Greengas AD (Limerick, Ireland)

A short introduction to Greengas AD

GreenGas AD Plant is a farm based anaerobic digestion plant located near Shanagolden in County Limerick, Ireland. The the 250 kW_{el} plant was constructed in the course of 2010 and when commissioned in 2011 it was one of the first such plants in Ireland. The plant has undergone a number of upgrades and now operates at $1MW_{el}$.

Feedstocks

The plant processes wastes from a poultry and dairy farm as well as other imported organic feedstocks such as waste agricultural residues and food wastes (Table 2).

Biogas production

Currently GreenGas AD Plant produces over 2,400,000m3 of energy rich renewable gas for the production of electricity and heat through use of a high efficiency combined heat and power unit (CHP). The electricity generatated is sold to the national grid under the Renewable Energy Feed In Tariff scheme (REFIT), the heat is recycled for use in the plant and the nearby poultry enterprise. The nutrient rich digestate is used on local farm land as a high quality eco fertiliser (Table 3).

Table 1. Technical information of the biogas plant

Characteristics	
Date of construction	2010
Size (MWel)	1
Volume (m^3)	3,248
Digester type	Mesophilic digestion

Table 2. Origin of feedstock

Type	Mass per year
Poultry manure	1 kt
Dairy manure	7 kt
Food waste	10 kt
Dairy sludge	3 kt
Total	21 kt

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	57,8
CO_2(%)	38,2
H_2S (ppm)	170
O_2 (%)	0,8
N_2 (%)	3,2
Siloxanes (‰)	0,1
Total biogas production (Mm^3)	2,424
Biogas per tonne of feedstock (m^3/t)	~65

Horizon 2020

*The H2020 EU-project SYSTEMIC (**Sy**stemic large **s**cale eco-innova**t**ion to advance circular **e**conomy and **m**ineral re**c**overy from organic waste in Europe) receives funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under Grant Agreement no. 730400*

Greengas AD (Limerick, Ireland)

Current process and disposal routes for end products

All digested feedstock is pastuerised by heating to 72°C for over one hour in 25 m^3 batches. All of the digestate is used on farm land controlled by the plant. The use of digestate has reduced the depedency on artificical ferteliser with little to no atrificial fertiliser added. Due to the increase in capacity in the plant and the resulting increase in digestate more digestate application options are needed.

Current problems and obstacles

The high moisture content of digestate adds unnecessary transport and land application cost. By reducing the digestate volume and maintaining the nutrient levels the fertiliser value of the digestate is enhanced and significantly lowers transportation and application costs providing an all important route to market for digestate.

Table 4. NPK content of digestate

	Percentage of total solids
N total	8,8
NH_4-N	6
P_2O_5	3,6
K_2O	5,9

Current drivers for interest in Nutrient Recovery and Reuse (NRR) technologies

By producing biogas from organic materials Greengas AD Plant acts as a sustainable alternative to landfill for their bio-waste suppliers.

The Systemic Project could help to find ways of enhancing nutrient recovery and see if there are ways to process the digestate into an organic fertiliser by reducing the moisture content of the digestate.

Horizon 2020

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Biogas Bree (Bree, Belgium)

A short introduction to Biogas Bree

Table 1. Technical information of the biogas plant

Date of construction	2013
Size (MWel)	3,6
Volume (m^3)	13.500
Digester type	Mesophilic digestion

Biogas Bree is Belgian biogas plant located in Bree, in the province of Limburg near the Dutch border. The region (Northern Limburg) is characterized by intensive livestock farming, mainly pigs and cattle. Like in almost all provinces in Flanders, the soil is P rich and strict national fertilization limits create a surplus of manure in this area. The plant is operational since 2013 and has a treatment capacity 85.000 tonnes/year. 28.000 MWh of electricity is produced per year (Table 1) The heat from the CHP is used to evaporate the manure and to dry the digestate.

Feedstocks

Biogas Bree receives pig slurry from pig farmers in a radius of 20 km. The manure is 30% of the total amount of feedstock yearly processed (Table 2). All animal manure is treated in a separate line without contamination with the anaerobic digestion of organic biological waste.
70% of the feedstock consists of products with a high biogas potential like agricultural waste products and f.e. molasses and glycerine.

Table 2. Origin of feedstock

Type	Mass per year
Pig slurry	25 kt
Agricultural waste	26 kt
Organic biological waste	34 kt
sludge WWT	
pet food	
molasse	
glycerine	
Total	85 kt

Biogas production

Due to the high quality of the feedstock, 12 Mm^3 of biogas is produced every year. The biogas is converted in a CHP into electrical and thermal energy. 6% of the electricity produced is used on site and 94% is put on the grid. All heat is re-used on the plant in the evaporator (2500 kW) and the belt dryer (2300 kW).

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	58
CO_2 (%)	35
H_2S (ppm)	50
O_2 (%)	0
Total biogas production (Mm^3)	12
Biogas per tonne of feedstock (not manure) (m^3/t)	200

BioGas-Bree Horizon 2020

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Biogas Bree (Bree, Belgium)

Current process and disposal routes for end products

Pig manure is first evaporated (in-house design) to and is anaerobically digested in a separate digester. Yearly 4,2 kt 'animal' digestate is dried in a belt dryer to 1,5-2 kt.
The organic biological waste is digested in 3 connected digesters. The 'vegetal' digestate (43.000 tonnes/year) undergoes a separation with a centrifuge to remove the phosphorus from the liquid fraction (37.000 tonnes/year).
The liquid and solid fraction are used on the Biogas Bree's own lands (100 ha) or sold (negative value) to arable farmers directly or indirectly through contractors.

Table 4. Average composition of the recovered products and estimiated separation efficiency

	Animal digestate			Vegetal digestate		
	Before drying	After drying		Before separation	Liquid fraction	Solid fraction
Mass (kt)	4,2	1,5-2		43	37	6
Dry matter (%)		92	DM separation efficiency (%)			80-85
N-total g/kg		20	N separation efficiency (%)		80-90	10-20
P_2O_5-total g/kg		35	P_2O_5 separation efficiency (%)		60	40
K_2O-total g/kg		43	K_2O separation efficiency (%)		90-95	5-10

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

The P and N content of the digestate(products) is too high for profitable and easy marketing in the surroundings. Also the large volume of digestate (43 kt per year) and the prospect of more stringent fertilizer application limits makes Biogas Bree think about their next move to be prepared for the future.

Current problems and obstacles

The OBW feedstock with high biogas potential renders the digestate very sticky and viscous. This contributes to a suboptimal separation of the digestate by the centrifuge (only 40% P-removal to the solid fraction) at a high cost due to polymer use and maintenance.
Biogas Bree would like to find a solution that includes optimizing their current separation technique with as little chemicals and polymers as possible.

Centrifuge: Pieralisi Jumbo 2

To lower the ammonia content of the liquid fraction of the digestate, Biogas Bree sees potential in an ammonia stripping/scrubbing technology with biogas as a stripping gas.

The question remains if an evaporation step should be included somewhere in the process to also lower the volume and concentrate the potassium.

Also Biogas Bree finds all current innovative (NRR)techniques too expensive or not technically stable enough to consider investment.

They hope SYSTEMIC can provide guidance and support in solving these problems.

Horizon 2020

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Waterleau New Energy (Ieper, Belgium)

A short introduction to Waterleau New Energy

Waterleau is an environmental services company in the fields of water, air and waste treatment as well as in new energy recovery. Waterleau New Energy is their biogas plant in Ieper. It's location in West-Flanders is characterized by intensive pig husbandry and therefore has to cope with a manure surplus and stringent local fertilizing legislation.

Table 1. Technical information of the biogas plant

Date of construction	2012
Size (MWel)	3,2
Volume (m^3)	12.000
Digester type	Mesophilic digestion

Feedstocks

The biogas plant is co-digestion of 45% manure and 55% biological waste streams.(Table 2).

Biogas production

The plant produces 1400Nm³ of biogas per hour (i.e. 800 Nm³ of methane per hour) which is valorized in a CHP to energy (7,5 MWth, 3,2 Mwel, 1,5 MW steam and 2,5 MW hot water).

Table 2. Origin of feedstock

Type	Mass per year
Manure and solid fraction of manure	54 kt
Grain waste	8,4 kt
Potato waste	9,6 kt
Glycerine	9,6 kt
Sludge industrial waste water treatment	16,8 kt
Other	21,6 kt
Total	120 kt

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	57
CO_2 (%)	
H_2S (ppm)	<200
O_2 (%)	
Total biogas production (Mm^3)	11,2
Biogas per tonne of feedstock (m^3/t)	120

Current process and disposal routes for end products

The feedstock is heated/mixed up to 40°C and is digested for 30 days (+10 days in the post digester). The digestate is hygienized (1hour 70°C) and separated by a centrifuge. The solid fraction is dried in a Hydrogone® dryer. This is an indirect dryer which can evaporate 1-1,8 tonnes of water per hour. This water goes, together with the liquid fraction of the digestate (15m³/h) to an biological aerobic water treatment for small removal of COD. In the next step (evaporator) ammonium is transferred to the gas phase and a concentrated (K rich) solution is condensed. The ammonia rich gas is stripped and an ammonium solution is recovered.
The dried digestate is exported to France, the concentrated liquid fraction is exported also outside Belgium as fertilizer and ammonium water is used as exhaust gas treatment.

WATERLEAU Horizon 2020
The H2020 EU-project SYSTEMIC (Systemic large scale eco-innovation to advance circular economy and mineral recovery from organic waste in Europe) receives funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under Grant Agreement no. 730400

SYSTEMIC
Circular solutions for biowaste

Factsheet
SYSTEMIC Outreach Location

Waterleau New Energy (Ieper, Belgium)

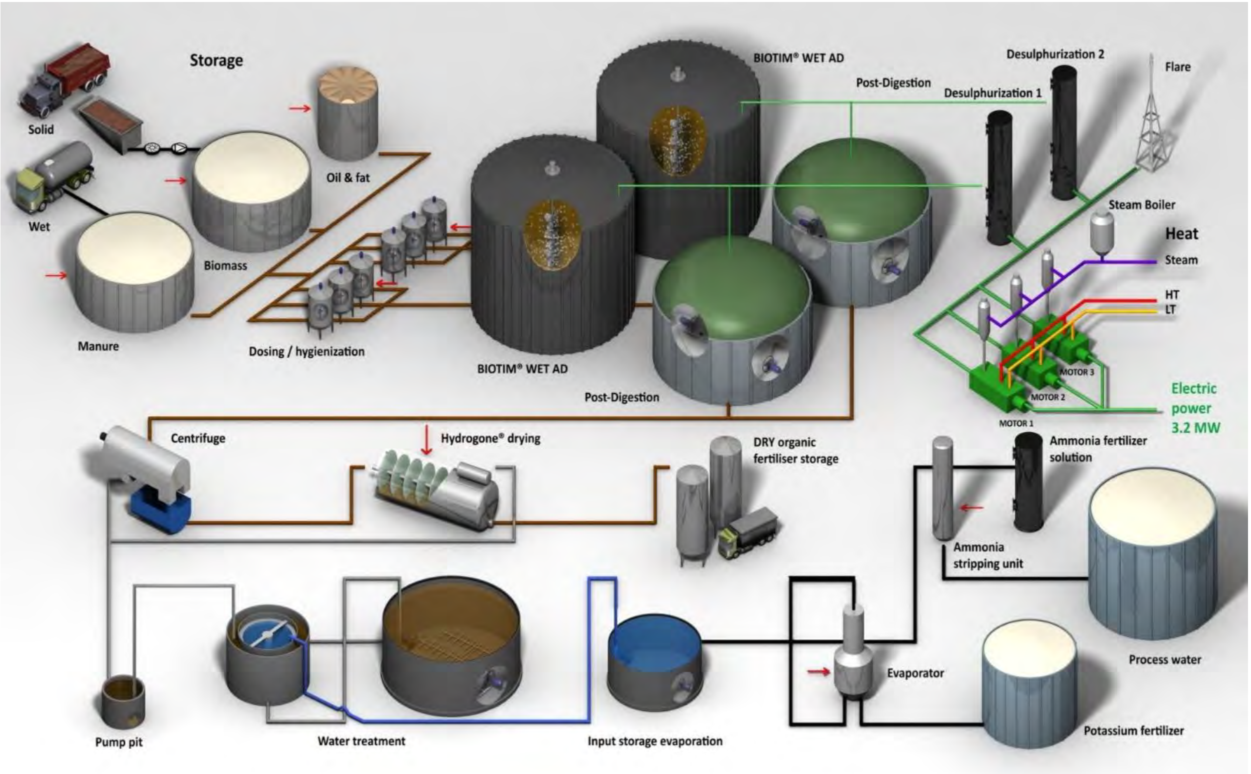

Table 4. Average composition of the recovered products and estimated separation efficiency

		Mass (kton/year)	Dry matter (%)	N- total (g/kg)	P-total (g/kg)	K_2O-total (g/kg)
Digestate	Raw digestate		10,0			
	Solid fraction after centrifuge		25			
	After drying	5	95	3	5	13
	Liquid fraction after centrifuge		2,5			
	After aerobic treatment		2,0			
	AmmS-solution	1,5		15% AmmS		
	K-concentrate	12	20	7	3,5	20

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

Getting rid of digestate (dried or concentrated) is getting harder or more expensive because of limited application and dosing. Production of separated nutrients gives more opportunities for the future and is more sustainable for the installation and the supplier who gets his biological waste streams or manure processed.

Waterleau New Energy hopes to learn in SYSTEMIC how to improve the efficiency of the evaporation and ammonium stripping unit. This could also create an end product of better quality and which could be easier to market.

Waterleau is also interested in learning more about membrane separation (reverse osmosis) which could be a possible polishing step of the liquid fraction towards dischargeable water.

WATERLEAU

Horizon 2020

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Factsheet
SYSTEMIC Outreach Location

SCRL Kessler (Attert, Belgium)

A short introduction to SCRL Kessler

Table 1. Technical information of the biogas plant

Date of construction	2003
Size (MWel)	0,905
Volume (m^3)	3000
Digester type	Mesophilic digestion

The biogas plant in Attert is located on the Faascht farm and built in 2003 by it's owners Jean and Nicolas Kessler. Back then, agriculture was in a crisis as a consequence of the dioxin crisis, mad cow and foot-and-mounth diseas outbreaks. As a result, farmers' incomes fell and the Kesslers saw energy production as an opportunity to escape this because of the stability of the electricity market.
Their project was supported by the non-profit organization Pays de l'Attert and several INTERREG research projects. Today the plant and farm is run by Mélody Kessler and Ludovic Peter.

Feedstocks

Manure from the farm's own dairy cows and meat cattle is digested (25% of the total input) and grass, biological waste from the supermarkets and from the food industry are imported (Table 2).

Table 2. Origin of feedstock

Type	Mass per year
Cattle manure	5 kt
Biological waste supermarket	10 kt
Waste from food industry	5 kt
Total	20 kt

Biogas production

Today, 20.000 MWh per year is produced. From the 6000 Mwel- produced per year, 20% is used on the Faascht farm and 80% goes to the grid.

The thermal energy (7.200 MWth/year) from the CHP is used on the plant (10%), to heat the farm and houses (5%), for hygienisation of the digestate (5%) and for drying digestate and wood (25%).
Plans are being made to use more heat on site, by building a greenhouse for tomato cultivation, where also digestate and CO2 can be locally used as as fertilizers.

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	57-60
CO_2(%)	40
H_2S (ppm)	50 (max 350)
O_2 (%)	0,08
Total biogas production (Mm^3)	4
Biogas per tonne of feedstock (m^3/t)	200

Horizon 2020

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SCRL Kessler (Attert, Belgium)

Current process and disposal routes for end products

The digestate is hygenized (1h 70°C) and stored in a covered digestate tank of 4000 m³. From there it is either directly dried on a band dryer of separated in a screw press in a solid and a liquid fraction. The liquid fraction of the digesate is used on grass land (20% of the 90 ha of the farm's own land). The solid fraction goes to fields as a fertilizer. The dried digestate pellets go to horticulture.

Table 4. Average composition of the recovered products

		Mass (kton/year)	Dry matter (%)	N- total (g/kg)	P_2O_5 (g/kg)	K_2O-total (g/kg)
Digestate	Raw digestate to dryer	1	7,2	7,6	1,87	3,9
	After drying	0,38	27,2	7,4	10,8	3,8
	Solid fraction after centrifuge	1				
	Liquid fraction after centrifuge	11				

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

SCRL Kessler is currently participating in the Interreg Grande Région project PERSEPHONE with partners form France, Luxembourg, Germany and Wallonia. Like SYSTEMIC, the projects intends to enhance the value of digestate. The site in Attert is testing the use of CO2, heat and liquid fraction of digestate for algae cultivation, which could for example be used in the pharmaceutical, bio-plastic, biodiesel field cultivation or one day maybe animal feed.

Interreg Grande Région | Großregion Perséphone
Fonds européen de développement régional | Europäischer Fonds für regionale Entwicklung

Intégr

Production d'**E**nergies **R**enouvelab

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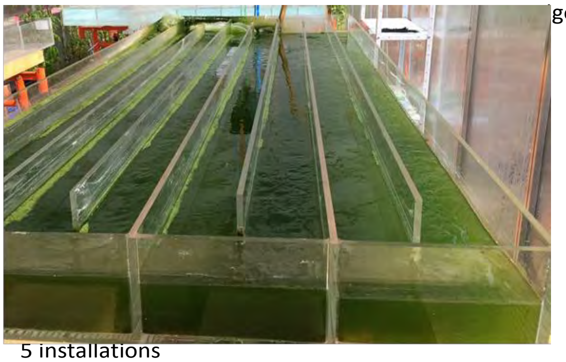

5 installations

The project also studies the recovery of H_2 and recirculating it to the digestor for conversion to methane.

Because both SYSTEMIC and PERSEPHONE are working on bio-refinery of digestate and circular economy, SCRL Kessler hopes to establish an interaction between both.

They are particularly interested in the management and reduction/recovery of nitrogen in the digestate.

They are also keen to see organic nitrogen recognized as less polluting for soils and water than nitrogen from gas.

2 partenaires industriels

2 partenaires méthodologiques

Ferme du Faascht
Horizon 2020
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Biogas plant Bojana (Čazna, Croatia)

A short introduction to Bojana

Bojana is a Croation biogas plant located in Čazna. The plant is operational since October 2014 and localized in a region characterized by agriculture and intensive cattle farming, which creates a manure surplus of manure in this area. The plant is operational since 2013 and has a treatment capacity 85.000 tonnes/year.

Table 1. Technical information of the biogas plant

Date of construction	2014
Size (MWel)	2
Volume (m^3)	12.000
Digester type	Thermophilic digestion

28.000 MWh of electricity is produced per year (Table 1) The heat from the CHP is used to evaporate the manure and to dry the digestate.

Feedstocks

Bojana receives solid cow manure from farmers in a radius of 10 km. No gate fee is charged for the manure, which makes up for 55% of the total amount of feedstock yearly processed (Table 2). 42% is corn silage.
Animal manure and vegetal residues are digested together (co-digestion).

Table 2. Origin of feedstock

Type	Mass per year
Corn silage	28 kt
Cow manure with hay	37,8 kt
Total	65,8 kt

Biogas production

Each year, the plant produces, 8,76 Mm^3 of biogas. The biogas is converted in 2 a CHPs with a capacity of 2MW into 16.400 MWh electrical and thermal energy per year. 8% of the electricity produced is used on site and 92% is put on the grid. 53,4% of the heat is used to warm up the digesters. Plans are made to use the rest of the heat for drying corn and Bojana is considering to invest in an orchard and a fridge for fruit.

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	55,3
CO_2(%)	44,5
H_2S (ppm)	118
O_2 (%)	0,04
Total biogas production (Mm^3)	8,76
Biogas per tonne of feedstock (m^3/t)	131

Horizon 2020

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Biogas plant Bojana (Čazna, Croatia)

Current process and disposal routes for end products

Cow manure and corn silage is digested and 65,6 kton of digestate is produced per year. This is separated with a screw press to 84,66% liquid fraction, which is stored in a lagoon and 15,34% solid fraction, stored in an open warehouse. Both are used for land spreading on the 1500 ha of partner lands, surrounding the biogas plant.
Currently, Bojana has agreements with farmers to exchange digestate is for cow manure (feedstock) and only transport costs are taken into account.

Table 4. Average composition of the recovered products

	Digestate		
	Before separation	Liquid fraction	Solid fraction
Mass (kt)	65,6	55,54	10,06
pH		7,91	8,58
Dry matter (%)		5,6	26,7
Kj-N (%)		0,33	0,58
NH4-N (%)		0,12	0,11
P-total g/kg		0,70	2,08
K_2O-total g/kg		2,35	2,52

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

Nonetheless, feed in tariffs are getting lower and dairy farming is starting to expand in the area. Bojana would like to be prepared for the future by creating a sustainable business case that further optimizes their production and reduces waste.

Creating a fertilizer that is more balanced for the demand of the crops (barley and corn) could render higher crop yields and therefore Bojana recognizes that nutrient recovery from the digestate could create an added value for the company.
With regard to this, Bojana is interested in nitrogen stripping technology.

Current problems and obstacles

At the moment, disposal of digestate is no issue due to a lot of arable land to spread it on and cattle farmers providing constant feedstock.

However, Bojana thinks that investing in nutrient recovery techniques is not yet profitable for them at this moment.

Therefore they would like to learn from the demo plants and other outreach locations and exchange practical experience on nutrient recovery technologies before considering an investment.

Bojana Horizon 2020
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Biogastur (Navia-Asturias, Spain)

A short introduction to Biogastur

BIOGASTUR originated in 2009 with the objective of promoting resource management projects (waste) of the primary sectors, based on the biogas generation as well as the production of biological fertilizers from the final digestate. In 2017 the construction started of one of the biggest projects in renewable energy.

Table 1. Technical information of the biogas plant

Date of construction	2017
Size (MWel)	4,5
Volume (m^3)	28.000
Digester type	Thermophilic digestion

Feedstocks

The biogas plant would treat cattle slurry (87,5% of total yearly input), crop residues and dairy waste from an agreement with a milk cooperative each count for 6,25% of the total input (Table 2).

Biogas production

This plant will be producing 17 Mm^3 of biogas per year. This will be valorised into 30GWh of energy per year by mean of 3 CHP engines (Jenbacher 420) of each 1500kWe with an efficiency of 42%. The heat coming from the CHP, hot water, hot air and flu gasses will be recovered as 4692 kWth.

Table 2. Origin of feedstock

Type	Mass per year
Cattle slurry	350 kt
Agro-industrial residues	25 kt
Dairy waste	25 kt
Total	400 kt

The CHP can only work efficient if the concentration of hydrogen sulphide is below 200 ppm. To remove hydrogen sulphide from the biogas, the BIDOX® system is used, which is a patented system based on biological desulfurization. Here, anaerobic bacteria carry out the oxidation of sulphate and the sulphate is removed in the form of a very dilute sulfuric acid solution. The concentrations of H_2S left in the biogas are lower than 1000 mg/L.

BIDOX ® tower

Horizon 2020

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Biogastur (Navia-Asturias, Spain)

Current process and disposal routes for end products

Feedstocks are digested in a residence time 3-4 weeks. The digestate is separated by a centrifuge in a liquid fraction and a solid fraction.
The liquid fraction is treated by MBR-NAS® process. This is a membrane reactor where a classic biological activated sludge system removes the nitrogen and organic material by oxidation and nitrification-denitrification to N_2 gas.
By applying the ANPHOS® system to the liquid fraction, phosphorus is recovered as 1 tonne of struvite per day.
350 kt of liquid fraction per year is dried with recovered heat.

The solid fraction is only dried if a water content of less than 20 % is preferred. Part of the biogas would be then be used in order to dry the solid fraction.

Biogastur owns his own truck fleed with which they can collect manure and distribute their fertilizers to farmland.

Table 4. Average composition of the recovered products and estimated separation efficiency

		Mass (kton/year)	Dry matter (%)	N- total (g/kg)	P-total (g/kg)	K_2O-total (g/kg)
Digestate	Raw digestate	360.000	10			
	Solid fraction after centrifuge	25.000	70			
	After drying	24.000	90	2,7	1,5	2
	Liquid fraction after centrifuge	300.000	12			
	Struvite	0,3				
	Dischargeble water					

Current problems and obstacles

At the moment, struvite is not needed as a fertilizer in the region, but there is a need for custom made ferilizers. Blending of different recovered nutriets (N-P-K) could create a market.

Nitrogen is not recovered in the biogas plant but is converted to an environmentally harmless form N2. Ammonia stripping scrubbing would create a problem for use of the ammonium sulphate as a fertilizer, since this product is subject to REACH regulation in Spain.

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

Biogastur wants to integrate wastes as a resource, through optimal treatment and guaranteeing its traceability.

The biogas market in Spain needs still to be developed and more specifically agro-industrial biogas, where Biogastur will be leading in production capacity, the technologies implemented and the level of management of waste and GHG reduction.
They considers it essential to be at the forefront of technology and information which is developed within the European framework, covered by the Horizon 2020 program objective.

Horizon 2020

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Biogas plant Makassar (Torregrosa, Spain)

A short introduction to Biogas Plant Makassar

Table 1. Technical information of the biogas plant

Date of construction	2013
Size (MWel)	0,5
Volume (m^3)	17,000
Digester type	Mesophilic digestion

Som Energia, a non-profit green energy consumption cooperative owns the biogas plant Makassar, which is operational since end 2013. The biogas plant is located in the municipality of Torregrossa (Catalonia), an area with intensive pig breeding and slurry treatment plants.

Daily monitoring of the operation of the plant is carried out by Som Energia by means of a remote monitoring system and follow-up meetings with the plant operators.

Feedstocks

(Table 2).

The plant is located close to a pig farm which supplies pig slurry (60% of the digester's input). Organic biological waste contributes for 40% of the yearly feedstock and the biogas plant receives a gate fee for processing this waste.

Table 2. Origin of feedstock

	Mass per year
Vegetal fat	1,2 kt
Municipal waste water sludge	4,5 kt
Water with oil form the food industry	2,4 kt
Organic household waste	2,4 kt
Water from vegetable extracts	1,5 kt
Pig slurry	17,8 kt
Total	29,8 kt

Biogas production

The biogas is cleaned by an active carbon filter and valorized in a CHP. Green electricity is injected to the grid. The thermal energy is used to heat up the digesters and on the neighbouring farm.

In 2017 Biogas Plant Makassar produced 2.701 MWh and is estimated to produce 3.200 MWh in 2018.

Table 3. Yearly biogas production and average composition 2017

Component	Estimation
CH_4 (%)	65-75
CO_2(%)	30-50
H_2S (ppm)	0-25
O_2 (%)	0,02
Total biogas production (Mm^3)	1,275
Biogas per tonne of feedstock (m^3/t)	42,78

Horizon 2020

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Factsheet
SYSTEMIC Outreach Location

Biogas plant Makassar (Torregrosa, Spain)

Current process and disposal routes for end products

Pig slurry and organic waste are received in concrete ponds and metal tanks in the floor. They are pumped to the mixing tank and from there to the digesters.
These are working in series and are equiped with a gasometer of double cover to store the gas. After a retention time of approximately 40-60 days the digestate passes to the open lagoons (11000 m^3) until it's collected for application to field. No disposal costs are charged.

Table 4. Average composition of the digestate in 2017

	Digestate
Mass (kt)	29,8
NH4-total g/kg	0,003
P_2O_5-total g/kg	0,409
K_2O-total g/kg	1,096
Spread on (ha)	524

Drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

- The changes in the new tariff framework (Royal Decree 413/2014) force Som Energia to find the balance between the operating costs, the electrical production and the number of hours of operation but always with the objective of producing the maximum amount of green energy possible.
- Digestate has no (negative or positive) value in Spain and the land to spread the digestate on in the area is limited.
- Application of digestate is becoming more complicated
- There are no subsidies for biogas in Spain

To improve their business case with regard to these problems, Som Energia applied as an outreach location in the SYSTEMIC project and hopes to find out if nutrient recovery could provide answers.

However, the technologies proposed by SYSTEMIC should be easy to fit into their current plant design and its environment and cost of operation and transport of end products should be acceptable within the current business model.

The technologies should prove to be mature and based on real experiences but above all that the resulting products have a defined and studied marketing route.

Separation of the digestate f.e. by means of a centrifuge is a simple way to introduce nutrient recovery.

Ammonia losses could be reduced by covering the digestate lagoon, installing air washers and learning more about NH_3 emmision poor application techniques.

Horizon 2020

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Emeraude Bio-énergie (Lamballe, France)

A short introduction to Emeraude Bio-énergie

Emeraude bio-energie is a collective project initiated by Dénitral, subsidiary of the Cooperl group .
Created in the 1990s to solve the problems of lack of spreadable surfaces, Dénitral is now specialized in the implementation of organic slurry treatment plants on pig farms.

Table 1. Technical information of the biogas plant

Characteristics	
Date of construction	2017
Size (MWel)	5,3
Volume (m^3)	14,700
Digester type	Mesophilic digestion

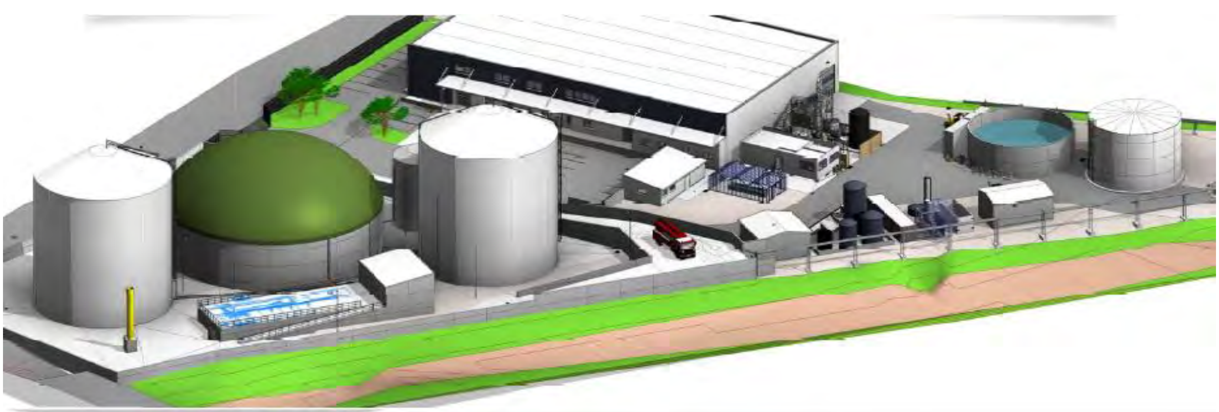
Emeraude Bio-énergie will be located in the municipality of Lamballe, in the industrial site of Ville Es Lan City, 2 km from the agglomeration, right next to the Cooperl's main slaughterhouse. This project will complete the environmental center, which already receives the organic materials collected from Cooperl pig breeders and waste streams from the meat processing industry.

Feedstocks

25% of the input of the digester is the solid fraction of pig manure, which is supplied by a hundred farms (average size of 100 sows) mainly located in the department of Côtes d'Armor. A lot of these farms work with the TRAC system (V scrapping separating), which integrates manure separation in the building.
40% of the feedstock is slaughterhouse wastewater of the Cooperl slaughterhouse and 25 % recycled water from the liquid fraction of the digestate (Table 2).

Table 2. Origin of feedstock

Type	Mass per year
Slaughterhouse waste water (6-8% DM)	65 kt
Solid pig manure (30% DM)	38 kt
Recycled water for dilution	53 kt
Total	156 kt



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Emeraude Bio-Energie (Lamballe, France)

Biogas production

530 m³ of bio-methane/h is purified and. directly fed into the gas grid where it will circulate with natural gas and can be directly distributed and used by consumers in Lamballe and its surroundings. This will represent 79 million kilowatt hours/ year, i.e. the annual natural gas consumption of about 3100 single-family homes.
The biogas is not valorised by means of a CHP to produce electricity because the current process, where bio-methane is injected directly is more suitable for large installations and guarantees a better energy efficiency.

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	66
CO_2(%)	32,2
H_2S (mg/m³)	61
O_2 (%)	0,11
Total biogas production (Mm³)	4,8
Biogas per tonne of feedstock (Nm³/t)	30,7

Current process and disposal routes for end products

The existing reception infrastructures on the industrial site will be modernized and the feedstocks, already stored on the site, will be transported by hermetic pipes to the digester.
The digestate is separated by a centrifuge in a liquid fraction and a solid fraction. Ammonia in the liquid fraction removed by an ammonia stripper/scrubber and recovered as an ammonia sulphate solution.

The ammonia-free liquid fraction in further treated in a waste water treatment to dischargeable water which is reused for the operation of the cooperative's industrial sites (non-food processes).

The solid fraction is transported to Fertival (on the other side of the railroad) where it is dried and sold as natural fertilizers.

Table 4. Average composition of the recovered products

		Mass (kton/year)	Dry matter (%)	N- total (g/kg)	P_2O_5 (g/kg)	K_2O-total (g/kg)
Digestate	Raw digestate	156	7,5	6	4,1	2,3
	Solid fraction after centrifuge	35,802	23	9,7	13,7	1,37
	After drying	13,316	85	21	46	26
	Liquid fraction after centrifuge (+polymer)	170,015	1,8	3,2	0,7	1,7
	AmmS-solution	7,205		7,7		
	Dischargeble water	91,383				

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

- With Emeraude bio-énergie, Dénitral wants to consolidate its activity and go further in the protection of the environment by valuing the waste it collects.
- In SYSTEMIC, they would like to compare the digestate treatment cost of evaporation and stripping an find out the benefits of commercilizing ammonia sulfate solution or in cristallized form.
- Also, they want to learn from the experiences of other outreach locations about main problems during construction and implementation on big projects.

Emeraude bio-énergie
Horizon 2020
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GMB BioEnergie (Lichtenvoorde, The Netherlands)

A short introduction to GMB

GMB is a company suppling services in design & construction, management & maintenance and operation. One of the six clusters of their organizational structure is GMB BioEnergy, which includes their biogas plant in Lichtenvoorde, named BIR BV.
BIR BV is a joint venture between Waterstromen BV and GMB BioEnergy BV.

Table 1. Technical information of the biogas plant

Date of construction	2004
Size (MWel)	1,2
Volume (m^3)	1600
Digester type	Mesophilic digestion

Feedstocks

Waste streams from chemical, pharmaceutical and food industry are used as feedstock (75%), also waste streams from the catering industry are digested (25%) (Table 2).

Table 2. Origin of feedstock

Type	Mass per year
Food waste from catering industry	12 kt
Waste streams from chemical, pharmaceutical of food industry	28 kt
Total	40 kt

Biogas production

Anaerobic digestion process produces yearly over 4 Mm^3 of biogas which is valorised in a CHP to electricity and heat.

The electricity is used on the waste water treatment site (next to the biogas plant) and 78% goes to the grid.

Heat from the CHP is used to heat up the waste water for optimal biological treatment and to pre-heat the feedstocks and keep the digesters on temperature. The rest of the heat (app. 21%) goes through an underground pipeline to the public swimming pool of Lichtenvoorde and plans are made to make the heat also available for other public buildings.

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	67
CO_2(%)	33
H_2S (ppm)	250
O_2 (%)	0,2
Total biogas production (Mm^3)	4
Biogas per tonne of feedstock (m^3/t)	100

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GMB BioEnergie (Lichtenvoorde, The Netherlands)

Current process and disposal routes for end products

GMB trucks unload the waste streams and manure in 1 of the 4 available buffers.
The feedstock is then pumped to the 2 digesters. During a residence time of 20 days, part of the organic components is converted to biogas.
The digestate transported to GMB Zutphen where it is further processed.
There, the digestate is separated together with sludge from WWT (industrial and communal) in a centrifuge or decanter.

The liquid fraction is processed in the WWTP of Waterschap Rijn en IJssel (located next to the site of GMB in Zutphen).

The solid fraction, together with sludge from several other communal wwtp's is composted in enclosed tunnels under carefully controlled conditions. The heat from biological processes is used these to heat up the newly filled tunnels and for hygienisation. After 25 days of biological drying, the compost is sieved. The dry compost has a granular form and can be used as biofuel in f.e. power plants. In countries where this is possible in terms of legislation, biogranulate is also used as a nutrient rich fertilizer.

The air with which the compost is aerated still contains a lot of ammonia and is therefore cleaned with an air scrubber by adding sulfuric acid. This sulfuric acid binds the ammoniacal nitrogen, resulting in ammonium sulphate. A nitrogenous sulfur fertilizer that is officially recognized and traded as such.

Table 4. Average composition of the recovered products and estimated separation efficiency

			Mass (kton/year)	Dry matter (%)	N- total (g/kg)	P-total (g/kg)	K_2O-total (g/kg)
Digestate		Raw digestate	40	5,8			
	+ WWT sludge	Digestate + sludge	250	4,5			
		Solid fraction after centrifuge	20	20-24	28	18	6
		Biogranulate	13	65	27	23	7
		Liquid fraction after centrifuge	190	0,4			
		AmmS-solution	1,1		80	-	-
		Dischargeble water	190	0,1			

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

The dried digestate from sewage sludge contains a lot of nutrients and organic matter but also heavy metals, pharmaceuticals, hormonally active substances, persistent organic pollutants, etc
The partition of these substances in digestate or composting products are not yet clear and the risks and effects when these products will be applied are unknown.
Dutch and European (waste) legislation and risk perception of customers and consumers prevents us from closing the nutrient cycles.
Therefore GMB is interested in technology which could deliver products with clearly defined properties regarding environmental and health impact and risks and that could be sold on the European market.

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Waternet (Amsterdam, The Netherlands)

A short introduction to Waternet

Waste Water Treatment Plant Amsterdam West (Waternet) is the second largest waste water treatment (WWT) plant of the Netherlands treating the waste water of more than 1 million inhabitants of Amsterdam with an active sludge system, i.e. nitrification-denitrification and enhanced biological phosphorus removal (EBPR), a modified process by the University of Cape Town (MUCT). EBPR exploits the potential of some micro-organisms, known as Phosphate Accumulating Organisms (PAOs), to accumulate phosphate (as intracellular polyphosphate).

Table 1. Technical information of the biogas plant

Date of construction	2007
Size (MWel)	4
Volume (m^3)	34400
Digester type	Mesophilic digestion

Feedstocks

Primary sludge from the primary sedimentation and activated sludge from the biological waste water treatment are anaerobically digested on site (Table 2).

Table 2. Origin of feedstock

Type	Mass per year
Waste activated sludge	325 kt
Primary sludge	325 kt
Total	650 kt

Biogas production

Yearly 13 million cubic meter of biogas is produced and valorized in the CHP of the nearby household waste incineration installation. 20000 MWh of electricity is used per year on the WWTP and the rest of the electricity produced goes to the grid. 50000 GJ thermal energy is used for heating of the digesters.

Table 3. Yearly biogas production and average composition

Component	Estimation
CH_4 (%)	60
CO_2(%)	40
H_2S (ppm)	400
Total biogas production (Mm^3)	13
Biogas per tonne of feedstock (m^3/t)	20

Current process and disposal routes for end products

The digestate is dewatered by a centrifuge and the liquid fraction is recycled to the waste water treatment. The solid fraction of the digestate is incinerated because of the heavy metal content (Figure 2).

Problems and obstacles

This system is running successfully at Waternet, yet a few years ago they realized that there was a lot of scaling in pipelines and on the dewatering equipment which causes wear and tear on the centrifuge. A massive build up of struvite crystals ($MgNH_4PO_4.6\ H_2O$ (N-P-K, 5-28-0)) in the sludge holding tank was discovered.

Figure 1. Struvite depositions in the pipes to the sludge holding tank

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Waternet (Amsterdam, The Netherlands)

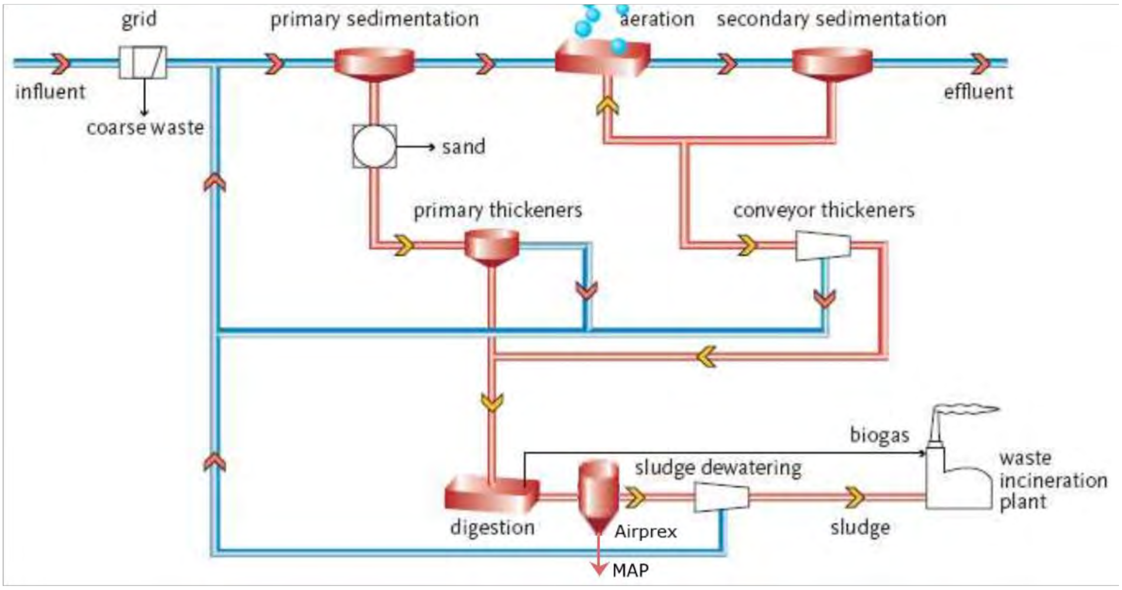

Figure 2. Scheme of the WWTP and digestate treatment

Two important factors where causing this struvite deposition.
1. The phosphorus captured in the biomass of the bacteria is released during anaerobic digestion and reacts with the present ammonium:
$Mg^{2+} + NH_4^+ + PO_4^{3+} + 6\ H_2O \rightarrow MgNH_4PO_4.6H_2O$ (mono-ammonium-phosphate or struvite)
2. The design of the digester, where CO2 is stripped through turbulence construction of the digester favored the formation of struvite crystals by a pH rise, pushing the equilibrium to the right.

Waternet started doing tests to precipitated the struvite in a controlled way in a reactor in stead of in the pipes and the equipment.

Eventually, the AirPrex® system was build on full scale before the dewatering step and 95% of the ortho-phosphate from the digestate is removed as struvite. This is sold to ICL fertilizers Europe, also located in Amsterdam, who uses it as resource for the production of tailor made fertilizers.

Figure 3. Recovered struvite

Table 4. Average composition of the recovered products

	Mass (kton/year)	Dry matter (%)	N- total (g/kg)	P-total (g/kg)	K_2O-total (g/kg)
Raw digestate	650	3,6	-	41	-
Solid fraction after centrifuge	90	23,5	-	40	-
Liquid fraction after centrifuge		-	1000 (mg/L)	-	-
Struvite	500	> 90	50	126	0

Current drivers for interest in Nutrient Recovery and Reuse (NRR) Technologies

Currently only 20% of the total phosphorus present in the digestate can be recovered as struvite. Waternet has the ambition to increase the amount of recovered phosphorus substantially and was therefore selected as one of the outreach locations of SYSTEMIC.

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Atria (Seinäjoki, Finland)

A short introduction to Atria

Atria Biogas and NRR Plant project is located in Seinäjoki (Finland), a region characterized by intensive primary production.
A-Farmers is a part of Atria Group and has been responsible of the project's first steps.
The plant will be built in 2019 and will have an estimated treatment capacity of 164,000 tonnes/year in the beginning.
Produced biogas (70 GWh) will be purified and liquefied and mainly used as Liquified Biogas (LBG) for heavy traffic. CHPs will provide electricity and heat for the plant.

Table 1. Technical information of the biogas plant

Characteristics	
Date of construction	2019
Size	17 tons of LBG/day 1.6 MWel
Volume (m^3)	>16 000
Digester type	Mesophilic digestion

Drivers for Nutrient Recycling

Nutrient recovery can provide a solution for the limited capacity to spread manure on land in the region. When manure can be valorised to recovered products, this would enhance the development of primary production of A-farmers in the neighbourhood of slaughterhouses.
This would also decrease transportation costs and contribute to better management practices of environmental aspects of primary production. Hereby the competition capability of Finnish meat in the global market will be enhanced.

In Finland, growing season is quite short. There are only <2 months per year when the digestate spreading makes sense, since spreading into frozen land is not allowed nor useful. The rest of the year, the produced digestate has to be stored, which requires a very large storing capacity.
Atria realized that digestate spreading as such is not going far enough in nutrient recycling, nor from the environmental or economic point of view and therefore nutrient recovery will be a central aspect in the new plant.

In a sustainable business there is also need for renewable energy in the production chain (industry, logistics) and the AD plant can supply for this.
And last but not least, business itself was also a driver for building an AD plant with nutrient recovery.

Feedstocks

In the beginning, the co-digestion plant will treat about 164 kt of feedstock per year out of which 70% is manure (i.e. pig, cattle, poultry). Co-substrates include slaughterhouse waste and food industry waste (Table 2). The capacity will be enlarged later into 240 kt at least. Environmental impact assessment has been made for 360 kt per year.

Table 2. Origin of Atria feedstock (estimated for business plan)

Type	Mass per year
Pig slurry	50 kt
Solid fraction of pig slurry	20 kt
Cow manure	10 kt
Chicken manure	10 kt
By-products slaughterhouse	22 kt
Food industry waste	10 kt
Plant biomass	20 kt
Potato fluid	20 kt
Total	164 kt

A-Tuottajat

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Atria (Seinäjoki, Finland)

Biogas production

The biogas produced will be around 10 Mm^3/year (estimation, Table 3). The biogas is mainly upgraded and liquefied into LBG and used as fuel for heavy traffic. The amount of LBG produced is estimated 50 GWh. Biogas plant own energy (electricity, heat) will be produced by CHPs.

Table 3. Yearly biogas production and average composition before purification

Component	Estimation
CH_4 (%)	65
CO_2 (%)	34
H_2S (ppm)	500
Total biogas production (Mm^3/year)	10
Biogas per tonne of feedstock (m^3/t)	60

Nutrient Recovery and Reuse (NRR) Technology

The envisaged process works as follows:

- Feedstocks are received into a continuously mixed tank and diluted into 12% with recycled water if needed.
- After the receiving tank, mixed feedstock is directed into a pre-digester/hydrolysation tank before pumping through hygienisation into the mesophilic digesters.
- Digestate (8% dry matter, DM) is sent to a centrifuge for solid/liquid separation. Coagulation and flocculation are enhanced by the addition of polymer which is prepared with recovered water from the RO.
- The solid fraction, containing ~70% of the initial total phosphorous (P) of the feedstock, is stored in the plant for 1 – 2 months before transport into end-users which use it as such in agriculture as a fertilising soil conditioner. The liquid fraction from which DM content will be <2% is directed through a step screening unit to a evaporation. The screen will purify rests of animal hairs, straw, fouling particles etc. before the evaporation unit. Acid (H_2SO_4) is used to maintain nitrogen in a NPK-concentrate produced by evaporation unit.
- To the produced condensate a small amount of base (NaOH) may be added to adjust the pH before going to the RO. This will ensure the required recovery of nitrogen and soluble organic compounds (biological oxygen demand (BOD) before discharging on waters. The concentrate from the RO has low nutrient levels and it is used for polymer manufacturing or feedstock dilution.

Products and market

The digestate treated with the NRR process will be transformed into 35 kt of biosolids (solid fraction digestate), 35 kt of NPK-concentrate and 70 kt of water. Part of the NPK-concentrate can be mixed with the solid fraction to improve the fertiliser properties of solid fraction. Product characteristics are listed in table 4.

Table 4. Composition of the recovered products (target values)

	Biosolids	NPK-concentrate
Dry matter (%)	30	20
Organic Matter (% of DM)	50	70
N-total g/kg	10	25
P_2O_5-total g/kg	8	2.5
K_2O-total g/kg	2	5

Economic and environmental benefits

- <50% of incoming material amount needs to be stored and transported: less costs and emissions
- Concentrated nutrient products can be transported economically into areas where nutrients are really needed: use of excess nutrients, less emissions to surface –and ground water
- Nutrients can be used in a more sustainable way, e.g. valuable quality nutrient products and using according to plant needs: less emissions to air and water
- Approximately 200 m^3 of water will become available for recycling and discharging on site, the amount of water doesn't have to be transported as diluted digestate or treated as waste water
- Fresh water need is very low: less costs of fresh water and waste water

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Annex 1: Atria Key Outreach location - Seinäjoki, Finland