

Development of business models for six large-scale anaerobic digesters

A product from the H2020 project SYSTEMIC



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A full list of all end products is available at www.systemicproject.eu. The SYSTEMIC project was coordinated by Oscar Schoumans (oscar.schoumans@wur.nl) and Inge Regelink (inge.regelink@wur.nl) from Wageningen Environmental Research.

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List of abbreviations

AD	Anaerobic digestion
ADR	A ccord européen relatif au transport international des marchandises D angereuses par R oute (Agreement concerning the International Carriage of Dangerous Goods by Road)
AS	Ammonium sulphate
ASL	Ammonium sulphate solution
BAT	Best available technique
BCE	Business case evaluation
CA	Conservation agriculture
CAP	Common Agricultural Policy
CAPEX	Capital expenditure
CBG	Compressed biogas
CEC	Cation exchange capacity
CHP	Combined heat and power plant
CIB	Consorzio Italiano Biogas (Italian Biogas Consortium)
CNG	Compressed natural gas
COD	Chemical oxygen demand
CSTR	Continuous stirred-tank reactor
DAF	Dissolved air flotation
DeNO _x	Denitrification
DM	Dry matter
EBA	European Biogas Association
EBIT	Earnings before interest and tax
EBITA	Earnings before interest, amortisation, and tax
EBT	Earnings before tax
EC	“EC” label on EU regulatory framework compliant products
EIB	European Investment Bank
EJ	Exajoule
ESIF	European Structural and Investment Funds
EUA	European Union Allowance (EUA) i.e. the tradable unit under the European Union Emissions Trading Scheme (EU ETS)
FPR	Fertilising Product Regulation (EU) 2019/1009
FGD	Flue gas desulfurization
FiP	Feed-in premium
FIT	Feed-in tariff
FTE	Full time equivalent
GC	Green certificates
GDP	Gross domestic product
GHG	Greenhouse gas
GZV	Groot Zevert Vergisting
HDF	High density fibreboard (hardboard)
HGV	Heavy goods vehicles
HHV	High heating value
ICE	International combustion engine

IEA	International Energy Agency
IEC	Installed electricity capacity
IP	Intellectual property
IPCC	Intergovernmental Panel on Climate Change
kWe	kW electricity
LBG	Liquid biogas
LHV	Lower heating value
LNG	Liquefied natural gas / liquid natural gas
LULUCF	Land use, land-use change and forestry
mDAF	Modified Dissolved Air Flotation
MDF	Medium-density fibreboard
NRR	Nutrient recovery and reuse (= recycling)
N-P-K	Nitrogen – Phosphorus (phosphate) – Potash
OPEX	Operational expenditure
Qu1	Quartal 1
Qu2	Quartal 2
R&D	Research and development
REACH	R egistration, E valuation, A uthorisation and Restriction of C hemicals
REC	Renewable Energy Certificate
RED II	Recast Renewable Energy Directive 2018/2001/EU
RENURE	R ecovered N itrogen from manure
RIA	Research and Innovation Action
RO	Reverse osmosis
SAM	Serviceable addressable market
SME	Small and medium private enterprises
SNCR	Selective noncatalytic reduction
SOM	Serviceable obtainable market
TAM	Total addressable market
UNFCCC	United Nations Framework Convention on Climate Change
USP	Unique selling proposition
Waterleau NE	Waterleau NewEnergy
WP	Work Package

Preface

This study was carried out as part of the European demonstration project SYSTEMIC funded by the H2020 programme (project number 730400). The project SYSTEMIC focused at five large scale biogas plants where innovative nutrient recovery processing techniques were implemented on existing biogas plants and monitored in order to collect data for a thorough evaluation. One of the tasks within the SYSTEMIC project was to do develop economic key performance indicators (KPIs) for the demonstration plants.

While working on this report in the course of October 2021, the natural gas price peaked at >100 € / MWh (<https://www.powernext.com/spot-market-data>), exceeding the current conversion cost of biomethane in larger anaerobic digestion plants. The International Energy Agency (IEA) published its World Energy Outlook 2021 report (<https://www.iea.org/reports/world-energy-outlook-2021>), forecasting some 4 EJ (95 Mtoe) for 2030 and between 5 EJ and 8 EJ (120-190 Mtoe) in 2050 biomethane consumption. Figures of the SYSTEMIC 2020 Business Case Evaluation Report [1] are consequently fully confirmed. The forecasted volumes require a 7-12 fold increase of anaerobic digestion plants on a global scale.

While the future of biogas supply from anaerobic digestion plants seems to be ascertained, new business models for digestates create additional revenues from products and attract investments. Consequently, the team has developed business models that are feasible with the available resources and the tested technologies, legal and commercially viable under the prevailing framework conditions and sustainable according to the results of the LCA. As far as possible, technology-independent business models will be presented. The report will prove that business models are transferable to other European regions, in particular to the outreach countries where similar models may be implemented after the project. The focus is on revenues that can be achieved from energy and product sales in a competitive European market and with fair incentives. Under the current European strategic and legal framework, avoiding emissions and zero pollution have high priority and biogas operators' contributions to climate protection and soil health should be rewarded. A climate or environmental service provided by technologies shown in SYSTEMIC should therefore be compensated by monetary incentives that must not be called subsidies. The SYSTEMIC policy recommendation is to reward biogas plants with CO₂ credits for both renewable energies and low-emission plant nutrition and soil improving products.

Whereas the full individual results of AD business case evaluations will only be distributed within the consortium and the European Commission, the team will publish and disseminate the business models and extrapolate the conclusions and recommendations. In this task, also legislative barriers will be identified for the demonstration plants.

The report exhibits the opportunities and threats of certain business models (based on the evaluation of the demonstration and one outreach plants) with regard to determined regulatory and commercial frameworks. It should also serve as a guideline for stakeholders for the preliminary, quick evaluation of projects.

30.10.2021



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Summary

For the development of Sustainable Business Models, the business cases, as reported in the updated (as of August 2020) *D2.2 Business Case Evaluation Report*, as well as the business models underlying the business cases were analysed. Barriers and success stories in regard to the use of biobased fertilisers of five demonstration and one outreach plant(s) were assessed. In addition, global and European business models and innovative products with regard to their history, background and markets were evaluated. The five demonstration and one outreach plants are:



Acqua & Sole S.r.l., a thermophilic anaerobic digestion plant in Vellezzo Bellini (30 km south of Milan), Pavia, Lombardy, Italy, in operation since 2016 with a total annual substrate processing capacity of 120,000 tonnes. Processing municipal sewage sludge and source separated domestic food waste.



AM-Power BVBA, a thermophilic anaerobic digestion plant in Pittem (40 km west of Ghent), West-Flanders, Belgium, in operation since 2011 with a total annual substrate processing capacity of 180,000 tonnes. Processing source separated biowaste.



BENAS GmbH, a thermophilic anaerobic digestion plant in Ottersberg (40 km east of Bremen), Lower Saxony, Germany, in operation since 2006 with a total annual substrate processing capacity of 174,000 tonnes. Processing corn silage, plant residues and poultry litter.



Groot Zevert Vergisting B.V., a mesophilic anaerobic digester plant in Beltrum (35 km southwest of Enschede), Achterhoek Region, Province Gelderland, The Netherlands, in operation since 2004 with a total annual substrate treatment capacity of 135,000 tonnes. Processing pig manure and residues from agro-food industry.



Waterleau BV, a mesophilic anaerobic digestion plant in Ypres (80 km west of Ghent), West-Flanders, Belgium, in operation since 2012 with a total annual substrate treatment capacity of 120,000 tonnes. Processing manure and biowaste.



Nurmon Bioenergia Ltd., a mesophilic anaerobic digester in Seinäjoki (80 km southeast of Vaasa), South Ostrobothnia, Finland currently under construction with a total annual substrate treatment capacity of 240,000 tonnes. Planned to process manure, industry by-products and crop-based biomass.

The business cases represent large-scale biogas installations owned and operated by small and medium enterprises (4-9 M€ sales) servicing the farming, the food industry and in the case of Acqua & Sole the wastewater sector. Plants are located in high livestock density regions (Belgium, The Netherlands), in regions with moderate livestock density (Germany, Finland) and low livestock density (Italy).

A variety of feedstock including manure, poultry litter, energy crops, agricultural residues, food industry residues and waste, source separated domestic food waste and sewage sludge are converted to heat, power, biomethane and bio-LNG. Five of the six participating plants have adopted a business model based on revenues from energy supplies paid by utilities, operators of electricity and gas networks. These models are supported by incentives for renewable energy and network stability.

One biogas plant, Acqua & Sole in the Lombardy region (Italy), operates under a radically different business model, generating most of its revenues from gate-fees for processing municipal sewage sludge.

The current business models of each plant are presented in detail in the report while their fundamentals are the assumptions about what (product / service) a company is paid for and by whom (the customer) [2]. The report aims at inspiring biogas plant owners to seize business opportunities. In regard to new models, it does not provide SWOT analyses and risk assessments.

New business models are based on opportunities derived from technologies and products developed in the course of the SYSTEMIC project and shown in table 1 below.

Table 1) SYSTEMIC plants, feedstock and biobased fertilisers

Name	Location	Feedstock	Biobased fertilisers
Acqua & Sole	Vellezzo Bellini (IT)	Sewage sludge, residues from agro-food industry	<ul style="list-style-type: none"> • Ammonium sulphate • Digestate
Am-Power	Pittem (BE)	Residues from agro-food industry	<ul style="list-style-type: none"> • Dried solid fraction of digestate • Evaporator concentrate • Permeate water
BENAS	Ottersberg (DE)	Energy crops (maize and rye) and poultry litter (until 2020)	<ul style="list-style-type: none"> • Solid fraction of digestate • Liquid fraction of digestate • Ammonium sulphate • Calcium carbonate • Low-N bio-degradable fibres
Groot Zevert Vergisting	Beltrum (NL)	Pig slurry, residues from agro-food industry, glycerine	<ul style="list-style-type: none"> • RO concentrate • MF concentrate • Solid fraction of digestate • Precipitated P salts • Low-P soil improver / growing media (peat substitute) • Purified water
Waterleau New Energy	Ieper (BE)	Pig manure, sewage sludge and residues from agro-food industry	<ul style="list-style-type: none"> • Dried solid fraction of digestate • Evaporator concentrate • Condensed ammonia water • Purified water
Nurmon Bioenergia	Seinäjoki (FI)	Manure, meat processing residues and agricultural residues	<ul style="list-style-type: none"> • Separated solid fraction of digestate • N-P-K (P-K-) concentrate) • Ammonium sulphate)

Some new business models are incremental, aiming at customers paying for modified products, e.g. use of the low-P solid fraction of Groot Zevert Vergisting as soil improver while others are more disrupting as fibres processed to bio-degradable mulching mats and packaging materials or low-P solid fraction as peat replacement in potting soils. Customers willing to pay may be farmers, agri-businesses but also high-value niche in different economic sectors.

The examples presented in this report are not exhaustive. They give examples of how creative ideas can have multiple, commercial and environmental benefits driving biogas plants to full-scale bio-refineries.

1 What is a Business Model?

A literature review reveals almost as many business model definitions as business models. A meaningful summary was published by Andrea Ovens in the Harvard Business Review in 2015 [2] and by Sergio Caredda in his own blog in 2020 [3].

A short and concise description goes back to Peter F. Drucker [4]: “assumptions about what a company gets paid for” as part of Drucker’s theory of the business while Drucker himself never used the term business model.

A good business model answers Peter Drucker’s age-old questions, “Who is the customer? And what does the customer value?” [5]. It describes the basic structure and the objective(s) of a business. It shows how a business creates added value from its resources and on which markets customers willing to pay are addressed. A business model shows the way how revenues are generated. By selling products or services. The goal is to generate enough revenues to cover the fixed and variable costs of processing raw materials to products of added value and to achieve a margin on top of processing, storage and handling costs which represents the profit.

A business model may include the following elements:

- The perceived business opportunity and the entrepreneur’s idea of how the opportunity may be addressed.
- Markets and resources a business has access to for activities in response to the perceived business opportunity covering the whole value chain from cradle to the final customer.
- A raw business concept describing the benefits that a product or service may bring to the customer and the strategy to be followed to make the product or service available on the market.
- The added value for the target customer, i.e., the rationale behind a potential buying decision of customers.
- The unique selling proposition, i.e., the beneficial features by which a specific product or service may be distinguished from competitive offerings

In short, the business model is a blueprint for the business, outlining how the business is run, and how it can generate added value that can be offered in exchange for money.

The development of the theory of business models is related to the fast evolution of IT and web-based businesses from the nineties of the 20th century [3]. For this study, not dealing with IT and web-based products, the basic interpretation is used about the Who (is the customer) and What (is the value the customer is paying for). Nonetheless, the current SYSTEMIC business partners’ models are described in the subsequent chapters in more details.

2 Business Models for Biogas and Nutrient Recovery Businesses

Anaerobic digestion is essentially a service business, has elements of a utility (supplying energy) and – in case of SYSTEMIC demonstration plants - handles large quantities of biogenic materials containing high mass fractions of water.

Anaerobic digestion (biogas) plants deal with processing three relevant in- and output flows - feedstock, energy and digestate - that should be considered in regard to the business model:

- (1) Feedstock: Organic waste flow (substrate) processing – a service to farmers, industries, municipalities, wastewater treatment plants and others. The corresponding revenue is typically a gate-fee. The gate-fee depends on multiple factors (regional market, legislation, type of substrate, content of volatile, conversable carbon, water content). However, the substrate can also have a price (if delivered by third parties and regardless of being a waste or by-products) or a cost (in case of energy or cover crops grown by the owner/operator of the anaerobic digestion plant). Availability and characteristics of the substrate can have a significant influence on the business model of the operating company.
- (2) Energy: Conversion of substrate to energy – a service to the public at large or to specific sectors like the industry (e.g. dairy plants) or transport (e.g. heavy good vehicles) sector. Revenues from energy supplies are usually the most important revenue of biogas plants and they are frequently fixed in a multiannual contract in form of feed-in tariffs, feed-in premiums or green certificates. Regardless of these characteristics, the operator still has instruments to improve the energy revenues, e.g. by adapting their business case to available bonuses by increasing the conversion efficiency (making best use of secondary energy flows like heat), increasing the supply flexibility to better adapt the business to its role as stabilising factor in an environment of highly volatile energy supplies by solar and wind energy and selecting the type of energy the biogas plant is selling – heat, biogas, electricity, biomethane, bio-LNG or bio-CNG. No costs should directly derive from this revenue source.
- (3) Digestate: Processing the digester effluents and selling them as a re- or upcycled product – the focus area of the SYSTEMIC project. Currently, the management of digester effluents typically causes operations costs (OPEX), sometimes very relevant ones. Some SYSTEMIC business models have the advantage of having cropland under the company's management. When using the fertilising by-products for the own production of agricultural products, operators save the equivalent amount of nutrients supplied by third parties and the corresponding costs. In this case, the cost of the nutrients in the market (if any) can be accounted as a benefit to the biogas business. When operators have to sell the by-products at the free market, they currently receive only a fraction of the typical market value of the nutrients supplied by conventional fertilising products. Nonetheless, in every SYSTEMIC business case, processing digestates and separating nutrients saves costs and is a relevant element of the business model.

Most biogas plants, including five of six SYSTEMIC partner plants, share one business model: conversion of biomass to energy carriers which is paid by network operators (electricity and/or gas). Acqua & Sole operates under a different model: customers pay for discharging sewage sludge while energy generates only a minor revenue stream. The business model is not working equally well for all plants due to the framework in which the plants operate. However, the current business models will not fundamentally change as a consequence of the SYSTEMIC project. Energy supplies paid for by network operators will remain what the companies are paid for. Acqua & Sole, which is paid for sewage (waste) treatment, will also continue working under its current business model.

However, task 2.7 and the rationale for this report is looking for a model extension, towards generating revenues from digestate. While feedstock is generating revenues for Acqua & Sole and energy carriers for all other SYSTEMIC demonstration plants, the third flow does not generate revenues, despite of containing carbon and nutrients of potential value for customers (farmers). Screening the market for

opportunities related to digestate and digestate derived products was the task and is subject to the report 2.7.

3 Legal Framework – Cross-Border Business

In contrast to many other businesses, biogas plants operate in a strictly regulated market: energy is supplied against long-term, contracted values and the use of digestate is restricted by limiting the nutrient volumes which may be applied to cropland in most regions where SYSTEMIC plants operate. Two demonstration plants operate in Belgium quite close to the French border where nutrients are in demand and digestate derived products from AM-Power and Waterleau NewEnergy could replace conventional fertilisers. This is the rationale for having revisited the legal framework in Europe with a particular attention to cross border business between Flanders and France, if not covered by the FPR from the time of its enforcement in July 2022.

3.1 Legal framework in the EU

The overall legal framework has been reported in Deliverable 2.1 “Report on regulations governing anaerobic digesters and nutrient recovery and reuse in EU member states” [6]. Since its publication, no significant new legal acts have entered into force at the European or national levels. The Fertilising Products Regulation (EU) 2019/1009 will become effective on 16th July 2022 with CMC-related provisions covered, e.g. the endpoint of the manufacturing chain for manure derived products. It will definitely support the viability of technical nutrient recovery business models for those AD plants processing feedstocks listed as CMCs to products in compliance with PFCs. The pan-European use of digestate derived fertilisers will also be facilitated. In addition, the SYSTEMIC consortium proposes the adoption of the proposed “RENURE” - “REcovered Nitrogen from manURE” - [7] criteria ($\text{NH}_4\text{-N} \geq 90\%$ and $\text{TOC/N} \leq 3.0\%$) for animal by-product-derived fertilising products with high nutrient use efficiencies (equivalent to synthetic N fertilisers) with a simultaneous tightening and improved control of use allowances for untreated animal by-products (manure / poultry litter) as fertilisers. Currently, RENURE criteria only apply in the Netherlands by temporary derogation and on a limited agricultural area.

On 14th July 2021 the European Commission has published “The European Green Deal” [8] which is a bundle of strategies aiming to make Europe the first climate-neutral continent by 2050. It is intended as a new, sustainable and inclusive growth strategy to boost the economy, improve people's health and quality of life, care for nature, and leave no one behind. The European Green Deal includes several strategies, target and action plans which are of relevance for SYSTEMIC partners.

- The Farm-to-Fork Strategy [9] is, next to the Climate Target Plan [10], one of the core elements of the European Green Deal. It addresses the challenges of accelerating the transition to sustainable food systems without compromising the economic, social and environmental foundations of food and nutrition security for current and future generations. It aims at enabling a “just transition” for all actors of the food systems, in which also social inequalities are reduced, food poverty is addressed, and a fair income for all actors is ensured. The Farm-to-Fork Strategy builds on innovative solutions that can be scaled up, such as agro-ecological and organic practices, alternative sources of protein (e.g. plant-based, ocean-based, insect-based, etc.), sustainable food from the oceans and aquaculture, and personalised advice relating to sustainable healthy diets. An ambitious objective is set regarding nutrients: “The Commission will act to reduce nutrient losses by at least 50%, while ensuring that there is no deterioration in soil fertility. This will reduce the use of fertilisers by at least 20% by 2030.”
- The Zero Pollution Action Plan [11] aims for air, water and soil pollution to be reduced to levels no longer considered harmful to health and natural ecosystems, that respect the boundaries with which our planet can cope, thereby creating a toxic-free environment.
- The Biodiversity Strategy for 2030 [12] is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030 and contains specific actions and commitments.

3.2 Legal framework between Flanders and France

The European Green Deal itself and the related strategies and action / target plans entail the revision of a large number of regulations and directives with a potential impact on the operations of anaerobic digestion plants. Readers are invited to consult the related European web-sites to remain up-to-date in regard to the legal framework governing their activities [8] [10] [9] [11] [12].

Currently, the legislation referred to in the D2.1 report [6] governs biogas plants and digestate derived products. SYSTEMIC partners in high-livestock-density regions in Flanders export digestate and derived products across member state borders. Cross-border digestate businesses within the EU are still not as easy as they should be in a common market, as outlined in a special report on the export of digestate derived products from Belgium to France: Regulatory framework for exporting end-products of biogas plants to France (Raymaekers, 2021 [13], in Annex I) which is summarised below:

Regulations for exporting digestate derived end-products from Flanders to France are complex, especially if sewage sludge or liquid fractions of digestate are involved.

The easiest administrative framework for export is the NFU procedure (Norm Francaise d'Unité). It is applicable to sanitised and composted digestate with a DM >30%. There are three norms: NFU 42-001 for fertiliser with more than 6 or 7% NPK, NFU 44-051 for organic fertiliser with less than 7% NPK (AM-Power) and NFU 44-095 for organic fertiliser containing sewage sludge. For the latter two, stricter requirements on composting conditions apply. Compliance of the product with the respective norms should (NFU 42-001 and NFU 44-051) or has to be (NFU 44-095) checked in a French laboratory. Transport of organic fertiliser to France and application has to be accompanied by a transport letter or label, which both carriers and farmers should have. Furthermore, the fertiliser must be sold at prices not compromising the French market.

Products not covered by a NFU norm can be exported under the "specifications", a degree developed for French digestors, which is not recommended as Flemish digestate usually does not meet its requirements, under a mutual recognition (reconnaissance mutuelle), i.e. a simplified certification procedure, if the product is certified in Belgium or after a homologation procedure to certify a new fertiliser in France. However, the latter two procedures take at least one year so that it may be more efficient for AM-Power to aim for a marketing under the Regulation EU 2019/1009, which will come into force in July 2022. Producers in border regions disposing of land both in Flanders and France can also obtain a derogation to spread their fertiliser on plots specified in a spreading plan.

Even though, contrary to Belgium, France allows the use of sewage sludge in agriculture, import of sewage sludge is discouraged and the presence of sewage sludge in organic fertiliser can cause failure of the certification process. Due to the COVID19 pandemic, a decree further tightening the regulations concerning sewage sludge was issued in April 2021 (Arrêté du 20 avril 2021 modifiant l'arrêté du 30 avril 2020 précisant les modalités d'épandage des boues issues du traitement des eaux usées urbaines pendant la période de covid-19). It says that digestates derived from feedstocks including municipal sewage sludge must be

- *Composted to be compliant with NFU 44-095 or*
 - *if a spreading plan is in place (act of 1998)*
- *Lime stabilised or sun dried or stored (stabilised) for at least 4 months*

In addition, every lot prepared for spreading needs to be analysed to confirm that the processes applied have reduced coli-bacteria by equal or superior log4, i.e. reduced by equal or greater than 99.99%.

Similar rules apply to digestate not containing municipal sewage sludge acc. to NFU 44-051 except for the analytical requirements to every lot.

For applying the import and use permit to French authorities, apart from the letter sent by the Belgian authorities,

- *The SDS (Safety Data Sheet) of the product*

- *The Belgian product labels*
- *The draft French product label*
- *Attestation from all raw materials suppliers*

are needed.

For AM-Power, this means that the solid fraction of the food waste derived digestate must be sanitised and composted to comply with the norm NFU 44-051. If not, a permit can still be obtained under mutual recognition scheme if the digestate is certified in Belgium or if a certification is pursued in France, but the corresponding processes are time consuming (at least one year) and success is not guaranteed

4 Current SYSTEMIC Business Models

Business Models of SYSTEMIC demonstration plants are quite conventional. The newly installed nutrient recovery systems allow additional revenue options, i.e. revenues from digestate derived products which are outlined in this report.

As mentioned before, the business models of SYSTEMIC demonstration plants are based on generating revenues from converting substrates (substrate availability is not a constraint for any of the partner plants) to

- To energy carriers while network operators pay for power and/or biomethane, i.e. renewable energy
- To a usable fertilising product as in the case of Acqua & Sole, with a business model based on revenues from off-taking (waste) sewage sludge and converting it.

In all current business models, digestate-derived products do not earn the production, handling and logistics cost associated with digestate management. Consequently, the business model advancement as presented in this report focuses primarily on improved digestate marketing models, i.e. customers willing to pay for services adding value to the carbon and / or nutrient content of digestate and derived products.

In terms of digestate derived products, all demonstration plants apply separation into solid and liquid fractions of digestate as a first treatment step. One plant produces a liquid fraction which is, without further processing, applied on fields. One plant processes the liquid fraction by reverse osmosis (RO) producing a concentrate which is compliant with the criteria for RENURE (REcovered Nitrogen from manURE) fertilisers ($\text{NH}_4/\text{N} \geq 90\%$ and $\text{TOC}/\text{N} \leq 3.0$), proposed by the EC Joint Research Centre. In the Netherlands, RO concentrates can be used as alternative for synthetic nitrogen fertilisers (*i.e.* applied on top of the limit for N from animal manure) by means of a temporary derogation for a limited number of farmers, pending the final implementation of RENURE criteria. RO concentrates of GZV are therefore applied within the region of the plant, avoiding long-distance transport of the liquid fraction. An additional benefit is that between 17% to 53% of the mass of the outgoing streams of the monitored plants consists of purified water (permeate) which meets criteria for discharge onto surface waters and consequently reduces the mass flow of materials to be handled. Blending of RO concentrate, a bio-based fertilising product, with other liquid N fertilisers into a tailor-made fertiliser is recommended in order to adjust the ratio between N, potassium and sulphur to meet the crops' nutrient demand. This reduces leaching of potassium and sulphur from the soil. Blending, before storage, of RO concentrate with manure or digestate or any of their organic matter containing products should however be discouraged because of the risks of toxic hydrogen sulphide emissions.

Bio-based fertilisers produced by SYSTEMIC demonstration plants can be broadly grouped into six categories; solid fractions (SFs) of digestate, phosphorus depleted solid fraction (low-P SFs) of digestate, liquid fractions of digestate, reverse osmosis and/or evaporator concentrates, ammonium sulphate solutions and calcium carbonate.

5 Opportunities for New Business Models

In essence, new business models can be based on more added value of the product. Consequently the areas where the added value could be produced were investigated within the SYSTEMIC demo-plants and outreach location, and outside the consortium. The most promising examples are described in this chapter in individual sections.

5.1 Matching Crop Nutrient (N-P-K) Demand with Digestate Derived Products

The lowest hanging fruit in terms of moderately advanced business models would be to match nutrient composition of digestate products supplied with nutrient demand of receiving crops. Currently, even the products from different separation steps do not match the N-P-K ratios of nutrient demand by crops.

Currently, nutrient concentrations largely depend on the feedstock and on the chemical properties of N-P-K, i.e. N mostly in the liquid fraction and P mostly in the solid fraction. Consequently, P is usually too high in the solid fraction while the liquid fraction is further treated for achieving a dischargeable water and a so-called mineral concentrate, containing a relevant fraction and concentration of N-K. Ammonia (N) stripping is practised by Acqua & Sole and Benas who produce a mineral ammonium sulphate solution. In both cases, the ammonium sulphate is recognised as an alternative for synthetic N fertiliser within the country of production.

Adapting nutrient ratios to crop demand is a challenge due to legal restrictions (digestates from different substrates must not be mixed) and the perception of operators – direct exchange of products is typically considered impossible, not least due to the lack of trust in cooperation. The function of mixing products with optimised N:P ratio could be assumed by third parties serving the AD industry: i) traders and / or ii) brokers. Actually, most feedstock is supplied by and most digestate sold to traders. However, similar concerns prevail as in regard to direct cooperation and if traders find a way to add value to the products, they do not share the margin with suppliers.

Brokers, independent companies or companies established by a group of cooperating AD plants could be the solution to the problem. In the Netherlands, the water sector uses this type of joint special purpose company. Eleven drinking water providers and five water boards are joint owners of “Aquaminerals” a company whose mission is “to provide services to its participants for the purpose of creating economic and sustainability value from the current and expected future resources from the water cycle. This year, Aquaminerals celebrates 25 years of successful operations. However, success has come after years of investing in applied research and development of marketable products from secondary resources. From the business model perspective, the advantage of such special purpose company is clear: it has only one mission – to find customers willing to pay for specific benefits provided by added value products that a specialised team has developed.

If such a joint development and marketing company is considered, biogas plant owners should be aware that success only may come after years of investment. Transparency and a smart contractual fundament are needed to avoid frictions between shareholders during the hard years of product and market development.

5.2 Digestate Derived low-P Solid Fraction as Soil Improver

Where P content in digestate is the limiting factor for direct application (due to legal P fertilisation limits) as in the Netherlands where P is in oversupply, producing a P-depleted solid fraction has a market as soil improver, albeit at a low value of up to 5 €/m³. Groot Zevent Vergisting follows that route by extracting P from the solid fraction and selling a P-rich product to the fertiliser industry. The main advantage of the low-P solid fraction is that it allows its use in the Netherlands, with an average transport distance of some 25 km in comparison to its use in Germany with an average transport distance of 250 km. The much lower distance to beneficial use saves transport costs and adds organic carbon to soils in the

Netherlands. The cost savings compensate for the process related expenses and the emissions caused during transport make the solution environmentally beneficial.

Efforts are still needed to adapt the P-rich fraction – currently in form of a slurry – to customers' needs. If the value of the P-rich product can be increased, industry demand for secondary P-resources could be satisfied and higher revenues could be achieved from the process.

5.3 Addressing Higher Value Niche Markets

5.3.1 Global Models

Magic Dirt™, introduced in the spring of 2014, is a blend of nutrient-rich digested – mainly cattle – manure and other recycled natural materials that has a pH within the 6-7 range and a guaranteed analysis of 1.15% total N, 0.30% available phosphate and 0.35% soluble potash. This is 6- to 10-times the nutrients found in other brands of premium potting soil (hence, high nutrient content sold as an advantage). It is packaged in 1 cu.ft. (28 litres) bags and distributed to garden centres and big box retailers in most states. Apart from making use of the solid, fibrous, hygienised fraction of the digestate, it replaces fossil-based natural peat. The use of peat in potting soils is associated with high greenhouse gas emissions, some 6,000 tonnes of methane per hectare of peat harvested (Magic Dirt, 2017). Magic Dirt™ is a perfect example for the Circular Economy and for upcycling the product – its retail price equivalent is about 700 USD/tonne. The manufacturing company is now located in Little Rock (AR), also named Magic Dirt and it has 5 manufacturing facilities in the USA.



Figure 9.1 Crystal Green™ struvite from sewage sludge

Figure 9.2 Magic Dirt™ potting soil from dairy digestate



Crystal Green™ is the brand of Ostara Nutrient Recovery Technologies Inc. (Vancouver, Canada) for its sludge derived struvite. Formulated with continuous (slow) release phosphorus, plus nitrogen and magnesium (Mg), Crystal Green is Root-Activated™, releasing in response to the organic acids produced by the roots with a healthy release of nutrients. Crystal Green gradually releases phosphorus according to root

demand; safely supplying the soil solution with nutrients needed for optimal plant growth. This citrate soluble mode of action provides continuous nutrient release which minimizes phosphorus tie up in the soil, lowers the risk of leaching and runoff, and also provides a season-long supply of phosphorus.

5.3.2 European Models developed withing SYSTEMIC

During the project, two SYSTEMIC partners have followed the model of addressing higher value niche markets, Groot Zevent Vergisting (GZV) and BENAS, both in cooperation with know-how and technology suppliers like Wageningen Environmental Research, Nijhuis Industries by GZV and GNS by BENAS. While GZV and Wageningen Research have focused their contribution on the technical feasibility of replacing peat in potting soils, BENAS has outlined its market research activities. In this report, the corresponding reports provided by Wageningen Research (Inge Regelink) and GNS (Ute Bauermeister) are summarised.

The technical report on potting soil shows the model of technical proceedings of developing a digestate derived product for the potting soil market while the BENAS report shows the market research efforts necessary to evaluate the market potential for a digestate derived product for the gardening, paper and packaging market.

5.3.2.1 Digestate Derived Products (low-P Solid Fraction) for Peat Replacement in Potting Soils – demonstrated by Groot Zevent Vergisting

The inorganic fraction of digestate is potentially suitable as a biobased peat substitute in potting soils. Three digestates from different origins (GZV, Benas, E-kwadraat¹) were investigated for their suitability as peat substitutes in lab cultivation trials, where the properties of the materials were determined, both on their own and in common potting soil mixtures. The chosen crops, pot chrysanthemum and begonia, are rather tolerant to salts (nonetheless they do not withstand high salt loads). A standard potting soil was used as a reference material.

A preliminary market investigation (not outlined in this report) showed that digestate derived, low-P solid fraction could attain 15-20 €/m³ market value if used as potting soil / mushroom growing media and confirmed the market size in the Netherlands to be large enough to absorb and producers / customers to be interested to accept digestates from several biogas plants, if the technical requirements are met.

Tests performed

The following tests were performed on the three types of digestate.

- Analyses on nutrients in solution
- Water behaviour, water retention
- Particle size analysis
- Mixing (loss of volume when mixing)
- Stability (potential micro-organism activity)
- Plant response test (phytotoxicity on germinating plants)
- Cultivation test with pot Chrysanthemum and Begonia.

The test was carried out on a sandpit with a sliding overflow where different pressures were applied. GZV with 13 vol.%, Benas with 30 vol.% and E-kwadraat with 30 vol.% have a similar water retention capacity as the reference soil. Benas and E-kwadraat have a high pH value. The electric conductivity (EC) of the GZV product is high, mainly due to the ammonium and sulphate contents. The GZV digestate also has high concentrations of trace elements.

The cultivation trial took place with mixtures of digestate and lime potting soil. Chrysanthemum and begonia are used as potting plants. Before the start of the greenhouse trial, a mixing model was used to assess the effects of mixing the digestate derived products and potting soil on EC and nutrient levels. Less N-P-K was added to the digestate than to the potting soil because the digestate contains nutrients.

¹ E-kwadraat is a digestate derived product from a third party, which has not participated in SYSTEMIC

$\text{Ca}(\text{NO}_3)_2$ was added to compensate for nitrate fixation during the decomposition by microorganisms. Due to GZV containing a lot of calcium, the extra nitrate was partly given in the form of extra N-P-K. The correction for nitrate fixation was added based on GZV's characteristics from 2019.

After a seven-week cultivation trial, the plants were harvested. Plant growth in digestate amended soils was not statistically different from growth in conventional potting soils.

Preliminary Results

- The high pH (Benas 8.1 and E-kwadraat 7.9) makes these digestates very appropriate for mixing with uncalcified peat (low pH). This requires special care by the plant nurseries.
- For greenhouse applications, a dilution with a different substrate is necessary for GZV, which has a high salt content.
- The high ammonium and sulphate concentrations in the soil lead to high EC and, as far as ammonium is concerned, lowering the pH during cultivation because of nitrification.
- The water retention is comparable to that of standard potting soil.
- The corn distribution makes the substrates suitable for use in horticulture, but E-kwadraat digestate has more larger particles (>4mm).
- In addition, all solutions had to be supplemented with complementary nutrients for a balanced crop nutrition, which may require some attention of the soil company.
- After pH correction, the mixture is not harmful for germinating plants. Admixture ratio of GZV needs to be lower because the EC is too high. In addition, all mixtures must be supplemented with complementary nutrients to achieve a balanced nutrient composition.
- The oxygen uptake rate values are high and too high for E-kwadraat (16). Good composts nowadays have values of 6-8. Composts with >12 are not accepted because they are subject to volume loss, change of water retention and higher nitrate fixation (this is compensated in the current mixtures).
- Complementary: For every combination of grower / crop / stage / cultivation system, there is an ideal basic fertiliser. Because the basic need for many elements is (partly) met when using digestate derived products with a relatively high level of nutrients, missing nutrients are still added. This is called complementary fertilisation.

Discussion

In this test, NPK-fertiliser was used as a supplementary fertiliser (practice conform). This is a standard potting soil mix of elements (PG-mix) with trace elements and without calcium.

This PG-mix is developed for peat mixtures from limed peat. The PG-mix is much less suitable for the digestates which contains relatively high quantities of nutrients, and therefore will almost never make the desired recipe possible.

The low stability of digestates ensures that more microorganisms are active in mixtures containing digestate. The microorganisms facilitate the uptake of trace elements more effectively to the plant. Known deficiencies high nitrate levels (nitrogen fixation) and iron deficiency. In the potting test, this fixation was corrected by adding extra calcium nitrate and iron chelate.

Both peat, compost and digestate contain negative charge sites which are occupied by cations. The negative charge sites are called the exchange complexes, and this can be measured as a molecular charge tissue. This is called the CEC (cation exchange capacity). This means that a calcium-loaded complex is stable (does not exchange with a nutrient solution), but a H^+ -loaded CEC will, when it comes into contact with the nutrient solution, immediately exchange all the H^+ ions for other elements with a preference to the order above. In a potting soil, this would mean that the solution would become more acidic and that a significant part of the Mg and Ca from the solution would be taken-up. Therefore, a potting soil company measures the CEC and base occupancy (that is, percentage of the loading positions are occupied by Na^+ , K^+ , Mg^{++} , Ca^{++}). It is important to realise that cations cannot be washed out of the complex. They can only be exchanged for a cation with higher binding energy. This is the case when

peat, which is naturally occupied with H^+ , is limed with $CaCO_3$. The calcium occupies the loading areas, and the released acid, H^+ , is neutralised by the reaction $2H^+ + CO_3^{2-} = H_2O + CO_2$. The CO_2 leaves the system as carbonic acid gas.

The CO_2 leaves the system as carbonic acid. The fibres of the digestate contain a large inventory of nutrients that are not readily available. This slow release inventory is hardly ever appreciated in greenhouse cultivation.

Recommendations

BENAS and E-kwadraat digestates are suitable for admixing in higher quantities (20-40 vol.%). For this purpose, the operator must consider the pH-value and the need for complementary fertilisation. Both pH and complementary fertilisation depend on the grower / crop and growing stage / crop system and are therefore of high importance for a potting soil company.

It is difficult to further improve the product by additional processing because the price for digestate as potting soil component is only 15-20 € per m^3 . It is therefore recommended to seek cooperation with a potting soil company to take care of appropriate admixture ratios and mixing.

Present GZV digestate is too salty for greenhouse applications above a 15% admixture rate. Making an improved product should be considered. The oxygen uptake rate values are too high, especially for E-kwadraat. It is worth improving this, although this will be at the expense of the mass to be delivered. The obvious solution is post-composting / post-ripening.

The potting compost company must be able to work with uncalcined peat (low pH). The digestates take over part of the neutralising effect of the lime. The potting compost company must be able to calculate and measure to what extent the load places on peat and digestate are occupied with calcium.

It makes a difference whether a potting soil company only uses NPK fertilisers (fixed ratios) or can dose each element separately. The latter technique makes a much more precise fertilisation possible.

The high ammonium and sulphate concentrations in GZV lead to high EC and, as far as ammonium is concerned, lower pH due to nitrification during cultivation. It is useful to have the ammonium converted to nitrate by bacteria. This can be done by composting, but a lot of ammonia will be lost due to the high pH. Converting the ammonium to nitrate in the water phase in a bioreactor without losing ammonia to the air could be a practicable solution.

Tests have confirmed that the use of the low-P solid fraction in potting soils is promising. While the use as soil improver in the Netherlands may achieve revenues of up to 5 €/m³, peat replacement may achieve up to 20 €/m³ without requiring transport over long distances.

5.3.2.2 Digestate Derived Products (low-P Solid Fraction) as Growing Media for Mushrooms

Even more promising than peat replacement in potting soils may be the use of digestate derived products as growing media (casing soil) for mushrooms. The attainable product value is the same as for use in potting soils (15-20 €/m³) while larger fractions of digestate derived products than 15-30 vol.% can be used for growing mushrooms. The test results from potting analyses and greenhouse tests are the baseline for the use in mushroom growing media and mushrooms have proven to be equally or even more resilient than chrysanthemum, begonia and other plants typically grown in potting soils.

Tests are underway and positive results can be assumed by extrapolating the potting soil results to mushroom growing media.

5.3.2.3 Digestate Derived Bio-Degradable Packaging and Mulching Materials – demonstrated by BENAS

Business Opportunity

In terms of price, biofibres are in the range of virgin fibres. Therefore, biofibres cannot compete with cheap recycled paper, but this holds true for all other alternatives (grass fibres are also more expensive, which is why they are usually only found processed with recycled paper into grass paper). Even when

used in wood-based materials, biofibres from digestate derived products could not compete with the cheap price of waste wood. However, the property of high biodegradability opens a high return market for these products.

5.3.2.4 Market

In contrast to Groot Zevert, the BENAS case is developed and reported from the market perspective.

Market for fibre-derived products:

a) Papers, cardboard, moulded parts

Germany's paper industry is the number one in Europe with a production volume of 22.7 million tonnes, of which 53% used in packaging. 50 % of packaging materials is used for food and beverages. The primary industry's turnover is 15.5 bn €, the turnover in end products is 34 bn €. The current recycling rate is 76 %. Less than 1% of the market is served by alternative fibres. The German forecast for sustainable materials is to attain a market share of 20% with a mass potential of 4.5 million tonnes per year.

b) Private horticulture, plant breeding

With a current – and growing - market volume of 8.6 billion €/year, Germany is one of the largest ornamental plant markets in the world. The market volume for plants bred and sold in pots the market is estimated at 131 million €/year. About 1.5 billion units of potted plants are sold per year, e.g. for balconies while some 3.3 billion units of perennial fruit and ornamental shrubs are sold. Web sales and shipments are estimated at some 100 million plants per year. The market potential for biodegradable pots is about 50,000 tonnes/year.

Products made from plastic-free, pollutant-free, compostable raw materials to be considered:

- Packaging solutions such as bags, paper, cardboard boxes, moulded parts
- Plant pots, cultivation pots, labels and plug-in labels

c) Agricultural fruit and wine growing, vegetable cultivation

In Germany, the area under cultivation of vegetable and strawberries is 150,000 ha while on some 100,000 ha grapes are cultivated.

Digestate derived fibre products for this market are mulching papers, mats, discs against weeds and for water regulation. The potential of this market is estimated at 50,000 tonnes/year.

d) Packaging for wholesale and retail trade

Total consumption of packaging material in Germany is around 18.6 billion tonnes/year of which 8.1 billion tonnes/year from paper and cardboard and 3.1 billion tonnes/year from plastics. The overall market is not accessible to the output of companies like BENAS but there are niches in the packaging market, e.g. packaging of products emphasizing their sustainability / organic origin which are serviceable.

5.3.2.5 Business Concept

Under the separately registered brand MAGAVERDE®, BENAS and GNS offer sustainable products made from regional natural materials in an environmentally sound cascade and a closed loop. Unique selling propositions of BENAS' / GNS' digestate derived fibre products are the natural, plant based origin and the biodegradability of the final products. The products are the result of close to 20 years of applied research and test work. Research is performed transdisciplinary in cooperation of scientists and practitioners.

MAGAVERDE® as a brand stands for environmentally friendly, highly efficient conversion of energy and cover crops to storable bioenergy and versatile, fibre based, biodegradable products, characterised by being

- pollutant-free and odourless due to an innovative and unique treatment process
- completely biodegradable, contributing to humus formation

- produced from digestate from bioenergy conversion in an environmentally friendly closed-loop and cascade process.

The patented production process of the biofibres is technologically unique. It combines energy supply, nutrient recovery and fibre use. There are currently no other known processes that can produce such a purified fibre after utilising the bioenergy potential of the substrate - energy crops in a sequence with rye to create a perennial soil cover for soil health and mitigating erosion.

MAGAVERDE® biofibre products help to prevent microplastics in the environment, conserve natural resources, reduce greenhouse gas emissions, are fully biodegradable and can be recycled or they biodegrade in soils. A wide range of products can be created for downstream sectors via paper production and fibre moulding processes. In addition, partners and interested parties are supported by know-how and mature technologies.

- Fibre derived products have proven full compostability.
- FiBL (the research institute for organic farming) has confirmed that Magaverde® biofibre paper meets the requirements for use in organic farming, according to the directive "VO (EG) 834/2007".
- The biofibre paper is certified as a recyclable packaging material (method PTS RH 021/97 from 2012, category II). It can therefore be recycled together with waste paper and cardboard via the blue recycling bin without hesitation.

Furthermore, biofibres do not contain unfavourable ingredients such as protein, fats or easily degradable carbohydrates. As a result, the biofibres are quite similar to cellulose in terms of material characteristics and can be processed with up to 100% content on paper making machines and fibre casting machines. MAGAVERDE® biofibres are already available on the market – currently the demand exceeds the production capacity of 8,000 tonnes/year.

5.3.2.6 Added Value

Fibre-derived products

a) Paper and cardboard

Papers of various thicknesses are produced from MAGAVERDE® organic fibres in rolls and cuts according to the customers' needs for further processing, e.g. into cardboard boxes, mulching papers and papers for artists' needs. There are many possible applications. Additives, such as waste paper are not used.

b) Packaging solutions

There is a great demand to offer products in ecological packaging, especially if they are ecologically produced. Customers are increasingly demanding ecologically closed solutions (product and packaging). MAGAVERDE® biofibre products can be used to meet a wide range of requests. They can be processed into sales packaging, gift packaging and transport packaging. Individual printing wishes can be realised.

c) Cast fibre products

Fibre cast products can be used as transport protection and transport packaging as well as for other purposes in agriculture and horticulture.

In cooperation with agricultural and horticultural companies it became clear that there was a demand for ecologically sustainable cast fibre products. Especially plant pots (as used in plant breeding companies) and transport trays for plants and food (e.g. eggs). Mulching mats for weed protection (mitigating weeds and partly replacing pesticides) made of ecological and completely degradable products are in demand. The processing challenges in regard to upscaling pilot tests to industrial production were largely overcome in the development phase. Main issues to be solved were the service life in contact with soil and the behaviour of the cast fibre products when exposed to water. Most of these issues have been solved and now products are manufactured which fully satisfy customer requirements.

5.3.2.7 Unique selling proposition

Consultancy and auditing

BENAS and GNS have been successfully dealing with tasks and challenges in regard to the symbiotic use of energy crops and biowaste for energy conversion and digestate use. The hereby generated know-how and experience are of added value to potential customers. BENAS and GNS offer know-how and advice to planners, engineers and entrepreneurs facing similar challenges.

Licences

MAGAVERDE® fibres are the result of many years of technical development in fibre preparation. The corresponding, IP protected technology is currently worldwide unique and only BENAS / GNS can grant licenses for the technology. Plants with up to 36,000 annual tonnes of production capacity can be engineered. Licensing to other anaerobic digestion plants is a vital component of the business model.

6 Business Models of SYSTEMIC Plants

6.1 Acqua & Sole S.r.l.

Operates a thermophilic anaerobic digestion plant in Vellezzo Bellini (30 km south of Milan), Pavia, Italy, in operation since 2016 with a total annual substrate processing capacity of 85,000 tonnes. Processing municipal sewage sludge and source separated domestic food waste.

Table 5.1.1 Acqua & Sole Plant characteristics

Date of commissioning	2016
Annual substrate processing capacity / processed	85,000 t / 72,000 t (62 kt sludge/10 kt food waste)
Installed electric capacity (IEC)	1.6 MW
Installed biomethane capacity	None
Digester volume	13,500 m ³
Annual biogas output / biogas per t of feedstock	4.0 Mm ³ / 56 m ³ /t
Annual electricity net-output (fed to the grid)	5,547 MWh
Annual bio-methane output	None
Digester type	Thermophilic Continuous Stirred-Tank Reactor (CSTR)
Nutrient recovery & reuse (NRR) facilities	Ammonium recovery system (stripper, scrubber, ancillary equipment)
NRR Products	<ul style="list-style-type: none"> • Sanitised digestate • Ammonium sulphate solution
Framework conditions relevant to the business case	<p>Owners cultivate 1,400 ha agricultural land</p> <p>Low livestock density in the region, dominant crop is rice.</p>

6.1.1 Business Opportunity

The main driver behind the investment was the desire for recycling organic waste flows and particularly urban waste flows to organic fertilisers. The products were designed for use on their own farming area, La Cassinazza, an area of about 1500 hectares and 7 old farmhouses, aiming at restoring biodiversity and achieving high yields. For this purpose, anaerobic digestion was chosen for producing renewable energy used on site and partly fed to the grid and simultaneously offering the opportunity to mix the feedstock for a balanced nutrient composition and eliminating pathogens by thermophilic operations. The business does not aim at revenues from energy conversion but on closing the nutrient and organic materials loop. Recycling of organic matter was considered of high importance due to the progressing degradation of the per-urban, industrially managed farmland south of Milano. Acqua & Sole is located in an area with some 100,000 ha of arable land of which 85% are used for rice cultivation (A.S.P. 2016). Livestock rearing is not a major activity in the region, as only 1.7% of animals reared in Lombardy live in the area, that is about 33,000 out of a total of 32 million. Animal manure is therefore neither an environmental issue, nor an available fertilising material (A.S.P. 2010). 7% of industry and commerce activities in the region deal with food production and organic waste management (A.S.P. 2015). The vicinity of Milano (15 km) with close to 3.3 million people and the food industry are the main sources of feedstock for Acqua & Sole.

6.1.2 Market and Resources

The target market for substrates is urban and agro-food industries organic residues, particularly sewage sludge and food industry residues from the urban agglomeration of Milan and Lombardy (about 50% of feedstock) and other parts of Italy (20% from Tuscany and 15% from Piedmont).

The target market for digestate-based fertilising products is farmland (about 1,000 ha) and some 4,000 ha farmland of farmers in the vicinity of the plant, where mainly rice is cultivated (85%). About 1,000 ha farmland absorb about 25,000 tonnes of digestate-based fertilising products.

Market trends in focus

- Disposal of sewage sludge has become a problem and expensive in Italy.
- Wastewater treatment plant number is increasing in Italy
- Regulation regarding the direct use of untreated sludge have been tightened and farmers do not trust in the fertilising quality of sewage sludge.
- In addition, the social perception of this practice has become very negative, among others due to odour nuisance and concerns about pollutants and pathogens present in untreated sewage sludge.
- Alternative routes such as sludge incineration could be a problem in Italy because of negative perception of incineration and the high need of organic matter in soils.
- These developments are strongly supporting the business model of Acqua & Sole processing urban sewage sludge as main fraction of the substrate mix.
- The short- and mid-term trends are still supporting the business case. Some municipalities are now considering incineration, but it will take at least 5 years until we will see the first incineration plants in operation if they will be built at all.

Drivers such as demographic changes, economic and legislative factors

- There are no indications of factors changing the current trend. On the contrary, the trend towards nutrient recycling is fostering the position of Acqua & Sole.

Plans to meet future demands and changes in the market

- Further improving the fertilising product quality for higher and balanced nutrient concentrations and absence of pathogens.

The digester is equipped with an ammonium stripping facility enabling the production of an ammonium sulphate solution. For prevention of odour nuisance, the feedstock reception section is provided with locks allowing the unloading of several trucks at once. The digestate delivery system is a closed system enabling the direct filling of tank trucks without any emissions to the environment. Tank trucks go to the fields where the digestate is pumped into trailers or digestate spreading tractors that inject the digestate directly to the soil, again preventing emissions. Hence, the plant is not only operating a nutrient recovery system. It provides all state-of-the-art techniques to produce balanced fertilisers suitable for effective on-farm rice and other crops nutrition and replenishing of organic matter. In addition, it is equipped for avoiding odour nuisance and greenhouse gas emissions. The fully closed system prevents all kinds of losses, including mud on roads and on the paved loading and unloading areas.

The agricultural land becomes a new economic and social integration facility, combining respect for the environment and retaining the rural heritage. The experience of the integration of environmental concerns in agricultural production has led to the application of innovative agronomic techniques, including the creation of unmanaged field margins, which are areas important for biodiversity as well as for pollinating insects. The adoption of technical conservation agriculture (CA) and the recovery of rice straw has reduced greenhouse gas emissions.

Apart from the energy activities relevant to SYSTEMIC, Acqua & Sole cares for conversion of solar energy by photovoltaic panels, for conversion of water borne energy by heat pumps and by geothermal energy.

6.1.3 Business Concept and Strategy

The concept is based on providing services in the form of offtake of organic waste (sewage sludge, food waste) from municipal and commercial suppliers. Products are conceived to meet the requirements of sustainable rice cultivation with two applications in mind:

- About 1,000 ha of own farmland.
- About 4,000 ha farmland in the neighbourhood of the plant.

A relevant fraction of the digestate-based fertilising product is used on own farmland and does not require a marketing or sales strategy. Use and showcase of fertilising products on own farmland aims at convincing farmers in the region to test the products on their farmlands. Acqua & Sole provides fertilising products free of charge to farmers in the region for testing. The strategy is consequently marketing and selling the product by convincing whereby the future buyer and user may use and assess the product at no cost on his own farmland.

The idea of complementing farming by nature- and social structure conservation practices will be further extended in the region.

- Nature conservation and biodiversity restoration means dedicating a part of farmland – typically 10-15% - to marginal lands, channels, wetlands, forests, and hedges as refuge for wildlife and for maintaining a natural balance.
- Social structure conservation means reviving old and partly abandoned rural structures such as farm and animal houses by offering them to start-ups and other entrepreneurial activities like conferences, workshops, etc. preserving the liveability of rural areas and counter the exodus of young and well- educated citizens.

6.1.4 Added Value

The direct added value of the AD & NRR business is:

- Effective nutrient recovery and high nutrient use efficiency.
- Balanced nutrient concentration in the digestate-derived products by feedstock selection and ammonia stripping for targeted N management in response to plant uptake.
- Hygienisation of the digestate by thermophilic digestion, thus elimination of pathogens.
- Odour free operations by closed systems and direct injection of digestate.
- As far as own farmland is served, nutrient value 100% accountable.

These are complemented by indirect benefits supporting the A&S business concept:

- Consulting of farmers and SME's (small and medium enterprises) towards the introduction of new and more sustainable technologies and processes.
- Using the old farmhouses for commercial activities including housing for start-ups and conferences.
- Developing the whole area and providing jobs and a liveable rural environment preventing young people from moving to the city.

6.1.5 Unique Selling Proposition

- Unique features - closed loops for substrate intake and digestate based fertilisers supply and distribution preventing odour and emissions to air.
- Advanced technologies such as ammonium stripping and production of ammonium sulphate.
- Ability to blend ammonium sulphate and produce a more concentrated fertilising product.

Stakeholder and environmental benefits

- Closed loops and direct injection complemented with a very high level of professionalism and cleanness are supporting a transformation in the perception of using digestate as a fertiliser.
- The whole set-up of Acqua & Sole as a promotor of sustainable agriculture that use traditional, nature-based systems without sacrificing the agricultural productivity supports the conversion of urban organic waste streams and their use as fertilising product.
- Increase efficiencies: a higher concentrated NPK product (compared to raw sludge) allows farmers to apply required fertilizers with fewer field passes.
- At present, all supply chain related services are provided by Acqua & Sole free of charge, costing the company about € 9 per ton of products.

6.1.6 Enhanced "Post SYSTEMIC" Business Model

The business model of Acqua & Sole is already advanced, fully in line with the Farm-to-Fork strategy and has a low short-term risk since wastewater treatment plants will continue to produce sewage sludge and are in need for disposal / use routes.

The mid- and long-term risk is higher. Larger municipalities may invest in sludge incineration plants. The cost of incineration may be € 60-80, depending on the size of the plant. Sludge incinerators would increase the capacity of disposal routes and possibly reduce the gate-fee for companies like Acqua & Sole. However, if a decision to build a sludge incinerator were taken, for instance in Milan, the plant would not be operational within 5 years from the time of the decision. Such decision, if taken, would leave plenty of time for Acqua & Sole to adopt a new strategy and, if necessary, use other feedstocks.

Acqua & Sole has a resilient business model with some room for improvement from higher nutrient-derived income from neighbouring farms. At least at short-term, almost no downside risk is visible. Additional upside is provided by the option to produce bio-methane including for transport which is supported by the Italian government.

6.2 AM-Power BVBA

A mesophilic anaerobic digestion plant in Pittem (40 km west of Ghent), West-Flanders, Belgium, in operation since 2011 with a total annual substrate processing capacity of 150,000 tonnes of biowaste and 21 kton of animal manure. Animal manure is processed in a separate digester and its digestate is disposed of without further treatment. Digestate of biowaste is further processed.

Table 5.2.1 AM-Power Plant characteristics

Date of commissioning	2016
Annual substrate processing capacity/processed	Biowaste digester: 150,000 t/y Manure digester: 21,000 t/y of manure
Installed electric capacity (IEC)	7.5 MW
Installed biomethane capacity	None
Digester volume	20,000 m ³
Digester type	Mesophilic Continuous Stirred-Tank Reactor (CSTR)
Annual biogas output / biogas per t of feedstock	30 Mm ³ / 170 m ³ /t
Annual electricity net-output (fed to the grid)	34,645 MWh (39,407 MWh _{el,tot} + 64,694 MWh _{heat})
Annual bio-methane output	None
Nutrient recovery & reuse (NRR) facilities	Solid/liquid separation by centrifuge; dryer for solid fraction; evaporator and reverse osmosis for liquid fraction
NRR Products	<ul style="list-style-type: none"> • Sanitised, P-rich dried solid fraction • Sanitised, evaporator concentrate from liquid fraction • Permeate water (possibly reusable after implementation of new RO).
Framework conditions relevant to the business case	High livestock density in the region Products need to be transported to other regions or treated

6.2.1 Business Opportunity

In 2011 the first biogas production activities started (digestion of organic waste and manure) at the plant of AM-Power. AM-Power is now the largest AD plant in Belgium. The plant has an annual treatment capacity of 180 000 tonnes. The dominant feedstocks are organic waste from the food industry, source segregated food waste, sludges from food industry and glycerine.

AM-Power generates every year 160,000 tonnes of digestate and strives to treat it in a cost effective, efficient, and relatively simple way, without losing the nutrients. Before SYSTEMIC, the plant has been equipped and operated with a technical solution for the recovery of nutrients which did not produce the expected results by processing raw digestate and produced a dried solid fraction, an RO concentrate (rich in N and K) and permeate water after RO which was used as process water and for cleaning purposes. The process was expensive to operate, consumed large amounts of chemicals in the DAF, and the liquid fraction expensive to dispose. The improved system implemented during the project aims at producing a more concentrated liquid fertiliser and clean, dischargeable water.

The biogas produced every year (including digesters and post-digester) is around 30 Mm³. The biogas is converted by a combined heat and power gas engine into electrical and thermal energy. The amount of heat and electricity produced is respectively 7360 and 7435 kW.

AM-Power is located in the Northern part of Belgium (Pittem) and this region is characterised by an excess of animal manure (having a negative value) and yet a high market demand for formulated synthetic fertilisers. This implies that there is an opportunity for end products with more custom-made nutrient ratios which are closer to the demand of farmers in the region. Yet, these products and application methods remain unknown and therefore not in demand by local farmers. Also, products are in direct competition with regional surplus of manure (digestate products, even if derived from food-waste feedstock, are being considered as similar to animal manure by farmers) and thus farmers automatically do not want to pay for it, they have a negative market value.

Since the commissioning of the plant, Stefaan Delabie, the owner and managing director and Henk Dedeyne have always been experimenting and investing in innovation towards the recovery and reuse of nutrients. They saw them as valuable elements that should not be destroyed or emitted as N₂ but used for their nutritional value. Activities during the SYSTEMIC project focus on optimisation of the process by means of adding an evaporator (±2 million €) before the reverse osmosis (RO) unit.

6.2.2 Market and Resources

Green electricity produced is sold to Luminus (in 2020-2022 to ELINDUS) for 35.15 €/MWh (market price, can fluctuate). Digestate is disposed of via local solid fertiliser contractor at a cost of 19 €/tonne (including transport + storage + application on land). The dried solid fraction of digestate is sold via direct contacts with end users at 5 €/tonne. In turn, AM-Power pays 18.5 € for the transport to France (i.e. net cost of 13.5 €/tonne).

Market trends

- Use of recovered nutrient products will become more common practice of local farmers.
- Drivers such as economic framework and particularly regulatory constraints.
- Pig intensive region will have constant supply for pig manure and hence competition with fertilisers from digestate.
- Close to France where nutrients are valued more than in Flanders (no P or N surplus).

Implications for AM-Power's products and services

- Lower price for digestate: Biogas plants in the neighbourhood will possibly not be able to compete with disposal of animal manure on the digestate/fertiliser market
- No long-term security for export to France if products will not be in compliance with the FPR

6.2.3 Business Concept and Strategy

Developing a positive business case with enhanced nutrient recovery and reuse hereby going further in lowering transport volumes and therefore transport costs. This includes, producing as many end products as possible that have a positive market value and can be sold more locally.

- Optimize fertiliser blending to meet demand of clients or the retail market (e.g. garden centres).
- A marketing/advertising strategy for marketing recycled products within the region needs to be developed.
- 2 x 3 stage evaporator: lower energy consumption due to configuration of the evaporator and because steam is re-used in different stages.
- Use of residual heat from CHPs (facilitates heat certificates)
- Flexible design to fit into existing NRR cascade and option to produce ammonia water instead of retaining ammonia within the evaporator concentrate. However, there was yet no buyer for ammonia water which made Am-Power switch to retaining ammonia within the concentrate through acidification of the influent of the evaporator.
- AM-Power's raw digestate is certified as sanitised by an authorised body in Flanders.

6.2.4 Added Value

- Disposal of digestate by paying a local fertiliser contractor.
- The dried solid fraction (enriched with N, K due to blending with evaporator concentrate) will be sold directly to clients in France.
- AM-Power will explore other higher value opportunities for the enriched solid fraction.
- AM-Power will analyse the clients' needs (nutrient ratios) and try to comply with its biobased products (e.g. making blends).

6.2.5 Unique Selling Proposition

- Dried solid fraction blended with evaporator concentrate (i.e. not dusty, 40-50% DM after blending).
- Not many biogas plants in the area have installed nutrient recovery and reuse (NRR) technologies or systems
- Be able to produce large volumes of final end products.
- The location of the plant is close to France where nutrients / fertilisers are in demand, but regulatory barriers make export difficult.

Benefits to Clients

- Increase efficiencies:
 - A higher N-P-K product formula allows farmers to apply required fertilizers with fewer field passes as compared to unseparated digestate or manure.
 - Lower price than conventional synthetic fertiliser, though also lower nutrient use efficiency as compared to synthetic fertiliser.
 - Evaporator concentrate is a low-pH product hence; generally lower risks for emissions of ammonia as compared to manure or digestate.
- Save money:
 - Reduced fuel costs for farmers spreading more concentrated products though upfront investment needed for modifying injectors to handle more concentrate products.
 - Lower price than conventional fertilisers, but higher price for product handling and field application as compared to synthetic fertilisers.

6.2.6 Risks and resilience of business case

- Am-Power has a high specific biogas production rate of 99 m³ CH₄ per ton of feedstock which is all converted into electricity and heat. Heat is used on-site by the digesters, dryers and evaporators. As a consequence, Am-Power has no option to switch to production of green gas since their digestate treatment line strongly relies on the availability of waste heat.
- Am-Power relies on export of end-products to France which makes them dependent on permits issued by French authorities. Implementation of the FPR is expected to improve this situation.

6.2.7 Enhanced "Post SYSTEMIC" Business Model

The suggested business model for AM-Power includes reviewing the substrate purchasing contracts and trying to improve the feedstock purchasing conditions.

The business model focus must be on producing more concentrated solid fertilising products with nutrient (N-P-K) ratios meeting the crop nutrient demand, adjusted to the main crops in targeted areas in eastern France. Attention must be paid to be in compliance with French NFU regulations as described in Annex I.

Compliance of AM-Power products with the FPR may significantly improve the cross-border business because there could be stricter regulations ahead for export and use in France (see ANNEX I) and this is currently their main disposal route for dried product. Consequently, AM-Power should focus on compliance with the EU FPR scheduled to enter into force on 16th July 2022. This may however mean that they should avoid certain feedstocks, such as sludges from food industry, that are not included as allowed feedstock for digestate under CMC 4/5.

Alternatively, Am-Power could still consider shifting their focus to the regional market since evaporator concentrate – being produced from non-manure feedstocks – can be applied on top of the limit of 170 kg N/ha for animal manure. In addition, AM-Power could invest further efforts to producing a low-emission N-fertiliser for use in the region. The company could follow the example of GZV and blend the concentrate with urea to an organic N-fertiliser with adjusted N-P-K-S ratio.

6.3 BENAS GmbH

A thermophilic anaerobic digestion plant in Ottersberg (40 km east of Bremen), Lower Saxony, Germany, in operation since 2006 with a total annual substrate processing capacity of 174,000 tonnes. Processing corn silage, plant residues and poultry litter.

Table 5.3.1 BENAS Plant characteristics

Date of commissioning	2006
Annual substrate processing capacity / processed	174,000 t / 102,000 t (82 kt corn & plant residues / 20 kt poultry litter)
Installed electric capacity (IEC)	11.3 MW
Installed biomethane capacity	1,200 m ³ /h
Digester volume	26,000 m ³
Annual biogas output / biogas per t of feedstock	20 Mm ³ / 194 m ³ /t
Annual electricity net-output (fed to the grid)	26,972 MWh (23,610 MWh _{el,tot} + 25,580 MWh _{heat})
Annual bio-methane output	8,78 Mm ³ (1,200 m ³ /h)
Digester type	Thermophilic Continuous Stirred-Tank Reactor (CSTR)
Nutrient recovery & reuse (NRR) facilities	FibrePlus ammonium stripping system Screw press for solid/liquid separation Rotary drum dryer for digestate
NRR Products	<ul style="list-style-type: none"> • Solid fraction of digestate (after screw press) • Liquid fraction of digestate • Ammonium sulphate (3,700 t/y) • Calcium carbonate (1,000 t/y) • Low N organic fibres (up to 8,000 t/y)
Framework conditions relevant to the business case	Biogas storage capacity 39,000 m ³ Owners cultivate 3,500 ha agricultural land, of which 2,000 ha about 200 km distant from biogas plant Multi pathway energy conversion installed for full flexibility: storage, two-fold power conversion capacity plus biomethane conversion Desulphurisation gypsum used for ammonium sulphate production FibrePlus system for production of fibres

6.3.1 Business Opportunity

The BENAS biogas plant, located near Bremen, was built in 2005/2006 with 5 MW power capacity that was extended by 6 MW in 2018. In 2012 an additional gas purification system was installed to convert biogas to 1,200 Nm³/h bio-methane for higher energy flexibility.

The thermophilic plant has 4 digesters and 3 covered storage tanks with a total volume of 39,000 m³. Its operational permit covers co-fermentation of animal waste, agricultural residues, crops, and food waste with a capacity of 174,000 tonnes/year.

BENAS grows energy and other crops on 3.500 ha owned and leased farmland with 35 employees. Part of the cropland is located up to 200 km from the biogas plant requiring transport of crops and digestate over long distances by an own truck fleet. In the early days, more liquid substrates were used and about 180 tonnes/day digestate was produced. Because of high transport costs and the limits for nitrogen

application on cropland, BENAS looked for a technology to recover nitrogen and reduce the amount of digestate for field application. In 2007, the GNS System ammonia stripping plant was built.

The GNS System is a modified ammonia stripping process, by which ammonia and carbon dioxide are removed under light negative pressure at temperatures of 50-85 °C without chemicals. By binding ammonia and carbon dioxide with gypsum, preferable flue gas desulfurization gypsum instead of sulfuric acid, CO₂ emissions are reduced. The process outputs are concentrated ammonium sulphate solution (25%) and a solid calcium carbonate fertilizer.

The utilization concept and mode of operation of the biogas and peripheral stripping plant have undergone multiple adjustments since 2008. In 2011, process flows of the stripping plant were optimized, which led to a notable reduction of operating expenses. The feedstock gradually changed to more solid and nitrogen-rich animal waste like poultry litter. By recycling the ammonia reduced liquid digestate into the digester, ammonia-inhibition is avoided and the amount of digestate for field application is reduced to about 30 %.

Typically the biogas plant processes on a daily base about 160 tonnes corn silage, 70 tonnes of other agricultural material and 50 tonnes of chicken litter. The stripping plant is operated with a flow rate of 8-10 m³/h digestate without solid/liquid separation by a screw press. It consumes about 800-1,000 kWh/h of exhaust heat. Chicken litter contributes up to 40 % of the nitrogen in the BENAS biogas plant. The stripping plant System GNS removes more than 30 % of the total nitrogen as NH₄-N bound to mineral fertilizers. The remaining, mostly organic nitrogen is mainly concentrated in the nutrient-rich organic solid fertilizer from the separation process.

Opening food market segments for fibrous packaging materials, e.g. trays for fresh eggs, may lead to total suspension of waste based substrates due to regulatory and customer requirements.

6.3.2 Market and Resources

Market segments

- Electricity = good prospects, with two new CHPs with an additional capacity of 6 MW_{el} BENAS can nicely adapt its power production to market fluctuations.
- Bio-methane as alternative to electricity with higher conversion efficiency and possibly higher revenues if feed-in tariffs are not provided in future scenarios.
- Mineral fertilisers (ammonium sulphate and calcium carbonate) = nutrient value fully accountable due to saving on purchase of synthetic fertilisers for use on own land.
- Biogas Fibres = expected growing acceptance.

Market Trends

Without unforeseeable major political disruptions, Germany is expected to continue its pathway towards reducing greenhouse gas emissions and replacing fossil by renewable energy carriers. Large biogas plants like BENAS can be a stabilising factor in power grids in the future with highly fluctuating energy sources: biogas is continuously produced and storable. It does not look like that biogas not being part of a future fuel mix – it could even play a more important role, e.g. biomethane-based CNG (compressed natural gas) or LNG (liquid natural gas) as transport fuel for long haul traffic as currently pursued in the Nordic countries.

In a Circular Economy, plants that recycle all of their input flows with potential for up-cycling (cellulosic fibres from fibrous input materials) should be very well positioned. If BENAS succeeds to sell fibres close to their real market value, the FibrePlus facility can become a third pillar of solid revenues next to energy and nutrients.

Profile of Competitors

- Typically, competitors have no, or not enough cropland for using all digestate derived products.
- Consequently, they need to sell fertilising products far below nutrient market value.
- Competitors typically have no energy product flexibility, i.e. to switch between power and bio-methane.
- Limited (energy) storage capacity.

- Classical ammonia stripping and evaporation: only with fine separated liquid (no fibres in it), ammonia is captured with sulphuric acid = higher operating costs.

6.3.3 Business Concept and Strategy

BENAS has developed a profitable “Circular Economy” business model by mixing home-grown energy crops with bio-waste and manure, and recycling digestate borne nutrients to own cropland with 100% credit for the nutrient value. The idea is that digestate borne nutrients can fully replace mineral fertilisers. However, the favourable power feed-in tariff is still significantly contributing to the business results.

Consequently, the company will continue its transition from an energy conversion facility to a bio-refinery centre, and pursuing to yield the maximum value from energy-, nutrient- and biomass flows:

- a) Energy: by maximising the benefits of storable biogas (bio-methane) in a highly fluctuating renewable energy supply world.
- b) Nutrients: by separating N and P to produce concentrated, transportable fertilising products that can be blended to the requirements of crops.
- c) Biomass: by producing cellulosic fibres, from about 1/3 of the dry matter plant input and recycling them in cooperation with companies that close the loop to the market.

In the long run, BENAS aims at being prepared for operating the plant without guaranteed feed-in tariffs, mainly by stabilizing the grid-load during periods of high fluctuation or insufficient supply of other renewable energy sources. For this purpose, BENAS invested in large biogas storage capacities.

In addition, resource recovery and reuse will become more important for long-term benefits, both for sustainability and profits. What was a simple biogas plant in the past, will become a full-scale bio-refinery.

6.3.4 Added Value

Competitive Advantage of the FibrePlus System

The FibrePlus technology is a stripping technology, not a total digestate treatment. This has to be combined with other technologies (phosphate recovery, drying, membrane technology). The main advantages are:

- Low energy consumption (electricity, heat) = low operating costs.
- Reuse of gypsum = which is a side product from desulphurisation of coal-fired electricity plants – and hence cheap as compared to virgin chemicals.
- FibrePlus treatment of digestate before separation reduces the costs of the combined technology (total treatment) and leads to an additional value material (fibres).

The FibrePlus technology is a competitive technology for digestate treatment > 5 m³/h. The total operating costs are between 5 €/m³ (only stripping and separation) to 16 €/m³ (combined with total treatment solutions to dischargeable water).

6.3.5 Unique Selling Proposition

BENAS and other potential users can have the following benefits from GNS’s FibrePlus System:

- Full integration of ammonia stripping (N recycling) and production of three fertilising materials (stripped digestate, ammonium sulphate and calcium carbonate) and cellulosic fibres.
- Internal recycling of low-ammonia digestate within the digester plant avoiding nitrogen inhibition of biogas conversion.
- Ammonia stripping cycle being less sensitive to fibres than conventional stripping technologies.
- The FibrePlus technology is an appropriate first step towards treating the liquid effluents to dischargeable water.

- After having installed a paper making machine and in fibre casting facilities, the use of recovered, bio-degradable fibres as raw material for production of paper- and cardboard products, including mulching mats, pots, and packaging materials for food and garden products.

6.3.6 Enhanced “Post SYSTEMIC” Business Model

After BENAS has proved the concept of supplying fibres for the production of fibreboards, it turned but the output of BENAS does not meet the quantitative requirements of fibreboard producers – production is too small for being approved as a regular supplier. In contrast, capacities and market figures for the above described products, i.e. the bio-degradable pots for plants (pots need not to be removed before planting the plants, e.g. in the garden) and special papers from the fibres are fully compatible. These products have the potential to improve the business case and generate a significant additional revenue stream.

An – at least theoretical – environmental improvement of the plant could be achieved by replacing the fossil fuel used for transporting raw materials and products by liquid biogas (LBG). This would require additional on-site investments to biogas liquefaction. If this would be undertaken, all input materials to any of the plant’s flows would be renewable and land use and competition with food production would be the only remaining issue. The corresponding benefits and impacts need to be discussed in the SYSTEMIC D2.6 LCA report.

In conclusion – BENAS represents a resilient, closed loop business case that partly owes its highly attractive EBIT margin to the current feed-in tariff and bonuses. However, the deeper analysis shows that even under a less favourable legal framework, BENAS would convert biomass to bioenergy and generate revenues for its owners. It can function as a certain supplement for biomass-based, fully flexible energy supplies compared to volatile sun- or wind-based power should of course always be provided by policy makers.

The suggested strategy for BENAS is to continue with gradual improvements, for instance in trying to reduce the feedstock cost which may be a consequence of replacing energy crops by waste materials. However, attention must be paid on keeping the high energy related performance and the very high financial substrate productivity. Also, shifts in feedstocks will affect the composition and possibly quality of the recovered fibres. Processing waste materials may also negatively affect the image and acceptance rate of paper- and cardboard products produced from the recovered fibres.

As to the product strategy, continued efforts to productise the fibrous fraction of digestate has turned out to be a very promising pathway. Currently, demand already exceeds the – not yet fully operational – capacity of 8,000 tonnes/year.

More information on the FibrePlus technology and the digestate derived products marketed now under the proprietary MAGAVERDE™ brand are given above in the high-value niche markets chapter 6.3.

6.4 Groot Zevert Vergisting B.V.

A mesophilic anaerobic digester plant in Beltrum (35 km southwest of Enschede), Achterhoek Region, Province Gelderland, The Netherlands, in operation since 2004 with a total annual substrate treatment capacity of 135,000 tonnes. Processing manure and organic residues from agro-food industry.

Table 5.4.1 Groot Zevert Vergisting Plant characteristics

Date of commissioning	2004
Annual substrate processing capacity / processed	135,000 t / 120,000 t (90 kt manure / 30 kt agri-food industry waste)
Installed electric capacity (IEC)	6.5 MW
Installed biomethane capacity	None, de-sulphurised biogas is directly sold to a nearby dairy factory.
Digester volume	15,000 m ³
Annual biogas output / biogas per t of feedstock	10 Mm ³ / 75 m ³ /t
Annual electricity net-output (fed to the grid)	3,200 MWh (5,000 MWh _{el,tot})
Annual biogas output	6,5 Mm ³
Digester type	Thermophilic Continuous Stirred-Tank Reactor (CSTR)
Nutrient recovery & reuse (NRR) facilities	GENIAAL (liquid fraction line) – decanter centrifuge, microfiltration, reverse osmosis RePeat (solid fraction line) – acidification, screw presses and P-precipitation reactors
NRR Products	<ul style="list-style-type: none"> • GENIAAL: Solid fraction of digestate and Mineral RO-concentrate (rich in N and K) • RePeat: Precipitated P salts and Low-P organic soil improver.
Framework conditions relevant to the business case	<p>High livestock density in the region</p> <p>Products need to be transported to other regions</p> <p>High demand for synthetic N fertilisers and low-P soil improvers</p>

6.4.1 Business Opportunity

Background: In 2004, GZV started with a relatively small AD plant. In the following years, the digestate treatment capacity was expanded several times and nowadays the plant has a capacity of over 100,000 tonnes of feedstock per year. Feedstock is mainly pig manure (80%) and 20% co-digestion products (unborn manure, glycerine, residues from food processing industry).

Manure treatment: GZV offers a sustainable and affordable solution for pig farmers who cannot use their manure on their own land. A beneficial aspect is that GZV has its own trucks and truck drivers which allows them to pick up manure from the farm as a service to the farmer. Furthermore, they take care of handling, application, and disposal of the produced digestate or the solid and liquid fraction of the digestate.

Until 2018, digestate was exported to Germany due to the excess amount of manure (mainly phosphorus) in The Netherlands. From 2019 onwards, GZV will process manure into various bio-based fertilisers that can be used within the region. Digestate will be separated into a solid and a liquid fraction. The GENIAAL installation will use the liquid fraction for further processing into RO-concentrate

and purified water. The clean water is allowed to be discharged directly to the surface water. The RePeat installation will process the solid digestate fraction into precipitated P salts (calcium-based phosphate or magnesium-based precipitates, struvite) and a low-P organic soil improver which can be used as soil conditioner on arable land. This product is potentially also suitable as substitute for peat material in potting soils.

6.4.2 Market and Resources

The RO concentrate is to be sold as an alternative for synthetic fertiliser and will dominantly be used on grassland and also on arable land. The market demand for bio-based N fertiliser is expected to grow in the coming years due to increasing knowledge on product quality and promotional activities but depends on whether the EC will implement the RENURE criteria.

The low-P organic soil improver is to be sold as a source of organic matter on arable soils. There is a growing demand for organic soil improvers with a very low nutrient content because organic matter input is limited by N and P application standards. Customers prefer a product with a high humification coefficient, which means that after one year still a high amount of the applied organic matter is available. Moreover, the sulphur content of the organic matter should not exceed sulphur uptake rate by crops, otherwise it becomes an agronomic obstacle for application on fields.

Precipitated P salts are to be sold as an ingredient for the production of granulated organic or mineral fertilisers. Outside of The Netherlands, in regions without a manure and thus P surplus, struvite is expected to have a market. It requires, however, the addition of magnesium (now sourced from non-renewable) and production of a concentrated and nearly dry product which can be easily transported over long distances at low costs.

Market Trends

The transition towards a Circular Economy will equally support the market roll-out of products produced by GZV. The current gas crisis likely results in increased market prices for synthetic N fertiliser which will benefit the business case of GZV as this will directly affect revenues from the sale of RO concentrate.

Profile of Competitors

Before the implementation of nutrient recovery and reuse, digestate competed with manure for crop- or grassland where it could be applied. Due to excess amount of manure in the region, digestate had to be transported to Germany. The biobased products can fit into specific markets within this nutrient overloaded context.

(Blends of) RO concentrates: There are no competitors within a radius of 30 km around the plant which is the area in which GZV aims to sell RO concentrates. However, the product has to compete with the use of synthetic N fertilisers that are far more concentrated and hence cheaper to store, transport and apply on the field. RO concentrates typically contains about 0.8% N; high costs for storage, sampling (compulsory), transport and field application by means of injection (compulsory) hinder successful market development for RO concentrates even when applied as alternative for synthetic N.

Low-P soil improver: This product competes with compost from green waste and (vegetable, fruit and garden) biowaste and hence has a low market value of 0 to 5 euro per ton at maximum.

Precipitated P salts: GZV needs to improve the installation in order to substantially increase the dry matter content of the recovered P salt. P salts with >50% dry matter can be transported over long distances and / or used by organic fertiliser industry for production of granular organic fertilisers for export. In 2021, GZV produced a P salt with 17% dry matter and this sludge competed with the present use of animal manure in the Netherlands.

Competitive Advantage

- Ability to blend RO concentrates with other liquid N fertilisers producing a liquid fertiliser that meets crop demand in terms of N-K-S ratio and meets product criteria as laid down in the pilot 'Bio-based fertilisers Achterhoek'

- Organic matter with a very low nutrient content, especially low in P.

6.4.3 Business Concept and Strategy

Turn manure into biogas, clean water and bio-based fertilisers and thereby offering a sustainable and affordable solution for the excess amount of (pig) manure in the region.

Objectives

Milestones:

- Investment in and commissioning of the 'GENIAAL' installation to produce RO concentrates (February 2019)
- Investment in and commissioning of the 'RePeat' installation to produce a P-rich and a low P soil improver fraction (May 2019)
- Pilot - Conventional Fertiliser-free Achterhoek: The national government granted a four-year exemption for the regional pilot in the sixth Nitrate Action Programme. That makes it possible to use RO concentrates instead of mineral fertiliser (see <https://kunstmestvrijeachterhoek.nl/reason-and-purpose/?lang=en>)
- Market development of bio-based fertilisers: 2019-2020

Marketing Strategy

RO concentrates:

- Blend RO concentrate with ammonium sulphate and urea to a 1.5% N fertiliser. Development of new injectors capable to inject concentrated fertilisers and initiate the pilot project 'Bio-based fertilisers Achterhoek'.

Low-P organic soil improver:

- Perform research and field trials to demonstrate and prove product quality as soil improver including humification coefficient.
- Communicate the trial outcomes to farmer organisations. Expected benefits are the high organic matter to phosphate ratio.
- Contact potting soil industry and supply material for practical tests and potential uptake of the material.

The long-term business model can be improved by a definite implementation of RENURE criteria for RO concentrates, replacing the current temporary exemption. Without this recognition, RO concentrate will compete with manure and shall be transported over distances of 150 km to regions with arable land where there is demand for animal manure. . Hence, N-based mineral fertilisers only have a positive economic value if they can be applied on top of the 170 kg N per ha limit in nitrate vulnerable zones (or 230/240 kg on grassland on farms with derogation).

6.4.4 Added Value

Investment in nutrient recovery and reuse offers pig farmers a sustainable and affordable solution for the disposal for their manure.

The RO concentrates are sold to farmers at a price equal to synthetic N fertiliser though this does hardly outweigh the costs for product handling and application. Hence, a subsidy on recovered N would be needed for a level playing field. The current shortage of mineral gas may also lead to higher prices for synthetic N fertilisers which would be profitable for GZVs business case. The nutrient ratio (N-K-S) will be adjusted to the customers' crops need through blending.

The low-P organic soil improver is characterized by a very high organic carbon to P₂O₅ ratio and is therefore a valuable soil improver. It enables farmers to apply a high amount of organic matter while keeping their phosphate application rate below the standards (60 kg P₂O₅/ha for arable land with a

neutral P status). This organic matter material can probably also be used as substitute for peat in potting soils, a potentially promising market.

6.4.5 Unique Selling Proposition

GZV is a partner in the 'Bio-based Fertilisers Achterhoek' (<https://kunstmestvrijeachterhoek.nl/reason-and-purpose/?lang=en>) pilot project. This allows them to blend recovered N-products (RO concentrates, ammonium sulphate) and synthetic N products (urea) to be used on grassland and arable land as alternative for synthetic fertiliser during a four-year exemption period. The exemption is regulated in the "6th Action Plan Nitrate Directive" in the Netherlands in a formal agreement with the EC Nitrate Committee.

The RePeat installation is the first full-scale installation for the recovery of phosphate from digestate into precipitated P salts and a low-P soil improver.

6.4.6 Enhanced "Post SYSTEMIC" Business Model

The post-SYSTEMIC business model is based on the strategy to become the first mover of making digestate derived products available to the growing media market. The potting soil and plant breeding business are addressed offering the following benefits:

- Key business benefit for potting soil producers will be the lower price as compared to peat.
- Key sustainability benefit will be reduced peat extraction rates, making a relevant contribution to less depletion of slow renewable resource, to biodiversity and to reduce CO₂ emissions.

In addition, a concentrated, precipitated P fertiliser is produced which can be exported from the Netherlands (where P supplies exceed crop needs) through the fertiliser trading companies or fertiliser industry or other stakeholders. The P fertilising product is subject to continuous development until the best cost / value ratio for future customers are found.

The preferred strategic option for GZV should focus on productising and marketing the recycled products produced from digestate. The strategy of developing the P-depleted solid fraction for peat replacement in potting soils and for use as growing media for mushrooms as outlined above in the chapter 6.3 "Higher Value Niche Markets" should be further pursued after the project period. With peat replacement products and growing media as well as concentrated P-fertilisers marketed at market value to the gardening / greenhouse sector and the industry, the business case could become a role model for anaerobic digesters processing manure due to overcoming the inherent low energy productivity of this substrate and digestate.

6.5 Waterleau NewEnergy BV

Waterleau NewEnergy BV is a mesophilic anaerobic digestion plant in Ieper (80 km west of Ghent), West-Flanders, Belgium, in operation since 2012 with a total annual substrate treatment capacity of 120,000 tonnes. In 2019, the plant converted 66,000 tonnes of manure and biowaste to about 10 Mm³ biogas. Table 1 shows the main plant characteristics.

Table 5.5.1 Waterleau plant characteristics

Date of commissioning	2012
Annual substrate processing capacity / processed	120,000 t / 66,000 t (25 kt manure / 41 kt biowaste)
IEC	3.2 MW
Installed biomethane capacity	None
Digester volume	12,000 m ³
Annual biogas output / biogas per t of feedstock	10 Mm ³ / 155 m ³ /t
Annual electricity net-output (fed to the grid)	3,200 MWh (5,000 MWh _{el,tot})
Annual biomethane output	none
Digester type	Mesophilic CSTR
Nutrient recovery & reuse (NRR) facilities	Hygienisation (70°C, 1 hour), solid / liquid separation, drying of the solid fraction; aerobic liquid phase treatment, evaporator
NRR Products	<ul style="list-style-type: none"> • Dried solid fraction for export to France • Evaporator concentrate (NPK); • Condensed ammonium water for treatment of flue gasses
Framework conditions relevant to the business case	<p>High livestock density in the region</p> <p>Products need to be transported to other regions or sold to industry</p>

6.5.1 Business Opportunity

The biogas plant was built in 2006. The original plant included the digesters and the current digestate treatment technology cascade, apart from the RO. Also, the hygienisation tanks were located upstream of the digesters. The plant was operational in 2010, but quickly went bankrupt. Waterleau NewEnergy bought the plant in 2013. The location of the hygienisation tanks was changed to downstream of the digesters. In 2017 the RO was installed to treat the process water coming from the evaporator.

Waterleau NewEnergy is a showcase plant for environmental technologies of Waterleau (Hydrogone® dryer, biological nitrification-denitrification). Waterleau has a state-of-the-art 'lab-pilot hall' equipped to do feasibility studies in lab and pilot scale for advanced wastewater and anaerobic digestion, which are monitored by 6 R&D (research and development) engineers.

Next to that, Waterleau cooperates in innovation projects with universities, research institutes and partner companies. Examples are the project "Proeftuinen Droogte en Nutriënten Synergy" (= Living Labs Drought and Nutrients Synergy, part of Circular Flanders grant: circular city and circular entrepreneurship), the project "Biorefine", testing nitrogen recovery from digestate with a pilot stripper-scrubber and the SYSTEMIC project.

6.5.2 Market and Resources

- Green electricity is sold at 50€/MWh (estimation of market price in 2020, can fluctuate).
- Dried solid fraction of digestate is sold to composting companies in the neighbourhood via direct contacts at 0-7€/tonne. This includes transport to the composter.
- There are many composting companies in the neighbourhood, so extra capacity for this product is available. Yet there is a trust relation between the biogas plant and the composting company. You cannot switch to the best buyer at any time. From these composting companies, the composted product is exported to France as a fertiliser.
- Ammonia water is sold to an incineration plant in Flanders where it is used as reductant for treatment of flue gasses. Waterleau NE pays the transport costs of 420 €/truck, corresponding to 17 €/ton and eating up most of the revenues. The sale of ammonia water to industry is no sustainable market for Waterleau NE because ammonia water competes with similar products from other producers and transport is expensive (ammonia water is still dilute compared to synthetic N products). As a consequence, they depend on the acceptance of one local buyer.
- NPK concentrate delivered with a cost of 40 €/tonne to a contractor who most likely mixes it with other organic fertilisers and distributes it as a fertiliser in the Netherlands. This includes transport cost, storage and spreading cost and profit margin for the contractor. This is an unsustainable solution considering the high pressure on the manure market in The Netherlands which also explains the high price for product disposal. NPK concentrate is a difficult product due to the high nutrient- and salt content and current N and P application limitations in Flanders. Salt content of the product is at least critical for direct use on cropland, grassland is less sensitive to salts in fertilising products.

Market Trends

- The cost for the disposal of N-P-K concentrate has been going up since 2017 to an almost unbearable point.
- Use of recovered products like ammonium sulphate will become more known practice by local farmers.
- Growing demand for dry, concentrated products (high K/NP ratio), even in Belgium.
- Adoption of RENURE criteria may increase the market potential for ammonium sulphate in Flanders and beyond. This may offer opportunities to shift from production of condensed ammonia water to ammonium sulphate. Implementation of RENURE however would not benefit disposal of WNE's evaporator concentrate because that does not comply with RENURE criteria ($N\text{-min}/TN = 34\%$ whereas $>95\%$ is required).
- Implications of possible changing export market for WNE's dried product
 - Plans to meet future demands and changes in the market, by creating products with characteristics in demand by farmers:
 - Optimize NPK concentrate through blending of end products
 - Create stable ammonium products
 - Look for synergies with other biogas plants and manure processors

Profile of Competitors

- Competing products and services
 - Manure, digestate, compost, mineral fertilisers, ammonia water.
- Advantages and disadvantages of the competitors' offerings
 - Nitrogen in digestate is more plant available than nitrogen in manure.

- Other AD plants selling plant-based digestate could use their digestate >170 kg N / ha / year whereas Waterleau NewEnergy's end-products are considered animal manure and shall thus have to comply with the 170 kg N / ha limit

6.5.3 Business Concept and Strategy

Waterleau sells its digestate-derived products to local composting companies after which it is being sold to farmers in France. At present, condensed ammonia water is sold to an incineration plant in Flanders – for use in flue gas treatment - and the NPK-rich evaporator concentrate through a trader to farmers in the Netherlands.

Products are in competition with manure and digestate from pig husbandries and biogas plants in the area. High and uniform product quality as well as established relations with local composting companies are benefits for composting companies intended to outperform competitors.

In the next 5 years Waterleau NewEnergy will further improve the business case of the plant by:

- Further investigate raising the biogas production by improving the handling of feedstock of the digesters. Now the pumpability of the mixed feedstock is limited by the viscosity. Direct feeding (of certain streams), instead of mixing, could increase biogas yield.
- Reducing costs of the evaporator concentrate disposal by drying it (possibly in an additional dryer) and mixing it with the solid fraction (for example, external solid fraction from composting plants or other AD plants).
- Finding a more resilient alternative for ammonia water, for use in agriculture: as (crystallized) ammonium sulphate solution.
- Cooperation with local manure processor for synergetic use of both companies' technologies (i.e. biological nitrification-denitrification and evaporator/N-stripper, RO-units) to reduce transport of liquid streams (liquid fraction, concentrate).
- Optimising heat and energy production and (re-)use throughout the plant.
- Creating dischargeable water or in the future even storing this as irrigation water for surrounding agriculture.

Future developments

- Waterleau NewEnergy wants to dry the evaporator concentrate to a higher dry matter content to reduce the volume, but in the current dryer, there is not enough drying capacity. Also, drying of an N-P-K concentrate, which is viscous, is not an easy task for the available types of dryers. A whole new concept of drying this kind of product should therefore be developed.
- Waterleau NE has heat available for this: the CHPs still have heat from the flue gasses (190°C) that is not fully re-used.
- A pilot is now in the very early stage of testing if the N-P-K product can be dried with the flue gasses to 30% DM and mixed with the existing dried solid fraction to 60% DM.
- Waterleau NE also thinks about changing from condensed ammonia water to ammonium sulphate. The market for ammonia water (DeNOx) is small and the transport of ammonia water is expensive. Ammonium sulphate is no high-risk product and the market for ammonium sulphate fertiliser seems to be growing in Flanders pending the implementation of ReNuRE criteria. Waterleau NE has been experimenting with crystallization of ammonium sulphate.

Added Value

Waterleau NE has a dedicated plant manager who is always looking for new solutions to improve the technologies and end products at the plant. The facility can count on the support of Waterleau Engineering's lab / pilot facility for research and test work, when necessary. The company cooperates with universities and research institutes in various innovation and improvement projects and tries hard to close carbon and nutrient cycles improving the resilience of the business case. In June 2020, the AD

plant became a SYSTEMIC demonstration plant after an amendment proposed by the consortium was approved by EASME.

Resources stewardship as a societal benefit: use of recovered nutrients from manure and bio-waste.

Added customer value:

- Increase efficiencies: A higher NPK concentration in the product allows farmers to apply required fertilisers with fewer field passes
- Save money:
 - Reduced fuel costs for farmers spreading more concentrated products as compared to raw manure but higher as compared to synthetic fertilisers.
 - Evaporator concentrate: lower price than mineral NK fertilisers
 - Dried solid fraction/blended solid fraction: lower price than mineral P fertiliser but similar potential in a balanced market.
 - Condensed ammonia water: lower price than urea (as DeNox reductant) but with lower efficiency.

6.5.4 Unique Selling Proposition

- The solid fraction of the digestate is dried and composted in Flanders. The dried solid fraction has a positive effect on the DM content and structure of the compost. The proximity of Waterleau NewEnergy to many composting companies and the French border reduces transport costs and the product, containing concentrated nutrients, is well accepted in northern France.
- The evaporator and RO produce purified water, condensed ammonia water (10% N), and an evaporator concentrate (N-P-K: 13-2-22).
- Ammonia water is not suitable as fertiliser, because of its high pH (11) and ammonium content and therefore also high risk of ammonia volatilisation and crop burning. The ammonium water is sold to a Belgian waste incineration plant and used as reductant for the DeNOx (Selective Non-Catalytic Reduction of NOx) exhaust gas treatment system.

6.5.5 Enhanced "Post SYSTEMIC" Business Model

The focus of Waterleau NewEnergy is on further concentrating the evaporator N-P-K concentrate using flue gases from the CHP. If N-org can be reduced, the potential of ammonium sulphate as a RENURE fertilising product (instead of producing ammonium water for flue gas cleaning) could be further explored.

In regard to processing, the feeding system of the digesters are re-engineered to remove bottlenecks and make better use of the total digester capacity.

N-P-K concentrates and ammonium sulphate will be sold to users in the region. This would require development of a market including demo projects to show fertilisers efficiency to local farmers.

Exporting fertilising products directly from WNE is currently not considered. There could be stricter regulations ahead for export and use in France (see ANNEX I) and this is currently their main disposal route for dried product. The EU FPR scheduled to enter into force on 16th July 2022. Compliance of WNE's dried product with the EU FPR may significantly improve the cross-border business however, this may mean that certain feedstocks of the digester that do not comply with the FPR shall be avoided.

6.6 Nurmon Bioenergia Ltd.

A-Farmers / Nurmon Bioenergia Ltd., a mesophilic AD in Seinäjoki (80 km southeast of Vaasa), South Ostrobothnia, Finland currently under construction with a total annual substrate treatment capacity of 240,000 tonnes. Planned to process manure, industry by-products and plant biomass.

Table 5.6.1 A-Farmers / Nurmon Bioenergia Plant characteristics

Date of commissioning	2021
Annual substrate processing capacity / to process	240,000 t / 210,000 t (90 kt manure, 100 kt industry by products and 20 kt plant biomass)
IEC	None
Installed biomethane capacity	~20 t of bio-LNG/d
Digester volume	~20,000 m ³
Annual biogas output / biogas per t of feedstock	15 Mm ³ /50–60 m ³
Annual electricity net-output (fed to the grid)	-
Annual bio-methane output	9 Mm ³ (90,000 MWh) bio-LNG
Digester type	Mesophilic CSTR
Nutrient recovery & reuse (NRR) facilities	Centrifuges for solid/liquid separation, N-stripper, and evaporator
NRR Products	Separated solid fraction of digestate, N-P-K- (or P-K-concentrate and ammonium sulphate)
Framework conditions relevant to the business case	Moderate livestock density in the region All feedstock converted to bio-LNG as a transport fuel

6.6.1 Business Opportunity

The first outreach plant within SYSTEMIC (currently under construction) is owned by Nurmon Bioenergia Ltd., a subsidiary of Heikas Ltd. (90%) and Atria Finland Ltd. (10%). The project matches the Finish political, legal, and economic framework promoting the Circular Economy and the use of liquid biogas for long-range, heavy duty transport.

The Nurmon Bioenergia plant is designed to process about 210,000 tonnes of biowaste per year, about half manure and half food industry by-products. Whereas most by-products from food industry are supplied with a gate-fee, manure is taken-in for free and some by-products can only be acquired by paying a price. All-in-all, feedstock contributes to the plant revenues.

The main revenue flow is generated by liquid biogas (LBG) to be sold to gas providers operating in Finland and then distributed across the country for use as transport fuel. The use of LBG as transport fuel is strongly promoted by Nordic countries. Major truck suppliers offer adapted heavy-duty trucks with an autonomy of up to 1,600 km, same performance, and comfort as the equivalent diesel models and – most important for the transport industry – the same cost per km. This approach seems to be very attractive due to allowing LBG production and use with modest subsidies and use of an alternative, low carbon footprint fuel without major infrastructure investments.

6.6.2 Market and Resources

Manure management service: Amount of manure (pigs, cow, poultry, and fur animals) in the area is 2 million tonnes, need for the biogas plant 100,000 – 200,000 tonnes. Amount of manure will be stable or slightly increasing. In any case, tightening environmental regulations will increase the need for manure management.

Market for nutrient products: available field hectares in the area are 220,000 hectares, need is for ~20,000 hectares. Thus, the size of the market is not limiting factor. Interest to recycled nutrients are generally increasing. Especially, organic farming needs efficient nutrient products. The main user will be agriculture. Some of the solid fraction can be sold as raw material for manufacturing growing media and soil amendments.

Market for liquefied biogas: basically infinite. However, the LBG, and also LNG, market is just emerging. First, the LBG will be sold mainly into industrial use (replacing, e.g., oil, LPG), and after five years, mainly for the traffic fuel use. Supposedly, LBG will be sold for customers as a mixture of LNG and LBG as the price of LNG is much lower than reasonable price of LBG. However, customers are willing to "green" their image by buying partly LBG in addition to LNG.

Market Trends

Fact is the growing need for renewable energy to mitigate climate change, and especially after IPCC (Intergovernmental Panel on Climate Change) report. Finland has quite ambitious targets for replacing fossil fuels in the transport sector, and biogas is seen as important source of energy especially for heavy duty traffic. Challenge is that LNG is quite cheap (~60 €/MWh), and a market price of ~100 €/MWh for LBG is needed for a commercially viable business case. However, such a price for LBG is possible due to the need of decreasing emissions and enhancing company images. During the next five years, energy taxes will be reviewed, and the aim is to make renewable energy a preferable to fossil energy.

Market of traditional organic, sewage sludge based fertilisers (digestate and compost) without treatment has declined very fast during the last two years. Several grain buyers have been denied using fertilisers of sewage sludge origin. This has improved the market of other organic fertilisers. Since Nurmon Bioenergia is not going to use sewage sludge as feedstock the related issues are no threat to marketing the digestate derived products.

Moreover, there is growing need and willingness for solutions of manure management and nutrient recycling, also at governmental level. The new CAP (Common Agricultural Policy) provisions encourage pollution mitigation and biodiversity protecting measures. However, incentivising regulation is just starting. In addition, it is interesting to see what the role of carbon sequestration in the future will be.

Nurmon Bioenergia's plan is to be the leading operator for development of new solutions for manure management in areas of intensive animal production.

Profile of Competitors

In manure management and nutrient market, the company is competing against traditional manure handling and inorganic fertilisers. This market is mainly cost-driven. In near future, no extra price can be achieved from food produced by recycled fertilisers, meaning farmers are not willing to pay extra. Consumers choose mainly the price, although they could say that environmental issues are important. However, there is increasing interest for clean food, e.g., in Asian market. High quality food is normal food for Finnish customers.

LBG market: Nurmon Bioenergia will be the biggest producer of LBG as soon as the plant will be operational. However, government owned gas company, Gasum Ltd, is a big company with revenues of 772 M€ as of December 2020. Gasum is a very strong player as their main business is based on natural gas market (single player in Finland so far, other ones coming). They are able to dictate the market price. More about Gasum see: <https://www.gasum.com/sv/languageselectionpage/>

Gasum is also the biggest biogas producer in Finland. Their business is so far based on municipal and industrial waste treatment with gate fees, and a significant part of their feedstock is sewage sludge. Thus, they may have faced some challenges with digestate disposal and need to make some changes to their operational strategies as well as to invest in new technologies. Moreover, Gasum is mainly an energy company and they have not been active in the agricultural sector so far. Thus, Nurmon Bioenergia has the possibility to get the leading role in biogas business relating to agricultural biomasses.

6.6.3 Business Concept and Strategy

The offering of Nurmon Bioenergia encompasses:

- Manure management service: Amount of manure (pigs, cow, poultry, and fur animals) in the area is 2 million tonnes, need for the biogas plant 100,000 – 200,000 tons. Amount of manure will be stable or slightly increasing. In any case, tightening environmental regulations will increase the need for manure management.
- Nutrient products: Available field hectares in the area are 220,000 hectares, need is for ~20,000 hectares. Thus, the size of the market is not limiting factor. Interest to recycled nutrients are generally increasing. Especially, organic farming needs efficient nutrient products. Main user will be agriculture. Some of the solid fraction can be sold as raw material for manufacturing growing media and soil amendments.
- Liquefied biogas: Basically infinite. However, the LBG, and also LNG, market is just emerging. First, the LBG will be sold mainly into industrial use (replacing, e.g., oil, LPG), and after five years, mainly for the traffic fuel use. Supposedly, LBG will be sold for customers as a mixture of LNG and LBG as the price of LNG is much lower than reasonable price of LBG. However, customers are willing to “green” their image by buying partly LBG in addition to LNG.

Currently, Nurmon Bioenergia has an annual manure supply potential of about 400,000 tons and an annual nutrient use (fertilising product) potential of more than 200,000 tons. The figures are continuously monitored and updated. The study represents the first step for selecting suppliers and end-user customers which will be followed by negotiations and pre-agreements.

The long-term strategy is the development of nationwide economically viable bio business network which meets tightening environmental criteria and decreases environmental footprint of Finnish food and thus, enhances acceptability of meat production in national market as well as the competitiveness of Finnish food on international markets. The future network will consist of 4 – 5 plant ecosystems which are adapted to local conditions and thus could include different process combinations.

6.6.4 Added Value

For waste producers: Nurmon Bioenergia will be a flexible partner and provide service 24/7. Gate fees will be competitive due to the economy of scale and technical solutions of Nurmon Bioenergia’s biogas plant concept. Nurmon Bioenergia can also offer closed loop-co-operation, meaning energy and nutrients from own waste materials.

For farmers: main issue is to provide economically viable nutrient solution for plant production compared to inorganic fertilisers as well as for manure management. Nurmon Energia’s recycled nutrient products are expected to behave better than raw manure in plant production and similarly or better than inorganic fertilisers, they will provide training service for ensuring the results. Nurmon Energia will also provide contractors with latest equipment for fertiliser application in the fields if needed. Nurmon intends to become the most knowledgeable operator in this sector supplying clean, organic fertilising products with similar performance as mineral fertilisers plus organic carbon for soil health and professional advice from experts.

For LBG customers: Unique product, limited availability so far. First movers will enjoy additional image benefits.

6.6.5 Unique Selling Proposition

In a recent statement the CEO of the envisaged LBG customer Gasum set the following targets: “In ten years from now, the majority of the energy used will be renewable, and biogas will already play a significant role in Finland’s energy production. A full switch to clean energy will have taken place in Baltic Sea shipping as well as in delivery and heavy-duty road transport. Major progress will also have been

made in hydrogen-to-gas conversion.” Consequently, one can assume that the future market for LBG offers good opportunities for sales contracts assuring profitable operations.

The key revenue source is the sales contract for upgraded biogas to be sold in the form of LBG. While LNG is still quite cheap in Finland (about 60 €/MWh), by forthcoming CO₂ taxes the plant expects to achieve revenues of ~100 €/MWh.

According to the level of interest for digestate generated during the market investigations, selling the processed digestate (free from sewage sludge borne pollutants) should not constitute a serious problem. However, it will not generate a significant revenue flow either.

6.6.6 Enhanced “Post SYSTEMIC” Business Model

The Nurmon Bioenergia business model demonstrates the prevailing trends for biogas, at least in Nordic countries. There is market for production of liquid biogas or compressed biogas as renewable fuel for trucks operating in transnational or transcontinental transport, requiring extended autonomy of up to 1600 km per tank. LBG can replace diesel without causing any inconvenience for the logistics sector: using the existing infrastructure, essentially the same diesel engines and being able to drive long distances without tank stops. Comparable services by electric trucks are not yet available and possibly never will be. Biogas to LBG conversion is more efficient than conversion to power and the commercial value of LBG or CBG (compressed biogas) is higher.

If all assumptions hold true, Nurmon Bioenergia will demonstrate a profitable, resilient, waste and industrial by-product based business case with a clear function in the future energy mix and an easy transition pathway, to which truck manufacturers like Iveco, Scania and Volvo have already adapted by offering LBG trucks with the same performance as diesel trucks but with much lower GHG (greenhouse gas) impact.

In conclusion, Nurmon Bioenergia will demonstrate an example for conversion of waste / residual biomass to gas which seems to have the potential for several similar projects, at least in Nordic countries. However, the pathway taken by Nordic countries may serve as a good example for other European member states for efficient use of waste-based biofuels with low environmental impact. The transition from diesel to LBG does not require high infrastructure investments and can be implemented right away.

7 Conclusions and Recommendations

SYSTEMIC has demonstrated the technical and commercial viability of nutrient recovery and reuse systems for digestates. However, revenues from digestate derived (recycled) products have room for improvement as shown in D2.2 Business Case Evaluation Report [1] and in D2.4 Final report on the development and application of economic key performance indicators (KPIs) [14].

The installation of technical processes for enhanced separation – producing dischargeable water and a mineral concentrate by reverse osmosis and/or evaporation – without an adequate business model is apparently not enough for significantly improving the marketability of the products. When the Fertilising Product Regulation will enter into force on 16th July 2022 and if the RENURE criteria will be adopted for use of manure-derived mineral products beyond the 170 kg N/ha threshold in nitrate vulnerable zones, framework conditions will be more favourable, but compliance may remain a challenge for biogas plants.

At least the “low hanging fruits” of adapting nutrient concentrations in solid products to meet N-P-K crop demand by one of the described concepts – either by direct cooperation between AD plants or by joint creation of a special purpose company acting as a broker - should be adopted as a business model by businesses which do not want to invest in concepts to sell more sophisticated products to higher value niche markets. This option is recommended for AM-Power and Waterleau NewEnergy, the partners who currently face the heaviest barriers to make their products available on the market with a reasonable commercial return.

A few American companies have shown that producing branded products from cattle manure and/or sewage sludge is possible and potentially profitable. Two SYSTEMIC partners have developed proprietary strategies and business models by addressing “Higher Value Niche Markets”:

(1) Growing media, where particularly products for peat replacement have a much higher value (15-20 €/m³) than products for soil improvement (5 €/m³) demonstrated by Groot Zevert, and

(2) Bio-degradable fibres for use as mulching papers or packaging materials, including biodegradable pots for plant nurseries by BENAS. Depending on the feedstock, up to 10% of the digestate could be separated as fibres which can be rolled to papers / cartons on a paper making machine or casted to packaging material, e.g. egg trays, pots of different sizes, etc. All digestate derived materials are fully compostable and degrade to soil.

Both models have attracted a strong interest from outreach plants as was confirmed during the outreach plant meeting on 12-13 October 2021 with guided tours to both operators of advanced business models, Groot Zevert and BENAS for outreach partners from Belgium, Croatia, Finland and the Netherlands,

Other SYSTEMIC partners are either already planning more sophisticated solutions like A-Farmers - Nurmon Bioenergia or are fully satisfied with their current model like Acqua & Sole – the latter mixing ammonium sulphate to digestate for adaption of NPK ratio to crop demand.

For followers of the SYSTEMIC models it is therefore recommended to develop strategies, product design and marketing plans including the following elements:

- (1) Identifying market niches that could absorb the – possibly adapted – products in terms of quantity and quality (quantity also means, that the addressed market is not by orders of magnitude larger than the supply potential which may lead to low interest).
- (2) Identifying relevant actors in the market niche.
- (3) Calculating the total market size in terms of quantity and value, total available market (TAM), serviceable available market (SAM) and serviceable obtainable market (SOM).
- (4) Contacting potential customers and looking for interest and potential environmental (e.g. peat replacement), usability (e.g. biodegradable plant pots) or commercial benefits.
- (5) Developing a strategy and work plan for introducing the envisaged product to the market.
- (6) Planning the product marketing (USP - Unique selling proposition, branding, narrative, etc.)
- (7) Calculating the estimated cost of (CAPEX, OPEX, marketing, branding) introducing the new product to the market.

- (8) Perform a risks assessment and define possible mitigation actions, have feed-back measures in place in the process of development of a plant.

Developing branded products from recycling materials is still a widely untapped potential that could significantly enhance the profitability and even the environmental impact (like for instance by replacing peat as building block for potting soils) of anaerobic digestion plant operators. The first results from SYSTEMIC partners following that route are very promising. The demand for biodegradable cast or rolled fibre products from BENAS already exceeds the still not fully use capacity of 8,000 tonnes/year.

Even in the case of branded niche market products, cooperation between several biogas plants is recommended whereby several partners implement the FibrePlus ammonia stripping equipment and only one partner or a third party invests in a paper making machine.

SYSTEMIC has demonstrated mature processing, separation and manufacturing technologies for digestate:

- (1) Solid / liquid separation to a N-rich liquid and a P-rich solid fraction (all except Acqua & Sole))
- (2) Extracting P from the solid fraction producing a P-fertiliser / P-fertilisers raw material and a low-P solid fraction for use as a soil improver (Groot Zevert Vergisting)
- (3) Extracting N (ammonia) from the digestate producing an ammonium sulphate solution by reaction with sulphuric acid (Acqua & Sole)
- (4) Extracting N (ammonia) from the digestate producing an ammonium sulphate solution and calcium carbonate (lime as soil improver) by reaction with flue gas cleaning derived gypsum (BENAS)
- (5) Treating the liquid fraction by reverse osmosis and / or evaporation to a mineral concentrate and dischargeable water (AM-Power, Groot Zevert Vergisting)
- (6) Adapting the low-P solid fraction for use as peat replacement in potting soils or for use as growing media for mushrooms (Groot Zevert Vergisting)
- (7) Separating biodegradable fibres from the solid fraction after ammonia stripping by the FibrePlus process of BENAS / GNS and producing moulded (e.g. pots, trays) or flat rolled paper products as packaging and mulching materials.

Two (Benas and Groot Zevert Vergisting) out of six project partners have developed sophisticated business models leading to sustainable products in demand with very high market- and value potential.

Finding customers in high value niche markets may be an opportunity and an option for very ambitious AD businesses, but not for all. The business model report has exhibited that, apart from revenues from the energy carriers, electricity and bio-LNG (Nurmon Bioenergia), business models based on revenues from materials may be commercially viable, for instance revenues from treating and valorising sewage sludge as shown by Acqua & Sole. SYSTEMIC has developed and tested processes and business models that can be implemented in a large number of commercial anaerobic digestion plants across Europe and beyond. Demonstration plants have covered all feedstocks from energy crops and agro-residues to food waste, food industry waste and manure. Results are consequently in full compliance with project objectives.

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Annex I Export of Digestate Derived End-products to France

Filip Raymaekers, DLV (United Experts), 19th August 2021

Report for dissemination
Ludwig Hermann - Marieke Verbeke
Systemic

Subject: Export soil improvers to France
Author: Filip Raymaekers
Date: 19/08/2021
Your reference:
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1 Introduction

Export of end-products from biogas plants to France

This research task should (at least) cover :

- The Flemish regulatory framework for the application of the products on agricultural land
- The Flemish & French regulatory framework for export of the end-products to France
- The Flemish & French regulatory framework for the application of the product on French agricultural land
- The Walloon & French regulatory framework for the export to and application of the products on Walloon agricultural land
- A description of other barriers for marketing the end-products (beyond the legal framework)

2 Flemish legislation for end products applied in Flanders

For the link to the European legal framework reference is made to the work package 2 of this H2020 Systemic project.

To bring an organic fertiliser on the market there are several legislations covering this activity in Flanders.

Which legislation is applicable, depends on the characteristics of the product.

- ⇒ Contains manure: the Manure Decree¹ of 22/02/2006 (last updated in 14/07/2020)
- ⇒ Contains organic waste: the VLAREMA² of 17/12/2012 and the Royal Decree on the marketing of fertilizers³ of 28/01/2013
- ⇒ Contains animal by-products: the VLAREMA⁴ of 1/06/1995 (based on EU/1069/2009 and EU/142/2013)
- ⇒ Contains sludges: the Royal Decree on the marketing of fertilizers of 28/01/2013

When the organic fertilizer only contains manure, the Manure Decree is applicable and only the spreading norms should be respected when applied in Flanders.

When the fertilizer contains plant waste, the fertilizer needs a “product declaration” (VLAREMA). This declaration change the status from waste to product. The next step is a derogation from the federal government (KB fertilizer) and an attestation as a producer of fertilizers (FAVV – KB 28/01/2013).

When the fertilizer contains animal by-products, the EU/1069/2009 regulation will apply.
The most important consequence is a pasteurisation step (1 hour at 70°C).

To make it possible to trace all fertilizers and nutrients, all (organic) fertilizers should be registered and declared at the Flemish manure authority (Mestbank – Manure Decree).

¹ Decree of 22 December 2006 containing the protection of waters against pollution by nitrates from agricultural sources.

² Decision of the Flemish Government of 17 February 2012 adopting the Flemish regulation on sustainable management of material cycles and waste.

³ Royal Decree of 28 January 2013 on the marketing and use of fertilizers, soil improvers and growing substrates.

⁴ Decision of the Flemish Government of 1 June 1995 containing the general and sectoral provisions on environmental hygiene.

3 Export of end products to France

3.1 Export under NFU (Norm Francaise d'Unité)

3.1.1 Procedure

The NFU procedure of exporting organic fertilisers to France is the easiest administrative framework for export. NF U-standardization (the exported product has to comply, there is no certification of the product) contains the following elements: Naming Components – Composition - Labelling - Self control - Transport documents.

Responsibility: the producer who exports has to buy the NFU-norm and receives a “code client” that needs to accompany the export documents. The farmer who buys the fertilizer is responsible for the acceptance and the application of the product

In practice, three norms are applicable on the digestate products, all of them requiring a solid phase (> 30% DM, dry matter):

- NFU 42-001 - fertilizer: more than 6 or 7 % NPK, hygienisation step (treatment during one hour on 70°C or similar) and a composting phase of the digestate;
- NFU 44-051 - Organic fertilizer: less than 7% NPK, hygienisation step (treatment during one hour on 70°C or similar) and a composting phase of the digestate. The denominations 5 (compost from food and household digestables) , 8 (mixture of plant and animal byproducts) and 10 (compost of plant and animal byproducts) are common. The compost phase should be a “compostage caractérisé” which means that the product should have an aerobic compost step with adding organic material, aeration, turning the compost, a time/temperature schedule that allows hygienisation, no cross contaminations.
- NFU 44-095 - Organic fertilizer with sludge: hygienisation step (treatment during one hour on 70°C or similar) and a composting (caractérisé) phase of the digestate. Send a sample to (French) lab.

3.1.2 Purchase

Every producer can buy the specific norm on the website of AFNOR (Association Francaise de Normalisation) and will receive a code client for his product. Make sure to buy the correct norm and the latest version.

A screenshot of the AFNOR website see annex 1.

3.1.3 Laboratory

Once the code client is obtained , the producer should check the composition of his product and compare it with the specifications of the norm. The easiest way is to ask for an analysis in a certified lab in France. It is advisable that this lab has an accreditation COFRAC 108 (Comité Francais d'Accreditation), like for example LDAR in Laon or SADEF in Anspach le bas. The lab will also classify the product under the correct NFU norm if possible (in line with the norms). If the product is not covered by any NFU norm, it's not possible to export under NFU.

Once the French lab has classified the product, the following analyses can be done in Flanders.

3.1.4 Etiquette NFU

Every transport of organic fertiliser to France should be accompanied by a transport letter or label. The farmer should always have a copy of this label and the invoice of the purchase of the fertiliser.

The fertilisers cannot be dumped on the French market. This is related to correct intracommunity trade and fair competition.

An example of the label see annex 2.

3.2 Specifications (Cahier de charges)

3.2.1 Procedure

Another procedure of spreading liquid digestate is through the “specifications”.

This decree was intended to create a legal framework for the French digestors. **Some foreign exporters also use this procedure but it is not recommendable.**

The Decree contains very strict specifications for the process and the product, for example strict process parameters (retention time, pH, temperature etc).

3.2.2 Liquid digestate characteristics

Inputs (at the entrée of the digester min. 20 % DM).

Most big biogas plants in Flanders do not comply with this specifications (sludge, industrial organic waste, etc)

- Manure (minimum 33 % of total mass);
- Content of digestive system;
- Cat III milk products or products from milk industry;
- Plant products or waste from plant production (+ manure minimum 60 %);
- Vegetative organic waste;
- Waste from gardening;
- Cat III waste from agro-food industry;
- Additives for the anaerobic biomethanic process (max 5 % of total mass);

Process parameters

- pH: 7-8.5;
- Continuous temperature and pH registration;
- For chicken manure a retention time of 60 days between leaving the stable and the application of the digestate on land.

Mesophilic conditions

- Retention time of 50 days;
- Temperature between 34-50 °C.

Thermophilic conditions

- Retention time of minimum 30 days;
- Temperature more than 50 °C.

Stock of digestate

- Covered;
- Mixed (some digestate storage in Flanders is not mixed)

3.3 Spreading plan (Plan d'épandage)

3.3.1 Procedure

This procedure is only for (border) farmers near the border departments. If the producer has land on both sides of the border Belgium – France, he can obtain a derogation .

The fertiliser should be included in his spreading plan in France.

3.3.2 Conditions

Fertilisers based on plant products: if the fertiliser only contains plant derivatives, this fertiliser is not resorting under the Regulation EU 1069/2009.

To sell the fertiliser on French market:

- The product should comply with a NFU (44-051);
- The product has a waste status without animal by-products. The product should figure on the list of RCE 1013/2006. A spreading plan is mandatory (plan d'épandage).

There is also the obligation to put together a dossier and to follow the whole procedure of notification and prior written consent. In addition, for the recovery of the fertiliser, a spreading plan must also be established. The disadvantage of this spreading plan is that the fertiliser application can only take place on the plots included in the spreading plan.

3.4 Mutual recognition (Reconnaissance mutuelle)

3.4.1 Description

If the product is certified in one member state, the EU provides the possibility follow a simplified procedure for certification in another state. In France: "Reconnaissance mutuelle" .

To obtain a mutual recognition, it is necessary to have the "proof" that the product is a fertiliser (and not waste) that is legally marketed in Belgium.

This "proof" requested by the French authorities is on the one hand the attestation from the Flemish Compost organisation VLACO that the product is not a waste and on the other hand a document from the Belgian authorities stating formally that the product complies with (all other) Belgian regulations on fertilisers. This document (often a letter) can be delivered in French by the Belgian Federal Public Service for Health, Food Chain Safety and Environment (FOD Volksgezondheid).

The demand for a mutual recognition should be addressed to the French National Agency for Food, Environmental and Occupational Health and Safety (ANSES).

3.4.2 Analysis

A complete analysis of the product:

- Agronomic;
- Organic and metallic pollutants;
- Pathogenic micro-organisms.

3.4.3 Additional information

In addition to the letter from the Belgian authorities, the demand should include:

- The SDS (Safety Data Sheet) of the product;
- The Belgian label of the product;
- The draft label for the French market;
- Attestation from all suppliers of raw materials.

During the Covid19 pandemic, the French government released a new Decree on 30/04/2021 that the sludge from water treatment probably in contact with COVID19 should be pre-treated (annex 5).

3.4.4 Procedure

1. VLACO attestation: from waste to product;
2. FOD derogation: document in French (see annex 3);
3. Contact a lab in France for mutual recognition: sample in refrigerated transport;
4. Handling the request takes at least 1 Year;

Very difficult because of potential inclusion of sludge (boues d'IAA: sludge from Agro-Food-Industry).

3.5 Homologation

3.5.1 Legal framework

If a situation does not fit into any of the previous procedures, a homologation (registration file) must be drawn up. However, given the time required to obtain this file (1 to 2 years) and the cost associated with its evaluation by ANSES (between 10 k euro and 20 k euro; see annexe 4 "File submission procedures"), this procedure might be overruled by the implementation of the new Regulation EU 2019/1009, which will take place in the same period of time, i.e. 2021-2022.

The homologation procedure is a long and difficult procedure to certify a new organic fertiliser. Every tests and risk analysis should be done to prove that the organic fertiliser is safe for food production.

The EU 2019/1009 will allow the solid digestate to comply with CMC 5 "other digestate than energy crop digestate" and the PFC "(organic) fertiliser".

3.5.2 Conditions

The conditions to apply for homologation are strict and long:

- Continuous production of minimal 2 years;
- Homogeneous product: 5 samples /batch of compost;
- Analysis of the agronomic parameters and all usual contaminants (heavy metals, DM, OM, bacterial analysis etc);
- Stability: the results should be constant for all 5 samples and in time (repeat the analysis several times over the production period of 2 years);
- Efficiency: to be proved by field tests, green house tests, laboratory tests etc;
- Nitrogen mineralisation;
- Ecotoxicology in aquatic and terrestrial conditions.
- Human health risks.

3.5.3 Laboratory

It is advisable that the lab has an accreditation COFRAC 108 (Comité Français d'Accreditation)

4 Export of soil improvers to Wallonia

Although the federal legislation (Royal Decree on the marketing of fertilizers) certifies soil improvers in Belgium, there is also regional legislation in Wallonia that makes all import of manure and soil improvers in Wallonia impossible (decision of minister Michel Foret of 24/01/2002).

A last update was requested and received in February 2021:

Monsieur,

La réglementation ainsi que les décisions du gouvernement en matière d'effluents d'élevage n'ont pas changé depuis 2008.

Cordialement,

Import of organic waste is only possible if the EU regulation is respected:

- Animal by-products: EU/1069/2009
- Organic plant waste: EU/1013/2006

Some Flemish exporters bring organic waste to Walloon waste industries.

5 Barriers for marketing soil improvers (beyond the legal framework)

This chapter will just mention briefly some barriers to put soil improvers on the market

5.1 Concentrates

The industrial processing of manure and digestate will generate some by-products with higher concentrations of minerals.

These concentrates are often high in salt content and not appreciated as soil improvers as such.

The fertiliser industry is not recycling these concentrates in the fertiliser production.

Often the concentrates are mixed with raw digestate or manure to spread on the land. In other cases the concentrates are dried with the solid fraction and eventually pelletised.

5.2 Scrubbing stripping

Other by-products from stripping or scrubbing will have a low pH and burn crops when directly applied in the field. Also, this by-products will be mixed with other liquid (organic) soil improvers.

5.3 Odour

A very important inconvenience of the most liquid organic soil improvers is the odour. Especially with digestate from animal by-products or with compost based on manure, the odour aspect is very important.

In Flanders, the liquid organic fertilisers are injected or immediately plowed. In other countries (France) the manure and liquid fertilisers are spread on the land.

5.4 Use of sludge

The use of septic waste water sludge (sewage sludge) as a soil improver is not allowed in Belgium.

All the septic waste water is separately evacuated and treated.

Some countries (France) allow the use of sewage sludge in agriculture but are discouraging the import of this sewage sludge. See higher and annex 5. Digester should avoid the use of sludge in the export production line.

In June 2021 some Reconnaissances mutuelles were refused because of the potential presence of sludge in the organic fertiliser.

It is very difficult to market soil improvers with organic waste on the international market. Soil improvers based on dried solid manure (cow dung or poultry manure) are the easiest to export.

5.5 Contaminants

Soil improvers based on organic waste are part of the circular economy.

The circular economy is based on the reuse of by-products from (industrial) production processes.

There is always a risk of contamination of these by-products.

The control on these contaminants is therefore huge.

In Flanders, all inputs are analysed on the standard parameters (heavy metals, PAHC, pH, etc) and at least once a year.

All end-products (soil organic improvers) are analysed 2 to 4 times a year.

The production plant is followed and audited yearly by an external environmental coordinator and by VLACO.

Nevertheless, it's always possible that a contaminant will pass all these controls and that the end-product is still contaminated. In that case the best practise is to do a risk analysis on the fertiliser and to limit the application dose.

In Flanders the tendency is to categorise these contaminated products as dangerous waste or "CAT I" animal by-products which to be destroyed (by incineration or on a landfill).

Due to improved analysis methods, more and more contaminants are detected. The detection limits are going down every year, showing more and more exceedances of the norms.

Research will shine the light on new contaminants that are persistently present in our environment, drinking water, arable land and food chain. Last year the focus was on new contaminants like PFAS, PFOA, Cr6 and pesticides. As long as there are no norms, the detection limit is the norm. This will probably convert all "CAT III" animal by-products in "CAT II" or "CAT I" animal by-products or will convert plant waste in dangerous waste.

The food production sector will have to accept certain contaminations in the production chain if circular economy becomes more and more embedded in our society.

6 Annexes

Annex 1: screenshot AFNOR

Purchase NFU on website AFNOR

STANDARDS

(4 most relevant results / **41180** results standards)

 <p>NF U42-001-1 October 2011 Fertilizers - Designations and specifications - Part 1 : inorganic fertilizers - Engrais</p> <p>NEW : REQUIREMENTS SERVICE</p> <p>Available languages : </p> <p>Mandatory standard</p> <p> Build your compilation</p> <p>➔ MORE INFORMATION</p> <p>🛒 ADD TO BASKET</p>	 <p>NF U42-001-1/A1 August 2019 Fertilisers - Denominations and specifications - Part 1 : inorganic fertilizers - Amendment 1 :...</p> <p>NEW : REQUIREMENTS SERVICE</p> <p>Available languages : </p> <p>Mandatory standard</p> <p> Build your compilation</p> <p>➔ MORE INFORMATION</p> <p>🛒 ADD TO BASKET</p>
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Annex 2: example of label (etiquette) NFU 44-051

Nutri-STAR EXP M35

AMENDEMENT ORGANIQUE - NF U 44-051

Compost de matières végétales et animales

Compost de fraction épaisse de digestat de fumier et lisiers, de déchets végétaux d'IAA, de graisses de cuisines, des issues d'IAA* et de déchets végétaux et animaux.

*Ne contient pas de boues d'IAA.

TENEURS (en % de produit brut)	
Matière sèche :	25 – 55 %
Matière organique :	20%
Azote totale :	0,8 %
Dont N organique :	0,7 %
C / N :	12,5

CULTURES ET DOSES

Cultures	Dose (T/ha)		Nbr apport(s)/an		Date d'apport
	Min.	Max	Min	Max	
Grandes cultures	10	23	1	1	Avant semis ou après récolte
Viticulture	5	10	1	1	Après récolte et avant la floraison suivante

RECOMMANDATIONS D'UTILISATION

Ne pas ingérer. Se laver et se sécher les mains après usage.

Utiliser un matériel adapté à l'épandage de solides (épandeur à hérisson verticaux, épandeur à table). Pour les grandes cultures, tout type d'enfouissement est possible. En viticulture, apporter le produit en surface.

Masse Nette
Tonnes

Annex 3: Reconnaissance Mutuelle SPF Belgium



Direction générale
Animaux, Végétaux et Alimentation

Service
Pesticides et Engrais

RECONNAISSANCE MUTUELLE

INFORMATIONS RELATIVES À L'AUTORISATION PRÉALABLE DES ENGRAIS, DES AMENDEMENTS DU SOL ET DES SUBSTRATS DE CULTURE.¹

Tous les engrais² ne doivent pas obtenir une autorisation préalable de mise sur le marché (appelée dérogation) pour être commercialisé en Belgique. Il faut donc distinguer 2 cas:

- les engrais répondant à la législation
- les engrais ne répondant pas à la législation et nécessitant une dérogation

Dossier en France



Version actualisée au 15/05/2018

Déposer une demande d'autorisation de mise sur le marché ou de permis pour une matière fertilisante, un adjuvant pour matière fertilisante, ou un support de culture

La mise sur le marché des matières fertilisantes, des adjuvants pour matières fertilisantes, et des supports de culture (MFSC) est régie par les réglementations européenne et nationale. Pour pouvoir être commercialisés ou utilisés en France, sauf cas de dispense d'obligations, les produits doivent disposer d'une autorisation de mise sur le marché (AMM) délivrée par l'agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (Anses) ou d'un permis d'introduction.

* La nature de la matière première peut être : fertilisant, support de culture, adjuvant, diluant, dissolvant, liant, complexant, tensio-actif, conservateur, émulsifiant, anti-évaporant, anti-moussant, colorant, L'eau matière première est considérée comme un diluant et / ou un dissolvant.

36. **PROCÉDÉ de FABRICATION :**

Description : _____

N° du brevet : _____ Titre du brevet : _____

41. **CONSTITUANTS pour 100 kg de PRODUIT FINI** : liser si nécessaire la "PAGE SPÉCIALE MATIÈRES PREMIÈRES - CONSTITUANTS" Cerfa N° 11385*01

TOTAL = 100 kg

Répartition granulométrique :

100 %

Matière sèche (% brut) : | | | , | | | Matière minérale (% brut) : | | | , | | | Matière organique (% brut) : | | | , | | |

Zinc total			,						Zn soluble eau			,						-----			,					
------------	--	--	---	--	--	--	--	--	----------------	--	--	---	--	--	--	--	--	-------	--	--	---	--	--	--	--	--

44. **ÉLÉMENTS EN TRACE en PARTIE PAR MILLION (ppm) de PRODUIT BRUT (mg par kg ou g par tonne) :**

<u>Arsenic total</u>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<u>Cadmium total</u>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	1.1.1.1.1.2 ome total	Chr	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<u>Mercuré total</u>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<u>Nickel total</u>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<u>Plomb total</u>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<u>Sélénium total</u>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	-----	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	-----	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Les formes des éléments chimiques, sauf indication contraire, sont exprimées en : N, P₂O₅, K₂O ; CaO, MgO, SO₃, Na₂O, Cl ; B, Co, Cu, Fe, Mn, Mo, Zn ; As, Cd, Cr, Hg, Ni, Pb, Se
 Les rubriques soulignées doivent être remplies ; pour les autres rubriques se reporter au Guide pour la constitution des dossiers de demande d'homologation Cerfa N°50644#01

45. CARACTÉRISTIQUES BIOLOGIQUES et / ou BIOCHIMIQUES :

Présence d'êtres vivants : ☐ non ☐ oui : ☐ algue ☐ champignon ☐ bactérie ☐ virus ☐ autres

En cas de présence d'inoculum de micro-organismes, remplacer ou compléter cette page par la "PAGE SPÉCIALE INOCULUM DE MICRO-ORGANISMES" Cerfa N° 11385*01.
Se référer également à la notice complémentaire Cerfa N° 50648#01

5. REVENDEICATION (S) :

51. EFFET PRINCIPAL REVENDIQUÉ : citer les constituants, matières actives, substances, espèces (cf paragraphes 35 ou 41) responsables de l'effet

Agent de l'effet	Effet revendiqué	Durée (en mois)

52. DÉNOMINATION du TYPE :

(réservé à l'administration)

6. CULTURES, DOSES, MODE d'EMPLOI :

61. MODE d'APPORT :

- ☐ épandage en plein ☐ épandage localisé ☐ pulvérisation ☐ incorporation par mélange massique
☐ injection ☐ poudrage ☐ pralinage ☐ enrobage de semence
☐ réserve d'eau ☐ goutte à goutte ☐ solution coulante ☐ -----

62. DESTINATION de l'APPORT :

- ☐ sol ☐ support de culture ☐ container, bac, pot ☐ semence
☐ plante feuille ☐ plante fruit ☐ plante racine ☐ -----

63. CULTURES PRÉCONISÉES :

	dose par apport (en kg / ha)		nombre d'apports par an		volume de dilution (en litres)		concentration de pulvérisation (kg / 100 l)		époques d'apport
	minimale	maximale	minimal	maximal	minimal	maximal	minimale	maximale	

64. STADES de DÉVELOPPEMENT des CULTURES au moment des APPORTS :

indiquer le stade de développement atteint par plus de 50 % des végétaux au moment des apports, dans l'ordre du tableau 63

7. PRÉCAUTIONS PARTICULIÈRES :

Mélanges possibles :



Mélanges déconseillés : _____

Conditions de climat à éviter : _____

Conditions de sol à éviter : _____

Apport interdit sur les cultures suivantes : _____

8. INNOCUITÉ :

81. NUMÉRATION MICROBIOLOGIQUE :

en indiquant dans quelle quantité de produit elle a été faite (par g, par 25 g)

Micro-organismes aérobies à 30°C :	_____	Entérocoques :	_____
<i>Escherichia coli</i> :	_____	<i>Clostridium perfringens</i> :	_____
Salmonelles :	_____	<i>Staphylococcus aureus</i> :	_____
Oeufs de nématodes :	_____	Larves de nématodes :	_____
_____ :	_____	_____ :	_____

82. DONNÉES PHYSICO-CHIMIQUES :

Pression de vapeur (Pa)	_____	Tension superficielle (N/m à 20°C)	_____
Hydrosolubilité (g/l à 20°C)	_____	Coefficient de partage (n-oct-eau)	_____
Liposolubilité (g/l à 20°C)	_____	Point de fusion	_____
Solvant : _____	Résultat _____	Solvant : _____	Résultat _____

Impuretés (% et nature) : _____

Nom des isomères et % correspondants : _____

83. DONNÉES TOXICOLOGIQUES :

toxicité	espèce	type / souche	véhicule	méthode	Résultat
orale					
cutanée					
inhalation					
peau (irritation)					
peau					
oeil					
poisson					
daphnies					
oiseau					

84. COMPORTEMENT dans le SOL :

nature du test	méthode	Résultat
mobilité		
persistance		

85. PRÉCAUTIONS à la MANIPULATION :

Stockage : _____

Transport : _____

Incendie : _____

Mesures d'urgence en cas d'accident de personne : _____

Mesures d'urgence en cas de dispersion accidentelle : _____

Possibilité de rendre la substance inoffensive : _____

Date, signature et nom du signataire en toutes lettres :

La loi n° 78-17 du 6 janvier 1978 relative à l'informatique, aux fichiers et aux libertés s'applique aux données nominatives portées dans ce formulaire.
Elle garantit un droit d'accès et de rectification pour ces données auprès de la Sous-Direction de la Qualité et de la Protection des Végétaux

Décrets, arrêtés, circulaires

TEXTES GÉNÉRAUX

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE

Arrêté du 20 avril 2021 modifiant l'arrêté du 30 avril 2020 précisant les modalités d'épandage des boues issues du traitement des eaux usées urbaines pendant la période de covid-19

Arrêtent :

Art. 1^{er}. – L'arrêté du 30 avril 2020 susvisé est ainsi modifié :

1° Après le *c* de l'article 2, il est ajouté un *d* et un *e* ainsi rédigés :

« *d*) Les boues extraites après le début d'exposition à risques pour le covid-19 ayant fait l'objet de l'un des traitements suivants :

« 1° Chaulage avec un taux d'incorporation minimum de chaux de 30 % équivalent CaO/MS (1) puis d'un stockage d'une durée minimale de 3 mois ;

« 2° Séchage solaire avec ou sans plancher chauffant permettant d'atteindre une siccité minimale de 80 % ;

« 3° Digestion anaérobie mésophile puis stockage d'une durée minimale de 4 mois ;

« *e*) Les boues extraites après le début d'exposition à risques pour le covid-19, dès lors qu'elles sont obtenues après un traitement des eaux usées par lagunage ou rhizofiltration ou dès lors qu'elles ont fait l'objet d'un traitement par rhizocompostage. Les boues doivent être extraites après une mise au repos du dispositif de traitement pendant au moins un an, sans que celle-ci n'entraîne de dysfonctionnement du système d'assainissement.





Horizon 2020

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Systemic large-scale eco-innovation to advance circular economy and mineral recovery from organic waste in Europe

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