Novafert

D1.2 – Inventory of available recycled products per region and type of waste

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Executive Summary

A comprehensive examination of available information on alternative fertilisers at the EU level is required in order to achieve synchronisation among the existing datasets. This current deliverable D1.2, titled 'Inventory of available recycled products per region and type of waste,' serves a user-friendly database encompassing 76 alternative fertilising products. These products are derived from six secondary raw materials: treated manure, digestate, sewage sludge, wastewater, biowaste, and biological byproduct.

The initial framework for amalgamating the technological and fertilising products data was formulated by TEAGASC. Each consortium member gathered information through their extensive networks, ongoing EU projects (e.g., NITROMAN, WALNUT, NUTRI2CYCLE, etc.), and nutrient recovery platforms and databases (e.g., the Nutriman Farmer Platform). The comprehensive report was submitted as D1.1. Furthermore, UGENT established communication with the sister project Fer-Play to facilitate a comparative analysis of the information they had gathered concerning recovered fertiliser value chains.

UGent collected and structured all pertinent information to create an open-access and well-organised database.
This database encompasses the following components:

1. Technology maturity and readiness level.
2. Output material (product)
3. Processing conditions proved the effectiveness of converting crude input material into safe, high-quality fertilising products.
4. Available CAPEX and OPEX: production costs.
5. Available legal status (regional/national/EU).

The analyses included the following primary technology categories: (i) thermochemical nutrient recovery, (ii) P precipitation, (iii) physical-chemical nutrient recovery, and (iv) biological nutrient recovery methods, such as composting and anaerobic digestion. Each primary technology category included a compilation of well-established technologies from various regions, displayed in blue. This database provides an extensive portrayal of the current state of the art for several alternative fertiliser products while revealing knowledge gaps that require attention for the advancement of their utilisation. The overview will be available for all stakeholders to assess. It will also contribute to forthcoming project endeavours, such as data acquisition for life cycle assessments.

The database, which is handled by UGent, is public and available via the project website https://www.novafert.eu/inventory/, and it can be readily updated during the project period as needed.

The database has also been added to this deliverable as Annex 1.

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Acknowledgements

All members within the NOVAFERT consortium contributed to this deliverable by collecting relevant information from their own resources.

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D1.2 – Inventory of available recycled products per region and type of waste

Annex 1

Database of technology & Product in Europe

	Technology main category	Technology sub category	Product main category	Product sub category	Secondary raw material	Country	Input material	Technology maturity and readiness level	Processing capacity	Process description	CAPEX	OPEX	Market	Considered as fertiliser in the national regulatory framework?	Considered as fertiliser in the European regulatory framework?	Component Material category (CMC)
1	Physical-chemical nutrient recovery	Bio drying	Compost , digestate & other biomass	Bio dried solid fraction	Treated manure	Spain	Pig slurry, solid fraction,poultry manure	7	6.5 - 8.5 t year	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.				Considered as animal manure	Considered as animal manure	
2	Physical-chemical nutrient recovery	Membrane systems (Microfiltration coupled to Reverse Osmosis and freeze concentration)	Scrubber soultion & mineral concentrares	Nutrient-rich concentrate	Treated manure	Spain	manure. Liquid fraction pig slurry	7	1-2 t year	The reverse osmosis produces a nutrient-rich retentate which is further concentrated through a freeze concentration technology						CMC 10
3	Physical-chemical nutrient recovery	Membrane filtration	Scrubber soultion & mineral concentrares	Mineral concentrate	Treated manure	Belgium	Pig manure, co product	9		Mineral concentrate is produced via membrane separation.	€ 680 000	5.76 €/m³ slurry		Seen as animal manure	Seen as animal manure	CMC 10, or CMC 15 if it is ever recognised as a synthetic fertiliser substitute, losing the status of animal manure
4	Thermochemical nutrient recovery	Combustion	Biochar, Hydrochar & Ash	Ash	Treated manure	Spain, Finland	pig slurry, biodried solid fraction	9	0.6 - 1.5 t year	Biothermal drying (composting) is a natural process in which living organisms (bacteria, fungi, protozoa, etc.) convert fresh organic matter under controlled conditions and in the presence of oxygen into homogeneous, stable and humus-rich (organic matter) compost.						CMC 13
	Thermochemical nutrient recovery	*BMC Moerdijk thermochemical process*	*Biochar, Hydrochar & Ash*	*Ash*	*Treated manure*	*Netherlands*	*Poultry manure*	*9*								
5	Physical-chemical nutrient recovery	Membrane contactor	Scrubber soultion & mineral concentrares	Ammonium salts	Treated manure	Spain	Pig slurry, solid fraction	7	2 t/ year	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.						CMC 15
6	Biological nutrient recovery	Enzymatic hydrolysis of microalgae		biostimulants	Treated manure	Spain	Manure	9	0.16 t year	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 .						CMC 1
7	Biological nutrient recovery	Composting	Compost , digestate & other biomass	Organic fertiliser	Treated manure	The Netherlands,Poland, France	Mix of composted poultry manure and composted pig manure, Chicken manure, cattle manure	9		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.				Considered as animal manure	Considered as animal manure	CMC 10
8	Thermochemical nutrient recovery	Manure heating-dispersing technology	Compost , digestate & other biomass	liquid fertiliser - AGROLINI JA-S	Treated manure	Poland	Cattle manure	9		Organic fertilizer obtained by means of an innovative - hydrodynamic cavitation technology of manure from beef cattle bedding and humic acids from leonardita 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.				Considered as animal manure	Considered as animal manure	
9	Physical-chemical nutrient recovery	Stripping & scrubbing	Scrubber soultion & mineral concentrares	Ammonium nitrate	Treated manure	Belgium, Belgium, The Netherland	liquid fraction of pig slurry	9	285 t/y	After S/L separation, liquid fraction is treated in a stripping/scrubbing system to recover nitrogen from it. The liquid fraction flows to the stripper where ammonia is stripped out to the gas phase and subsequently scrubbed with sulphuric acid into ammonium sulphate. Exhaust digestate is rich in potassium and identified as liquid potassium fertiliser.	€ 220 000-550 000	1.3 €/kg, based on 0.9 €/kg N	100 €/tonne	Seen as animal manure	Seen as animal manure	CMC 10, or CMC 15 if it is ever recognised as a synthetic fertiliser substitute, losing the status of animal manure
			Scrubber soultion & mineral concentrares	Ammonium sulphate	Treated manure	France, Belgium, The Netherlands	liquid fraction of pig slurry		40 t/y					Seen as animal manure	Seen as animal manure	CMC 10, or CMC 15 if it is ever recognised as a synthetic fertiliser substitute, losing the status of animal manure
			Scrubber soultion & mineral concentrares	Ammonium water	Treated manure	Belgium			724 t/y							
	Physical-chemical nutrient recovery	*Poul-AR stripping and acidic washing process*	*Scrubber soultion & mineral concentrares*	*Ammonium nitrate/ sulphate*	*Treated manure*	*Belgium*	*Mix of manure organic wastes*	*advanced development stage*								
	Physical-chemical nutrient recovery	*Ortricon stripping and scrubbing process*	*Scrubber soultion & mineral concentrares*	*Ammonium nitrate/sulphate*	*Treated manure*	*Belgium*	*Liquid fraction of manure*	*9*								
	Physical-chemical nutrient recovery	*BENAS process*	*Scrubber soultion & mineral concentrares*	*Ammonium nitrate/sulphate*	*Treated manure*	*Germany*	*Maize silage & poultry manure*	*advanced development stage*								
	Physical-chemical nutrient recovery	*On farm scrubbing*	*Scrubber soultion & mineral concentrares*	*Ammonium sulphate (recovered from NH3 emissions)*	*Treated manure*	*Belgium*										

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	Technology main category	Technology sub category	Product main category	Product sub category	Secondary raw material	Country	Input material	Technology maturity and readiness level	Processing capacity	Process description	CAPEX	OPEX	Market	Considered as fertiliser in the national regulatory framework?	Considered as fertiliser in the European regulatory framework?	Component Material category (CMC)
10	Thermochemical nutrient recovery	Pyrolysis	Biochar, Hydrochar & Ash	Biochar	Treated manure	France	poultry manure (solid)	7	0.3-0.4 t/y	Slow pyrolysis of poultry manure.	10 M EUR		436-863 EUR/ tonne (for conventional pyrolysis) 564-979 EUR/tonne (for microwave pyrolysis)	Yes, but often it's mixed with manure and than it has to be seen as animal manure.	Yes, but often it's mixed with manure and than it has to be seen as animal manure.	CM 14 pyrolisis and gasification materials
	Thermochemical nutrient recovery	*Thermo Catalytic Reforming*	*Biochar, Hydrochar & Ash*	*Biochar*	*Treated manure*	*Germany*	*Cattle dung*	*7*	*65 t/y*	*Thermo-catalytic reforming of pelletised (and terated with citric acid) cattle dung*						
11	Thermochemical nutrient recovery	Thermochemical nutrient recovery	Struvite & other P-products	PK fertilizer from ash	Treated manure	The Netherlands	Ash from poultry manure		57.000 t /year	The PK fertiliser is derived from hydrated ash of incinerated poultry manure. Poultry manureis obtained from poultry farms in the Netherlands meeting EU compliances for animal production. The material is produced from the ash of incinerated poultry manure and water. 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.						CM 13
12	Physical-chemical nutrient recovery	Mechanical separation	Compost , digestate & other biomass	Liquid fraction of manure (after separation)	Treated manure	Ireland	Cattle manure						-20 - -18 EUR/tonne	Considered as animal manure	Considered as animal manure	
			Compost , digestate & other biomass	Solid fraction of manure (after separation)									-20 - -18 EUR/tonne	Considered as animal manure	Considered as animal manure	
	Physical-chemical nutrient recovery	*field dewatering and drying*	*Compost , digestate & other biomass*	*Hygienized liquid and solid fertilizer*	*Treated manure*	*Germany*	*Liquid manure*									
	Physical-chemical nutrient recovery	*Physical chemical nitrogen recovery (VeDoWS adapted stable construction system)*	*Compost , digestate & other biomass*	*Urine from pig manure*	*Treated manure*	*Belgium*	*raw pig manure*	*9*		*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.*						
	Physical-chemical nutrient recovery	*TerraSaline S (ASL)" water extraction*	*Scrubber soultion & mineral concentrates*	*ammonium sulphate (N-fertilizer 21% N, 24% S added with lime)*	*Treated manure*	*Germany*	*Ammonia Sulphate Solution (ASL) of any concentration, for example from digestate; manure recovery other streams*	*9*								
	Physical-chemical nutrient recovery	*TerraOrganic FFT&HEF system*		*solidorganic phase, P-concentrate, N-concentrate: Ammonium sulphate*	*Treated manure*		*Manure*	*9*								
	Physical-chemical nutrient recovery	*Geamix housing system*	*Compost , digestate & other biomass*	*Liquid manure*	*Treated manure*	*The netherlands*	*Raw manure from calves*	*9*								
	Physical-chemical nutrient recovery	*decanter centrifuge*	*Compost , digestate & other biomass*	*liquid manure*	*Treated manure*	*Germany*	*Solid fraction and clarified liquid*	*9*								
13	Physical-chemical nutrient recovery	Reverse osmosis, evaporation	Scrubber soultion & mineral concentrates	Mineral nitrogen concentrates	Treated manure	The Netherlands	raw pig manure	9		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.				Considered as animal manure	Considered as animal manure	CM10, or CM15 if it is ever recognised as a synthetic fertiliser substitute, losing the status of animal manure
14	Physical-chemical nutrient recovery	Drying, mixing, pelletizing and granulation	Granular/Pelletised & Powder	Biolan Kasvimaalannoite	Treated manure	Finland	Chicken manure,									
			Granular/Pelletised & Powder	Biolan Peruna - ja juureslannoite	Treated manure	Finland	Chicken manure,									
			Granular/Pelletised & Powder	Biolan Ravinnepuikko	Treated manure	Finland										
			Granular/Pelletised & Powder	Biolan Kanankakka	Treated manure	Finland										
			Granular/Pelletised & Powder	Biolan Luonnonlannoite	Treated manure	Finland										
			Granular/Pelletised & Powder	Biolan Marja- ja hedelmälannoite	Treated manure	Finland										
			Granular/Pelletised & Powder	Biolan Peruna - ja juureslannoite	Treated manure	Finland										
			Granular/Pelletised & Powder	Arvo 3-1-7-3	Treated manure	Finland										
			Granular/Pelletised & Powder	Arvo 3-1-15-5	Treated manure	Finland										
			Granular/Pelletised & Powder	Arvo 4-1-6-2	Treated manure	Finland										
			Granular/Pelletised & Powder	Arvo 4-1-3-1	Treated manure	Finland										
15	Physical-chemical nutrient recovery	Gas scrubber	Scrubber soultion & mineral concentrates	Novarbo Aino 3-0-3	Treated manure	Finland	Chicken manure									
			Scrubber soultion & mineral concentrates	Novarbo Aino 1-0-3	Treated manure	Finland										
			Scrubber soultion & mineral concentrates	Novarbo Aino 5-0-0	Treated manure	Finland										
			Scrubber soultion & mineral concentrates	Biolan Ravinneneste	Treated manure	Finland, The Netherlands										
16	Physical-chemical nutrient recovery	MAP reactor	Struvite & other P-products	Monoammonium phosphate	Treated manure	Germany	Cattle dung	7	150 t/y	MAP Reactor filled with perlite for the adsorption of nitrogen in off gases of TCR.						
17	Physical-chemical nutrient recovery	Chemical addition	Scrubber soultion & mineral concentrates	N recovery as ammonium	Treated manure	Denmark	Pig slurry	9		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.						
18	Physical-chemical nutrient recovery	With mix fertilizer biological and stripping process	Compost , digestate & other biomass	Enriched compost	Treated manure	Spain	chicken manure from poultry farm,	8		The installed stripping prototype recovered 80 % of the nitrogen from the liquid fraction of the pig manure .						

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19	**Phosphoru precipitation**	REVAWASTE crystallisation process	**Compost , digestate & other biomass**	Struvite	Treated manure	Spain	Pig manure digestate, magnesium chloride and NaOH	Advanced development stage						Precipitated phosphate salts can be legally used as a fertiliser in the Netherlands, Belgium, Germany, France, Denmark and the UK	Yes	CM 12
20	**Thermochemical nutrient recovery**	Hydrothermal carbonisation	**Biochar, Hydrochar & Ash**	Hydrochar	Treated manure	EU	Treated manure from cattle, pig and poultry	8		1. SL separation of the manure. This stage may not be necessary depending on the humidity of the manure, since it is highly variable depending on the type (cattle manure, pig slurry, etc.). 2. Hydrothermal carbonisation. The operation takes place in the liquid phase. This can condition the previous stage of separation SL 3. SL separation of the carbonised media. 4. Treatment of the liquid fraction and dewatering - drying of the solid fraction.	27.3 Million euros for treating 78 000 tonnes/yr	20 €/tonne	130-200 €/tonne	Specific regulation at national level of the Member-States not found	Yes	CM 14 pyrolisis and gasification materials
21	**Physical-chemical nutrient recovery**	Chemical phosphorus removal	**Struvite & other P-products**	Vivianite	Treated manure	EU	Treated manure from cattle, pig and poultry	6		Vivianite is formed to a greater or lesser extent in aerobic digesters, especially if some Fe coagulant has previously been added (chemical phosphorus removal in WWTP for example) or to control the formation of H2S in the biogas. Its formation can also be promoted from the addition of Fe (II or III) and subsequent separation (mainly magnetically) of the mineral from the digested sludge. Therefore, in the case of the manure as raw material, the production process would imply the previous anaerobic digestion of the manure. The procedures to promote the production of vivianite and its recovery from a digested sludge are still at a low TRL level.			10,000 €/tonne (potential)	Yes, but often it's mixed with manure and than it has to be seen as animal manure.No		CM 12
22	**Physical-chemical nutrient recovery**	Pelletising	**Granular/Pelletised & Powder**	Pelletised broiler manure	Treated manure	Ireland	Broiler manure	9	250,000t/year							
23	**Biological nutrient recovery**	Anaerobic digestion	**Compost , digestate & other biomass**	Untreated (raw) digestate incl. animal manure	Digestate	EU				Digestate is obtained after the anaerobic digestion of organic feedstocks in a reactor. The organic material is digested by different groups of microorganisms, which convert large organic compounds in smaller molecules to finally produce methane, carbon dioxide and other gases in small portion. After a period of time in the digester, the remaining organic material is taken out from the reactor and is what is called digestate. Manure was used to produce biogas. The final digestate is spread on the soils without any pre- treatment.	0,2-0,7 EUR/tonne FM	11 €/tonne			When an end-point for products derived from animal by-product will be determined under the ABPR, yes	
			Compost , digestate & other biomass	Untreated (raw) digestate without animal manure	Digestate	EU		9			0,2-0,7 EUR/tonne FM				Yes, when fulfilling FPR requirements	
			Compost , digestate & other biomass	Digestate	Digestate	Belgium	Digestate of cattle slurry									
			Compost , digestate & other biomass	Liquid and solid equivalent digestate	Digestate	Mainly Italy, but also EU in general	Livestock manure alone amounts to ca 1,400 106 tons/year in EU. - Organic fraction of municipal waste 140 106 tons/year in EU. - Number of biogas plants in EU ca 20,000.			Digestate is composed of mixtures of biomasses transformed as a result of an anaerobic digestion process. Agricultural matrices, agro-industrial by-products, organic fraction of organic waste from separate collection. In particular it consists of a stabilized organic fraction formed by the most recalcitrant organic molecules of biological origin and a mineral fraction represented by nutrients in mineral form and other more or less soluble mineral compounds.	storage tanks = 0.5 €/t; pushed solid/liquid separators = 0.2-0.5 €/t complex post-treatment plants (e.g., membranes, stripping) = 1.5-2.5 €/t	related to digestate management and use in the field = 2.5-3 €/t. related to pushed solid-liquid separation = 0.5-1 €/t. membrane treatments and/or stripping 0 4 €/t.	There is no market value, however, a potential substitute value of 6-9 €/t of digestate as such can be applied. Post treatment and eventual marketing of finished products could lead to market values equal to that of synthetic fertilizers.	No, but Italy is waiting for a reply from the EU Commission after a set of explanations provided by the Italian government as per request of the Commission itself. Italy provided these explanations on Sept.2022. Regulatory references: - Decree Law 21/2022 converted into Law n.51 of 20 may 2022. THis states that the digestate can be considered equivalent to fertilizers under certain conditions. On these conditions, the EC requested some explanations provided on Sept. 2022. - Ministerial Decree February 25, 2016 General technical criteria and standards for the regional regulation of the agronomic use of livestock manure and wastewater, as well as the production and agronomic use of digestate. Published in the Official Gazette April 18, 2016, No. 90, S.O. Issued by the Ministry of Agricultural Food and Forestry Policy.	No, at EU level it is not considered fertilizer. Regulatory reference: - REGULATION (EU) 2019/1009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of June 5, 2019.	
	Biological nutrient recovery	*Farm scale anaerobic digestion*	**Compost , digestate & other biomass**	*Digestate*	*Digestate*	*Belgium*	*Digestate pig slurry*	*9*		*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.*						
24	**Physical-chemical nutrient recovery**	Solid-Liquid separation	**Compost , digestate & other biomass**	Liquid fraction of digestate	Digestate	Belgium	digestate		180 Mt/y	Digestate is obtained after the anaerobic digestion of organic feedstocks in a reactor. In order to retrieve the liquid phase of the digestate, a phase separation process is required. It separates the liquid phase from the solid fraction of the digestate. Several technologies are available: belt press, sieve drum, screw press, sieve or decanter centrifuge, and possibly with the use of chemicals to boost separation. It is important to note that the separation process might impact the characteristic of the solid and liquid fractions. Furthermore, some plants also apply a treatment to the liquid fraction such as ammonia-stripping. The liquid fraction of digestate contains high residual of organic compounds.	The CAPEX include the cost for the separation process (which is supposed to be limited) and for storage	4 EUR/tonne (transport for 15 km distance) 4 EUR/tonne (spreading cost)	5 €/tonne	Yes, with different requirements per country	Yes, if EU Regulation for fertilising products 2019/1009 is met	CMC 4 and 5

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			Compost , digestate & other biomass	Solid fraction of digestate	Digestate	Belgium	digestate			Digestate is obtained after the anaerobic digestion of organic feedstocks in a reactor. In order to retrieve the liquid phase of the digestate, a phase separation process is required. It separates the liquid phase from the solid fraction of the digestate. Several technologies are available: belt press, sieve drum, screw press, sieve or decanter centrifuge, and possibly with the use of chemicals to boost separation. It is important to note that the separation process might impact the characteristic of the solid and liquid fractions. Solid fractions of digestate contain more phosphorous. In this database, the data on the solid fraction of the digestate are gathered for the after source separation, and not for the further processing of the solid fraction using for instance composting methods.	N/A		10 €/tonne	Yes, with different requirements per country	Yes, if EU Regulation for fertilising products 2019/1009 is met	CMC 4 and 5
			Compost , digestate & other biomass	Organic soil conditioner	Digestate	The Netherlands	Digested cattle and pig slurry	7	172 t/y	solid fraction of the digestate						
25	Physical-chemical nutrient recovery	Stripping & scrubbing	Scrubber soultion & mineral concentrares	Ammonium sulphate solution	Digestate	The Netherlands	Digested cattle slurry		40 t/y	The liquid fraction flows to the stripper where ammonia is stripped out to the gas phase and subsequently scrubbed with sulphuric acid into ammonium sulphate. Exhaust digestate is rich in potassium and identified as liquid potassium fertiliser						
			Scrubber soultion & mineral concentrares	Ammonium sulphate	Digestate	The Netherlands, Belgium,Poland, France	Digested cattle slurry		285-85,300 t/y							CMC 10
			Scrubber soultion & mineral concentrares	Ammonium nitrate	Digestate	The Netherlands, Belgium, Poland	Digested cattle slurry		285 t/y							CMC 10
	Physical-chemical nutrient recovery	*AMFER stripping process*	*Scrubber soultion & mineral concentrares*	*Ammonium nitrate/sulphate from raw digestate*	*Digestate*	*The Netherlands*	*Whole digestate or liquid fraction*	*9*	*from 1 to 500 ton/hour*	*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.*						
	Physical-chemical nutrient recovery	*VP-Habe manure and digestate valorisation system*	*Scrubber soultion & mineral concentrares*	*Mineral- and Potassium-concentrate, NH3-water, Ammonium sulphate, Clean dischargeable water*	*Digestate*	*The Netherlands*	*Digestate*	*9*	*50.000, 125.000, 250.000 ton/yea*	*Solid-Liquid-separation: Separation takes place in a flotation unit and in a belt filter press. The manure is separated into a solid and a liquid fraction. A flocculant is added. In the flotation system, small air bubbles bring particles to the surface of the tank where it forms a layer of sludge. This layer is scraped off and de-watered in the belt filter press into a solid fraction of 30% dry matter (DM). Reverse Osmosis (RO): A RO processes the liquid fraction (1,7% DM) into a retentate concentrated-N/K2O product (3,4% DM) and a permeate product to be processed in the clean water production. Evaporator/ Stripper/ Scrubber (ESS): The RO-concentrate or thin fraction will be further de-watered in an evaporator. The liquid passes through a falling film 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 concentration into NH3-water (14% N). The evaporator further produces a Potassium concentrate (25% DM), ammonium sulphate by scrubbing the vapour coming out of the evaporator. And condensate. Clean water production (RO-iE): The condensate from ESS unit and the permeate from the RO is cleaned in the RO water polisher and the ion exchanger to achieve the right quality for discharge into surface waters.*						
26	Thermochemical nutrient recovery	Pyrolysis	Biochar, Hydrochar & Ash	Biochar	Digestate	France	Solid fraction of digestate		0.3-0.4 t/y	After S/L separation. Slow pyrolysis of solid fraction of digestate.						CMC 14
27	Phosphoru precipitation	The crystallization of nitrogen and phosphorus in the form of magnesium ammonium phosphate hexahydrate	Struvite & other P-products	Struvite	Digestate	Spain	Digestate from pig manure	7		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.	16 EUR/tonne (CAPEX And OPEX)	16 EUR/tonne (CAPEX And OPEX)	250 EUR/tonne	End of waste declaration (Grondstofverklaring OVAM, Belgium)		CMC12
28	Phosphoru precipitation	P precipitation	Struvite & other P-products	Wet organic phosphorus rich fertiliser	Digestate	The Netherlands,Spain	Digested cattle slurry	Pilot	9 t/y	1. Dewatering of the digestate. 2. Precipitation of calcium phosphates in the liquid fraction obtained in the dewatering, by raising the pH and adding Ca2+ 3. Settling, dewatering, washing and drying of precipitated phosphates. Phosphates precipitation can also be done by acting on the digestate before dewatering, and also in the solid fraction abtained after dewatering. These processes have a higher P recovery potential than treatment of the liquid fraction from dewatering, but will produce precipitates with more impurities, which must be washed and purified.						CM 12
	Phosphoru precipitation	*NuReSys process*	*Struvite & other P-products*	*MgNH4PO4.6H2O Struvite Pellets*	*Digestate*	*Belgium*	*Digestate*	*9*	*Range 0.1 – 2.5 tons/day*	*NuReSys technology can be applied both on digested sludge or post dewatering a number of case specific approaches are possible.*						
	Phosphoru precipitation	*Precipitation*	*Struvite & other P-products*	*K-struvite*	*Digestate*		*Digestate*	*8*	*180 M tonnes/year*	*1. Dewatering of the digestate. 2. Precipitation of K-struvite in the liquid fraction obtained in the dewatering. Process consisting of raising the pH and subsequent addition of Mg2+. NH4+ competes with K+ to precipitate with PO43- and Mg2+, so the NH4+/K+ ratio of the liquid fraction is relevant. In this sense, some digestates, such as the digestate from manure, are more appropriate than others. 3. Growth of crystals, settling, dewatering, washing and drying of crystals.*				*Precipitated phosphate salts can be legally used as a fertiliser in the Netherlands, Belgium, Germany, France, Denmark and the UK*	*Yes*	
29	recovery	Drying	Struvite & other P-products	90% dried organic phosphorus rich fertiliser (calc.)	Digestate	The Netherlands	Digested cattle slurry		1 t/y	drying of the wet P fertilizer						
30	Thermochemical nutrient recovery	Combustion	Biochar, Hydrochar & Ash	Ash	Digestate	Spain, Finland	Digestate	8	0.6 - 1.5 t year	1. Dewatering and drying of the obtained digestate. 2. Dried digestate direct combustión. The ashes obtained will contain a large part of the heavy metals contained in the initial digestate. On the other hand, the P from the ashes will be in a less soluble form and available to plants. For this reason, the ashes can be treated in a second stage to recover the P from the ashes, concentrate it and separate it as much as possible from the contaminants. This can be done in two ways: a) Wet-chemical treatment of the ashes. Dissolution of the ashes in an acid medium and subsequent recovery. It also involves the dissolution of part of the heavy metals in the ashes, as well as the Fe and Al present or added as coagulants. These metals can be removed, through various techniques, thus purifying the final product. P recovery yields between 70 and 98%. b) Thermal treatment of the ashes. Nutrients can be recovered from ashes by high temperature treatments. Volatile heavy metals such as Zn, Pb, Cd and Hg are separated from the product via the gas phase and further collected in the flue dust, and heavy metals with high boiling points such as Fe, Cu, Ni and Cr are separated in the form of a liquid alloy. P recovery yields between 80 and 98%.	40.7-51.7 M€	3.0-3.8 M €/year	N/A	Austria, Denmark, Finland, Germany and Sweden have specific regulations for biomass ash. Not found for digestate ashes or other Member-States	Yes	CM13

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31	**Biological nutrient recovery**	Composting	**Compost , digestate & other biomass**	Composted digestate	Digestate		Digestate			For digestate to be composted, other feedstocks are generally used, such as garden waste. Practically, some AD plants compost their raw digestate, while other compost the solid fraction of the digestate after it undergoes a solid/liquid separation.		Spreading costs: 5 EUR/tonne Transport costs: 5-10 EUR/tonne (15-20 km away)	0-50 EUR/tonne	Yes (requirements differ from one country to another)	Yes (if meetinf the standards set by EU Regulation for fertilising products 2019/1009)	CMC 3-4-5
32	**Biological nutrient recovery**	Anaerobic digestion of several organic and biodegradable wastes.	**Struvite & other P-products**	Vivianite	Digestate		Digestate			Vivianite is formed to a greater or lesser extent in aerobic digesters, especially if some Fe coagulant has previously been added (chemical phosphorus removal in WWTP for example) or to control the formation of H2S in the biogas. Its formation can also be promoted from the addition of Fe (II or III) and subsequent separation (mainly magnetically) of the mineral from the digested sludge. The procedures to promote the production of vivianite and its recovery from a digested sludge are still at a low TRL level.			10,000 €/tonne (potential)	No	No	CMC 12
33	**Physical-chemical nutrient recovery**	FuelCAL®	**Granular/Pelletised & Powder**	Organo-mineral fertilizer OrCal®CM12	Sewage sludge	Poland	Sewage sludge, biodegradable waste, selected animal by-products	9		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						
34	**Thermochemical nutrient recovery**	Activated sludge wastewater treatmen	**Granular/Pelletised & Powder**	Granbial - organic fertiliser	Sewage sludge	Poland	Sexage sludge	9	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	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.						
35	**Thermochemical nutrient recovery**	Bioral technology	**Biochar, Hydrochar & Ash**	BIOROL Natural Fertiliser	Sewage sludge	Poland	Sewage sludge, ashes from biomass combustion	9	Capacity up to 1 Mg/h and biofertiliser productivity from 150-400 kg/h		Capex; 5 mln zł (1,06 mln €)					
36	**Thermochemical nutrient recovery**		**Struvite & other P-products**	Phosphorus	Sewage sludge	Poland	Ashes from incinerated dried sludge from sewage treatment plants and products resulting from the processing of bones			Recovery of phosphorus from both bones and ash from sewage sludge incineration. Bacteria are used for this purpose. These bacteria are used to change the properties of phosphate raw materials. The bacteria make it easier for plants to absorb them.						CM 12
37	**Thermochemical nutrient recovery**	AshDec thermochemical process	**Biochar, Hydrochar & Ash**	Ash	Sewage sludge	Germany	Sewage sludge	7	15.000 t per year	convert the low plant available phosphorus compound in the ash (Ca3(PO4)2) to the highly plant available compound CaNaPO4 while reducing the heavy metal content.The core process encompasses feeding ash to a rotary kiln where it is mixed with sodium compounds (e.g. Na2CO3) and a reducing agent, preferably sewage sludge.						CM 13
38	**Phosphoru precipitation**	The crystallization of nitrogen and phosphorus in the form of magnesium ammonium phosphate hexahydrate	**Struvite & other P-products**	Struvite	Sewage sludge	Spain	Sewage sludge	8		The treatment to produce struvite begins with the reception/accumulation of the wastewater. The currents from the WWTP used for the production of struvite are the sludge supernatants. These streams presents the higher phosphate and ammonia concentration in the WWTP. These influents are introduced into a crystallizer whit addition of magnesium chloride and sodium hydroxide. The addition of magnesium chloride is necessary to provide sufficient Mg2+ ions for the precipitation of the struvite. The amount added will be a function of the magnesium concentration present in the reactor and in the feed, and in accordance with the Mg/P molar ratio. The dosing of the soda is carried out to raise and maintain the pH at an optimal value to favour the crystallization and precipitation. To favour the fluidization of the struvite in the crystallizer, air is also introduced through the lower part of the reactor. After some time with the crystallizer in "production" mode, part of the struvite formed must be extracted.	€ 6.15 M	183 €/tonne	350 €/tonne	Not in Spain	Yes, according to EU Regulation 2019/1009. From: 16/06/2022	CMC 12
	Phosphoru precipitation	PHORWater - biological processess and struvite scaling process	**Struvite & other P-products**	struvite	Sewage sludge	Spain	Waste water sewage	6	10kg/day	The innovation of PHORWater is that faces the problem from less to more. Moving from the optimization of the integral management to increase phosphorus availability and decrease uncontrolled precipitation of phosphorus, to a new simple-operational P-recovery reactor.						
39	**Phosphoru precipitation**	AshDec™ process	**Struvite & other P-products**	Precipitated calcium phophate	Sewage sludge	Sweden	Sewage sludge ash	8	30,000t/year	a thermochemical process designed to convert the low plant available phosphorus compound in the ash (Ca3(PO4)2) to the highly plant available compound CaNaPO4 while reducing the heavy metal content.The core process encompasses feeding ash to a rotary kiln where it is mixed with sodium compounds (e.g. Na2CO3) and a reducing agent, preferably sewage sludge. The material is treated at around 900 °C for 15-20 min. Sodium ions replace calcium ions in the phosphates and formcitrate-soluble CaNaPO4 compounds.						CM 12
40	**Physical-chemical nutrient recovery**	Anaerobic digestion of sewage sludge	**Struvite & other P-products**	Vivianite	Sewage sludge	The Netherlands	Sewage sludge	6		Vivianite is the main iron phosphate mineral that forms during the digestion of sewage sludge. Vivianite (paramagnetic) can be recovered from the sludge after digestion using a magnetic separator. This has been demonstrated on a laboratory scale and on a pilot scale (ViviMag project). This technological process consists of a separation process to recover vivianite from the digested sludge by means of magnetic separation.				Not in Spain	Yes, according to EU regulation 2019/	CMC 12
41	**Physical-chemical nutrient recovery**	Membrane systems (Microfiltration coupled to Reverse Osmosis and freeze concentration)	**Scrubber soultion & mineral concentrares**	Nutrient-rich concentrate	Sewage sludge	Spain	Liquid fraction of Fish sludge from RAS	4		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						

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42	**Biological nutrient recovery**	Biodrying	**Compost , digestate & other biomass**	Biodried solid fraction	Sewage sludge	Spain	Solid fraction of fish sludge from RAS	7		Solid fraction of fish sludge collected in recirculating aquaculture system is treated by biodrying						
43	**Biological nutrient recovery**	Composting	**Compost , digestate & other biomass**	Composted sewage sludge (IT)		Italy		9					1-15 €/tonne Average: 7 €/tonne	Yes, in Italy from 1998. Actual law is the D.lgs 75/2010	Not required by the EU Regulation 2019/1009, though it is by several national laws all over Europe.	CMC 3
44	**Physical-chemical nutrient recovery**	Digestion followed by magnetic separation	**Struvite & other P-products**	Vivianite		The netherlands		6		Vivianite is the main iron phosphate mineral that forms during the digestion of sewage sludge. Vivianite (paramagnetic) can be recovered from the sludge after digestion using a magnetic separator. This has been demonstrated on a laboratory scale and on a pilot scale (VivMag project). This technological process consists of a separation process to recover vivianite from the digested sludge by means of magnetic separation.			10,000 €/tonne (potential)	Not in Spain	Yes, according to EU Regulation 2019/1009. From: 16/06/2022	
45	**Physical-chemical nutrient recovery**	Sequencing batch reactor (SBR) + nutrients recovery module	**Scrubber soultion & mineral concentrares**	Enriched reclaimed water (rich in N (especially organic nitrogen), P and K)	Waste water	Spain (Andalusia region, Salteras municipality)	Wastewater from the slaughtering industry	9	The raw material used in this project was slaugtherwhouse 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	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.	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	
46	**Physical-chemical nutrient recovery**	RichWater® system	**Scrubber soultion & mineral concentrares**	Enriched reclaimed water	Waste water	Spain (Andalusia region, Algarrobo municipality)	Urban wastewater	6	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.	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.	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				
47	**Physical-chemical nutrient recovery**	Secondary wastewater treatment with ultrafiltration, active carbon and reverse osmosis (DW) 2. Secondary wastewater treatment mixed with brine (RW)	**Scrubber soultion & mineral concentrares**	Enriched reclaimed water	Waste water	Spain (Murcia region - borders Andalusia to the East - , Roldán municipality)	Urban wastewater	6		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.						
48	**Physical-chemical nutrient recovery**	Ultrasonic treatment and a ring filtration system	**Scrubber soultion & mineral concentrares**	Enriched reclaimed water	Waste water	Spain (Murcia region - borders Andalusia to the East - , Roldán municipality)		6		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.					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	
49	**Phosphoru precipitation**	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.	**Struvite & other P-products**	Recovered N and P - struvite, ammonium nitrate and sludge	Waste water	Spain (Murcia region - borders Andalusia to the East - , Murcia municipality)	Urban wastewater	6	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€).	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.	OPEX for struvite production is 202 k€/y (183 €/t) and for AN, 891 k€/y (460 €/t). 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. Overall, a positive margin of 322 k€/y would be achieved.	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.			The recovered struvite and ammonium nitrate were characterised to accomplish the legislative requirements for new fertilising materials (EU 2019/1009)	

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50	**Phosphoru precipitation**	Phorwater process	**Struvite & other P-products**	Struvite	Waste water	Spain	waste water	7	Pilot plant has a capacity of 20m3/d (recovery of 10 kg/d), but it is easy to scale up a full scale reactor	Struvite crystallisation process. Struvite is produced in a CSTR with agitation and pH control. Mg salt is dosed according to the selected molar dosage ratio Mg/P.	struvite production (75 k€ for elutriation process) and 1.39 M€ for ammonium nitrate production (total of 6.15 M€)	6-42 €/kg P	0 - 1,000 €/tonne (100 €/tonne as most probable value)	End of waste declaration (Grondstofverklaring Ovam, Belgium), Precipitated phosphate salts can be legally used as a fertiliser in the Netherlands, Belgium, Germany, France, Denmark and the UK	CMC12 compliant	CMC 12
			Struvite & other P-products	K-Struvite	Waste water		Urban waste water	3		Source-separated human urine is considered one of the most important target effluents to produce K-struvite. Urine is present in urban wastewater; however, the studies were performed with synthetic water (synthetic human urine). The precipitation of k-struvite is characterized by great complexity due to its solubility and the substances that inhibit the process. . In addition, to apply K-struvite as a slow-release fertilizer, technological improvements are required to produce high purity crystals and large dimensions (so that they can be easily recovered). The formation of fine crystals is the most frequent problem during precipitation applications.	€ 100 000 as pilot unit for demonstration. (Does not really reflect a resonable CAPEX or the concept of economy of scales)	4 €/kg P	200 €/tonne			CM 12
51	**Biological nutrient recovery**	Wastewater-based algae bio-refinery (WWAB).	**Alternative biomass**	Microalgae hydrolysate	Waste water	Spain (Andalusia region, Almeria municipality)	Wastewater (sewage, centrate and pig manure) + marine water	5		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.						
52	**Biological nutrient recovery**	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	**Struvite & other P-products**	Phosphorus	Waste water	Spain (Andalusia region, Almeria municipality)	Urban wastewater	6		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.						
53	**Biological nutrient recovery**	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.	**Biostimulant**	Biofertilisers and biostimulant products	Waste water	Spain (Andalusia region, Almeria municipality)	Urban wastewater + marine water	7		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 /m3, 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/						
54	**Physical-chemical nutrient recovery**	Mebrane systems (UF, RO) coupled with freeze concentration	**Scrubber soultion & mineral concentrares**	Nutrient-rich concentrate	Waste water	Spain	Liquid fraction from WWTP in the transformation industry of fish (aquaculture)	4		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.						
55	**Biological nutrient recovery**	Biodrying	**Compost , digestate & other biomass**	Biodried solid fraction	Waste water	Spain	Solid fraction from WWTP in the transformation industry of fish (aquaculture)	7		Solid fraction of fish sludge collected in WWTP in fish transformation industry is treated by biodrying.						
56	**Physical-chemical nutrient recovery**	HRAS, ion exchange, absorption/desorption	**Scrubber soultion & mineral concentrares**	Ammonium-rich irrigation water, Ammonium-loaded natural adsorbent	Waste water	Belgium	Urban WW and sewage sludge	5	1,500 L WW/day							
57	**Physical-chemical nutrient recovery**	Crystalisation	**Struvite & other P-products**	Vivianite	Waste water		Industrial waste water			Some laboratory-scale studies have studied the possibility of producing vivianite from industrial wastewater. However, a review of potentials of phosphorous recovery as vivianite from wastewater (Wu et al.m 2019) concluded "Phosphorus recovery from vivianite as an innovative practice has been creatively considered. However, studies on vivianite formation and phosphorus recovery from wastewater are inadequate and still in their childhood.			10,000 €/tonne (potential)	NO	Yes	CMC 12
58	**Phosphoru precipitation**	Precipitation of P using cations		Dairy processing sludge	Waste water	Ireland	Wastewater from milk processing plants	6	126,718 t/year							
59	**Phosphoru precipitation**	Ostara's Pearl phosphorus recovery	**Struvite & other P-products**	Struvite	Waste water	Ireland	Urban wastewater	9								

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60	Physical-chemical nutrient recovery	Gas scrubber	Scrubber soultion & mineral concentrares	Biolan Ravinneneste	Biowaste	Finland	Seaweed			NH4 from the composting reactor is scrubbed into lactic acid to get ammonium lactate liquid. Additional nutrients mixed to the liquid						
61	Physical-chemical nutrient recovery	Drying, mixing, pelletizing and granulation	Granular/Pelletised & Powder	Biolan Ravinnepulkko	Biowaste	Finland	Seaweed			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						
			Granular/Pelletised & Powder	Biolan Hevonkakkalannoite	Biowaste		Seaweed, feather meal									
			Granular/Pelletised & Powder	Biolan Hava- ja rodolannoite	Biowaste		Seaweed, feather meal, meat and bone meal									
			Granular/Pelletised & Powder	Biolan Kanankalkka	Biowaste		Seaweed									
			Granular/Pelletised & Powder	Biolan Luonnonlannoite	Biowaste		Seaweed									
			Granular/Pelletised & Powder	Biolan Parvekekasvilannoite	Biowaste		Seaweed, Meat and bone meal, blood meal, seaweed									
			Granular/Pelletised & Powder	Biolan Tomaatti- ja vihanneslannoite	Biowaste		Seaweed,Meat and bone meal, blood meal, seaweed									
			Granular/Pelletised & Powder	Biolan Yrtti- ja taimilannoite	Biowaste		Meat and bone meal, blood meal, seaweed									
			Granular/Pelletised & Powder	Biolan Marja- ja hedelmälannoite	Biowaste		Seaweed, feather meal									
62	Thermochemical nutrient recovery	Pyrolysis	Biochar, Hydrochar & Ash	Biochar	Biowaste	EU	Biowaste such as food and garden waste	8		The stages of the process are: 1. Physical separation of improper materials (sieving/shorting). 2. Drying of the pretreated BW at least 85% dry solids 3. Pyrolysis of the pretreated BW and separation of the biochar from the rest of the products obtained. An alternative is to treat the BW by AD, and use the solid fraction of the digestate obtained as raw material for pyrolysis. In this case, it is necessary to previously dry said solid fraction.	14.5 M€ 3 ton/h biochar production plant	N/A	450 - 850 €/tonne From plant materials	National regulation in Germany, Austria, Switzerland, and Italy. Biochar of vegetable origin only.	Yes	CMC 14
63	Biological nutrient recovery	Composting	Compost , digestate & other biomass	Compost	Biowaste	EU	Biowaste	9		Bio-waste (food waste and garden waste) can be composted either aerobically or anaerobically therefore producing a fertilizer or soil enhancer.	€ 30 M for a 60 000 tonnes annual capacity	51 €/t	10Eur/t (fresh mass) - 55 €/t	Yes, in Italy from 1998. Actual law is the D.lgs 75/2010	Yes, European Union Regulation 2019/1009	CMC 3
	Biological nutrient recovery	Composting	Compost , digestate & other biomass	compost	Biowaste	Ireland	Household waste	9								
	Biological nutrient recovery	Biociclo	Compost , digestate & other biomass	Compost	Biowaste	Italy	Green waste and food waste	9	69.000 t/year of waste	Waste undergoes an aerobic treatment: treatment takes place in a large enclosed space in a depression environment. The intake system constantly conveys the air present in the covered structure into the external filters of 752 square meters to be purified						
	Biological nutrient recovery	IOK Afvalbeheer	Compost , digestate & other biomass	Compost	Biowaste	Belgium	Veg, fruit & garden waste	9	25.000 ton vfg-compost/y							
	Biological nutrient recovery	ACEA pinerolese	Compost , digestate & other biomass	Compost	Biowaste	Italy	municipal organic waste	9	60000 t/y of organic waste	The first phase of the process consists of an anaerobic biodigestion (in the absence of oxygen), which allows the recovery of material (compost) with an innovative energy recovery system (biogas). In the future framework, all the biogas is going to be used for biomethane production.						
	Biological nutrient recovery	IMOG process	Compost , digestate & other biomass	Compost	Biowaste	Belgium	green waste (from parks, public domain, gardens)		12.000 ton green compost/y	At IMOG the accepted green waste follows undergoes a 4-phase composting: (a) reduce (chip) and mix the green waste, (b) 5 weeks : set up compost heap on windrow with membrane and forced aeration, (c) 3 weeks: converting windrow to a higher pile ("table"), (d) 3 weeks: conversion from table to table.						
64	Biological nutrient recovery and Thermochemical nutrient recovery	anaerobic digestion, N stripper and scrubber	Scrubber soultion & mineral concentrares	AS solution	Biowaste	Italy	Biowaste	9	77 kt y-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.						

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	Technology main category	Technology sub category	Product main category	Product sub category	Secondary raw material	Country	Input material	Technology maturity and readiness level	Processing capacity	Process description	CAPEX	OPEX	Market	Considered as fertiliser in the national regulatory framework?	Considered as fertiliser in the European regulatory framework?	Component Material category (CMC)
65	**Physical-chemical nutrient recovery**	Evaporation and reverse osmosis	**Scrubber soultion & mineral concentrares**	Evaporator concentrate	Biowaste	Belgium	Biowaste from agrofood industry	9	134 kt y-2	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.						
66	**Physical-chemical nutrient recovery**	Microfiltration and reverse osmosis, ion exchange, RePeat system	**Scrubber soultion & mineral concentrares**	RO concentrate	Biowaste	The netherlands	Biowaste from agroindustry/pig slurry	9	134 kt y-2	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.						
			Compost , digestate & other biomass	Solid fraction of digestate	Biowaste											
			Struvite & other P-products	Low-P soil improver	Biowaste											
			Struvite & other P-products	Precipitated P salt	Biowaste											
67	**Physical-chemical nutrient recovery and Thermochemical nutrient recovery**	Sieving/sorting, shredding/pelletizing, possibly drying	**Biochar, Hydrochar & Ash**	Hydrochar	Biowaste	EU	Biowaste	8		The stages of the process are: 1. Physical separation of improper materials (sieving/shorting). 2. Mixing of the pre-treated BW with water and hydrothermal carbonization of the mixture. 3. SL separation of the carbonised media. 4. Treatment of the liquid fraction and dewatering-drying of the solid fraction. An alternative is to treat the BW by AD, and use the digestate (undried) as feedstock for hydrothermal carbonization.	€ 1.8-10.8 M (capacity 9300-43 000 tonnes biowaste/year)	20 €/tonne of bio-waste for capacity of 78 000 tonnes/year	130-200 €/tonne	Specific regulation at national level of the Member-States not found	Yes	CMC 14
68	**Thermochemical nutrient recovery**	Sieving/sorting. Possibly drying depending on the biowaste moisture	**Biochar, Hydrochar & Ash**	Ash	Biowaste	EU	Two major fractions are garden & park waste and food & kitchen waste.	9		1. BW direct combustion. The ashes obtained will contain a large part of the heavy metals contained in the initial BW. On the other hand, the P from the ashes will be in a less soluble and available to plants form. For this reason, the ashes can be treated in a second stage to recover the P from the ashes, concentrate it and separate it as much as possible from the pollutans. This can be done in two ways: a) Wet-chemical treatment of the ashes. Dissolution of the ashes in an acid medium and subsequent recovery. It also involves the dissolution of part of the heavy metals in the ashes, as well as the Fe and Al present or added as coagulants. These metals can be removed, through various techniques, thus purifying the final product. P recovery yields between 70 and 98%. b) Thermal treatment of the ashes. Nutrients can be recovered from ashes by high temperature treatments. Volatile heavy metals such as Zn, Pb, Cd and Hg are separated from the product via the gas phase and further collected in the flue dust, and heavy metals with high boiling points such as Fe, Cu, Ni and Cr are separated in the form of a liquid alloy. P recovery yields between 80 and 98%.	40.7-51.7 M€	3.0-3.8 M €/year	N/A	Austria, Denmark, Finland, Germany and Sweden have specific regulations for biomass ash. Not found for digestate ashes or other Member-States	Yes	CMC 13
69	**Phosphoru precipitation**	Struvite crystallisation process	**Struvite & other P-products**	Struvite	Biowaste	Murcia, Spain	Selective organic biowaste	7		Struvite crystallisation process. Struvite is produced in a CSTR with agitation and pH control. Mg salt is dosed according to the selected molar dosage ratio Mg/P	€ 100 000		80-120 €/tonne	Precipitated phosphate salts can be legally used as a fertiliser in the Netherlands, Belgium, Germany,	Yes	CMC 12
70	**Physical-chemical nutrient recovery**	Drying, mixing, pelletizing and granulation	**Granular/Pelletised & Powder**	Arvo 11-1-2-1	Biogical byproduct	Finland	blood meal									
			Granular/Pelletised & Powder	Arvo 8-1-5-2	Biogical byproduct	Finland	blood meal									
			Granular/Pelletised & Powder	Arvo 8-1-2-1	Biogical byproduct	Finland	blood meal									
71	**Physical-chemical nutrient recovery**	Pelletizing	**Granular/Pelletised & Powder**	Mineral NPKS	Biogical byproduct	Finland	MBM									
72	**Thermochemical nutrient recovery**	Recycle, recover, reuse high temperature pyrolosis process	**Struvite & other P-products**	Bio-phosphate	Biogical byproduct	Hungary	Food grade animal bone	8	20.800t/year							
73	**Physical-chemical nutrient recovery**	Drying, mixing, pelletizing and granulation	**Granular/Pelletised & Powder**	Biolan Parvekekasvilannoite	Biogical byproduct		Seaweed, Meat and bone meal, blood meal, seaweed									
				Biolan Tomaatti- ja vihanneslannoite	Biogical byproduct		Seaweed,Meat and bone meal, blood meal, seaweed									
74	**Biological nutrient recovery**	Composting	**Compost , digestate & other biomass**	Composted biological by-products	Biogical byproduct	Germany	Biological by-produt	9				6-13 €/t FM	4-6 €/t FM			
75	**Phosphoru precipitation**	The crystallization	**Struvite & other P-products**	Struvite	Biogical byproduct	EU	Biological by-produt	9						Precipitated phosphate salts can be legally used as a fertiliser in the Netherlands, Belgium, Germany, France, Denmark and the UK	Yes	
76	**Biological nutrient recovery**	Composting	**Compost , digestate & other biomass**	Spent mushroom compost	Biogical byproduct	Ireland	Chopped wheatan straw, poultry manure, horse manure & gypsum	6								

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