Nutri2Cycle
Nurturing the Circular Economy

Nutri2Cycle

D.3.6 CBA report comparing baseline production systems with optimized systems using innovations – Final update

Deliverable: CBA report comparing baseline production systems with optimized systems using innovations - Final update

Author(s): Lies Bamelis[1], Astrid Croes[1], Filip Raymaekers[1], Ana – Marija Špicnagel Ćurko[2], Barbara Đukić[2]

[1.] United Experts cvba, [2.] IPS Konzalting d.o.o.

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Co-ordinator: Prof. Erik Meers, Ghent University

Contact details: Erik.meers@ugent.be

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List of Abbreviations

AD	Anaerobic Digestion
AN	Ammonium Nitrate
AS	Ammonium Sulphate
BBF	Bio-Based Fertilisers
C	Carbon
Ca	Calcium
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CH_4	Methane
d	Day
DM	Dry Matter
EU	European Union
g	Gram
GHG	Greenhouse Gases
h	Hour
H2020	Horizon Europe 2020
H_2SO_4	Sulfuric Acid
ha	Hectare
K	Potassium
CAN	Calcium Ammonium Nitrate Mineral Fertiliser
KCl	Potassium Chloride
kg	Kilogram
L	Litre
LF	Liquid Fraction
LL	Longlist
M	Million
N	Nitrogen
N2C	Nutri2Cycle Project
NH_3	Ammonia
NH_4-N	Ammonium-Nitrogen
NH_4NO_3	Ammonium Nitrate
NIR	Near-Infrared
OC	Organic Carbon
OM	Organic Matter
OPEX	Operating Expense
P	Phosphorus
S	Sulphur
SF	Solid Fraction
t	Ton
T	Temperature
TRL	Technology Readiness Level
UREA	Nitrogen Fertiliser
WP	Work Package
y	Year

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Glossary

Ammonium stripping/scrubbing: Technology that aims to strip the ammonia from airflows by "washing" it with an acid solution. The result of the stripping is on one hand a filtered air flow (low in emissions) and on the other hand a liquid solution containing ammonium. Depending on the acid used (HNO_3 or H_2SO_4), this liquid solution is ammonium nitrate (AN) or ammonium sulphate (AS).

Anaerobic digestion: A series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen and produce biogas.

CAPEX: Capital expenditure - funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment.

Cost benefit analysis: A cost-benefit analysis is the process of comparing the projected or estimated costs and benefits (or opportunities) associated with a project decision to determine whether it makes sense from a business perspective.

Digestate: A nutrient-rich substance produced by anaerobic digestion that can be used as a fertiliser.

Floating wetland plants grown on liquid agro-residues: Recuperation of nutrients from liquid agro-residues by growing protein-rich floating wetland plants.

High temperature reductive thermal process recovery of concentrated phosphorus from food grade animal bones: Technology that aims to recover phosphorus from food grade animal bone by-products using specialized pyrolysis processing technology and animal bone char product (ABC - BioPhosphate) development.

Low temperature ammonium-stripping using vacuum: Technology that is based on the evaporation of ammonia in vacuum conditions with the aim to recover ammonia from livestock slurry and obtain an ammonia salt that can be reused as a fertiliser.

OPEX: Operating expenses - costs a company incurs for running its day-to-day operations (rent and utilities, wages and salaries, property taxes).

Pig manure evaporation plant: Technology that aims to process all fractions of the pig manure into separate fertilizer products for N, P and K. N is recovered using N-stripping technology and the K-concentrate remains after evaporating water.

Precision farming: A farming management concept based on observing, measuring, and responding to inter and intra-field variability in crops; concept of improving crop yields and assisting management decisions using high technology sensor and analysis tools.

Struvite crystallisation: Crystallization of nitrogen and phosphorus in the form of magnesium ammonium phosphate hexahydrate (MAP).

Vacuum evaporation/stripping: Technology that consists of the boiling of a liquid substrate at negative pressure, at a temperature lower than the typical boiling temperature at atmospheric conditions with a purpose to optimize nutrient recovery from the waste streams and produce organic fertilizer with high content of nutrients in small volumes.

Willingness to pay: The maximum price that a customer is willing to pay for a product or service.

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Executive Summary

Purpose of the study / What's new

This document can be considered as an "add on" to the former CBA Deliverable (D3.3 CBA report comparing baseline production systems with optimized systems using innovations) as it was drafted and submitted in June 2022. The purpose of this report is multiple :

- Evaluate the current market situation compared to the study as performed beginning of 2022,
- Evaluate the outcomes of the research done in the Nutri2Cycle project since June 2022 and whether (or not) there is an impact on the outcomes of the CBA report.

Apart from the research done in the Nutri2Cycle project, some of the results of the CBA study will also be compared to the outcome of some other EU-projects (FertiCycle and FertiManure) in which the willingness of the end consumers to make the switch to the new recovered biobased fertilizers is further assessed.

Major points

In the former CBA report, 8 main conclusions were drafted based on the CBA report. Those were :

- Where manure is to be considered a (financial) problem in the regions with high nutrient pressure (i.e. it is a cost to dispose), it generates an income in those regions that have a shortage in nutrients. For example: in Flanders disposing manure is a cost that fluctuates around 17.5 €/ton, where in Croatia manure can be considered generating an income of 10.5 €/ton in Croatia. The (economic) impact of this difference (of 28€/ton) on economic feasibility of the N2C-solutions in very significant;
- The prices for energy (power & heat) and mineral fertilizers are determinant for the economic feasibility of most of the proposed N2C-solutions;
- Pocket digestion appears to have a very positive economic impact for pig farms in manure extensive regions, considering the current energy costs (payback period of around 2 years);
- The Vedows-stable system is only economically viable in the regions under nutrient pressure (i.e. manure intensive regions). In manure extensive regions there is no direct benefit from manure separation;
- With the current information it is not possible to define yet whether the use of precision farming for the application of recovered nutrients can be considered as an economically sustainable development;
- The maximal market price of recovered N-fertilizers can be 34 to 38 % higher for manure extensive regions compared to a manure intensive region without risking economic losses for the end-user;
- The maximum price for struvite can be 62 % higher in manure extensive regions;
- The cheapest method for handling biological effluent is the investment in a classic constructed wetland. The investment of a floating wetland (producing duck weed as a protein source) is economically competitive with the solution of storage combined with disposal on land.

The additional assessment done in this study adds the following take-home messages :

- Given the current market conditions the investment in a small scale digester (farm scale) appears to be more financially interesting than before in Flanders. This is mainly due to the change in energy prices. The impact for the manure extensive regions seems less significant;

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- Even with the increase energy prices the investment in a small scale digester appears to be more interesting than the investment in an innovative stable concept, though the difference in financial return slinks;
- In order to have a good market uptake of the biobased fertilizers it is important to assure that there is a financial gain for the end consumer. The research in FertiCycle and FertiManure show that in order to support a full market uptake a cost of 30% reduction of the cost for the mineral fertilizer is the most promising for a quick market uptake. Therefore it is required that the end user can also easily estimate what would be a relevant cost for the biobased fertilizer with zero reduction of cost. This is possible in the Nutri2Cycle tool that is online available.

Recommendations

This study showed that the economic boundary conditions (= market and economic figures) have a direct impact on the financial feasibility for the innovations. End users will need support on making the shift towards the use of the innovations. Projects like Nutri2Cycle with a well-developed network of demonstrations (Lighthouse demos – check the Nutri2Cycle website for more information) in combination with stakeholder interaction are therefore crucial.

The aim should be to provide the end user all possible low-threshold support for gaining his/her interest and taking the first steps towards the use of the innovations. This can only be achieved when the stakeholder can do (easy accessible) evaluations on his proper situation (tailor made) in combination with the general dissemination of knowledge and demonstrations.

Further development of tools will therefore be required also beyond the scope of the Nutri2Cycle project. As the aim is to bundle different possible tools on the platform of the EU Systemic project, further elaboration from this platform on is recommended.

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Introduction

For the general outline of the project, the technologies researched and the overall methodology of the CBA study can be consulted in the CBA-report D3.3 (June 2022). It is not the intention to repeat the information in this report, as it would elaborate and duplicate too much. As a reminder and to be able to keep a good overview the technologies assessed in the CBA-report are summarised in Table 1 (= identical to the Table 1 in D3.3).

The aim of this report is to give insights on the impact of changes in the economic framework on the economic feasibility of the innovations researched and whether or not the CBA-report covers the current market situation. Where prices on certain commodities (e.g. energy) were already gradually increasing end of 2021, there was a steep increase in the period of February 2022 until the summer of 2022. After that some prices have restabilized to a more normal situation, though hardly ever returned to the same level of 2021.

As the Nutri2Cycle project aims at supporting the end-users (stakeholders) to make the shift towards the use of the innovations researched in this project, it is important to evaluate whether or not the CBA-study done in 2022 is still valid. If it shows that the current market goes beyond the sensitivity assessment performed (see D3.3), the assessment will be elaborated in this report. Besides that, also an online tool in which the end-users can assess the economic feasibility in their own situation (using their own details and figures) will allow the end users to have a first level screening of the possibilities.

Both in this report and in the online tool the following technologies will be further assessed :

- The installation of a small scale / farm scale digester
- The installation of a new stable concept for separated collection of solid manure and urine in pig housing (followed by separate post-processing)
- The use of biobased-N-fertilizers
- The use of biobased-P-fertilizers

For the evaluation of the other technologies the CBA-report of 2022 (see D3.3) can be consulted.

For the use of the biobased fertilizers (N and P) there will be an additional aspect added to this report: within this report the interaction between the NUTRI2CYCLE project and two other projects is further supported, being the FERTICYCLE project and the FERTIMANURE project. In both these projects an assessment was done on the willingness to accept biobased fertilizers by the end-users. The combination with theses outcomes and the results of the CBA study of Nutri2Cycle show to give better insights in how to further trigger the uptake of the use of biobased fertilizers by the end-users.

The FERTIMANURE Project (Horizon 2020) is a project that is dedicated to innovative nutrient recovery form secondary sources (animal manure) for the production of high-added-value fertilizers.

The FERTICYCLE project (Horizon 2020 – Marie Curie actions) has the aim to train 15 early stage researched in the field of the bio-based fertilizers. Within the project there is a focus on the development of new technical solutions for the production of bio-based fertilizers, but also on the management and the marketing of the final products.

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Table 1. NUTRI2CYCLE technologies – priority list

Research Line	SL#	Shortlist Solution	LL#	Long-list Abstract Title	TRL	Country of research
2. Innovative soil, fertilisation & crop management systems & practices	1	Practices for increasing soil organic matter content	16	Using digestate, precision agriculture and no-tillage focusing on OM stocking in an area characterized by the lack of OM in sandy soil	9	Italy
	2	Catch crops to reduce N losses in soil and increase biogas production by anaerobic co-digestion	17	Crop farmers use a variety of manure and dairy processing residues to recycle and build soil C, N, P fertility	6	Ireland
4. Biobased fertilisers (N, P) and soil enhancers (OC) from agro-residues	4	Substituting external mineral nutrient input from synthetic fertilisers by recycled organic-based fertilizers in arable farming	1	Ammonium stripping/scrubbing and NH_4NO_3 as a substitute for synthetic N fertilizers	7	Belgium
			2	Ammonium stripping/scrubbing and NH_4SO_4 as substitute for synthetic N fertilizers	9	Belgium
			9	The liquid fraction of digestate as a substitute for mineral N & K fertilizer	8	Belgium
			6	Concentrate from vacuum evaporation/stripping as nutrient-rich organic fertilizer	4	Belgium
	6	P recovery from organic waste (water) streams via struvite crystallization	65	Struvite is a substitute for synthetic P fertilizer	4	Belgium
			49	Nitrogen and phosphorus recovery from pig manure via struvite crystallization and design of struvite based tailor-made fertilizers	6	Spain
	7	Pig manure processing and replacing mineral fertilizers	20	Low-temperature ammonium stripping using vacuum	4	Spain
			43	Pig manure evaporation plant	4,5	The Netherlands
	8	P recovery from animal bones	22	BIO-PHOSPHATE: high temperature reductive thermal process recovery of concentrated Phosphorus from food grade animal bones	8,5	Hungary
5. Novel animal feeds produced from agro-residues	12	Floating wetland plants are grown on liquid agro residues as a new source of proteins + ALGAE	41	Floating wetland plants are grown on liquid agro residues as a new source of proteins	6	Belgium
1. Innovative solutions for optimized nutrient & GHG in animal husbandry	13	Anaerobic digestion strategies for optimized nutrient and energy recovery from animal manure	10	Small/Farm scale anaerobic digestion of agro residues to increase local nutrient cycling & improve the nutrient use efficiency	8	Belgium
	15	Organic matter recovery from manure and associated valorisation strategies	24	Adapted stable construction for separated collection of solid manure and urine in pig housing (followed by separate post-processing)	9	Belgium
3. Tools, techniques & systems for higher-precision fertilization	19	Precision farming coping with heterogeneous qualities of organic fertilizers in the whole chain	30	Precision farming coping with heterogeneous qualities of organic fertilizers in the whole chain	9	Germany
	21	Field assessment of precision fertilization of maize & cereals using bio-based fertilizers	73	Precision arable farming using bio-based fertilizers in potato growing	5,5	The Netherlands

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1 Methodology

1.1 Step 1: review results and data collected in the former CBA study

This report is to be considered an “add-on” to the CBA-study done in the Nutri2Cycle project in 2021 and 2022. The methodology to draft this report is NOT to repeat the assessment done in the former report, though critically review whether or not the outcomes are still valid for the current (sept 2023) market situation. Therefore, the first step is to summarize and overview the data used before.

The Functional unit and the Reference scenario as such do not change compared to the former study.

The research (both the former report, but also this current report) considered a “manure intensive region” and a “manure extensive region”. As a reference for the manure intensive region **Flanders** was considered, where **Croatia** is the reference for the manure extensive region.

1.2 Step 2: Collecting Data

As in the former report, data were collected in order to make the cost benefit analysis. The sources of the data have not changed. Technical data have not changed since 2022. Only the economic data were updated. These updated data were collected from mainly the following sources :

- **Belgium** : Several online data compilation platforms (e.g. IndexMundi, Konema, Numbeo and Eurostat) and data from the sector.
- **Croatia** : data from the Advisory service of the Ministry of Agriculture and the Market Information System for data on the price and yield of certain agricultural crops in Croatia. For fertiliser prices in Croatia, an overview of the market trends was made, and based on the collected data, the average price was calculated. The same method was used for calculating prices for GPS locators as well as drones for precision farming.

Information on specific scientific data to validate claims made in the report was compiled from various scientific research papers, articles, reports and other similar types of scientific work. A compiled list of all such literature is present in the references section as well as all other resources used in this report.

1.3 Step 3: Comparison of the current data with the data used in prior research and elaborate the CBA evaluation if required

This report assesses the impact of current market data on the research performed in 2021 – 2022. Given the fact that in the beginning of 2022 the markets (and prices) were unstable due to the situation in Ukraine, it is important to assess whether or not the current market is to be considered as stabilized again, or that the assessment should be elaborated even further.

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2 Research Line 1: Innovative solutions for optimized nutrient & GHG in animal husbandry (LL#10 and LL#24)

2.1 LL10 Small/Farm scale anaerobic digestion

2.1.1 Data overview and comparison

The table below (Table 2) shows the data that were used in the former CBA-assessment (May 2022) and the comparison with the current situation. For the sensitivity analysis only the energy related costs were taken into account.

Manure intensive region (ref. Flanders)

Table 2 : overview data used in the CBA study compared to the current market situation in Flanders (sources : data from the energy authorities (VREG) and average data consulted in the sector).

Cost	Unit	Average (2019)	Sensit analysis Minimum	Sensit analysis Maximum	Current market situation
Disposal of raw manure (slurry)	€/ton	17.5	*n.a.*	*n.a.*	**22.5** (1)
Disposal of thin fraction of	€/ton	14	*n.a.*	*n.a.*	**17.5** (1)
Disposal of thick fraction	€/ton	16	*n.a.*	*n.a.*	**20** (1)
Disposal of digestate	€/ton	27.5	*n.a.*	*n.a.*	**32.5** (1)
Electricity costs	€/kWh_e	0.24	0.12	0.63	**0.3** (2)
Price of natural gas	€/kWh_{th}	0.05	0.025	0.18	**0.08** (2)
Income heat certificates	€/kWh_{th}	0.031	*n.a.*	*n.a.*	**0.036** (2)
Income green electricity certificates	€/kWh_e	0.067	*n.a.*	*n.a.*	**0.094** (2)
Labour costs	€/year	40000	*n.a.*	*n.a.*	**46000** (1)

From this table, following conclusions can be drafted for the region of Flanders:

- The sensitivity analysis on the energy costs as done in the CBA-study covers the current market situation. Both current prices of electricity (0.3 €/kWh_e) and of heat (0.08 €/kWh_{th}) fall within the ranges set in the former document;
- The costs for the disposal of manure and digestate have increased further compared to the market situation in 2019. Prices have increased 20 – 30 %;
- Labour costs have increased (estim. an increase with about 15%);
- The market value of the certificates (heat and green electricity) have increased.

Note : although the current energy prices fall within the range of the performed sensitivity analysis, there has been a period in 2022 in which the actual energy prices in Flanders went beyond the maximal considered value in the sensitivity analysis (0.63 €/kWh_e and 0.18 €/kWh_{th}). As can be seen in the graphs below (figure 1 and Figure 2) the cost for electricity for a company consuming around 50MWhe/year was above the maximum value in the months of September ‘22 (0.85 €/kWh_e) and October ’22 (0.66 €/kWh_e). For the cost for natural gas, the actual prices were even beyond the upper limit of the sensitivity analysis (0.18 €/kW_{th}) for a longer period of time, being from august ’22 up to November ’22 included.

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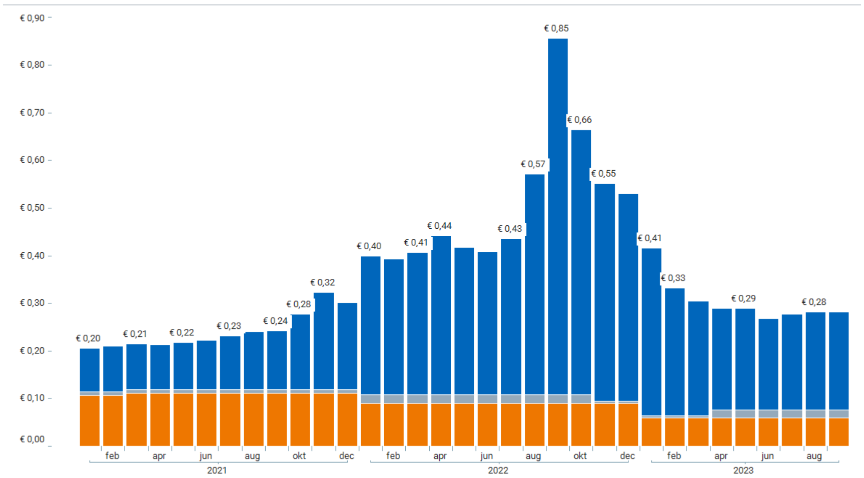

Figure 1 : evolution of the electricity price in Flanders for a company consuming around 50 MWhe/year (Source : dashboard.vreg.be, *(2)*)

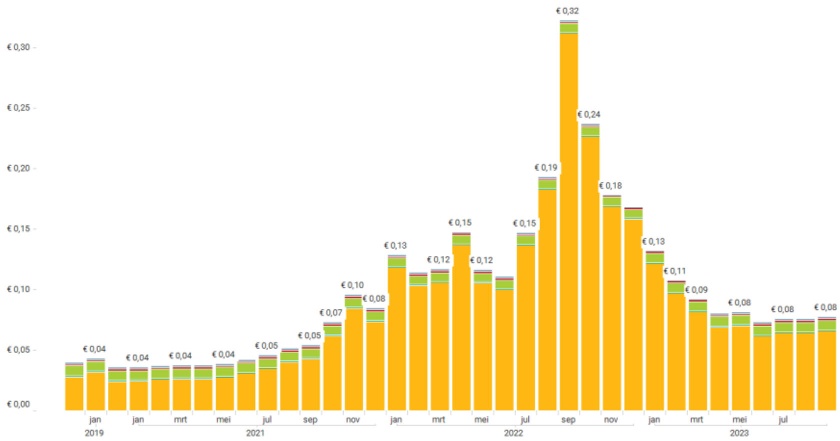

Figure 2 : Evolution of the price for natural gas in Flanders for a company consuming around 116 MWth/year (source : dashboard.vreg.be, *(2)*)

Manure extensive region (ref. Croatia)

Table 3 : overview data used in the CBA study compared to the current market situation in Croatia

Cost	Unit	Average (2019)	Sensit analysis Minimum	Sensit analysis Maximum	Current market situation
Disposal of raw manure (slurry)	€/ton	-10.5	*n.a.*	*n.a.*	**-20.77** (3)
Disposal of thin fraction of	€/ton	*n.a.*	*n.a.*	*n.a.*	*n.a.*
Disposal of thick fraction	€/ton	-40	*n.a.*	*n.a.*	**-40**
Disposal of digestate	€/ton	-10.5	*n.a.*	*n.a.*	**-20.77** (3)
Electricity costs	€/kWh_e	0.132	0.066	0.3465	**0.1479** (4)
Price of natural gas	€/kWh_{th}	0.028	0.014	0.099	**0.03595** (5)
Subsidies on investment	%	70	*n.a.*	*n.a.*	**70%**
Labour costs	€/year	20000	*n.a.*	*n.a.*	**20000**

Also for the situation in Croatia some important conclusions can be drafted from this overview :

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- In general the energy costs remain more or less stable (compared to the situation in 2019), and the current energy prices fall definitely within the sensitivity analysis as performed in the CBA in 2022. Therefor the CBA analysis done can be considered valid;
- A big change is though that the economic value of manure and digestate has significantly increased to a value even twice as high as in 2019. Given the fact that both the economic value of manure and digestate increase, the overall impact will be neglectable for this type of innovation, though for other types of innovation (e.g. recovery of nutrients) it might have a significant impact.

Conclusion after data collection

Based on the data of the current market situation it can be stated that for the manure extensive region (Croatia) the CBA study as performed in 2022 remains valid. Some of the number have shifted, though increased equally (e.g. the price for manure and digestate) and the energy prices fall within the range of the sensitivity analysis.

For the manure intensive regions more numbers have shifted. For example the cost for the disposal of raw manure seems to have increased more than for disposal of raw manure, labour costs have increased and the energy prices have shifted. Therefore it is important to:

- Repeat the evaluation of the CBA for the small scale digester
- Provide an online tool in which the end user can easily perform a first level assessment on the economic feasibility of the installation of a small scale / farm scale digester.

2.1.2 New CBA evaluation of the small scale digester for the situation in Flanders

When doing this evaluation the boundary conditions (e.g. types of feedstock, disposal of manure / digestate / …, no consideration of the value price for pig meat, …) and assumptions (e.g. biogas production) remain unchanged compared to the former CBA evaluation. The investment cost was also considered to remain unchanged.

Given the new market data for the region of Flanders, the table below gives the overview of the CBA for the pocket digester at a pig farm:

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Table 4 : Overview of the CBA assessment for the installation of a pocket digester at a pig farm with the economic data of summer 2023 in Flanders

			Manure intensive	
PIG Farm		Unit	Reference	With small scale digester
Benefits	Disposal of manure			
	Disposal of digestate			
	Subsidies (heat & power certificates)	€/ton	0	4,7
	TOTAL BENEFITS	**€/ton.year**	**0,00**	**4,73**
Costs	Disposal of manure	€/ton$_{manure}$	22,5	
	Heating costs (average fattening pig & sow)	€/ton$_{manure}$	8,84	
	Electricity costs	€/ton$_{manure}$	9,7	
	Disposal of digestate	€/ton$_{manure}$		32,5
	Labour	€/ton$_{manure}$		1,0 0,5hr per day
	Repair & maintenance	€/ton$_{manure}$		1,8 9000 €/year for 5000 ton installation
	Total COST	**€/ton$_{manure}$**	**41,08**	**35,25**
	OPEX balance (benefits - cost)	€/ton$_{manure}$	-41,08	-30,52
	OPEX benefit (by investment) (a)	**€/ton$_{manure}$**		**10,55**
Investment	Total investment Installation of 5.000 ton/yr	€		175000
	Netto investment 70% subsidy on investment	€		0
	Investment per unit (CAPEX) (b)	€/ton		35
	Annualized investment cost (c) 8 year	€/ton.year		4,38
	Overall yearly balance (a) - (c)	**€/ton.year**		**6,18**
	Payback period (b)/(a)	**year**		**3,32**

The table below compares the current CBA results with the results from the former CBA of the pocket digester in Flanders :

Table 5 : Comparison of the outcomes of the CBA assessment for the small scale digester

	Reference		With small scale digester	
	2019	2023	2019	2023
Benefits	0	0	3.6 €/ton.year	4.73 €/ton.year
Costs	30.82 €/ton.year	41.08 €/ton.year	29.8 €/ton.year	35.25 €/ton.year
Yearly Balance (OPEX)	-30.82 €/ton.year	-41.08 €/ton.year	-26.2 €/ton.year	-30.52 €/ton.year
Payback period			7.58 year	3.32 year

This table shows that although the operational costs when installing a small scale digester have increased over the years (from 29.8 €/ton.year up to 35.25 €/ton.year), the payback period has decreased from 7.6 year to 3.32 year. This is mainly due to the fact that the energy prices have increased, what makes that the positive economic impact of the small scale digester is more significant is the installations covers the heat en electricity demands.

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2.2 #LL24 Adapted stable construction for separated collection of solid manure and urine in pig housing (followed by separate post-processing)

When doing this assessment, the scenarios from the former CBA assessment will remain unchanged, being :

- Scenario 1: Classic stable construction with air treatment & regular disposal of manure (no manure separation)
- Scenario 2: Classic stable construction with air treatment & small scale digester (mono-digester)
- Scenario 3: Vedows system & regular disposal of manure
- Scenario 4: Vedows system & small scale digester (mono-digester)

2.2.1 Data overview and comparison

Given the similarity of some of the data, also the data overview as shown in Table 2 and Table 3 are applicable for this technology, though the following additional data should be considered:

For the region of Flanders :

Table 6 : overview of the used data for the CBA and the current market situation in Flanders

Cost	Unit	Average (2019)	Current market situation
Injected green electricity to the grid	€/kWh_e	0.067	**0.12** (2)
Investment cost – classic stable	€/pig place	400	**504** (6)
Investment cost - VEDOWS	€/pig place	490	**594** (6)

This shows that in Flanders both the price for the injected green electricity significantly increased, but also the construction costs have increased. Therefore a new evaluation for the 4 different scenarios in Flanders will be performed.

For the region of Croatia no significant changes in the economic data as shown in Table 6 are recorded.

2.2.2 New CBA evaluation of adapted stable construction for the situation in Flanders

Table 7 gives an overview of the CBA evaluation in the current market situation in Flanders. As currently there are the higher prices for energy and certificates the benefits of the investment in a small scale digester are higher than in 2019.

Table 8 gives an overview of the most relevant numbers in the CBA-assessment

Again – comparable with the small scale digester – it can be concluded that for all the scenarios the costs increase significantly (i.e. an increase of above 28% compared to the situation in 2019). The results show that the investment of moving beyond a classic stable construction will pay off. Also when taking into account the current market situation, the small scale digester remains economically the most interesting one, though the differences between different technologies shrink.

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Table 7 : CBA evaluation adapted stable construction in Flanders

Manure intensive region	Per Ton Manure			Scen 1	Scen 2	Scen 3	Scen 4
Technical	Stable system			Classic	Classic	Vedows	Vedows
	Manure treatment	Separation			Screw press	Vedows	Vedows
		Energy recovery			Digester		Digester
		Disposal		Disposal to treatment facility			
	Digester (technical)	Biogas production	m3/ton manure		25		67,5
		Electricity production	kWe/ton manure		35		94,5
		Heat production	kWth/ton manure		75		202,5
	Subsidy	Grey electricity injection	€/ton manure				7,14
		Heat Certificates (only 40 kWth/ton manure consumed)	€/ton manure		1,4		1,2
		Green electricity certificates	€/ton manure		3,3		6,3
	TOTAL BENEFITS		**€/ton manure**	**0**	**4,73**	**0**	**14,71**
OPEX	Manure disposal	Slurry	ton /ton manure input	1			
			€/ton manure	22,5			
		Thick fraction	ton /ton manure input			0,4	
			€/ton manure			7	
		Thin fraction	ton /ton manure input		0,8	0,6	0,6
			€/ton manure		16	12	12
		Digestate	ton /ton manure input		0,2		0,4
			€/ton manure		6,5		13
		Total disposal costs	**€/ton manure**	**22,5**	**22,5**	**19**	**25**
	Energy	Electricity	€/ton manure	9,74		9,74	
		Heating	€/ton manure	8,84		8,84	
		Total energy costs	**€/ton manure**	**18,58**		**18,58**	
	Air Treatment	Additives (water / chemicals)	€/ton manure	1,3	1,3		
		Energy	kWh$_e$/year.ton manure	20	20		
			€/ton manure	6	6		
		Maintenance	€/ton manure	1	1		
		Total costs air treatment	**€/ton manure**	**8,3**	**8,3**		
	Separation system	Energy	kWh$_e$/year.ton manure		1	0,55	0,55
			€/ton manure		0,3	0,165	0,165
		Maintenance	€/ton manure		0,3	1	1
		Total costs Manure separation	**€/ton manure**		**0,6**	**1,165**	**1,165**
	Digester	Labour	€/ton manure		0,95		0,95
		Repair & Maintenance	€/ton manure		1,8		1,8
		Total costs digester	**€/ton manure**		**2,75**		**2,75**
	TOTAL COSTS		**€/ton manure**	**49,38**	**34,15**	**38,74**	**28,92**
	Yearly balance (Benefits - costs)		**€/ton manure**	**-49,38**	**-29,42**	**-38,74**	**-14,21**
		impact of investment (comparison to scen 1)	**€/ton manure**		**19,95**	**10,635**	**35,17**
Investment	Stable system	Total investment (incl. air treatment in the classic system)	€/pig place	400	400	490	490
			€/ton	266,7	266,7	326,7	326,7
		Annualised investment costs (15 year; 1,5 ton manure /pig place.year)	€/ton.year	17,8	17,8	21,8	21,8
	Separation system	Total investment	€		30000		
			€/ton		6		
		Annualised investment costs (8 year; 5000 ton/yr)	€/ton.year		0,75		
	Small scale digester	Total investment	€		175000		225000
			€/ton		35		45
		Annualised investment cost (8 year)	€/ton.year		4,38		5,63
	TOTAL INVESTMENT COST		€/ton	266,67	307,67	326,67	371,67
		impact of investment (comparison to scen 1)	€/ton		41,00	60,00	105,00
			€/ton manure.year	**17,8**	**22,9**	**21,8**	**27,4**
		impact of investment (comparison to scen 1)	**€/ton manure.year**		**5,1**	**4,0**	**9,6**
	Overall comparison to scenario 1		**€/ton manure.year**		**14,83**	**6,64**	**25,55**
		Period to equal classic system (scen 1)	**year**		**2,05**	**5,64**	**2,99**

Table 8 : Comparison of the outcomes of the CBA assessment for the different scenarios

		Reference		Scen 2		Scen 3		Scen 4	
		2019	2023	2019	2023	2019	2023	2019	2023
Benefits		0	0	3.59	4.73	0	0	11.56	14.71
Costs	€/ton.year	37.9	49.38	26.64	34.15	29.23	38.74	22.83	28.92
Yearly Balance (OPEX)	€/ton.year	-37.9	-49.38	-23.06	-29.42	-29.23	-38.74	-11.27	-14.21
Investment (CAPEX)	€/pig place	400	504	400	504	490	594	490	594
Period to equal ref.scen.	year	n.a.	n.a.	2.76	**2.05**	6.92	**5.64**	3.94	**2.99**

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2.3 Overall conclusions on the technologies assessed from research line 1

For those technologies assessed the main impact so far came from the change in the energy prices. Taking into account the current market data it shows that the CBA-assessment performed before was still valid, though it did not cover a period at the end of 2022 with enormously high energy costs. Therefore it was decided to provide the possibility to the stakeholders for doing a first level assessment of the innovation using an online tool. After answering questions on the market data, the stakeholder will receive the exact output as seen in table 4 or table 7.

The tool is available through https://www.systemictools.eu/n2c

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3 Research Line 4: Biobased fertilizers (N, P) and soil enhancers (OC) from agro-residues

Within this research line several different biobased fertilizers were researched.

Table 9. Overview of the different types of fertilizers that will be evaluated in the CBA assessment

Type of Biobased Fertiliser or soil enhancer	#LL	Substitution for	Production process
Ammonium nitrate (NH_4NO_3)	1	Mineral N fertilizer	Stripping / Scrubbing
Ammonia sulphate ($(NH_4)_2SO_4$)	2	Mineral N fertilizer	Stripping / Scrubbing
Liquid fraction of digestate	9	Mineral N K fertilizer	
Concentrate	6 & 43	Mineral N fertilizer	Vacuum evaporation / stripping
Struvite	49 & 65	Mineral P fertilizer	
Ammonia concentrate	20	Mineral N fertilizer	Vacuum stripping
Bio-phosphate	22	Mineral P fertilizer	High temperature reductive thermal process

For the CBA assessment on the use of those biobased fertilizers, the technologies will be jointly assessed, indicating that technologies #LL 1, #LL 2, #9, #LL 20, #LL 6 & # LL43 will be discussed first. Next will be the comparison of #LL 22, #LL49 and #LL65.

3.1 Data overview and comparison

For this assessment the use of biobased fertilizers (BBF's) is compared to the use of manure + mineral fertilizers (situation Flanders) or to the use of mineral fertilizers only (situation Croatia). The prices of mineral fertilizers have fluctuated significantly over the past years.

As an illustration the figures below show the evolution of both urea (left) and Triple Super Phosphate TSP (right).

Figure 3 : evolution of the price of urea (in €/ton) over the past 5 years (source : indexmundi.com)

Figure 4 : evolution of the price of TSP (in €/ton) over the past 5 years (source : indexmundi.com)

Figures 3 and 4 show that the prices for urea and TSP had a significant increase and are gradually decreasing again. At this point the market value is not completely back to the former level, though they seem to be gradually moving there.

Table 10 gives an overview of the data used in the former CBA study, including the ranges assessed in the sensitivity analysis. When evaluating this overview it shows that the CBA performed in 2022 covered fully the different price ranges of the current market prices, even including the highest prices

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noted in the past 5 years. Therefore it can be stated that the CBA study (and it's results) are still valid in general.

Table 10 : overview of the data used in the former CBA and the current market situation

Cost	Unit	Average (2019)	Sensit analysis Minimum	Sensit analysis Maximum	Current market situation (7)
Urea	€/kg	0.29	*0.225*	*1.8*	**0.265** (7)
TSP	€/kg	0.3	*0.225*	*1.8*	**0.36** (7)
CAN	€/kg	0.21	*0.1575*	*1.26*	**0.26** (8)
NPK – 1	€/kg	0.32	*0.24*	*1.92*	**0.51** (8)
NPK – 2	€/kg	0.47	0.375	3	**0.4** (8)
KCl	€/kg	0.19	0.15	1.2	**0.3** (7)
Transport	€/ton	4 (Flanders) 2 (Croatia)	*n.a.*	*n.a.*	4.4 (Flanders) 2 (Croatia)

3.2 Need for an assessment tool on biobased fertilizers

In order to support stakeholders in the economic evaluation of the use of biobased fertilizers, it is important to make the assessment as "tailor made" as possible. The end-user, i.e. the farmer knows best what the amount of fertilizers can and should be applied on the arable land (taking into account the type of crops, the soil-capacity, the location of the parcel and the applicable regulations). This reference situation is the starting point in the assessment tool.

The tool that was developed follows the same methodology as applied when performing the CBA-study : the amount of nutrients applied on land remain unchanged, but it is intended to substitute mineral fertilizers with biobased fertilizers.

In the tool the composition of the biobased fertilizers as analyzed in the Nutri2Cycle project are suggested, but the end-user can adjust the concentrations when relevant.

At the end of the tool the farmer gets an indication of the maximal price he can pay for the BBF's in order not to lose money on the fertilization.

The tool is available on https://www.systemictools.eu/n2c

3.3 Willingness to pay / to accept

With the tool developed in Nutri2Cycle, the final users of the biobased fertilizers can deduct the maximal price they can pay without making financial losses on the fertilization of their arable land.

In 2 other European projects (FertiCycle and FertiManure) were questioned about their willingness to accept and willingness to pay for those biobased fertilizers.

The results of the FertiManure project – as presented on the ESNI conference (20/09/2023) – show that there is clearly a regional difference in the willingness to accept biobased fertilizers (9). It shows for example that the farmers in France tend the most to continue using existing mineral and organic fertilizers, where Spain and Croatia show to be more open for it. For those latter regions the actual price they would have to pay for the biobased fertilizers would be decisive, rather than a good knowledge of the quality of the biobased fertilizer. Several different aspects will have an impact on the willingness to pay for biobased fertilizers, like the original sources that it originated from and the

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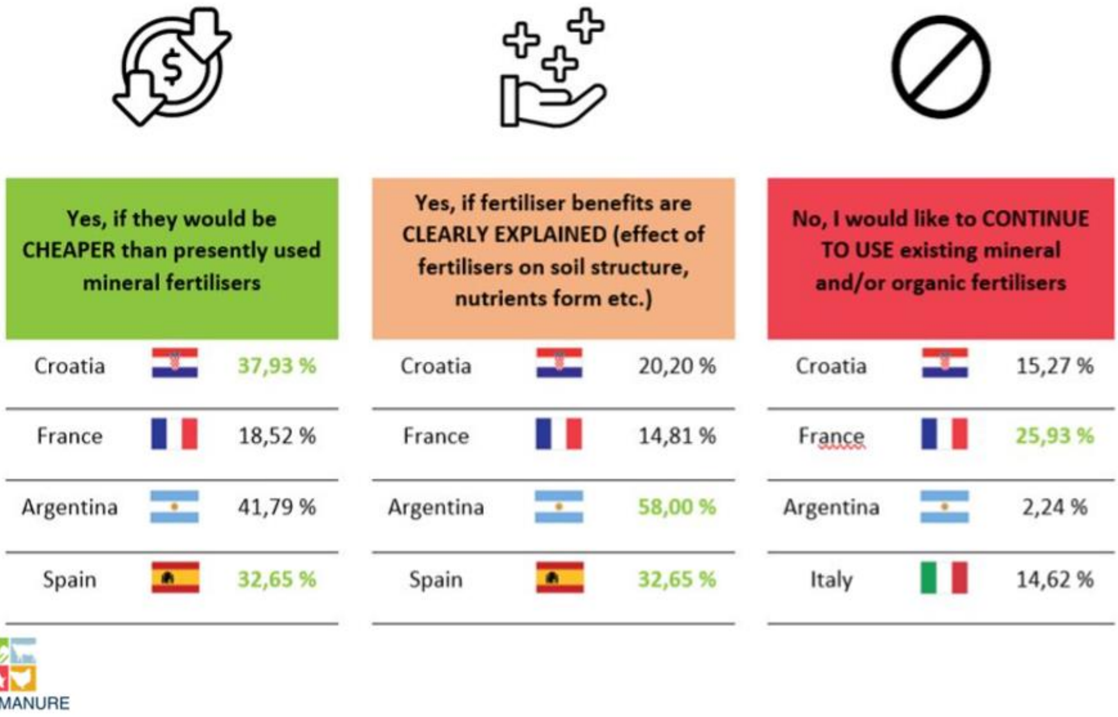
consequently deducted (or assumed) risks on infection. In general, it can be stated that the majority of the respondents in the FertiManure project were not willing to pay more for biobased fertilizers than for mineral fertilizers. In the FertiCycle project, a same type of assessment is done, resulting in the conclusion that to achieve the fast adoption of bio-based fertilizers, their cost should be 30-46% below the cost for the mineral fertilizer (10).

This supports the development of the tool in the Nutri2Cycle project, as this will support the stakeholders in doing the evaluation of the maximal price they should pay for the biobased fertilizers not to lose money.



Yes, if they would be CHEAPER than presently used mineral fertilisers		Yes, if fertiliser benefits are CLEARLY EXPLAINED (effect of fertilisers on soil structure, nutrients form etc.)		No, I would like to CONTINUE TO USE existing mineral and/or organic fertilisers	
Croatia	37,93 %	Croatia	20,20 %	Croatia	15,27 %
France	18,52 %	France	14,81 %	France	25,93 %
Argentina	41,79 %	Argentina	58,00 %	Argentina	2,24 %
Spain	32,65 %	Spain	32,65 %	Italy	14,62 %

Figure 5 : overview of results of stakeholder willingness to accept biobased fertilizers (BBF's) in the FertiManure project (3)

The FertiManure project also develops business plans for the production of the biobased fertilizers. For the authorities that want to further support the development and use of the biobased fertilizers, it is important to compare those production costs with the maximal accepted cost for biobased fertilizers. If there is a gap (i.e. production cost per ton > willingness to pay per ton) then one could look into the possibilities to provide a financial support to the producer and/or the end-user. The research done in FertiCycle (10) shows that the fastest uptake of the biobased fertilizers can be achieved when the cost of the biobased fertilizer is about 30 – 46% below the cost of the mineral fertilizer, but on the other hand this would result in a loss of 25 – 32% of potential revenue for the producer. If the producer would envision a maximum revenue he should aim a keeping the price as high as for the mineral fertilizer, but then the market uptake of the biobased fertilizers would be a lot lower.

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4 Conclusions

For the general conclusions of the CBA at farm scale it is best to consult the conclusions as described in the former study (see D3.3). Nevertheless, this report consisted of re-evaluating the innovations within the current economic framework (by September 2023). It has shown that the changes in the market situation have a direct and important impact on the economic feasibility of the innovations. For example the investment in a small scale digester (farm scale) in Flanders appears to be even more interesting in the current market situation compared to the situation before. The payback period dropped significantly (< 2 to 3 years). Also the investment in an the innovative stable concept combined with a small scale digester shows to have a better economic feasibility.

On the other hand the research has indicated that in order to convince farmers to switch using biobased fertilizers (BBF's) the actual price should be lower (preferably 20 – 30%) than the mineral fertilizers. In order to support the end-users (farmers) in making the assessment, it is important that they can easily make this economic evaluation.

As the intention of a CBA is to evaluate the economic feasibility for the stakeholders, it is important that those stakeholders can actually make the assessment based on the actual market situation. It has shown that – thanks to the sensitivity analysis – the CBA report covers the majority of the situations, but not all. On top of that the evaluation was now only done for 2 reference regions (Croatia and Flanders), what will of course also influence the validity of the results for the stakeholders beyond those regions.

All of the above resulted in the need for an tool that can serve as a first line assessment for investing in innovative technologies and the maximal economic price that should be paid for the BBFs. Those tools are made available thanks to the Nutri2Cycle project and will be accessible via https://www.systemictools.eu/n2c .

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