	K %	K20	S %	SO3	Organic carbon	pH	Form	Availibility estimate				
10	Biolan Tomaatti- ja vihanneslann	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Meat and bone meal, potassium sulphate, kiserite, blood meal, seaweed	Finland	4	96	6	2		9		7			6,2	powder	available	Fertilizer spreader			www.biolan.fi
11	Biolan Kasvimaalannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3,8	1		6,2		2,2			6,4	granular	available	Fertilizer spreader			www.biolan.fi
12	Biolan Marja- ja hedelmälannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, apatite, feather meal, potasium sulphate	Finland	10	90	5	3		7		3			6,6	granular	available	Fertilizer spreader			www.biolan.fi
13	Biolan Peruna- ja juureslannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3	1		7		2			6,5	granular	available	Fertilizer spreader			www.biolan.fi
14	Arvo 11-1-2-1	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, blood meal, potassium sulphate	Finland	10	90	11	1		2		1			6,6	granular	available	Fertilizer spreader			www.novarbo.fi
15	Arvo 3-1-7-3	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3	1		7		2			6,5	granular	available	Fertilizer spreader			www.novarbo.fi
16	Arvo 3-1-15-5	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3	1		15		5			6,4	granular	available	Fertilizer spreader			www.novarbo.fi

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1	Alternative fertilsing product	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Project	Source	Country	Humidity %	Dry matter %	Kg/tonne of DM										Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
											N %	P %	P2O5	K %	K20	S %	SO3	Organic carbon	pH	Form	Availibility estimate				
17	Arvo 4-1-3-1	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure	Finland	10	90	4	1		3		1			6,5	granular	available	Fertilizer spreader			www.novarbo.fi
18	Arvo 4-1-6-2	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3,8	1		6,2		2,2			6,4	granular	available	Fertilizer spreader			www.novarbo.fi
19	Arvo 8-1-2-1	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, blood meal	Finland	10	90	8,1	0,9		1,9		0,6			6,4	granular	available	Fertilizer spreader			www.novarbo.fi
20	Arvo 8-1-5-2	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, blood meal, potassium sulphate	Finland	10	90	7,8	0,7		5		1,9			6,6	granular	available	Fertilizer spreader			www.novarbo.fi
21	Novarbo Aino 3-0-3	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, potassium sulphate, water potassium sorbate	Finland	90	10	3	0		3		1			6,0	Liquid	available	Liquid injection systems			www.novarbo.fi
22	Novarbo Aino 1-0-3	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, potassium sulphate, water potassium sorbate	Finland	90	10	1	0		3		1			5,4	Liquid	available	Liquid injection systems			www.novarbo.fi
23	Novarbo Aino 5-0-0	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, water, potassium	Finland	94	6	5	0		0		0			6,2	Liquid	available	Liquid injection systems			www.novarbo.fi

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1	Alternative fertilsing product	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Project	Source	Country	Humidity %	Dry matter %	Kg/tonne of DM										Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
											N %	P %	P2O5	K %	K20	S %	SO3	Organic carbon	pH	Form	Availibility estimate				
24	Biocompost	composting	Composting, followed by field composting for 2-8 months. Sieving the final product with a 12 mm sieve	10000 t/a	TRL 9		Household biowaste	Finland	37	63	24,4	8,9	20,4	16	19,3	5,1	12,7	32,6	8	Solid	continuously available	manure spreaders	carbon footprint	yes	
25	Mineral NPKS	Pelletizing	Physical mixing of set of raw materials which are subsequently pelletized	25-30 kt	Available on the market	Yara Eco ltd	MBM	Finland	8%	92%	10%	4%		1%		0,80%		37-40%	N/A	solid	available	Incorporation / broadcasting	N/A	Compatible with EU regulation 2018/848 for organic farming	
26	Biolan Ravinneneste	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, water, potassium sulphate, potassium sorbate	Finland	86	14	1	0		2		1			6,8	liquid	available	Liquid injection systems			www.biolan.fi
27	Biolan Ravinnepuikko	Drying, mixing, pelletizing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized				Chicken manure, seaweed, potato starch	Finland	10	90	4	1		2,7		0,6			6,5	granular	available	Fertilizer spreader			www.biolan.fi
28	Biolan Kanankakka	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, seaweed	Finland	10	90	4	1		2,7		0,6			6,5	granular	available	Fertilizer spreader			www.biolan.fi
29	Biolan Luonnonlannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, seaweed	Finland	10	90	4	1		2,7		0,6			6,5	granular	available	Fertilizer spreader			www.biolan.fi
30	Biolan Hevonkakkalannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Horse manure, feather meal, potassium sulphate	Finland	10	90	3	1		4		2,6			5,1	granular	available	Fertilizer spreader			www.biolan.fi
31	Biolan Havu- ja rodolannoite	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Feather meal, meat and bone meal, potassium sulphate, vinasse powder	Finland	4	96	8,4	1,3		8,2		4,3			5,9	powder	available	Fertilizer spreader			www.biolan.fi

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1	Alternative fertilsing product	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Project	Source	Country	Humidity %	Dry matter %	Kg/tonne of DM										Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
											N %	P %	P2O5	K %	K20	S %	SO3	Organic carbon	pH	Form	Availibility estimate				
32	Biolan Parvekekasvilannoite	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Meat and bone meal, potassium sulphate, kiserite, blood meal, seaweed	Finland	4	96	6	2		9		7			6,2	powder	available	Fertilizer spreader			www.biolan.fi
33	Biolan Yrtti- ja taimilannoite	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Meat and bone meal, blood meal, potassium sulphate	Finland	3	97	9,4	2,7		4,7		2,2			6,1	powder	available	Fertilizer spreader			www.biolan.fi
34	Biolan Tomaatti- ja vihanneslann	Mixing	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are mixed				Meat and bone meal, potassium sulphate, kiserite, blood meal, seaweed	Finland	4	96	6	2		9		7			6,2	powder	available	Fertilizer spreader			www.biolan.fi
35	Biolan Kasvimaalannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3,8	1		6,2		2,2			6,4	granular	available	Fertilizer spreader			www.biolan.fi
36	Biolan Marja- ja hedelmälannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, apatite, feather meal, potasium sulphate	Finland	10	90	5	3		7		3			6,6	granular	available	Fertilizer spreader			www.biolan.fi
37	Biolan Peruna- ja juureslannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3	1		7		2			6,5	granular	available	Fertilizer spreader			www.biolan.fi
38	Arvo 11-1-2-1	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, blood meal, potassium sulphate	Finland	10	90	11	1		2		1			6,6	granular	available	Fertilizer spreader			www.novarbo.fi
39	Arvo 3-1-7-3	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3	1		7		2			6,5	granular	available	Fertilizer spreader			www.novarbo.fi

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1	Alternative fertilsing product	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Project	Source	Country	Humidity %	Dry matter %	Kg/tonne of DM											Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
											N %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon	pH	Form	Availibility estimate				
40	Arvo 3-1-15-5	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3	1		15		5			6,4	granular	available	Fertilizer spreader			www.novarbo.fi
41	Biolan Kasvimaalannoite	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	4,6	0,733		11,27		3,5			6,48	granular	available	Fertilizer spreader			www.biolan.fi
42	Arvo 4-1-6-2	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, potassium sulphate	Finland	10	90	3,8	1		6,2		2,2			6,4	granular	available	Fertilizer spreader			www.novarbo.fi
43	Arvo 8-1-2-1	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, blood meal	Finland	10	90	8,1	0,9		1,9		0,6			6,4	granular	available	Fertilizer spreader			www.novarbo.fi
44	Arvo 8-1-5-2	Drying, mixing, pelletizing and granulation	Side streams that have to be treated according to the (EY) N:o 1069/2009 and (EU) 142/2011 are treated in the dryer, possible other raw materials are added and the mix is pelletized and granulated				Chicken manure, blood meal, potassium sulphate	Finland	10	90	7,8	0,7		5		1,9			6,6	granular	available	Fertilizer spreader			www.novarbo.fi
45	Novarbo Aino 3-0-3	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, potassium sulphate, water potassium sorbate	Finland	90	10	3	0		3		1			6,0	Liquid	available	Liquid injection systems			www.novarbo.fi
46	Novarbo Aino 1-0-3	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, potassium sulphate, water potassium sorbate	Finland	90	10	1	0		3		1			5,4	Liquid	available	Liquid injection systems			www.novarbo.fi

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1	Alternative fertilsing product	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Project	Source	Country	Humidity %	Dry matter %	Kg/tonne of DM											Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
											N %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon	pH	Form	Availibility estimate				
47	Novarbo Aino 5-0-0	Gas scrubber	NH_4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid				Ammonia from chicken manure composting, lactic acid, water, potassium	Finland	94	6	5	0		0		0			6,2	Liquid	available	Liquid injection systems			www.novarbo.fi

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Alternative fertilsing product	Technology	Processing conditions, effectiveness to convert crude material into safe and high quality	Processing capacity	Technology status (TRL)	CAPEX production costs	OPEX production costs	Legal status (regional/ national /EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availability estimate tonnes nationally	Kg/tonne fresh weight											pH	Organic carbon %	Form/state (liquid/pelletized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments inc. legal aspects - website
															N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3							
Dissolved Air Flotation Sludge (DAF)	Precipitation of P by cations			6					Nutri2Cycle	Wastewater from dairy processing	Ireland		23,8		5,3						23,8	54,4789	1,2	1,41300911	0,7	1,8311	6.8 to 7.7	26,3	Semi-dessicated/ clumpy	FYM spreader				
Activated Sludge	Precipitation of P by cations			6					Nutri2Cycle	Wastewater from dairy processing	Ireland		10,2		6,1						4,9	11,3342	1,6	1,9237825	0,6	1,5335	6.9 to 7	31,0	Semi-dessicated/ clumpy	FYM spreader				
Cattle Slurry				6					Nutri2Cycle	Cattle	Ireland		7.7 to 9.1		2.7 to 4.3						0.5 to 0.7	1,1455 to 1,6037	3.5 to 4	4,2175 to 4,82	0.4 to 0.5	1 to 1,25	6.8 to 7.7	32.3 to 37.8	Slurry	Liquid manure injection				
Lime Treated Pig Slurry				6					Nutri2Cycle	Piggery	Ireland		78,3		1,7						19,1	43,7421	77,3	93,1517297	8,2	20,388	12,6	56,3	Slurry	Liquid manure injection				
Crab Shell				N/A					Nutri2Cycle	Shellfish de la Mer, Castletownbere	Ireland		62,4		2.29% DO NOT KNOW IF VALUE REFERS TO FRESH WEIGHT OR DRY WEIGHT (note differen						10,9	24,9719	0,6	0,723	2,1	5,25	8,3	N/A	Milled crab shell					
Broiler Manure				6					Nutri2Cycle	Broilers	Ireland		45,3		20,4						5,1	11,7029	9,2	11,1037096	3,1	7,6714	6.5 to 8	164,1	Manure	FYM spreader				
Poultry Manure	Belt dryer facility			6					Nutri2Cycle	Poultry	Ireland		84,7		30,7						10,0	22,9571	17,4	20,9343394	6,0	15,035	7,7	310,9	Manure	FYM spreader				
Spent mushroom	Composting			6					Own resource		Ireland		N/A		3						7	16,037	30	36,15	N/A	N/A	Contains lime	N/A	Fine/crumbly mass material	FYM spreader				
Grass whey	Grass biorefinery			6					Own resource	Grass	Ireland		2-4%																Liquid injection system				
Sepearated cattle slurry	Seperators			6				Liquid & solid fractions	Own resource	Cattle manure	Ireland																		Liquid injection system & FYM spreader				
Pelletised broiler manure (Dynamo)	Drying, heating, cooling, pelletising, sieving and bagging		Disc drier - 6 T/hr , CPM pellet presses - 15 T/hr, Packaging - 30T/hr, Bagging - 17T/hr	9				Pelletised fertiliser	Own resource	Broiler manure	Ireland			425,000 T /year	40	N/A	N/A	N/A	N/A	N/A	15		25		6,1			41,8	Pelletised	Fertiliser spreader		Both		https://soilworx.ie/
Biochar	Pyrolysis			6				Biochar	own resource	Rushes, bracken, hazel, furze	Ireland																	Biochar	Lime spreader				
Digestate	Anaerobic digestion			9				Digestate	Own resource	Organic material from all sectors	Ireland																	Semi dessicated	FYM spreader				

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Annex 2 – Raw data from technology & product template Southern Europe

	MINIMUN INFO			TECHNOLOGY				PRODUCT																	
											Kg/tonne of DM														
2	Alternative fertilising product	Country	Project	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Source	Humidity %	Dry matter %	N (kg TN/t)	TP (kg TP/t)	P2O5 (%, db)	K (kg TK/t)	K2O (%, db)	S (kg S/t)	SO3	Organic carbon (kg C/t)	pH	Form	Availibility estimate	Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
3	Nutrient-rich concentrate	Spain	Fertimanure	Membrane systems (Microfiltration coupled to Reverse Osmosis and freeze concentration)	The reverse osmosis produces a nutrient-rich retentate which is further concentrated through a freeze concentration technology	1-2 t year	pilot	manure. Liquid fraction pig slurry	96,68	3,32	3,8	0,5	3,449	1,8	6,534	0,4		13*	7,7	liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 10. even though ABP end-point reached
4	Biodried solid fraction	Spain	Fertimanure	Biodrying	The solid fraction of pig slurry feeds the biodrying reactor, or trench, to remove part of the moisture contained in the stream and concentrate nutrients	6.5 - 8.5 t year	pilot	pig slurry, solid fraction	49,8	50,2	11,4	2,7	1,232	5	1,2	5,9		251*	7,1	solid	Available	Base fertilization in soil before crop sowing			Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 10. even though ABP end-point reached
5	Biodried solid fraction	Spain	Fertimanure	Biodrying	Poultry manure is treated in the biodrying reactor, to remove part of the moisture contained in the stream and concentrate nutrients	6.5 - 8.5 t year	pilot	Poltry manure	48,9	51,1	22	3,6	1,613	16,1	3,797	4,1		240*	8,6	solid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 10. even though ABP end-point reached
6	Phosphorous (ashes)	Spain	Fertimanure	Combustion	After the combustion of the biodried solid fraction in the boiler	0.6 - 1.5 t year	pilot	pig slurry, biodried solid fraction	0	100	-	66,4	15,206	56,2	6,773	10		-	11,9	solid	Available			Included in FERTIMANURE position paper increasing the scope of BBFs to be used in organic farming sector (currently data gathering towards the inclusion of the product in the positive list of EGTOP)	Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 13
7	Ammonium salts	Spain	Fertimanure	Membrane contactor	The liquid fraction of pig slurry is firstly treated through MF.. Then, the membrane contactor is fed with the permeate from the previous unit (MF) and ammonium sulphate solution is obtained as product	2 t year	pilot	pig slurry, solid fraction	95,32	4,68	19,97	<1		< 1		34,7		-	6,3	liquid	Available	Cover fertilisation			Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 15
8	biostimulants	Spain	Fertimanure	Enzymatic hydrolysis of microalgae	The permeate obtained from the membrane systems is used as growth media to cultivate microalgae, which are then enzymatically hydrolysed after harvesting to obtain biostimulants	0.16 t year	pilot	manure	96	4	5,12	<1		<1		-		-	7,9	Liquid	Available			Included in FERTIMANURE position paper increasing the scope of BBFs to be used in organic farming sector (currently data gathering towards the inclusion of the product in the positive list of EGTOP)	Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 1, ABP end-point needs to be reached
9	Ammonium sulphate solution	Netherlands	Fertimanure	stripping and scrubbing of the liquid fraction of digestate	The liquid fraction flows to the stripper where ammonia is stripped out to the gas phase and subsequently scrubbed with	40 t/y	pilot	digested cattle slurry	67,3	32,7	66	0,02	0,014	0,2	0,074	73		0,7	5,5	Liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 15
10	Liquid potassium fertiliser	Netherlands	Fertimanure	strippin and scrubbing	sulphuric acid into ammonium sulphate. Exhaust digestate is rich in potassium and identified as liquid potassium fertiliser	1,712 t/y	pilot	digested cattle slurry	95,9	4,1	3,1	0,4	2,234	5	14,696	0,4		14	8,3	Liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. CMC5, ABP end point needs to be reached
11	Organic soil conditioner	Netherlands	Fertimanure	solid liquid separation of digestate	solid fraction of the digestate	172 t/y	pilot	digested cattle slurry	72,9	27,1	6,5	2,3	1,944	4,9	2,179	1,7		126	8,5	solid	Available			Included in FERTIMANURE position paper increasing the scope of BBFs to be used in organic farming sector (currently data gathering towards the inclusion of the product in the positive list of EGTOP)	Cross check with FPR being made to identify CMC and FPC categories. CMC5, ABP end point needs to be reached

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	MINIMUN INFO			TECHNOLOGY				PRODUCT																
											Kg/tonne of DM													
2	Alternative fertilising product	Country	Project	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Source	Humidity %	Dry matter %	N (kg TN/t)	TP (kg TP/t)	P2O5 (%, db)	K (kg TK/t)	K2O (%, db)	S (kg S/t)	SO3	Organic carbon (kg C/t)	pH	Form	Availibility estimate	Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
12	Wet organic phosphorus rich fertiliser	Netherlands	Fertimanure	precipitation	The liquid fraction of digestate is pumped to a settling (reactor) tank to settle part of the remaining particles before it is treated in the stripper. The settling (reactor) tank operates in batches and a base can be added to raise the pH of its content in such way a part of the P in solution precipitates	9 t/y	pilot	digested cattle slurry	70,7	29,3	6,2	3,1	2,423	4,6	1,892	1,5		48	8,1	Liquid (slurry like)	Available				Cross check with FPR being made to identify CMC and FPC categories. CMC5, ABP end point needs to be reached
13	90% dried organic phosphorus rich fertiliser (calc.)	Netherlands	Fertimanure	drying	drying of the wet P fertilizer	1 t/y	pilot	digested cattle slurry	10	90	19	9,5	2,417	14	1,875	4,6		147	8	Solid	Available				Cross check with FPR being made to identify CMC and FPC categories. CMC5, ABP end point needs to be reached
14	Biochar	Germany	Fertimanure	Thermo Catalytic Reforming	Thermo-catalytic reforming of pelletised (and terated with citric acid) cattle dung	65 t/y	pilot	cattle dung	2	98	10,2	30,4	7,104	95	11,682	2,5		393	12,3	Solid	Available			Included in FERTIMANURE position paper increasing the scope of BBFs to be used in organic farming sector (currently data gathering towards the inclusion of the product in the positive list of EGTOP)	Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 14. End-point of ABP needs to be reached
15	Monoammonium phosphate	Germany	Fertimanure	MAP reactor	MAP Reactor filled with perlite for the adsorption of nitrogen in off gases of TCR	150 t/y	pilot	cattle dung	1	99	119	198	45,8	0	0	0		0	4,15	Solid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 15
16	Ammonium nitrate	Belgium	Fertimanure	stripping-scrubbing of liquid fraction of pig manure	After S/L separation, liquid fraction is treated in a stripping/scrubbing system to recover nitrogen from it. The exhaust	285 t/y	pilot	liquid fraction of pig slurry	60,92	39,08	153,1	0,06	0,035	0,55	0,17	0,37		0,12	6	Liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 15
17	Ammonium sulphate	Belgium	Fertimanure	stripping-scrubbing of liquid fraction of pig manure	material is treated then in a NDN system coupled with contructed wetland	285-85,300 t/y	pilot	liquid fraction of pig slurry	71,09	28,91	74,4	0,05	0,04	0,68	0,283	81,3		0,82	5,7	Liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 15
18	Ammonium water	Belgium	Fertimanure	stripping-scrubbing of liquid fraction of pig manure		724 t/y	pilot	liquid fraction of pig slurry			158,2	0,03		0,89		0,55		0,56	10,3	Liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 15
19	Biochar from poultry manure (700 °C)	France	Fertimanure	Slow pyrolysis of poultry manure	Slow pyrolysis of poultry manure. Mobile pilot plant	0.3-0.4 t/y	pilot	poultry manure (solid)	2,1	97,9	23,2	23,8	5,567	79,5	9,786	7,2		298	10,86	Solid	Available			Included in FERTIMANURE position paper increasing the scope of BBFs to be used in organic farming sector (currently data gathering towards the inclusion of the product in the positive list of EGTOP)	Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 14. End-point of ABP needs to be reached
20	Biochar from digestate (550 °C)	France	Fertimanure	Slow pyrolysis of solid fraction of digestate	After S/L separation. Slow pyrolysis of solid fraction of digestate. Pobile pilot plant	0.3-0.4 t/y	pilot	solid fraction of digestate	4,44	95,56	17,9	18,9	4,529	41,2	5,196	2,1		436.5	10,05	Solid	Available			Included in FERTIMANURE position paper increasing the scope of BBFs to be used in organic farming sector (currently data gathering towards the inclusion of the product in the positive list of EGTOP)	Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 14. End-point of ABP needs to be reached
21	Ammonium sulphate	France	Fertimanure	Stripping scrubbing of pig slurry	Striping-scrubbing system in mobile pilot plant	0.4-0.5 t/y	pilot	pig slurry	69,71	30,29	47,9	<1		<1		130,6		<1	4,5	Liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 15
22	K-fertiliser	France	Fertimanure	Stripping scrubbing of pig slurry (exhaust slurry)	Striping-scrubbing system in mobile pilot plant	1.5 t/y	pilot	pig slurry (after N stripping)	98,43	1,57	2,29	0,12	1,75	2,79	21,415	0,16		3	8,45	Liquid	Available				Cross check with FPR being made to identify CMC and FPC categories. CMC5, ABP end point needs to be reached

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	MINIMUN INFO			TECHNOLOGY				PRODUCT															
											Kg/tonne of DM												
2	Alternative fertilising product	Country	Project	Technology	Short description of technology (include link)	Processing capacity	Technology status (TRL)	Source	Humidity %	Dry matter %	N (kg TN/t)	TP (kg TP/t)	P2O5 (%, db)	K (kg TK/t)	K2O (%, db)	S (kg S/t)	SO3	Organic carbon (kg C/t)	pH	Form	Availibility estimate	Spreading method	LCA reference	Organic certified	Comments inc. legal aspects - website
23	Nutrient-rich concentrate	Spain (Mediterranean case study)	Sea2Land	Mebrane systems (UF, RO) coupled with freeze concentration	Liquid fraction of fish sludge collected in recirculating aquaculture system is treated with ultrafiltration, reverse osmosis and both retentates are valorised through freeze concentration into nutrient rich concentrate		bench/lab	Liquid fraction of Fish sludge from RAS			0,718	0,054		0,236					7,88	Liquid					Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 10. even though ABP end-point reached
24	Biodried solid fraction	Spain (Mediterranean case study)	Sea2Land	Biodrying	Solid fraction of fish sludge collected in recirculating aquaculture system is treated by biodrying		pilot	Solid fraction of fish sludge from RAS	45,4	54,6	15,95	41,08	17,23	0,686	0,1514			125,44	7,88						Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 10. even though ABP end-point reached
25	Nutrient-rich concentrate	Spain (Fresh aquaculture case study)	Sea2Land	Mebrane systems (UF, RO) coupled with freeze concentration	Liquid fraction of fish sludge collected in WWTP in fish transformation industry is treated with ultrafiltration, reverse osmosis and both retentates are valorised through freeze concentration into nutrient rich concentrate		bench/lab	Liquid fraction from WWTP in the transformation industry of fish (aquaculture)	97,266	2,734	1,82	0,13	1,081	0,054	0,238										Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 10. even though ABP end-point reached
26	Biodried solid fraction	Spain (Fresh aquaculture case study)	Sea2Land	Biodrying	Solid fraction of fish sludge collected in WWTP in fish transformation industry is treated by biodrying		pilot	Solid fraction from WWTP in the transformation industry of fish (aquaculture)	41,3	58,7	26,7	7,428	2,9	2,811	0,58			258,72	7,8						Cross check with FPR being made to identify CMC and FPC categories. Temptative CMC 10. even though ABP end-point reached

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU)	Output material
1									
2	Enriched reclaimed water (rich in N (especially organic nitrogen), P and K)	Sequencing batch reactor (SBR) + nutrients recovery module	Wastewater from the slaughterhouse directly enters the SBR, a wastewater treatment solution capable of removing organic carbon, nutrients and suspended solids from wastewater in a single tank, while delivering an effluent in line with legal requirements for discharge. The SBR has a treatment capacity of 50m3 per day, and afterwards goes through a nutrients recovery module, where a filtration process (microfiltration, ultrafiltration and reverse osmosis) takes place. https://water2return.eu/water-line/	The raw material used in this project was slagutherwhouse watewater. The amount of nutrients contained in the wastewater of each slaughterhouse depends a lot on the type of animals slaughtered, the protocols followed in the slaughterhouse, etc. This concrete application in the selected slaughterhouse revealed a poor N and P composition of the concrete stream treated, which does not necessarily need to be the same as in other slaughterhouses. Thus, in this case, the "zero kilometre" approach was selected, aiming to fertigate the fields with the enriched reclaimed water.	Available on the market (TRL 9)	Depends on the flow to be treated	Depends on the flow to be treated	The enriched reclaimed water fulfils all requirements set by the corresponding applicable legislation, i.e., the Council Directive on May 21st, 1991 91/271/EEC	Enriched reclaimed water
3	Biostimulant based on hydrolysed sludge	Fermentation process using *Bacillus sp.*	The sludge resulting from wastewater treatment (via an SBR) goes through a first pre-treatment process where pathogenic microorganisms are eliminated and its sanitisation is achieved. Subsequently, it enters a fermentation unit composed of a bioreactor, where the sludge is fermented with *Bacillus sp.* . As a result, a hydrolysed sludge with high availability of organic matter is obtained, which can be used in other biological processes. https://water2return.eu/sludge-line/	The sludge, that initially had a dry matter of approximately 20g/L, was concentrated to 49.4 ±0.84 g/L. The concentration of *Bacillus* in the product is relatively high, which makes this hydrolysed sludge a potential agronomic product with PGPB (Plant Growth Promoting Bacteria) properties. A biostimulant was formulated and produced from this hydrolysed sludge. The recommended rate was 5 L/ha (both for irrigation and soil spraying application), being preferably applied on a regular basis, anticipating critical moments of the crop when the elements are blocked due to low temperatures or under stress conditions.	Demonstrated in relevant environment (TRL 6)			CMC 10: Derived products within the meaning of Regulation (EC) No 1069/2009: An EU fertilising product may contain derived products within the meaning of Regulation (EC) No 1069/2009, having reached the end point in the manufacturing chain as determined in accordance with that Regulation. The *Bacillus Licheniformis* is not included in the list of microorganisms categorised as CMC 7. To be used in a fertiliser, its inclusion in this category must be requested.	Hydrolysed sludge
4	Biostimulant based on algal biomass	AlgaeBioGas (ABG) technology, validated in the frame of Eco-innovation pilot and market replication project AlgaeBioGas	The sludge resuting from wastewater treatment (via an SBR) and the hydrolysed sludge produced via fermentation with *Bacillus sp.* feed this algae system. Algae are used to recover the remaining N and P from the anaerobic digestate, acting as biostimulant in agricultural production. As a result, an algal biomass with biostimulnt properties is obtained. ABG system consisted of a 400 m2 main algal pond and two 9 m2 inoculation ponds for maintaining the inoculum culture. The cultures were mixed by the custom-made paddlewheels to enable illumination to all algal cells and prevent the settlement or unmixed anaerobic areas in the pond. The waste stream²s treatment and main biomass production was performed in the main pond. https://water2return.eu/algae-line/	The prevailing species were from *Scenedesmus genus* , with occasional *Dictyosphaerium sp.* and filamentous cyanobacteria. During the whole study, the algal species composition remained the same, with slight morphological changes in the colony size (1, 2 or 4 cells). This means we can expect repeatable quality of biomass material while applying the treatment. The biostimulant produced from the algal biomass resulted to have very positive effects in one special behaviour: flowering and fruit set (a known activity of macroalgae based biostimulant). The recommended rate was 2 to 4 L/ha when irrigating, 2-4cc/L when running a foliar application.	Demonstrated in relevant environment (TRL 6)			CMC 10: Derived products within the meaning of Regulation (EC) No 1069/2009: An EU fertilising product may contain derived products within the meaning of Regulation (EC) No 1069/2009, having reached the end point in the manufacturing chain as determined in accordance with that Regulation. CMC 4: An EU fertilising product may contain digestate obtained through anaerobic digestion of exclusively one or more of the plants or plant parts grown to produce biogas. To this point, plants include algae and exclude blue-green algae.	Algal biomass
5	Enriched reclaimed water	RichWater® system	The RichWater® system is based on a new groundbreaking system combining low-cost and energy efficient Membrane Bioreactor (MBR) treatment, a module for mixing the optimal fertigation water connected to the up-to-date irrigation technology and an advanced monitoring /control module including soil sensors to guarantee demand-driven and pathogen-free fertigation. The MBR has been designed for a 150 m3/day flow, and it works in a way that the nutrients it contains (mainly N and P, but also other nutrients such as K, Mg and Ca) remain after the treatment, whilst pathogens are removed. https://richwater.eu/	The effluent produced is free of pathogens and rich in nutrients, showing 99.99% of *E.Coli* removal, 69% of total N recovery, 80% of total P recovery and 94% of K recovery. The average content of N in RichWater® effluent was about 36.4 mg/L. RichWater® technology obtained in 2020 the Environmental Technology Verification (ETV), which is a guarantee on the technology performance. ETV has been conducted by an external and independent verification body, the Institute for Ecology of Industrial Areas (IETU) located in Poland, which certified that RichWater® is able to treat urban wastewater up to the necessary quality standards required for irrigation. https://circabc.europa.eu/ui/group/od5138da-9303-4dec-b82c-bb29409ecdbd/library/dd543001-214d-4628-aaff-d7d9e71b4fbc?p=1&n=10&sort=modified_DESC%20	Demonstrated in relevant environment (TRL 6)	Business plan show that RichWater® solution requires a high investment of approximately 200 – 250m I for treating and reuse urban wastewater from 1,000 inhabitants. Benefits obtained for using the water in irrigation (estimated at 0.30l/m3) result in a pay-back period of 5.33 years when adding reuse to conventional wastewater treatment.			Enriched reclaimed water

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU)	Output material
6	Enriched reclaimed water	1. Secondary wastewater treatment with ultrafiltration, active carbon and reverse osmosis (DW) 2. Secondary wastewater treatment mixed with brine (RW)	Treated effluent from the Roldán-Balsicas wastewater treatment plant is reclaimed using a prototype module and then used for agricultural irrigation by the Irrigation District of Campo de Cartagena. Cultivation techniques include horticultural crops (59 %), citrus trees (30 %), fruit trees (4 %) and greenhouses (7 %). Greenhouses cover about 1,300 ha of irrigated land, with about 96 % of that surface devoted to pepper cultivation; the rest is devoted to cultivation of zucchini, tomato and ornamental flowers. Cultivation is mainly (93 %) conducted using drip irrigation techniques. http://www.waterjpi.eu/joint-calls/joint-call-2015-waterworks-2014/desert https://www.researchgate.net/publication/330374676_Using_saline_reclaimed_water_on_almond_grown_in_Mediterranean_conditions_deficit_irrigation_strategies_and_salinity_effects		Demonstrated in relevant environment (TRL 6)				Enriched reclaimed water
7	Enriched reclaimed water	Optimisation of the reclamation treatment for the specific use of the olive grove based on a settling pond, a storage basin with ultrasonic treatment and a ring filtration system	The wastewater treated at Montilla WWTP, by means of a prolonged low-load aeration process and subsequent secondary decantation, is sent to a decantation pond in sector I of the CR TINTIN. This pond has a useful capacity of 9,143.45 m3, being used for irrigating a surface of 650.53 hectares. The water coming from the settling pond accumulates in the storage pond, with a useful capacity of 222,604 m3, being used for irrigating a surface of 150 hectares. Two ultrasound units are installed in the storage pond for the elimination of microalgae. The water from the storage pond, taken via a floating water intake, is filtered by means of rings, consisting of several units of automatic filters of 130 microns, self-cleaning by opening the package of rings. https://reutivar.eu/ https://reutivar.eu/wp-content/uploads/2021/05/Reutivar_Resumen-Ejecutivo_v4.pdf		Demonstrated in relevant environment (TRL 6)			The minimum requirements for the water reuse established in the majority of existing regulations, like RD 1620/2007 and the new Regulation (EU) 2020/741, must be applied as long as reclaimed water from municipal sewage treatment plants is used for irrigation in agriculture, in accordance with Directive 91/271/EEC. The quality of the reclaimed water complies with the quality criteria established in annex I.A, Quality 2.3 of RD 1620/2007, related to eggs of intestinal nematodes, E. coli and solids in suspension, which guarantees that said water can be used with security for agricultural irrigation of the olive grove, also ensuring a level of environmental protection, human health and animal health.	Enriched reclaimed water
8	Recovered N and P - struvite, ammonium nitrate and sludge	Different technologies for N & P recovery are integrated in the existing Murcia Este WWTP. First, an elutriation process full-scale wa implemented, in a reversible configuration, to extract and concentrate phosphates before they enter anaerobic digestion, were uncontrolled P precipitation starts causing operational problems. Phosphates concentrate in the supernatant of primary thickeners can feed the P recovery unit for struvite production.	Depending on the configuration of the WWTP, phosphate can accumulate in centrates or in the supernatant from primary thickeners, so both streams were fed to the P recovery unit, where ammonium accumulates in higher concentrations, allowing struvite production. N recovery was assessed in centrates stream, since it accumulates ammonium in high concentrations allowing high N recovery rates. Altogether, LIFE ENRICH integrated P&N recovery solution enables a flexible and robust process that maximises nutrient recovery. http://www.life-enrich.eu/wp-content/uploads/LIFE-ENRICH_Laymans-Report.pdf	The new fertilisers were used as raw materials for manufacturing the optimal nutrient solution for fertigation of three horticultural crop species. Three different compositions of nutrient solution were tested, differing on the P and N sources: 1. Struvite. With 100% and 17±2% of P and N recovered source, respectively. 2. Struvite and ammonium nitrate. With 100% and 34±6% of P and N recovered source, respectively. 3. The conventional fertilisation using solely synthetic fertilisers. The recovered sources were the P and N from ground struvite and the N-NH4+ from liquid ammonium nitrate. The reference P fertiliser conventional nutrient solution was KH2PO4. Other commercial fertilisers were used to complete the nutrient solution and to lower the pH. Murcia Este full-scale projection will produce 1100 t/y of struvite and 1937 t/y of ammonium nitrate (21%w), which accounts for 42% of P recovery and 11% of N recovery (8.4% as AN) of total P and N present in wastewater influent, under a favorable scenario of high bio-P removal and 9.1 mg/L of Ptot in WWTP influent. Considering market prices of 350 and 410 €/t of struvite and ammonium nitrate, revenues would be of 385 k€/y and 794 k€/y, respectively (total of 1.17 M€).	Demonstrated in relevant environment (TRL 6)	The estimated CAPEX will be of 4.76 M€ for struvite production (75 k€ for elutriation process) and 1.39 M€ for ammonium nitrate production (total of 6.15 M€)	Regarding operational costs of nutrient recovery technologies, OPEX for struvite production is 202 k€/y (183 €/t) and for AN, 891 k€/y (460 €/t), being the main costs NHO3 and zeolites (N recovery) and NaOH (P recovery) over other chemicals and energy consumption. Also, this nutrient recovery process has other benefits regarding WWTP performance, which translate in OPEX savings for the installation. They come from improving sludge dewaterability, avoiding uncontrolled P precipitation problems, and reduce the N load to biological reactors. Results pointed out that, at full-scale for maximise P&N recovery, Murcia Este WWTP would benefit from savings of 7.4% in aeration requirements (nitrification) (31k€/y), 17.9% in dewatering energy consumption (8k€/y), 27% in polymer requirement for dewatering (52 k€/y), 20% in sludge management (119 k€/y), 85% in antiscaling and maintenance due to uncontrolled P precipitation (11k€/ and 14 k€/y respectively). This is a total savings of 235 k€/y. Overall, a positive margin of 322 k€/y would be achieved.	The recovered struvite and ammonium nitrate were characterised to accomplish the legislative requirements for new fertilising materials (EU 2019/1009)	Struvite, ammonium nitrate and sludge

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU)	Output material
9	Microalgae hydrolysate	Wastewater-based algae biorefinery (WWAB). Up to 1.7 ha of raceway and tubular reactors located inside a greenhouse were installed to produce biomass for agriculture and aquaculture related applications. Using marine water and wastewater the plant is managing up to 2.000 m³ of microalgaecultures. http://www2.ual.es/sabanal/project/			Validated in relevant environment (TRL 5)				Microalgae hydrolysate
10	Phosphorous	Wastewater is treated by a 3000 m² High Rate Algae Pond (HRAP) and tertiary treatment composed of 250 m² planted filter with natural material for enhancing phosphorous recovery. Irrigation water is finally obtained and reused with a solar anodic oxidtion disinfection and smart irrigation system. The biomass obtained is anaerobically digested and biomethane is produced by an innovative biogas upgrading system. https://incover-project.eu/case-study/case-study-2			Demonstrated in relevant environment (TRL 6)				
11	Nutrients recovered	Two 500 m² HRAPs treat wastewater and the algae biomass used is harvested and transformed into biogas through thermal pre-treatment and anaerobic co-digestion. A 250 m² evaporative system is used for the digestate stabilisation and nutrient recovery, with zero liquid discharge https://incover-project.eu/case-study/case-study-2			Demonstrated in relevant environment (TRL 6)				

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU)	Output material
1									
12	Biofertilisers and biostimulant products	Five selected strains with proven antifungal, antibacterial and biostimulant activity will be cultivated using wastewater. Culture conditions and operational aspects of microalgae production will be optimised, and the yield and efficiency of large-scale production systems. Wastewater and marine water will be used to achieve sustainable processes.	Microalgae systems optimised will be able to operate in continuous mode for six months without collapses, at productivities higher than 70 t/ha·year, with power consumptions lower than 5 /m^3, and recovering more than 90% of nutrients contained into wastes. Up to 10 t /ha·year and 2 tP/ha·year will be recovered at biomass production cost below 1.0 /kg. The harvesting process will allow recovering more than 95% of produced biomass, with power consumptions below 0.1 kWh/m3. Mild processing technologies will be used to extract up to 80% of high-value products from the microalgae biomass, without damaging the residual biomass for its latter utilisation to produce biofertilisers. Only wet processes will be used to enhance the sustainability of the process, the utilisation of non-safe solvents being disregarded. https://www.algaenauts.eu/		Demonstrated in operational environment (TRL 7)				Algal biomass

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally	Kg/tonne of DM															Form/state (liquid/pelletized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1								N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH						
2	Enriched reclaimed water (rich in N (especially organic nitrogen), P and K)	Water2REturn (H2020 project, G.A. 730398)	Wastewater from the slaughtering industry	Spain (Andalusia region, Salteras municipality)							Average Ammonia N weekly measured from September 2020 to March 2022: 2,1 mg/L	Average N-NO3 weekly measured from September 2020 to March 2022: 1,1 mg/L	Average Total N weekly measured from June 2021 to March 2022: 9,1 mg/L										Liquid	Irrigation	Water2REturn Layman's report			
3	Biostimulant based on hydrolysed sludge	Water2REturn (H2020 project, G.A. 730398)	Sludge by-product resulting from wastewater treatment (via an SBR) from the slaughtering industry	Spain (Andalusia region, Salteras municipality)				Total nitrogen 0.12 ± 0.01 % (p/p)	Organic nitrogen 0.07 ± 0.02 % (p/p)		Ammoniacal nitrogen 0.05 ± 0.01 % (p/p)										6,83	Liquid	Irrigation Soil spraying	Water2REturn Layman's report			
4	Biostimulant based on algal biomass	Water2REturn (H2020 project, G.A. 730398)	Sludge by-product resulting from wastewater treatment (via an SBR) from the slaughtering industry + hydrolysed sludge produced via fermentation with *Bacillus sp.*	Spain (Andalusia region, Salteras municipality)				Total nitrogen 0.16 ± 0.02 % (p/p)	Organic nitrogen 0.06 ± 0.03 % (p/p)		Ammoniacal nitrogen 0.10 ± 0.01 % (p/p)										6,01	Liquid	Irrigation Foliar spraying	Water2REturn Layman's report			
5	Enriched reclaimed water	RichWater (H2020 project, G.A. 691402)	Urban wastewater	Spain (Andalusia region, Algarrobo municipality)				Total N, 26 g N/m³				Nitrates, 92,31 g N/m3		Total P, 4,34 g/m3		Total K, 4,43 g/m3					7,91	Liquid	Irrigation				

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally	Kg/tonne of DM															Form/state (liquid/pelletized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
								N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH						
6	Enriched reclaimed water	DESERT (Water Works 2014-2019 in Support of the Water JPI, Reference Number: WaterJPI-JC 2015-03)	Urban wastewater	Spain (Murcia region - borders Andalusia to the East - , Roldán municipality)								1. DW, NO_3, , 15.83 ± 2.53 mg l^{-1} 2. RW, NO_3, , 36.16 ± 9.28 mg l^{-1}		1. DW, PO_4^{3-}, 1.3 ± 0.61 mg l^{-1} 2. RW, PO_4^{3-}, 3.1 ± 0.52 mg l^{-1}		1. DW, 20.67 ± 8.81 mg l^{-1} 2. RW, 42.76 ± 6.30 mg l^{-1}		1. DW, SO_4^{2-}, 97.98 ± 16.2 mg l^{-1} 2. RW, SO_4^{2-}, 97.98 ± 16.2 mg l^{-1}			1. DW, 7.53 ±0.31 2. RW, 8.15 ± 0.20	Liquid	Drip and sprinker irrigation				
7	Enriched reclaimed water	REUTIVAR (FEADER 2014-20, EIP-Agri operational groups, Reference number: GOP31-SE-16-0005)	Urban wastewater	Spain (Andalusia region, Montilla municipality)																			Liquid					
8	Recovered N and P - struvite, ammonium nitrate and sludge	ENRICH (LIFE project, G.A. LIFE16 ENV/ES/000375)	Urban wastewater	Spain (Murcia region - borders Andalusia to the East - , Murcia municipality)				Potential recovery of up to 11%						Potential recovery of up to 42%									Liquid (injection of water-soluble fertilisers into the irrigation system)	The fertigation system was established by 2 tanks per treatment, containing concentrated nutrient solution x100 to be released into passing irrigation water through venturi system with automatic control of irrigation.	ENRICH Layman's report		The results of the agronomic assays revealed that struvite and ammonium nitrate used as fertilisers in fertigation systems for tomato, broccoli, cauliflower and lettuce crops were equally effective in total yield (fresh or dry matter) and quality product to conventional fertilisers, both in the greenhouse and open-air conditions.	

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally	Kg/tonne of DM														Form/state (liquid/pelletized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1								N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH						
9	Microalgae hydrolysate	SABANA (H2020 project, G.A. 727874)	Wastewater (sewage, centrate and pig manure) + marine water	Spain (Andalusia region, Almeria municipality)																						Field trials were performed to evaluate the benefits of microalgae hydrolysate in the yield and quality of fruits in different crops. Different formulations were evaluated, and it was observed that both fruits yield and quality largely increased when providing microalgae based products. This behaviour was observed in largely different crops such as tomato, pepper, but also in grapes, olive trees, orange and maize. http://www2.ual.es/sabana/wp-content/uploads/2021/03/SABANA-6th-e-bulletin-cuaderno-v1.pdf	
10	Phosphorous	INCOVER (H2020 project, G.A. 689242)	Urban wastewater	Spain (Andalusia region, Chiclana de la Frontera municipality)																						No agronomic studies were conducted in the framework of the project	
11	Nutrients recovered	INCOVER (H2020 project, G.A. 689242)	Urban wastewater	Spain (Andalusia region, Almeria municipality)																							

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally	Kg/tonne of DM															Form/state (liquid/pelletized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1								N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH						
12	Biofertilisers and biostimulant products	ALGAENAUTS (European Maritime and Fisheries Fund (EMFF) project, G.A. 101038250)	Urban wastewater + marine water	Spain (Andalusia region, Almeria municipality)																							Final products formulated (biopesticides and biofertilisers) will be validated through field trials at real crop conditions. Field trials will be developed in an Experimental Center with fully monitored conditions in horticultural and fruits crops. Additionally, target products will be evaluated and validated with end-users such as distributors and farmers.	

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally	Kg/tonne of DM													Form/state (liquid/pelletized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
															N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH						
Organic-mineral	Anaerobic digestion	It is extremely suitable for acidic soils because its composition is pH neutral and has excellent solubility.		Available on the market (TRL 9)						Digestate	Croatia		85			2						7		11			27	7	pelletized	Pre-sowing should be introduced into the seed layer, for fertilising it is recommended to incorporate into the soil.		Organic certified	https://ecodig.eu/	
Organic-mineral	Anaerobic digestion	It is extremely suitable for acidic soils because its composition is pH neutral and has excellent solubility.		Available on the market (TRL 9)						Digestate	Croatia		85			2						5		8			33	7	pelletized	Pre-sowing should be introduced into the seed layer, for fertilising it is recommended to incorporate into the soil.		Organic certified	https://ecodig.eu/	
Inorganic soil conditioner		https://br.timacagro.com/en/products/soil-conditioners/soil-conditioner/physio-max-975/		Available on the market (TRL 9)						It contains special supplements Mescal and Physio + complex. PHYSIO + - a powerful organic biostimulant for root strengthening that allows the efficient intake of nutrients and water from the soil - aminopurines stimulate root system growth and allow increased uptake of P and K - accelerates the initial growth, improves the plant resistance to stressful conditions such as drought, low temperatures, etc., and allows a stable and quality yield in different weather conditions MESCAL - greater calcium absorption required for root and root hair development - better activity of microorganisms in the soil - improves bacterial environment, e.g. micro-pH for bacterial activity - better storage of nutrients, e.g., P, K within the clay-humic complex	Croatia																			Organic certified		

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Annex 3 – Raw data from technology & product template Eastern Europe

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/ national/ EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally	Kg/tonne of DM														Form/state (liquid/pelletized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH					
2	Monoammonium phosphate (MAP)	PolForAsh - Polish Fertilizers form Ash	Phosphorus recovery from SSA with mineral acid. https://www.transfer.edu.pl/pl/wideo,27,nowozy-polforash-oferta-technologiczna-politechniki-krakowskiej,1357.chtm; http://wast.ntua.gr/athens2017/proceedings/pdfs/Athens2017_Gorazda_Tarko_Worek_Nowak_Kulczycka_Smol_Henclik.pdf		Available on the market (TRL 9)					This study was supported by The National Centre for Research and Development (NCBiR) through the research grant PBS1/A1/3/2012 and by The National Centre for Research and Development together with National Fund for Environmental Protection and Water Management through the research grant GEKON2/05/268313/8/2015	Ash from industrial sewage sludge	Poland																5	Pulp, Solid					
3	Potassium thiosulfate		Stage I A technology for the production of potassium sulfate (IV) was developed, and produced as a result of the absorption of sulfur dioxide from the installation for the production of sulfuric acid. As a result, emissions of sulfur dioxide and nitrogen oxides into the atmosphere were reduced by approximately 90%, which has a measurable impact on reducing greenhouse gas emissions, improving air quality and is in line with the principles of the circular economy. Stage II Potassium thiosulfate was produced from potassium (IV) sulfate and sulfur from the Claus desulfurisation process. Thanks to the innovative technology, a product of very high purity and, most importantly, high resistance to UV radiation was obtained. https://naszarola.pl/tiosiarczan-potasu-plynny-nawoz/ ; https://www.fosfory.pl/fundusze-	This technology will be implemented in the business activities of Grupa Azoty "Fosfory" Sp. z o. o. as an industrial installation with a planned capacity of 10 000 t/y.	Preparation of a patent application for the technology of producing potassium thiosulfate (TRL 9)					P-Thios	Sulfur dioxide from the installation for the production of sulfuric acid	Poland																	Liquid					Project No. POIR.01.02.00-00-0061/17 received funding from the National Center for Research and Development under the sectoral program "INNOCHEM", Measure 1.2 "Sectoral R&D programs" of the Smart Growth Operational Program 2014-2020. The work was carried out by Grupa Azoty Zakłady Azotowe "Puławy" S.A. as a project leader and Grupa Azoty Zakłady Fosforowe Gdańsk Sp. z o. o. The 50% potassium thiosulfate solution produced in this mode can be separated as an independent potassium-sulfur fertilizer liquid, and can also be introduced as a raw material for the production of compound
4	Organo-mineral fertilizer OrCal®	FuelCAl®	The principle of operation of the technology is based on a controlled electronic exothermic reaction, which takes place with the participation of a certified WapCal® reagent. https://orcal.pl/fuelcal/		Available on the market (TRL 9)					\	Sewage sludge, biodegradable waste, selected animal by-products	Poland				1,50%						0,48%	11	0,20%	2,4				12,6	Powder					CaO - 30,97%, Ca(OH)2 - 42,11%, Ca - 22,12%, Organic substance - 35,80%

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

1	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/ national/ EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally
5	Granular BIOPOWER - organic fertiliser	Composting and air drying	Fermented chicken manure after drying and granulation, an ecological product. http://www.ipm.iung.pulawy.pl/fert/fert.aspx?show=true		Available on the market (TRL 9)					\	Chicken manure	Poland			
6	ROLPOWER - organic fertiliser	Composting and air drying	Poultry manure is obtained from free-range farms. The manure is composted and then air-dried (no dryer is used), then undergoes a granulation process. In the final stage, high temperature eliminates undesirable pathogens, weed seeds or eggs or young stages of insect development. https://www.e-sadownictwo.pl/wiadomosci/a-		Available on the market (TRL 9)					\	Chicken manure	Poland			
7	Granbial - organic fertiliser	Activated sludge wastewater treatment	Wastewater entering the treatment plant undergoes Many technological changes based on mechanical and biological treatment methods. In the individual stages of the process, deposits are formed, which are the basis for the production of fertilizer. After dehydrating them to approx. 20% d.m. are directed to the dryer. The sludge is dried on heating trays at a temperature of approx. 205÷270°C. The temperature of the granules after drying is approx. 100°C. The dried sludge is discharged to a storage silo and then to storage boxes. https://seidel-przywecki.eu/2021/07/13/nawoz-organiczny-produkowany/ ; https://www.wobi.pl/images/oferta/Sprzedaz_nawozu_organicznego/	Currently, in the sewage treatment plant belonging to Wodociągi Białostockie Sp. z o. o. around 4,000 tonnes of Granbial organic fertilizer are produced annually.	Available on the market (TRL 9)						Sewage sludge	Poland			
8	BIOROL Natural Fertiliser	Biorol technolog	The Biorol technology is a process used to produce a product that is a natural fertiliser - Biorol from waste. The process is carried out using an innovative method of simultaneous processing of stabilized municipal sewage sludge and ashes resulting from biomass combustion. The Technological Line consists of the following modules: 1. Preparation of the mixture for drying together with warehouses for raw materials and transmission, 2. Drying a standardized mixture of waste; 3. Packaging of the final product - biofertiliser, 4. Purification of gases and dusts from the drying process and feeding the dryer, 5. Control and measurement equipment.	Capacity up to 1 Mg/h and biofertiliser productivity from 150-400 kg/h	Both the Biorol technology and the Biorol fertiliser are in the process of patent protection because they are registered with the Patent Office of the Republic of Poland (TRL9)	5 mln zł (1,06 mln I)				Development of innovative and environmentally friendly technology for producing biofertiliser from waste (Opracowanie innowacyjnej i przyjaznej dla środowiska technologii wytwarzania bionawozu z odpadów)	Sewage sludge, ashes from biomass combustion	Poland			

1	Alternative fertilsing product	Kg/tonne of DM N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH	Form/state (liquid/pelletized/solid/granular /powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
5	Granular BIOPOWER - organic fertiliser	3,44%							36		23					Granular			NE/430/2018		Organic substance - 67%
6	ROLPOWER - organic fertiliser	4,20%						3%	30	2%	20				9,5	Granular					Organic substance - 60-75%
7	Granbial - organic fertiliser	2,50%							3,80%							Granular					Organic substance - 40%
8	BIOROL Natural Fertiliser							1,20%		1,20%						Granular					Organic substance - 35% , Ca -2,6%, Cd < 0.62 mg/kg, Pb < 6.4 mg/kg, Cr<15 mg/kg, Ni<3.8 mg/kg

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/ national/ EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nationally	Kg/tonne of DM													Form/state (liquid/pellet ized/solid/granular/powder etc.	Type of application method/methods for best environmental and economic performance	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P2O5	K %	K2O	S %	SO3	Organic carbon %	pH						
9	liquid fertiliser - AGROLINIJA-S	Manure heating-	Organic fertilizer obtained by means of an innovative - hydrodynamic cavitation technology of manure from beef cattle bedding and humic acids from leonardite humates. Thanks to this technology, an ecological fertiliser is obtained in concentrate with a very large amount of fulvic and humic acids, rich in micro- and macroelements. http://www.biodinamika.lt/pl/produkty/nawoz-naturalny-w-plynie-agrolinija-s-15		Available on the market (TRL 9)						Cattle manure	Poland				0,17%							0,07%		1%				10,8 st	Liquid					Organic matter on dry basis (the ash content was determined at the temperature +800 °C) - 65,8%, Organic matter - 3,7%, moisture - 34,3%, dry matter - 5,7%, Total Humic acids on dry basis - 52,6%, Total humic adids - 3,0%, B - 4,3 mg/kg, Mn - 8,7mg/kg, Mo <1mg/kg, Co<1mg/kg, Cu - 2,2 mg/kg, Zn - 3,3 mg/kg, Fe - 176 mg/kg, Ni - 2,8 mg/kg, Mg - 487 mg/kg
10	Phosphorus		Recovery of phosphorus from both bones and ash from sewage sludge incineration. Bacteria are used for this purpose. It is known that it accompanies tooth disease - caries in young children. These bacteria are used to change the properties of phosphate raw materials. The bacteria makes it easier for plants to absorb them. https://zpalurnie-odpadow.pl/fosfor-na-nawozy-odzyskiwany-z-odpadow/							Biofert - Renewable sources of phosphorus - resource base for a new generation fertilizer (Odnawialne źródła fosforu - baza surowcowa nowej generacji nawozów)	Ashes from incinerated dried sludge from sewage treatment plants and products resulting from the processing of bones and fish bones	Poland																				
11	Fertilizer from sewage sludge with the addition of dusty mineral materials		https://zeidel-przywecki.eu/2020/03/21/nawoz-organiczno-mineralny-z-osadow-sciekowych/							Development of an organic-mineral fertilizer based on sewage sludge with the addition of mineral micronutrients (Opracowanie nawozu organiczno-mineralnego na bazie osadów ściekowych z dodatkiem mikroelementów mineralnych)	Sewage sludge	Poland																Granular					

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Annex 4 – Raw data from technology & product template Western Europe

	Alternative fertilsing product	Technolog	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nation	Kg/tonne of DM													Form/state (liquid/pelletized/solid/granular/powder	Type of application method/methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH					
2	Ammonium nitrate (AN)	Stripping and scrubbing with HNO3	AN is an end-product of (stripping-scrubbing technology. This technology is currently applied in livestock operations to recover N from waste streams such as animal manure, digestate and their respective liquid fractions. The operating principle of (stripping-)scrubbing is that ammonia (NH3) can be stripped by air, steam or vacuum through the N rich waste stream in an NH3 stripping reactor, resulting in NH3 transfer from the aqueous phase to a gas phase. The released NH3 is removed in a chemical air scrubber by washing it with a strong acidic solution such as nitric acid (HNO3), resulting in AN.	The available scale of operations in livestock sector is still on pilot scale with capacity to treat around 30 000 tonnes - 40 000 tonnes of N rich waste stream per year (case study in Flanders, Belgium) http://www.digestmart.eu/documentos/D3.3%20Final%20report%20on%20the%20trials%20-%20technologies%20for%20nutrient%20recovery%20from%20di	7					Nutri2Cycle	Digestate or manure slurries	Belgium	N/A	N/A	N/A	13-20%	0					0	0	0	0	7	0	N/A		Liquid	Low emmision liquid injection systems	Nutri2Cycle Deliverable D3.4	Conventional low input		The product does not contain P or C and as such has some similar traits as synthetic N fertilizers.
3	Ammonium sulphate (AS)	Stripping and scrubbing with (NH4)2SO4	AS is an end-product of (stripping-)scrubbing technology. It can be obtained from scrubbing ammonia (NH3) rich air from livestock operational units (i.e. stables, drying and composting) or from stripping and scrubbing NH3 from nitrogen (N) rich waste streams. In the case of air cleaning, the air from animal stables is blown into the system either horizontally (cross-current) or upwards (counter-current), and scrubbed in a scrubbing reactor by means of sulphuric acid (H2SO4). The second option is to first strip NH3 from N rich waste streams, by adjusting pH and/or temperature levels, to achieve NH3 transfer from liquid to gaseous phase. Once stripped, the NH3 in gaseous form is transferred to a scrubbing column where it gets scrubbed with H2SO4.	Currently this product is produced at large number of livestock farms in Flanders by treating air from livestock operational units. On average 1.5 L of H2SO4 is applied to remove 1 kg of NH3 which results in approximately 30 L of AS, depending on the amount of NH3 to be removed and the amount of NH3 that can be in scrubbing water before it is saturated.	9					Nutri2Cycle	Digestate or manure slurries	Belgium	N/A	N/A	N/A	3-9%						0	0	0	0	0	1	N/A		Liquid	Low emmision liquid injection systems	Nutri2Cycle Deliverable D3.5	Conventional low input		Ammonium sulphate is a liquid end-product that can contain 3-9% of total N completely present in mineral form. The product does not contain P or C and as such has some similar traits as synthetic N fertilizers. MS authority permit in Flanders, but not on European level

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technolog	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes	Kg/tonne of DM														Form/state (liquid/pelletized/solid/granular/powder	Type of application method/ methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH					
4	Liquid fraction of digestate	Solid-Liquid separation	Solid–Liquid separation is the most frequent first step in digestate processing and is usually carried out on-site to reduce transportation costs for disposal, to free up storage space or for further upgrading (such as nutrient extraction). To mechanically separate the raw digestate into its liquid and solid forms. The most commonly used techniques are the screw-press, the centrifuge (decanter) and the belt filter press. The phase separation leads to a P-rich solid fraction (SF) and a N and K-rich liquid fraction (LF). The SF contains high phosphorous and organic fractions, which is interesting for soil properties and humus formation. It can be further dried, composted, granulated or directly applied to the field as soil amendment. The LF, with high contents of plant-available N and K, is more suitable as a fertiliser applied via soil mixing (slurry cultivator), mechanical injection, drag hoses or surface dressing.	For the year 2016, in Flanders alone, the total processing capacity of liquid digestate was reported to be 71,979 tonnes (and 55,782 tonnes of solid digestate). In Flanders, in 2017, the quantity of processed input material for separation into SF and LF ranged from 23,500 (low end) to 225,000 tonnes (highest). 31 biogas plants are reported to separate digestate into LF and SF totalling 2,214,000 tonnes of fresh	7						Nutri2Cycle	Digestate or manure slurries	Belgium	N/A	N/A	N/A														7.5-8.5	Liquid				
5	Digestate									Nutri2Cycle	Manure	Netherlands																					
6	olid fraction of digestate									Nutri2Cycle	Manure	Netherlands																					
7	Membrane filtration									Nutri2Cycle	Manure	Netherlands																					
8	Reverse osmosis concentrat									Nutri2Cycle	Manure	Netherlands																					
9	High N/P pelletized digestate	co-digestion + digestate post treatments separation, concentration and backmixing	The digestate is separated into a liquid and a solid fraction. The liquid fraction is concentrated via Reverse Osmosis (RO). 60% water and 40% 'concentrate': an ammoniacal nitrogen liquid (animal manure-status Arbio). This concentrate is then 'back mixed into the drying of the solid fraction digestate - mixing of the mineral concentrate (N and K) over the solid fraction just before it goes to a (belt) dryer. If, finally, pelletised this results in an easy to distribute fertiliser-pellet with an optimised (higher) N/P-content	Production of 90.000 tonnes digestates per year	7	3.800 l/kWe Belt filter press: 75.000 à 150.000 l , RO: 200.000 l , Backmix: 35.000 l , Belt dryer: 400.000 à 800.000 l	423 l/kWe ; Input: organic waste streams: 15 à 25 l/T & , Output: Liquid fraction digestate: 5 l/ton		Digestate incl high N/P-dried digestate pellets	NUTRIMAN	Mnaure and organic waste digestate	Belgium		90%		5.5%						2.8%	3%		2.5%			40%	8.5-9.3	pelletized			low input, conventional		

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technolog	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output materal	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nation	Kg/tonne of DM															Form/state (liquid/pelletized/solid/granular/powder	Type of application method/ methods for best environm	LCA reference	Organic certified /conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH						
10	PK fertilizer from ash of poutry manure	Thermochemical nutrient recovery	The PK fertiliser is derived from hydrated ash of incinerated poultry manure. Poultry manure is obtained from poultry farms in the Netherlands meeting EU compliances for animal production. Main nutrients are phosphorus and potassium. The fertiliser has a neutralizing value due to the presence of hydrated burnt lime and the fertiliser contains secondary and micro nutrients.	Every year incinerates about 430.000 tonnes poultry litter and produces 292.000 MWh gross and 57.000 tonnes PK fertiliser	9				PK fertiliser	NUTRIMAN	Ash from poultry manure	Netherlands				0							10%		12%		7%					conventional	INFO SHEET Inutriman.eu	The fertiliser has a neutralizing value due to the presence of hydrated burnt lime and the fertiliser contains secondary and micro nutrients
11	Organic fertilizer+2:2	Composting	The composting takes place in a controlled batch process, using forced aeriation. Temperature and moisture content are constantly monitored.		9						Mix of composted poultry manure and compos	Netherlands		65%		2%						3%	30 kg/t	1.8%	18 kg/t		18 kg/t	41%				https://nutriman.net/farmer-platform/product/id_451	Conventional low input		Extra rich in phosphate.
12	mineral nitrogen concentrates	reverse osmosis.	From the reactor tank the manure goes to the sieve belt press. Within this press the liquid part of the manure, with minerals is separated from the solid manure, liquid fraction send to flotation unit and then to paper filter where lefte over organic materials are filtered out. Then it goes through reverse osmosis where membrane filtration separtes wlean filtration separates clean water from the mineral concentrate.	135. 000 m3/year input	Availalble on the marcket						raw pig manure	Netherlands				5-6.5 kg/t							0-0.1 kg/t		6-9 kg/t	3.2 kg/ton					Liquid	Open field		Conventional		
13	Solid fraction from livestock manure	belt press sieve	The process starts in a reactor tank where sulphuric acid and iron sulphate are added to the slurry. From the reactor tank the manure goes to the sieve belt press. Within this press the liquid part of the manure, with minerals is separated from the solid manure, which will later be pasteurized for export and sales as organic phosphate fertilizer.	135. 000 m3/year input	Availalble on the marcket (9)				Solid manure fraction , mineral concentrate and clean water		Slurry/ manure from pigs and cattles	Netherlands		30		13.3 kg/ton							18 kg/ton		5.1 kg/ton			23%			Solid	Open field		Conventional		Due to the organic origin of the fertilizer, nutrient content may vary

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes	Kg/tonne of DM													Form/state (liquid/pelletized/solid/granular/powder	Type of application method/methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P₂O₅	K %	K₂0	S %	SO₃	Organic carbon %	pH						
14	Ammonium nitrate/sulphate from raw digestate	AMFER stripping process	The AMFER® nitrogen stripper operates as a batch or (semi-) continuous system. Digestate (or other liquids) is sprayed in the tank and aerated to strip the ammonia to the air. The air is scrubbed with an acid, to produce the nitrogen fertilizer, which can be ammonium nitrate or ammonium sulphate.	1 to 500 ton/hr	Available on marcket						Digestate, liquid fraction, pre-treated manure	Netherlands				18						0		0						Liquid	Green house and open field		Conventional, low input		
15	Compost	Local composting process	The temperature rise comes from the micro-biomass aerobic activity (bacteria, fungi, yeast...) and is maintained above 50°C for at least 4-5 weeks.								Cattle manure	France				0.8						0.71		1.82					8.9						
16	Urine from pig manure	Physic-chemical nitrogen recovery from manure: primary separation (VeDoWS" adapted stable consctructions	By adaption of a stable system, pig manure is being primary separated in solid manure and urine in the stable. This primary separation of manure in the cellar is the basis of lower ammonia emissions. There is no need for chemicals by using this technique.	2000 Tonnes/year	Available on Marcket (9)	90-110 l/ pig place	80-90 euro per pig place and operational expenditure: maximum 1.50 euros per pig place yearly.		urine		Raw pig manure	Belgium		23.73 kg/ton		3.28-3.70 g/kg					0.01-0.19 g/kg	0.01-0.19 kg/ton	4.21 kg/ton				7.86-10.92	8.70-9.26					
17	Liquid ammonium sumphate or ammonium nitrate	Stripping and scrubbing with H2SO4 or HNO3	By increasing the temperature and/or pH of the slurry the ammonium-N will turn into gas NH3. Depending on the availability of heat from CHP and the capacity we add some alkaline (CAOH) to increase the pH. This gas will go into the air stream that is blown in the opposite way. This air will go into a washer. Here the wash water is low in pH due to the added acid (H2SO4 or HNO3) hence liquidizing the ammonia again (NH3 to NH4)	static units can be profitable when the farmer has production of 4000 kg N and more (>1000 tons manure/digestate). For lower than 4000 kg a mobile Circular Values solution can fit.	Available on marcket				Ammonium sulphate or ammonium nitrate		Separated liquid slurry	Netherlands				7-18 %											0		Liquid					
18	Ammonium sulphate from pig manure	On-farm scrubbing	At the pig farm owned by Mr. Kris Casier, NH3 emission from the pig manure is recovered by scrubbing with sulphuric acid. T		Available on marcket						Pig manure	Belgium		20		4.1%												4.6 - 6.1	Liquid in light brown color		Conventional		Agronomic values may vary slightly due to the on-farm conditions and input materials.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nation	Kg/tonne of DM													Form/state (liquid/pelletized/solid/granular/powder	Type of application method/ methods for best environm	LCA reference	Organic certified /conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P₂O₅	K %	K₂0	S %	SO₃	Organic carbon %	pH						
19		Detricon stripping and scrubbing process		100-5,000t/y inorganic fertilizer production	Available on marcket				Inorganic fertilizer	Nutriman	Liquid fraction of manure,	Belgium				10-18 %						0	0										
20	Mineral concentrate	MEMBRANE FILTRATION	Anaerobic digestion								Pig manure, co product			3.4%		0.8						0.04	0.04	0.9	0.9					liquid					
21	Ammonium suphate	Evaporate	Liquid fraction of the anaerobically digested pig slurry and digestate (LF) is produced in an anaerobic digester that operates under 38 °C (30-day retention time). Ammonium sulphate was produced from heating LF to volatilize ammonium in a 4-stage thermal vacuum evaporation system results in a gas stream. This stream was washed by H2SO4 solution to dissolve the ammonia. This resulted in the final product ammonium sulphate.	50,000 ton/yr.		2,100,00 l			Ammonium suphate	Nutri2cycle		Belgium				77 g/Kg	9.9 g/Kg					0.03g/Kg	0.07 g/Kg	<0.1 g/Kg	<0.2 g/Kg						Conventional		
22	Struvite	The crystallization of nitrogen and phosphorus in the form of magnesium ammonium phosphate hexahydrate	The digestate leaving the methanogenic reactor is introduced into a crystallization unit and converted to struvite (magnesium ammonium phosphate) taking advantage of its nutrient content. This procedure allows to recover, jointly, the phosphorus contained in the digestate (an undeniably scarce component) and nitrogen, in the form of a compound with fertilizing properties that can be used in agriculture. T	1t/day	7	Depends on plant capacity (2,000,00 0 l for 650 t/y of struvite)	200,00 l		Struvite	Nutri2cycle	Digestate from pig manure	Spain				5%						28%		0%						Powder or little solid particles			Conventional		
23	Digestate of cattle slurry	Small-Farm scale anaerobic digestion	Farm scale AD is characterized by the use of on-farm residues to produce on-farm energy. The fermentation process takes place in a large reactor in the absence of oxygen. During fermentation, organic matter is converted into biogas. The biogas (mainly consisting out of methane) is subsequently burned in a combined heat and power unit (CHP) and results in a renewable energy source in the form of heat and electricity. The fermented biomass is called digestate and can be used on the farm as organic fertilizer.	5000 tonnes/year.	7 to 9	10-20 kW: 150.000 - 200.000 l 20-30 kW: 200.000 - 300.000 l 30-40 kW: 200.000 - 350.000 l			Digestate of cattle slurry	Inagro (living lab)	Cattle slurry			6.54%		3.91 kg/ton						1.4 kg/ton			4.33 kg/ton			4.69%						
24	Digestate of pig slurry	Small-Farm scale anaerobic digestion	Farm scale AD is characterized by the use of on-farm residues to produce on-farm energy. It has a maximal input of 5000 tonnes/year.	5000 tonnes/year.	7 to 9	10-20 kW: 150.000 - 200.000 l 20-30 kW: 200.000 - 300.000 l 30-40 kW: 200.000 - 350.000 l			Digestate of pig slurry	Inagro (living lab)	Pig slurry/ Pig manure	Belgium		15.03		3.60 kg/ton						7.60 kg/ton			6.75 kg/ton			10.53 %						

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technology	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes pation	Kg/tonne of DM													Form/state (liquid/pelletized/solid/granular/powder	Type of application method/ methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH						
25	N recovery as ammonium	Chemical addition	The SyreN system automatically defines and lowers the pH of the slurry. It uses sulphuric acid to lower the pH, as this is 100% environmentally balanced product and the most concentrated and effective acid to lower the pH. The ammonia is thus transformed to ammonium and readily available to the plants after application, when the slurry penetrates the soil.	100.000 m3/y pr. system - 138 systems	9	200.000 l	2,000l/ year		NH4, SO4	Nutriman	Pig slurry	Denmark																				
26											Vegetable oil waste with pig manure																							
27	Digestate	Two-phase anaerobic digestion	VALUVOIL technology demonstrates the viability of the improved anaerobic digestion process for biofuel production and the potential uses of the organic by-products for stimulating plant growth and as compost for improving soils	50 l/h	6					Nutriman		Spain				0.03%						0.2%		0%						powder or little soil particles			Conventional		
28	Enriched compost	With mix fertilizer biological and stripping process	The installed stripping prototype recovered 80 % of the nitrogen from the liquid fraction of the pig manure.	1 t/d	8				Enriched compost	Nutriman	digestate of pig manure, chicken manure from poultry farm,	Spain				10%						4%		4%						pellet			Conventional		
29	NH3-water/Scrubber water	Physic-chemical nitrogen recovery from manure, digestate and wastewaters : solid liquid separation, reverse osmosis, stripping	Solid liquid separation; The input manure is separated in a flotation unit and in a belt filter press which results in a liquid and a solid fraction of 30% dry matter (DM). The solid fraction is dried on a belt dryer to 90% DM. Reverse osmosis; The liquid fraction (1,7% DM) goes to a reverse osmosis (RO) process where a retentate concentrated-N/K2O product (3,4% DM) and a permeate are produced. evaporator with mechanical vapour recompression. Heating the liquid in the evaporator causes water to evaporate. A vacuum lowers the boiling point, less energy is needed than when evaporating at normal atmospheric pressure. The ammonia in the incoming liquid is removed from the product flow by stripping and concentrated into NH3-water (14% N). The evaporator further produces a potassium concentrate (25% DM) and an ammonium sulphate solution by scrubbing the vapour coming out of the evaporator. The condensate from the Evaporator/ Stripper/ Scrubber (ESS) unit and the permeate from the RO is cleaned in the RO water polisher and the ion exchanger (RO-IE) to achieve the right quality for discharge into surface waters.	50.000, 125.000, 250.000 ton/year	9				Mineral- and Potassium- concentrate, NH3-water, Ammonium sulphate, Clean dischargeable water	Nutriman	pig manure, digestate						14%						0%		0%						Liquid			Conventional		Currently max 170 kg N/ha as livestock manure (230-250 kg N/ha for derogation farms in NL)

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Novafert

1	Alternative fertilsing product	Technolog	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nation	Kg/tonne of DM														Form/state (liquid/pelletized/solid/granular/powder	Type of application method/methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P2O5	K %	K2O	S %	SO3	Organic carbon %	pH						
30	Ammonium sulphate	digestate by "Biogas Bree" process	The digestate coming from the manure-input line is submitted to a drying process (with heat from a biogas fueled CHP) more particularly a belt dryer (Dorset) (cfr https://www.vlaco.be/sites/default/files/generated/files/page/technische-fiche-banddroger-10-11-16.pdf). The end product is dried digestate. Throughout 2019-2020 a new dryer, type fluidised bed dryer will be installed for greater capacity (3,5 MWth/h or 32.000 ton liquid fractionfg) (https://www.vlaco.be/sites/default/files/generated/files/page/technische-fiche-wervelbeddroger-10-11-2016.pdf). The exhaust air is saturated with ammonia which is being captured by a chemical air scrubber. In a chemical scrubber, acid is added to the washing water to remove the ammonia and a part of the odour compounds from the exhaust air. Water, acidified with sulphuric acid (96 % or 98 %), flows continuously over the filter package. This humidifies the filter. The acidic washing water reacts with the ammonia in the air. A salt (ammonium sulphate) is formed. T		9					Nutriman	mix of manure, organic wastes (cfr Vlarema (Flanders) and positive list FOD (B)) and/or energy maize	Belgium				8%														Liquid, transparent			low input, conventional		
31	• RO concentrate • SF of digestate • Low-P soil improver • Precipitated P salt	Microfiltration and reverse osmosis, ion exchange, RePeat system	The NRR process consist of two independent NRR systems. In the GENIUS system, digestate is first separated into a solid (SF) and a liquid fraction (LF) of digestate by a decanter centrifuge. The SF of digestate is subsequently processed by the RePeat system. The RePeat system separates the P from the organic matter through leaching with water and sulphuric acid. Two sequential leaching steps remove in total 70–90% of the P present in the ingoing digestate, thereby producing a low-P soil improver. The dissolved P subsequently precipitates through addition of lime (Ca(OH)2) or magnesium hydroxide (Mg(OH)2), thereby producing precipitated P salts. Part of the sulphate, which was added as sulphuric acid, precipitates with calcium as gypsum. The gypsum partly ends up in precipitated P salts and partly in a separated organic gypsum-rich sludge which can be used as fertiliser. Water is continuously reused within the process, thereby preventing the creation of a waste stream. The LF of digestate is further processed by the rest of the GENIUS system: a second decanter centrifuge, a microfiltration (MF) unit, two RO units placed in series and ion exchangers. The following end products are thereby produced: RO concentrate, rich in N and potassium (K), purified water and a blend of the SF of the second decanter centrifuge and MF concentrate.	Feedstock quantity = 115 kt y-1	Available on the market (TRL 9)					Systemic	Pig slurry, Biowaste from agroindustry	Netherlands		37, 313, 284, 159 g kg-1,		6.9,12, 5.9, 6.9 g N kg-1						0.15, 8.9, 1.9, 8.8 g kg-1		7.9, 4.6, 1.8, 2.3 g kg-1		1.5, 1.9, 5.8,12 g kg-1		14, 242, 252, 73 g kg-1						All information available at: https://systemicproject.eu/downloads/#toggle-id-2
32	• Evaporator concentrate • Dried SF of digestate	Evaporation, reverse osmosis	The decanter centrifuge, with addition of polymer flocculant to improve separation, separates the digestate in an SF and an LF of digestate. • As in the previous process, the SF of digestate (25–30% DM) is dried up to 80–90% DM. • The LF of digestate (3.5–4.5% DM) flows into an acidification tank where addition of sulphuric acid lowers the pH to 6.5–7 to prevent ammonia losses in the subsequent evaporation step. Compared to the previous NRR system, the amount of polymer flocculant needed decreased from 63 to 38 tonnes per year. • The vapour produced by the vacuum evaporator, containing <0.1% mineral N, is condensed to form condensed water. Currently, the condensed water is reused to a.o. dilute the digester feedstock, make the polymer flocculant solution or clean the evaporator plates. In the future, the RO unit (57 kWe) will process it into dischargeable purified water. • The evaporator concentrate, which has a DM content > 10%, will be blended with the dried SF of digestate into an organic NPK fertiliser and applied on agricultural land. Each of the two evaporator units require about 381 kWe and 1500 kWth, which is a lot more than the DAF unit did require.	Feedstock quantity = 134 kt y-2	Available on the market (TRL 9)					Systemic	Biowaste from agrofood industry	Belgium		115, 823 g kg-1		7.1, 23 g kg-1,			3, 1.3 g kg-1,			2.2, 19 g kg-1,		5.6, 14 g kg-1,			63, 529 g kg-1,	6.2,8.1					All information available at: https://systemicproject.eu/downloads/#toggle-id-3

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technolog	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nation	Kg/tonne of DM														Form/state (liquid/pelletized/solid/granular/powder	Type of application method/methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH					
33	• AS solution • Digestate	anaerobic digestion, N stripper and scrubber	From April 2016 onwards, the plant has operated as follows (Figure 3): • Feedstock (organic waste) is collected in basins located in a closed building to prevent the release of odour. A biofilter placed on the roof of the building purifies the exhausted air; • The organic waste is then heated and mixed with digestate from the third digester; • The mixed feedstock then undergoes thermophilic AD (minimum retention time of 20 days at a temperature of 55 °C) which ensures hygienisation of the ingoing sewage sludge; • The system of digesters is equipped with a side-stream N-stripper, in which NH3 is stripped from the stripping agent, biogas. This is done by leading biogas through 50% sulphuric acid resulting in an ammonium sulphate solution. • For the previous absorption unit biogas was used as stripping agent. For the new Nscrubber, biogas has been replaced by air. Moreover, the novel N-absorber is made of the high-performance material Alloy 825, which allows higher process temperatures. • The novel absorber design enables a higher gas flow rate, thereby increasing the recovery of NH4-N from the digestate entering the N-stripper to up to 35%. With the previous absorption unit an NH4-N recovery of just about 20% was achieved. • Both the digestate and the ammonium sulphate solution are stored in close tanks.	Feedstock quantity = 77 kt y-3	Available on the market (TRL 9)					Systemic	Sewage sludge, Biowaste	Italy		106,360 g kg-1		8,75 g kg-1							3.4, 0.012 g kg-1		0.53, 0.017 g kg-1		1.1, 85 g kg-1		63, - g kg-1						All information available at: https://systemicproject.eu/downloads/#toggle-id-4
34	• AS solution • Calcium carbonate sludge • LF of digestate • SF of digestate	N stripper, fibre production	After storage in the post-digesters, the digestate is separated by the first screw press in a liquid fraction (LF) and solid fraction (SF) which both are applied on agricultural land. A second way of processing is also possible: in an internal recirculation loop, digestate is fed to the FiberPlus system for removal of NH3 (detailed description below). In this system, NH3 and carbon dioxide are brought into contact with gypsum resulting in ammonium sulphate solution and calcium carbonate sludge (Figure 2). The produced N-stripped digestate is separated into an SF and LF, the latter is fed back to the digester. The SF is further processed in a fibre moulding and paper making machine. The resulting product is dried, with excess heat from the CHP installation to remove residual moisture, to the end product low-N fibres. The fibres are suitable for different applications such as production of paper, mulch mats or plant pots.	Feedstock quantity = 87 kt y-4	Available on the market (TRL 9)					Systemic	Corn silage, Poultry litter	Germany		221,690,94,248 g kg-1		45,13,7.2,7.9 g kg-1							0.0027, 0.17, 1.6, 1.8		0.0059, 0.4, 6.4, 8.9		58, 28, 1.0, 1.4		0.35, 29, 222, 83,68 g kg-1						All information available at: https://systemicproject.eu/downloads/#toggle-id-5

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technolog	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nation	Kg/tonne of DM																Form/state (liquid/pelletized/solid/granular/powder	Type of application method/methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH					
35	• Condensed ammonia water • Evaporator concentrate • Dried SF of digestate	Evaporator + reverse osmosis	The feedstock is pre-heated to 40 °C and mixed to an optimal DM content before being pumped into the anaerobic digesters. The residence time in the digester is around 30 days and an additional 10 days in the post-digester. The produced digestate is hygienised (1 hour at 70 °C) and subsequently separated in a solid fraction (SF) and a liquid fraction (LF) of digestate by means of a decanter centrifuge. The SF of digestate is dried in a rotating disc dryer (Hydrogone® dryer) which can evaporate 1-1.8 t of water per hour. In this type of dryer there is no direct contact between hot air and the SF of digestate. Instead, the SF of digestate is mixed with discs filled with steam or hot oil. This reduces ammonia (NH_3) losses due to drying. The exhaust air from the dryer is treated by an air scrubber, thereby producing air scrubber water. The LF of digestate, together with the air scrubber water and the evaporated water from the dryer flow to an aerobic treatment tank for lowering of the mixture's biochemical oxygen demand. The effluent subsequently flows to an evaporator which operates at 50-60 °C. NH_3 and water partially evaporate and are largely separated from each other based on volatility in the three consecutive stages of the evaporator. Condensation of these vapours in the condenser results in the following process streams: condensed ammonia water, process water and evaporator concentrate. The condensed ammonia water is sold as reductant in the DeNOx system of a local incineration plant. The process water flows to an RO installation and the resulting permeate is either reused	Feedstock quantity = 60 kt y-S	Available on the market (TRL 9)					Systemic	Pig slurry Biowaste Sewage sludge	Belgium		Na, 187, 304 g kg-1		96, 13, 29 g kg-1							0.000 5, 2.1, 24 g kg-1		0.000 55, 22, 15 g kg-1		0.5, 11, 10 g kg-1		Na, 31, 637 g kg-1							All information available at: https://systemicproject.eu/downloads/#toggle-id-6
36	Algae-based biofertiliser, P and N biofertiliser obtained from MFC	*Hybrid system of photoautotrophic and heterotrophic microalgal cultivation or *Microbial F		500 L WW/day	TRL 5					Walnut	Industrial WW: paper, foodprocessing, bottle water and cosmeti	Spain																						Detailed information not available at the moment. Pilots will be constructed in 2023
37	Ammonium-rich irrigation water, Ammonium-loaded natural adsorbent	HRAS, ion exchange, absorption/desorption		1,500 L WW/day	TRL 5					Walnut	Urban WW and sewage sludge	Belgium																						Detailed information not available at the moment. Pilots will be
38	ABC Animal Bone Char adsorber (CMC14 - PFC1-A-I.), Solid fermented spent ABC adsorbent for compound BBF	*High temperature pyrolysis for biotech carrier/adsorber production -Liquid fermentation -Solid fermentation and formulation -Liquid phase adsorption		150 L WW/batch	TRL 5					Walnut	Food industrial WW in combination with food industrial by-products	Hungary																						Detailed information not available at the moment. Pilots will be constructed in 2025

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

	Alternative fertilsing product	Technolog	Processing conditions, effectiveness to covert crude material into safe and high quality fertilizing products (include link)	Processing capacity	Technology status (TRL)	CAPEX production cost	OPEX production cost	Legal status (regional/national/EU	Output material	Project	Source	Country	Humidity %	Dry matter %	Availibility estimate Tonnes nation	Kg/tonne of DM															Form/state (liquid/pelletized/solid/granular/powder	Type of application method/methods for best environm	LCA reference	Organic certified/conventional	Agronomic performance of fertiliser (include link)	Comments
1																N %	N organic %	N inorganic %	Ammonium %	Nitrate %	Nitrite %	P %	P_2O_5	K %	K_2O	S %	SO_3	Organic carbon %	pH					
39	KCl, Mg(OH)2, CaCO3	*Nanofiltration – Multiple Effect Distillation – Selective crystallisation		500 L brine/day	TRL 5					Walnut	Brine	Greece																						Detailed information not available at the moment. Pilots will be constructed in 2026
40	Ammonium nitrate/sulphate	*Ion exchange – Membrane contactor – Formulation technology		1,440 L WW/day	TRL 5					Walnut	Urban WW and sewage sludge	Spain																						Detailed information not available at the moment. Pilots will be constructed in 2027

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.