MAINSTREAM BIO

MAINSTREAMING SMALL-SCALE BIO-BASED SOLUTIONS ACROSS RURAL EUROPE

D2.2

Best practices for improved nutrient recycling

IUNG

21 June 2024

Funded by the European Union

PROJECT INFORMATION

PROGRAMME	Horizon Europe
TOPIC	HORIZON-CL6-2021-CIRCBIO-01-08
TYPE OF ACTION	HORIZON Coordination and Support Actions
PROJECT NUMBER	101059420
START DAY	1 September 2022
DURATION	36 months

DOCUMENT INFORMATION

TITLE	Best practices for improved nutrient recycling
WORK PACKAGE	WP2
TASK	2.2
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DATE	21 June 2024

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Classified S-UE/EU-S	EU SECRET under the Commission Decision No2015/444	

DOCUMENT HISTORY

Version	Date	Changes	Responsible partner
0.1	04/04/2023	First draft	IUNG
0.2	19/04/2023	Second draft	IUNG
0.3	24/04/2023	Final draft for review by AUP & WR	IUNG
1.0	28/04/2023	Final report	IUNG
2.0	21/6/2024	Updated version addressing comments of the 1st review	IUNG

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ABBREVIATIONS

BAT	Best available techniques
BET	Brunauer-Emmett-Teller surface analysis
BREF	BAT reference document
BSAP	Baltic Sea Action Plan
BSR	Baltic Sea region
CAP	Common Agricultural Policy
CEC	Cation exchange capacity
CEN	European Committee for Standardisation
CEN/CR	European Committee for Standardisation Report
CEN/TC	European Committee for Standardisation Technical Committee
CEN/TR	European Committee for Standardisation Technical Report
CEN/TS	European Committee for Standardisation Technical Specifications
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CHP	Combined heat and power
DM	Dry matter
EBC	European Biochar Certificate

EEA	European Environment Agency
EPRS	European Parliamentary Research Service
GHG	Greenhouse gasses
GMO	Genetically modified organism
GROT	(NO: Greiner og topper) Branches and tops
GWP	Global warming potential
H_2	Hydrogen
H_2S	Hydrogen sulfide
H_2SO_4	Sulphuric acid
H_2O	Water
HHV	High Heating Values
HNO_3	Nitric acid
HTC	Hydrothermal carbonization
IACS	Integrated Administration and Control System
IED	Industrial Emissions Directive
IPM	Integrated pest management
K	Potassium
LPIS	Land Parcel Identification System
MFE	Mineral fertilizer equivalent
$MgNH_4PO_4 \cdot 6H_2O$	Magnesium ammonium orthophosphate hexahydrate
MIPS	Multi-actor Innovation Platform
N	Nitrogen
N_2	Molecular nitrogen
N_2O	Nitrous oxide

NEC	National Emission reduction Commitments
NaOH	Natrium hydroxide
NGO	Non-government organization
NH_3	Ammonia
NH_4^+	Ammonium
NH_4-N	Ammoniacal nitrogen
NH_4NO_3	Ammonium nitrate
$(NH_4)_2SO_4$	Ammonium sulphate
NO_x	Nitrogen oxides
NRT	Nutrient retention capacity
NRP	Nutrient recycling practices
NRS	Nutrient Recycling Strategy
NUTS	Nomenclature of territorial units for statistics
OM	Organic matter
P	Phosphorous
PFAS	Per- and polyfluoroalkyl substances
pH	Potential of hydrogen
RDF	Recycling-derived fertiliser
RO	Reverse osmosis
SAT	Slurry acidification techniques
SME	Small to medium sized enterprise
SOCS	Soil organic carbon sequestration
SO_x	Sulfur oxides
SSD	Sewage Sludge Directive

UNECE	The United Nations Economic Commission for Europe
UWWTD	Urban Waste Water Treatment Directive
VFG	Vegetable, fruit and garden waste
VOC	Volatile organic compounds
WFD	Waste Framework Directive
WHC	Water holding capacity

Executive Summary

Report D2.2 "Best Practices for Improved Nutrient Recycling" is a result of the implementation of task T2.2 “Collection of best practices for improved nutrient recycling in the circular bioeconomy”. Report D2.2 is supplemented by D2.2 Annex “Nutrient Recycling Practices & Interviews”, which contains a developed set of nutrient recycling practices (NRP) and a collection of Interview Questionnaires completed during the implementation of task T2.2

In T2.2, task leader IUNG designed tools to prepare the set of NRP and conduct interviews with stakeholders. Using these tools, project partners prepared 31 practice sheets for digital tool and conducted 32 interviews to obtain information about social perception and acceptance of NRP.

Most of the selected practices are widely used mainly in agriculture, but also in forestry. A large group of them is well recognized and accepted by stakeholders, but some of them are associated with a specific location where appropriate biomass and technology is available. A certain group of practices presents an innovative approach to the problem of nutrient recycling and these practices are not widely known and implemented. The dissemination of knowledge about them is the basis for achieving the MainstreamBIO project's goals - to provide information about the many possibilities of recovering nutrients in agriculture based on bioeconomy.

D2.2 Annex “Nutrient Recycling Practices & Interviews” is a supplement to report D2.2 "Best Practices for Improved Nutrient Recycling".

The annex contains a developed set of nutrient recycling practices (NRP) and a collection of Interview Questionnaires completed during the implementation of task T2.2 “Collection of best practices for improved nutrient recycling in the circular bioeconomy”.

The MS Excel sheets presenting the NRP were converted to MS Word format and placed in Chapter 3 of the annex to the D2.2 report. The MS Excel sheets were also uploaded as a dataset in Zenodo, as foreseen in the project's Data Management Plan.

Interview Questionnaires were completed during in-depth interviews with relevant stakeholders from 6 Multi-actor Innovation Platforms (MIPS) and placed in Chapter 4 of the annex to the D2.2 report.

1. Introduction

One of the objectives of the MainstreamBIO project is to create a digital platform that would support stakeholders in meeting the challenges posed by modern agriculture based on bioeconomy. One of the elements of this toolkit is the nutrient recycling practices (NRP) catalog, designed to help choose the NRP methods that will best suit the needs of stakeholders in a variety of conditions and activities.

1.1 Description of Task 2.2 in Grant Agreement

Task 2.2 “Collection of best practices for improved nutrient recycling in the circular bioeconomy”, will collect practical information on efficient and cost-effective NRP, with a focus on: (i) safe use of waste streams and fertiliser products obtained from their processing; (ii) social perception and acceptance of such practices from farmers and consumers across the value chain; and (iii) relevant legislation and how it affects their wider adoption. Each practice will be assessed against specific criteria (type, geographic spread, value chains involvement and synergies, replication potential, farmer acceptance, environmental sustainability etc.) by IUNG and presented in a dedicated best practice template. Our analysis will be enriched through in-depth interviews (>15) with relevant stakeholders (questionnaires will be prepared by IUNG, while interviews will be conducted by the partners involved in this task). The outcomes of this task will be gathered and presented in D2.2.

1.2 Approach and methodology

- IUNG is overall responsible for Task 2.2 and coordinates the course of work and storage of the results.
- IUNG develops an NRP Set of tools to collect information on the best NRP and recognition of their acceptance: Two MS Excel files - Practice form (Extended), Practice template (Essential) and one MS Word file format - Interview questionnaire.
- The NRP set of tools is reviewed by all project partners, and next is ready for use by all partners involved in Task 2.2 (IUNG, AUP, FBCD, MTU, PROC, Q-PLAN, WHITE, and WR) for describing NRP.
- The partners fill out the Practice form (Extended) mainly based on literature, expert knowledge, and their own research. One NRP will be described as one MS Excel file
- The initial NRP List is proposed by IUNG, developed by all project partners, and finally, is created as a Set of NRP.
- The partners perform in-depth interviews inside Multi-actor Innovation Platforms (MIPS) to obtain information from relevant stakeholders on NRP social perception and acceptance, using an Interview questionnaire.
- The MS Excel sheets presenting the NRP are converted to MS Word format and annexed to the report of D2.2. The MS Excel sheets are also uploaded as a dataset in Zenodo, as foreseen in the Data Management Plan.
- The D2.2 will serve as input for Task 2.4 and Task 2.5

1.3 Action plan

The action plan in Table 1 was presented at kick-off meeting in Thessaloniki, and updated at 2nd project meeting in Cork

Table 1: Action plan for Task 2.2 was presented at kick-off meeting, and updated at 2nd project meeting.

No.	Action point	Who	By When
1	Practice form draft (extended), Practice template draft (essential) and Interview questionnaire draft ready for comments and send to partners	IUNG	31 Oct 2022 (M2)
2	Practice form draft (extended), Practice template draft (essential) and Interview questionnaire draft partners' comments return deadline, practices proposal & selection	Q-PLAN, MTU, WR, AUP, FBCD, DRAXIS, WHITE	15 Nov 2022 (M3)
3	Practice form (extended), Practice template (essential) and Interview questionnaire send to partners	IUNG	30 Nov 2022 (M4)
4	Practice forms (extended) and Interview questionnaires filled up by partners and return to IUNG	Q-PLAN, MTU, WR, AUP, FBCD, DRAXIS, WHITE	31 Mar 2023 (M7)
5	Nutrient recycling practices evaluation and final tuning	IUNG	7 Apr 2023 (M8)
6	Harmonization of descriptions of small-scale bio-based technologies and NRP	IUNG & WR	14 Apr 2023 (M8)
7	Edit final version of D2.2	IUNG	18 Apr 2023 (M8)
8	Submit D2.2 to quality reviewers (WR, AUP)	IUNG	19 Apr 2023 (M8)
9	Receive comments from quality reviewers	WR, AUP	24 Apr 2023 (M8)
10	Nutrient recycling practices set is delivered in D 2.2	IUNG	28 Apr 2023 (M8)

1.4 Content of deliverable

Deliverable D2.2 consists of two parts: the report and the annex. The report presents the scope of Task 2.2, the methodology of its implementation, the implemented action plan, required definitions, and a summary. The annex contains a developed set of 31 NRPs and a collection of 32 Interview Questionnaires carried out during the implementation of Task 2. The Set of 31 independent files of NRPs in the format of MS Excel sheets are also available on the dedicated Zenodo repository.

2. Collection of best practices for improved nutrient recycling

2.1 Definition of nutrient recycling practice (NRP)

Food production would not be possible without three basic nutrients – nitrogen, phosphorus, and potassium. Due to the huge demand for food for the ever-growing population, mineral fertilizers have played a key role in agricultural (food) production for 70 years. The production and transportation of these fertilizers require significant amounts of energy from fossil fuels. On the other hand, the resources of phosphorus used in producing fertilizers are limited, non-renewable, and will be exhausted soon.

Nutrient recycling practice (NRP) refers to the processes of recovering nutrients from organic waste and wastewater and returning them to agricultural land as recycled nutrient fertilizers (RNFs). In the processes, nutrients from nutrient-rich materials created during production and consumption are reused sustainably and safely as recycled nutrients. NRP is a sustainable practice that helps reduce waste and pollution while improving soil health and increasing crop yields. NRP also reduces the use of non-renewable natural resources and can reduce nutrient emissions into the environment. Figure 2 illustrates various NRPs stages and options, which recover nutrients to higher quality final products.

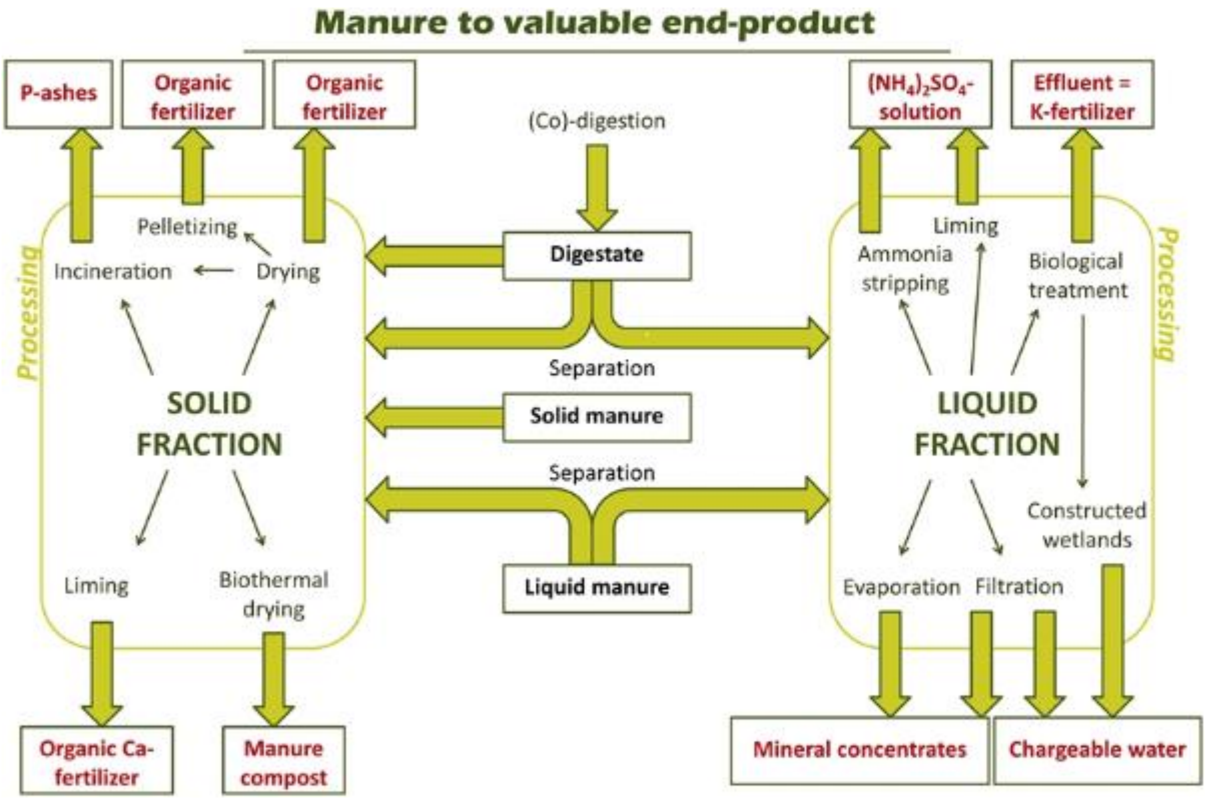

Figure 1: Treatment processes that allow the upcycling of organic waste streams to nutrients and organic products. Source: https://www.vcm-mestverwerking.be/en/manureprocessing/10305/techniques-and-end-products

The environmental impact of nutrient management is not limited by national borders. Therefore, international cooperation is necessary to achieve common goals of the regional circular economy and nutrient recovery. An example of such cooperation constitute the activities of the Baltic Marine Environment Protection Commission (HELCOM), such as the Baltic Sea Action Plan (BSAP) and Nutrient Recycling Strategy (NRS) which were adopted by all Baltic Sea region (BSR) countries in 2021. Both BSAP and NRS include measures related to NRP. Nutrient recycling is also a complex issue that requires the participation and cooperation of policymakers, municipalities, SMEs, biomass producers, farmers, the food industry, and scientists.

Literature:

Hidalgo, D., Corona, F. & Martín-Marroquín, J.M., 2021, Nutrient recycling: from waste to crop. Biomass Conv. Bioref. 11, 207–217 (2021). https://doi.org/10.1007/s13399-019-00590-3

Egan A., Saju A., Sigurnjak I., Meers E., Power N., 2022, What are the desired properties of recycling-derived fertilisers from an end-user perspective?, Cleaner and Responsible Consumption, 5, https://doi.org/10.1016/j.clrc.2022.100057.

The Flemish Coordination Center for Manure Processing (VCM), Techniques for manure processing in Flanders, https://www.vcm-mestverwerking.be/en/manureprocessing/10305/techniques-and-end-products

2.2 Set of nutrient recycling practices

The converted MS Excel sheets presenting the NRP were placed in Chapter 3 of the annex to the D2.2 report. Table 2 presents list of 31 NRPs with practice codes and their location in the annex.

Each practice was described in detail, with particular attention to biomass type, and the possible final product. The nutrient recycling practices were analysed including the value chain of available biomass, over 60% of which involve co-products (valuable biomass obtained in the production of primary products), 35% waste (low-quality biomass of null or negative values), and 9% dedicated raw biomass and a primary product for processing. It is important to notice that 30% of technologies can work with all types of biomass. The most frequently used biomass for NRP was as follows: manure, slurry, digestate, agricultural wastes, grass, algae, forest residues, and fish waste.

The NRP collection also includes a few practices that do not directly use biomass but complement its processing because they increase the efficiency of nutrient recycling and minimize its losses. Combining these practices with NRP that produces nutrient-rich RNFs is the best solution for a sustainable circular economy. These are for example: P5 and P6, Proper storage and application of manure allows you to limit the loss of nutrients (especially nitrogen and phosphorus), so that a larger amount of nutrients can be used by plants.

P11 A fertilizer plan is a tool to describe, plan, and calculate the distribution requirements of organic and inorganic fertilizer; A properly designed fertilization plan taking into account plants requirements allows for the most effective recovery of nutrients from fertilizers at the field level. It should be consistent with bio-based technologies and consider the specific characteristics of the RNFs produced in this way.

P16 Integrated pest management (IPM) is an effective and environmentally sensitive strategy to protect plants and manage pests. It ensures proper growth and development of plants, which results in an appropriate level of yield, and therefore the intake of the amount of nutrients assumed in the fertilization plan and balanced loss of nutrients outside the soil-plant system.

P31 Wetlands (collection of nutrients) to naturally reduce nutrient runoff. Wetlands are the last line of defence against water pollution with excessive amounts of nutrients. The biomass obtained in this way can be returned to appropriate NRPs.

The Spatial coverage (Farm, Local, Regional, National, Industry) was taken into consideration and it shows that over 70% of the practices can be used at farm or local level, 20% at regional, 12% at national and 9% is dedicated for industry. This reflects the large impact of the costs of transporting RNFs on their potential use. Future strategies for nutrient recovery should take into account that local NRPs are often the most profitable and allow closing the nutrient cycle within one or several farms that are located relatively close to each other.

The described nutrient recycling practices in most cases are available commercially in most of the European countries. The best solutions are quickly disseminated thanks to, among others, dedicated EU projects, as well as commercial activities of enterprises and support for innovation in EU countries.

There might be limitations due to the environmental conditions and practice location like with for example P.31 Wetlands. Other limiting element may be available knowledge. Practices such as P 10, 11, 16 require a lot of knowledge and commitment on the part of the farmer, although they are often complicated and influence the change of habits, they are quite readily accepted by farmers and even more so by society. The level of acceptance increases significantly in the process of dissemination of NRP, especially when the efforts of stakeholders are compensated by the benefits.

The level of acceptance is a highly dynamic parameter that changes due to the need to adapt to applicable law, search for economically reasonable solutions, or increased awareness.

When introducing new practices, the availability of substrates and the possibility of using the resulting products are crucial, as they are a key element of the investment's success. However, social acceptance is playing an increasingly important role because the introduction of new nutrient recovery practices may raise some concerns among local communities, especially those immediately adjacent to the installations. This is often observed with anaerobic digestion. For the remaining practices there is a wide acceptance of most NRPs in the rural communities, especially when it is considered a cheap and reliable energy supply as well as a source of quality fertilizers.

The cost for new bio-based fertilisers must be sufficiently competitive for the acceptance of farmers and the entire society with respect to traditional mineral fertilisers, when considering elements such as: logistics (transport and application), nutrient content and plant availability, physical parameters (compatibility with handling and spreading equipment) and potential nuisances (odour, dust) for neighbours. or financial resources, as in the case of P 2, 3, 7, 20, 24. Among the EU member countries of the MainstreamBIO consortium, recycling practices were considered acceptable by the majority of people surveyed. It should also be taken into account that the cost of NRPs may change over time, and technologies currently with low profitability rates may be widely used in response to political changes, a decrease in the availability of resources, and an increase in the costs of production based on industrial mineral fertilizers.

Table 2: List of nutrient recycling practices in the Annex

Code	Nutrient recycling practice	Responsible partner	Annex page
P1	Algae cultivation	WR	11
P2	Ammonia stripping	WR	18
P3	Anaerobic digestion MTU	MTU	22
P4	Anaerobic digestion WR	WR	25
P5	Appropriate manure application	AUP	29
P6	Appropriate manure storage	IUNG	33
P7	Ash recycling	PROC	37
P8	Catch crops	FBCD	41
P9	Combustion/Incineration	WHITE	45
P10	Conservation Tillage	AUP	51
P11	Fertilization plan	FBCD	55
P12	Fish meal production	FBCD	58
P13	Gasification	Q-PLAN	62

P14	Hydrothermal carbonization	Q-PLAN	65
P15	Increased outtake of slurry from pig stables	FBCD	69
P16	Integrated pest management (IPM)	FBCD	73
P17	Manure composting	MTU	77
P18	Mechanical Solid-liquid separation	IUNG	80
P19	Pelletizing/granulation	WHITE	86
P20	Propagation technology/precision farming	AUP	95
P21	Pyrolysis	Q-PLAN	99
P22	Sewage Sludge treatment MTU	MTU	103
P23	Sewage Sludge treatment WHITE	WHITE	107
P24	Slurry acidification	IUNG	115
P25	Small-scale green biorefining	Q-PLAN	120
P26	Smart combined stable system	WR	123
P27	Struvite precipitation	IUNG	126
P28	Thermal drying	IUNG	129
P29	Vacuum evaporation	IUNG	132
P30	Waste composting/hygienization	IUNG	135
P31	Wetlands (collection of nutrients)	FBCD	138

2.3 Interviews with stakeholders

For performing in-depth interviews inside MIPS to obtain information from relevant stakeholders on NRP social perception and acceptance, the partners used the interview questionnaire presented in Table 4, placed in Chapter 4 of the annex to the D2.2 report.

Interviews with stakeholders carried out in T2.2 allowed for the assessment of the set of practices in terms of their social perception and acceptance. After analyzing the interviews, it can be concluded that some of the practices contained in the “Set of nutrient recycling practices” are well known to the respondents. Among the most frequently pointed out practices are those related to manure processing such as slurry acidification or mechanical separation, manure composting, manure drying, or anaerobic digestion. Respondents also mentioned practices related to the recovery of nutrients from sewage sludge, mainly composting.

Analyzing the relationships between the groups of respondents and their knowledge of issues related to nutrient recycling practices, it can be concluded that biomass producers, especially farmers, have less knowledge of these practices compared to other groups of respondents. As a consequence, it would be necessary to consider directing awareness-raising campaigns and various types of training related to nutrient recycling practices to this group of respondents.

2.4 Results of interviews

The most important nutrient recycling practices reported in **the Netherlands** are practices dealing with manure processing (composting, digestion) which produces different fertilizer products or soil improvers. A huge effort is also put into composting organic household waste, including grass clippings and pruning waste from private gardens and use of the compost as a soil improver (VFG-compost (vegetable, fruit, and garden waste)). Due to a huge amount of livestock production, an effort is put to install air scrubbers in, for example, intensive livestock barns that remove ammonium from the air which then can be used as a nitrogen fertilizer (mostly in the form of ammonium sulphate). Moreover, the residuals like starch generated during sugar and starch extraction are agriculturally used. Extraction of struvite from sewage treatment and its use as a fertilizer is gaining more and more importance. Manure and other liquid fertilizer products are widely accepted by farmers. They are commonly used as their price is low and they are good sources of nutrients and organic matter. Due to the crisis, their quotations are growing and they are becoming more and more popular. The high price of manure pellets causes its lower acceptance by farmers. Compost is partly accepted. Farmers endorse its value as a soil improver, especially because of its organic matter supply, but the price may keep some of them from applying it. VFG-compost is not always accepted, due to contaminations with glass and plastic particles. The acceptance of P-fertilizers made out of struvite is neutral. Popular nutrient recycling practices in the Netherlands are safe, and regulated by the appropriate types of legislation and/or national/regional recommendations.

The most important nutrient recycling practices reported in **Bulgaria** are practices dealing with manure processing which produces different fertilizer products or soil improvers. The produced fertilizers are mainly used by farmers. There is a high acceptance of natural fertilizers in Bulgaria. There is also a high need to improve nutrient recycling regulatory practices through the appropriate types of legislation and/or national/regional recommendations. Moreover, the legislation for recycling and processing all kinds of biomass would widen the field of activities and would create new opportunities.

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The most important nutrient recycling practices reported in **Sweden** are ash recycling and horse manure composting. The ash return is not done on a large scale. Ash that is bio-classified may be returned to the forest, but it must meet all requirements for it to be sent back to the forest. The safety of the procedure of spreading the ashes is regulated according to a different legislation than the one the Swedish Forest Agency oversees. When it comes to the safety of fertilizers, meaning the ashes that are recycled back to the forest, all ashes in means of analysis are controlled by the Swedish Forest Agency. The Forest Protection Act legislates this. In addition, Sweden produced recommendations, guidance, and rules. Examples of this can be found in report 2019:4 of the Swedish Forest Agency to control the spreading of ashes, and the recycling of ash is controlled according to Environmental Code 12:6. Moreover, there is an obligation to report ash to return no later than 6 weeks before spreading to the Swedish Forest Agency.

The most important nutrient recycling practices reported in **Denmark** are practices dealing with manure processing (composting, digestion) which produces different fertilizer products or soil improvers, the establishment of wetlands and miniwetlands to remove nutrients from farmland to avoid entry into lakes, coastal waters and inlets, as well as all waste is recycled from households. The recovered nutrients are mostly used by farmers, municipalities, and private companies investing in green products. There is a wide acceptance of all the practices in the community, especially when it is considered a cheap and reliable energy supply as well as a good fertilizer.

The most important nutrient recycling practices reported in **Ireland** are practices for agricultural slurry and manure recovery, digestate from anaerobic digestion, composted organic material and household nutrients, sludge, and wastewater sludge. Those are used to produce different fertilizer products or soil improvement soil e.g. dried/pelletized poultry manures, struvite processed from waste facilities, digestate from the Anaerobic digestion sector. Slurry and manure are very acceptable in the agricultural sector. Composted materials depend on where you use them. Sludge is the most challenging to raise acceptance. Respondents indicated that social awareness and knowledge in the field of nutrient recycling product safeness should be further developed, especially those originating from sludge. The legislation surrounding the area of biorefining needs to be improved so that they are categorized correctly. However, existing legislation is not set up to deal with these evolving technologies and this can act as a barrier.

The most important nutrient recycling practices reported in **Poland** are practices for agricultural slurry and manure recovery, digestate from anaerobic digestion, and composted organic material. Those are used to produce different dried and/or pelletized fertilizer products to improve the soil. Most of these products, especially those of agricultural origin, are widely accepted by society and widely used by farmers. Municipal sewage sludge has a low level of acceptance. Processed natural plant residues and vegetable or mushroom substrates are considered safe. Also, most manures that are processed are considered safe. Animal production waste and sewage of various origins - municipal and industrial - are usually considered potentially dangerous. Farmers are afraid of heavy metals that can permanently contaminate the soil. In Poland, the main legislation in this regard is an ordinance of the Minister of the Environment on January 20, 2015, on the R10 recovery process. Farmers believe that some regulations are even overly restrictive.

In summary, manure processing practices were the most frequently mentioned by respondents from all the partner countries included in the survey. Moreover, these practices have the highest social acceptance among nutrient recycling practices and are known as safe and environmentally friendly. Manure processing products are widely used by farmers. Sewage sludge processing practices are less socially acceptable. Respondents explain that it may be related to the fact that sludge processing products may contain contaminants (e.g. heavy metals) or their production may generate

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odours. Respondents pointed out that work on legislative changes is needed, especially related to new technologies for the processing and recovery of nutrients and the use of obtained products.

2.5 Conclusions

Food security in Europe and the world results mainly from the availability of nutrients and their main source in sustainable plant production are fertilizers. The production of all mineral fertilizers uses significant amounts of fossil fuels, and, in the case of phosphorus and potash fertilizers, the main substrate for their production are limited mineral deposits. It, therefore, seems logical that the developed set of NRPs is very important for many stakeholders related to agriculture, due to the need to reduce the dependence of crop production on mineral fertilizers based on fossil fuels and resources (especially N, P, and K).

Currently, NRPs are being developed and assessed in terms of profitability, availability and acceptance, which will allow in the future to use the best solutions tailored to local conditions. Such an analysis is also crucial due to the need to build extensive knowledge resources allowing for future use in changing climatic conditions and unstable political situations.

Therefore, European and global agriculture should move towards closed cycles of nutrient supply. These assumptions should be applicable both in the agricultural sector and in the mineral fertilizer industry, where recovered nutrients can be used as input. It should be emphasized that nutrient recycling can make farmers less dependent on imported and purchased mineral fertilizers and therefore less exposed to price fluctuations or supply problems. Another important aspect is that Nutrient Recycling can create jobs in rural areas in the processing, marketing and distribution of recycled nutritional products.

Annex. Nutrient Recycling Practices & Interviews

Table 3: Row content title and their explanation used in tables of NRP set

Row content title	Row content explanation/comment/option
Short title	–
Short summary for stakeholders	On the (final or expected) results/effects of the practice.
Practice full title	–
Practice objective and context	What problems/opportunities does the practice address that are relevant for the practitioner/end-user, and how will they be solved? Factors in legislation/markets or other reasons that led to the development of the practice.
Practice description	General information describing the principle of operation. Explanation of the main processes involved. Step by step actions overview. Basic and extended requirements and conditions for optimal performance.

General diagram	Graphic diagram of the practice showing the key elements and processes.
Input components	–
Biomass type	*Co-product* - valuable biomass obtained in the production of primary products. *Waste* - low quality biomass of null or negative values. *Dedicated* - raw biomass and a primary product for processing.
Final products and their use	Product category / name. Main direction of use. Main nutrient content.
Visual examples of final product	Attached filename or repository URL.
Spatial coverage	*Farm, Local, Regional, National, Industry.*
Practice mobility	*Static* - practice assigned to permanent infrastructure, *Mobile* - the practice can be done in mobile or temporary installation.
Level of complexity	*Low* - mainly mechanical and/or thermal processes are involved with minimum engineering skills. *Medium* - mainly mechanical and/or chemical and/or biotech processes are involved, with more steps than for *Low*. *High* - many processes (mechanical, chemical and biotech, etc.) are involved, with significant engineering resources.
Replication potential	*Low* - needs to meet specific conditions (technology, engineering background), limited to small area. *Medium* - possible to repeat in other localization but require specific conditions. *High* - easy to repeat in other localization, do not require special conditions (generally available).
Innovation stage	*Commercially available, Under development, Prior to market introduction.*
Country / Region of implementation	–
Statistical location	(NUTS1, NUTS2, NUTS3) if appropriate.
Practice implementation	How commonly is the practice used. What is the implementation stage. Real scale references.
Environmental effects	Environmental benefits and risks.
Limitations	Factors and obstacles limiting the wide implementation of the practice.

Relevant stakeholders	Actors (person/organization) involved in the performance and implementation of the practice.
EU legislation/recommendation	–
National legislation/recommendation	–
References	–
Additional information and comments	Free text field which can be used by the editor e.g. for suggestions for future actions/research, for messages to end-users etc.
Editor of the template	Person/organization responsible for completing the template.

3. Nutrient recycling practices set

3.1 Algae cultivation

P1

Practice summary	
Short title	Algae cultivation
Short summary for stakeholders on the (final or expected) results/effects of the practice	Algae cultivation is one technique or way of valorizing manure and digestate. Algae are cultivated worldwide and can grow in all kinds of reactors (open pond raceway, cascade systems or closed tubular systems). The algae need light, CO_2 and nutrients, such as N, P and K. They produce biomass and O_2. Algae can also be grown on other C sources (other than CO_2), for example organic carbon sources such as sugars. The first mentioned systems whereas light and CO_2 are the input feedstocks is called heterotrophic. Autotrophic is a system wherein the algae are grown on other organic carbon sources, and light is not necessary. A combination of those systems is also possible, which is called mixotrophy. The algae are first cultivated in the presence of light and CO_2 as carbon source. After a while, the algae are switched sugar as the main carbon sources, which can be done in the dark or with light. The advantage of this systems is the allowance of different cultivation methods, such as a 'regular' dark reactor instead of a system which allows a lot of natural or led lights. Digestate can be used as a source of nutrients for the algae. The benefit of growing algae on digestate or the liquid fraction of manure is to valorize a small part of the excess manure in the Netherlands and secondly CO_2 is captured by the algae. Cultivation of algae on manure or digestate would be best suitable as an on-farm technique or installation. Part of the manure can be used for the algae and the algae produce biomass with a high protein concentration. The algae can be fed directly to cows, pigs or poultry. This would be an ideal situation; however, algae installations are costly for a farmer. So, price and ease of operating would be crucial factors before an algae reactor can be operated on a farm. Furthermore, it is not possible to grow algae on manure or digestate and feed it directly to livestock. This is forbidden by law in the Netherlands for now.

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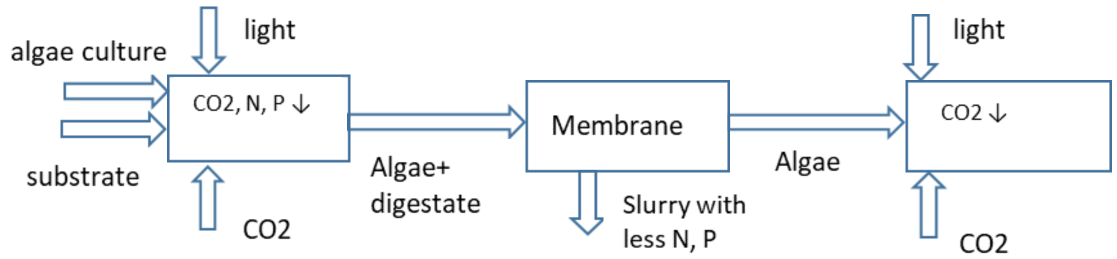
Practice details	
Practice full title	Algae cultivation
Practice objective and context What problems/opportunities does the practice address that are relevant for the practitioner/end-user, and how will they be solved? Factors in legislation/markets or other reasons that led to the development of the practice	Algae can be grown on the liquid fraction of cattle manure or on digestate from anaerobic digestion. In these feed streams there are (still) nutrients and sugars, which can be used by the algae. These nutrients and sugars are valuable so that retrieving them is worthwhile. Thereby, the amount of waste is reduced. A lot of protein is tilled on the field for cattle feed (grass for example), using land which could also be used to till food for humans (feed/food topic). Cultivating proteins in algae can contribute to reducing the land needed for feeding animals. Some algae species are on the lists of approved animal feeds. However, there can be still a problem with the legislation within Europe, in case particles of the manure are harvested together with the algae. Within Europe the process of production should be safe. Algae sold abroad Europe are only tested as product. A farmer in Belgium with a cattle farm is an example of a farmer producing algae. He however does not use digestate as a fertilizer for the algae, but he uses a feed safe medium. In this way, he is able to sell his products as food. He makes algae ice cream, cheeses and many other products
Practice description General information describing the principle of operation, Explanation of the main processes involved, Step by step actions overview, Basic and extended requirements and conditions for optimal performance	Algae can be grown in multiple ways. See the short practice summary in the previous page. A two phase reactor is one of the possibilities already used on a small pilot scale, whereas digestate is used as a nutrient source in the culture. This work is done in the scope of ALG-AD, a European project who uses digestate to produce algae, in order to make the livestock industry more circular https://www.alg-ad-dst.com/. The liquid fraction of cattle manure or digestate is used as substrate. In the first phase algae are grown phototrophical autotrophically. Light is used as an energy source, CO_2 is used as carbon source and nutrients (mainly nitrogen (N) and phosphorous (P)) are used to grow algae (Fuentes-Grünewald et al., 2021). After this phase the algae are concentrated using membrane technology. During the second phase the algae are grown mixotrophically. During this phase, microalgae use inorganic CO_2 as well as organic carbon sources in the presence of light to increase the biomass (Fuentes-Grünewald et al., 2021). During these experiments, only a small percentage of the media is digestate, around 2%. The difficulty with digestate is its dark color. Algae were grown in tubular closed loop reactors in the presence of light, a too dark medium blocks the light. Filtration of the digestate or a different cultivation method could be a possible solution for this problem. Van der Weide et al (2014) did experiments to cultivate algae with digestate. The digestate should be diluted but although still a bit dark the algae were able to grow on these diluted streams.

General diagram Graphic diagram of the practice showing the key elements and processes	
Input components	Carbon source for example liquid fraction cattle manure or digestate residue from anaerobic digestion or another medium with the right nutrients, algae culture, CO_2 sparging which can also be done with smoke gas out of the combined heat and power unit.
Biomass type *Co-product* - valuable biomass obtained in the production of primary products, *Waste* - low quality biomass of null or negative values, *Dedicated* - raw biomass and a primary product for processing	In combination with digestion and/or treatment of digestates or manure in thick and thin nutrient rich fraction are especially the liquid fractions in countries with too much manure a negative biomass stream (in case the nutrients are much diluted also expensive to distribute to area where they can be used - so waste
Final products and their use Product category / name, Main direction of use, Main nutrient content	Protein rich algae (50% proteins)

Visual examples of final product Attached filename or repository URL	https://www.nweurope.eu/projects/project-search/alg-ad-creating-value-from-waste-nutrients-by-integrating-algal-and-anaerobic-digestion-technology/#tab-1
Spatial coverage *Farm, Local, Regional, National, Industry*	Local
Practice mobility *Static* - practice assigned to permanent infrastructure, *Mobile* - the practice can be done in mobile or temporary installation	Static
Level of complexity *Low* - mainly mechanical and/or thermal processes are involved with minimum engineering skills, *Medium* - mainly mechanical and/or chemical and/or biotech processes are involved, with more steps than for *Low*, *High* - many processes (mechanical, chemical and biotech, etc.) are involved, with significant engineering resources	Medium to high

Replication potential *Low* - needs to meet specific conditions (technology, engineering background), limited to small area, *Medium* - possible to repeat in other localization but require specific conditions, *High* - easy to repeat in other localization, do not require special conditions (generally available**)**	Low to Medium
Innovation stage *Commercially available, Under development, Prior to market introduction*	Commercially available, but cheaper production methods are under development. Commercially available systems are open pond and closed tubular loop reactors. The open pond systems are cheaper, but need a lot of surface area and are difficult to keep warm during colder winter months. The tubular systems are more expensive and is often not sold to farmers, but there are exceptions.

Country / Region of implementation	The Netherlands
Statistical location (NUTS1, NUTS2, NUTS3) if appropriate	Province of Friesland and Flevoland
Practice implementation how commonly is the practice used, what is the implementation stage, real scale references	There are several pilots. Also a 5000-liter scale has been reported (Fuentes-Grünewald et al., 2021). The TRL is estimated at 7. Due to the costs, labor and low concentration of digestate/manure this technology is not (yet) ready for farms.
Environmental effects environmental benefits and risks	CO_2 (from air or concentrated) is used to let the algae grow. However, when the protein rich algae are used as feed for cattle than the cattle will produce methane (with a much higher GWP), so basically CO_2 is converted into CH_4 in the air. This is an environmental risk. On the other hand, if feed for animals remains a must, then the alternative is tilling feed on the land. Here diesel is used for growing the crop, and in this case cattle also produces CH_4. So in this case the greenhouse gas emissions are higher than when the feed is produced with algae cultivation. Furthermore in case of using the manure of the cattle to produce green gas to increase on sustainability, smoke gas or other CO_2 gas streams in this process can be used for the algae cultivation.
Limitations factors and obstacles limiting the wide implementation of the practice	Costs, labor and low concentration of digestate/manure
Relevant stakeholders actors (person / organization) involved in the performance and implementation of the practice	There are some businesses in the Netherlands that produce algae reactors, but most is custom made. There are 2 companies cultivating algae in our region but not using liquid manure or digestate. A few farmers using manure and cultivating algae.
EU legislation/recommendation	Use algae species which are on the EU list of approved feed.
	Make a description of the system and do checks how to use manure/digestate on a safe way.

	Develop a basis for sound legislation and discuss with authorities to get approvals.
National legislation/recommendation	same as for EU
References	Fuentes-Grünewald, C., Ignacio Gayo-Peláez, J., Ndovela, V., Wood, E., Vijay Kapoore, R., & Anne Llewellyn, C. (2021). Towards a circular economy: A novel microalgal two-step growth approach to treat excess nutrients from digestate and to produce biomass for animal feed. Bioresource Technology, 320, 124349. https://doi.org/10.1016/J.BIORTECH.2020.124349
	Algae cultivation using digestate as nutrient source: opportunities and challenges R.Y. van der Weide, R. Schipperus, W. van Dijk (2014) https://edepot.wur.nl/316948 https://www.nweurope.eu/projects/project-search/alg-ad-creating-value-from-waste-nutrients-by-integrating-algal-and-anaerobic-digestion-technology/ https://www.heirbauthoeveproducten.be/
Additional information and comments free text field which can be used by the editor e.g. for suggestions for future actions/research, for messages to end-users etc.	
Editor of the template person/organization responsible for completing the template	WUR ACRRES

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3.2 Ammonia stripping

P2

Practice summary	
Short title	Ammonia stripping & Scrubbing
Short summary for stakeholders	Ammonia stripping & Scrubbing is a treatment used to reduce NH_3 emissions to allow farms to comply with national or EU legislation. Addition of bases (increasing pH) or increasing the temperature aids shifting the equilibrium of ammonia (NH_3) and ammonium (NH_4^+) towards the gaseous NH_3. In this sense ammonia removal of ammonia stripping is also referred to as NH_4^-N removal. On lab scale (50 L reactor, 10 days' reactor time) an ammonia removal efficiency in digestate of 87% is obtained with 40C and a pH of 9 (using sodium hydroxide), an ammonia removal efficiency of 69% is obtained with 40C and no pH adjustment and an ammonia removal efficiency of approximately 85% is obtained with 50C and no pH adjustment (Provolo et al., 2017). The air with added NH_3 gas is then separated and washed (in a separate device) with an acidic liquid with a pH of 3 up to 5, but a pH of 1.3 is also possible (Melse and Ogink, 2005). When the NH_3 gas gets in contact with the low pH liquid it dissolves in the liquid (transforms from NH_3 to NH_4^+). Depending on the acid that is used the output varies. When H_2SO_4 is used as acid, then $(NH_4)_2SO_4$ (ammonium sulphate) is produced. When HNO_3 is used as acid, then NH_4NO_3 (ammonium nitrate) is produced. There remain two streams. The first one is the slurry where ammonia is subtracted. The second one is a liquid with concentrated N minerals. There are commercially available technologies for stripping and scrubbing ammonia in animal houses.
Practice details	
Practice full title	Ammonia stripping & Scrubbing
Practice objective and context	Reduce the loss of ammonia nitrogen from animal manure. Slurry contains nitrogen in the form of organic nitrogen and ammoniacal nitrogen. In liquid solutions ammoniacal nitrogen existing as a both ammonia (NH_3) and ammonium (NH_4^+) form. The equilibrium between these forms are largely dependent on solution pH. Ammonia is a gas that easily vaporizes whereas ammonium is stabile in solution. Ammonia stripping & scrubbing is a treatment used to reduce NH_3 emissions to allow farms to comply with national or EU legislation (BAT conclusion, NEC directive).

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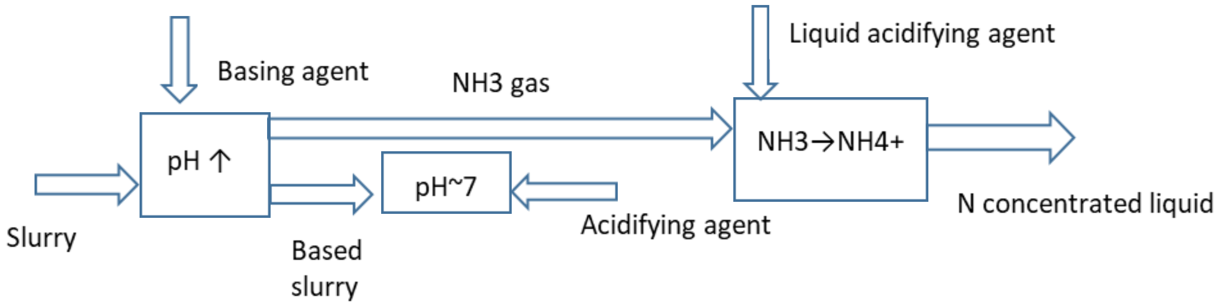
Practice description	Addition of bases (increasing pH) or increasing the temperature aids shifting the equilibrium of ammonia (NH_3) and ammonium (NH_4^+) towards the gaseous NH_3. The NH_3 gas is then separated and washed (in a separate device) with an acidic liquid (low pH). When the NH_3 gas gets in contact with the low pH liquid it dissolves in the liquid (transforms from NH_3 to NH_4^+). Depending on the acid that is used the output varies. When H_2SO_4 is used as acid, then $(NH_4)_2SO_4$ (ammonium sulfate) is produced. When HNO_3 is used as acid, then NH_4NO_3 (ammonium nitrate) is produced. There remain two streams. The first one is the slurry where ammonia is subtracted. The second one is a liquid with concentrated N minerals. There are commercially available technologies for stripping and scrubbing ammonia in the animal house.
General diagram	
Input components	Animal slurry, liquid manure, digestate, separated liquid fraction of manure , or stable air
Biomass type	Co-product, or Waste
Final products and their use	Fertilizer / N concentrate liquid and slurry with less nitrogen
Visual examples of final product	
Spatial coverage	Farm
Practice mobility	Static, Mobile
Level of complexity	Medium to High
Replication potential	Low to Medium

Innovation stage	Commercially available
Country / Region of implementation	EU
Statistical location	
Practice implementation	This technique is commercially available. There are several full scale examples. Examples are the installations of Farmair and Dorset GM.
Environmental effects	Melse and Ogink (2005) report five researches done on five different farms in the Netherlands where scrubbing ammonia decreased the ammonia emissions by 90%, 91%, 95%, 98% and 99%. This is applicable only for the NH_3 in the air. The efficiency is not applicable for the N in the liquid slurry
Limitations	
Relevant stakeholders	Farmair, Dorset GM, LelySphere
EU legislation/recommendation	The National Emission Ceilings (NEC) Directive (EU 2016/2284)
	Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control) – BAT 16, 21, 23, 30,
National legislation/recommendation	Regeling beoordeling luchtkwaliteit, in Dutch https://wetten.overheid.nl/BWBR0022817/2021-04-03/#Hoofdstuk4_Paragraaf4.3_Artikel73 Regeling ammoniak en veehouderij, Rav https://www.infomil.nl/onderwerpen/landbouw/emissiearme-stalsystemen/stalbeschrijvingen/
References	Melse, R. W., Verdoes, N., Willers, H. C., & de Buisonjé F.E. (2004). Quick scan van be- en verwerkingstechnieken voor dierlijke mest. http://www.asg.wur.nl/po
	Melse, R.W., Ogink, N., (2005). Air scrubbing techniques for ammonia and odor reduction at livestock operations: review of on-farm research in the Netherlands. Trans. ASAE 48, 2303–2313. Provolo, G., Manuli, G., Finzi, A., Lucchini, G., Riva, E., Sacchi, G.A., (2018). Effect of pig and cattle slurry application on heavy metal composition of maize grown on different soils. Sustain. 10. https://doi.org/10.3390/su10082684.

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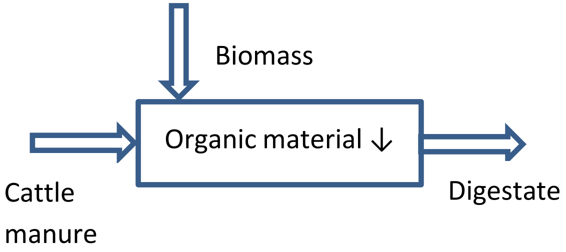
Additional information and comments	https://systemicproject.eu/wp-content/uploads/NH3stripping-scrubbing-1.pdf
Editor of the template	WUR (ACRRES)

3.3 Anaerobic digestion MTU

P3

Practice summary	
Short title	Anaerobic digestion
Short summary for stakeholders	The Green Generation Anaerobic Digestion plants processes 23,000 tons of food waste a year and this is processed along with slurry from pigs which is used to produce biogas. The leftovers from that or digestate is used as an organic fertilizer. This digestate consists of around 6/7 kg nitrogen, 1/2kg phosphorus, 2/3 kg potassium per cubic meter along with some sulphur and organic matter which is good for restoring soil health. They supply local farmers who have been using that and some have even replaced chemical fertilizer. It has around 6-8% solids and it's spread using traditional slurry spreading equipment due to the high-water content. There are conversations around drying it or pelletizing it however in reality you need a high capital expenditure to set up production facilities for that and at present the return doesn't exist to warrant that level of investment. https://greengeneration.ie/
Practice details	
Practice full title	Anaerobic Digestion
Practice objective and context	The anaerobic digestion facility is surrounded by farmers, so the local benefits from things like employment for people spreading the digestate to getting free fertilizer so for the most the community benefits and so this drives general acceptance of it in the area. Using low emission spreading techniques help with this and as they are becoming compulsory the odor issue is dealt with. Education of the local community is crucial, letting them know who we are and what we do and the benefits and value that an Anaerobic Digestion facility can bring to a community. The facility must adhere Department of Agriculture regulations or more specifically EU regulations on pasteurization. As they take in animal byproducts there is a risk of pathogen transfer and so everything must be pasteurized and heated to above 70 degrees for more than one hour and this is effective at killing off any existing pathogens. EPA regulations must also be followed on covered storage of the digestate to mitigate against emissions to the wider environment. Other regulations around nitrates which are also set by the EU must adhered to, that is 170kg per hectare means there is less risk of runoff to local bodies of water.

Practice description	The Green Generation Anaerobic Digestion plants processes 23,000 tons of food waste a year and this is processed along with slurry from pigs which is used to produce biogas. The leftovers from that or digestate is used as an organic fertilizer. This digestate consists of around 6/7 kg nitrogen, 1/2kg phosphorus, 2/3 kg potassium per cubic meter along with some sulphur and organic matter which is good for restoring soil health. It has around 6-8% solids and it's spread using traditional slurry spreading equipment due to the high-water content.
General diagram	
Input components	At Green Generation they take in food processing waste right the way from meat processing to residues from food processing and retail waste and repackage and food waste from brown bins in canteens and processes it through the facility.
Biomass type	Waste (most common for wet digestion)
Final products and their use	Fertilizer / Acidified slurry or digestate used to crop fertilization, digested biomass
Visual examples of final product	
Spatial coverage	Farm, local or regional - outputting to Cush Gas Injection Site
Practice mobility	Static
Level of complexity	Medium
Replication potential	High
Innovation stage	Commercially available (wet digestion)

Country / Region of implementation	Ireland
Statistical location	
Practice implementation	Local farmers have been using the digestate for a while now as previously mentioned and several of them have decided to replace their chemical fertilizers exclusively with the digestate. We're way behind the rest with Anaerobic Digestion compared to the rest of Europe. Italy, France, and Germany would be the main ones and Sweden and the Netherlands are also pretty well developed and it's those that Ireland should be looking to replicate when developing Anaerobic Digestion.
Environmental effects	Using low emission spreading techniques help with this and as they are becoming compulsory the odor issue is dealt with.
Limitations	
Relevant stakeholders	https://greengeneration.ie/ https://www.gasnetworks.ie/home/, local agri community & suppliers of feedstocks.
EU legislation/recommendation	Regulation for chemical fertilizers Regulation for Slurry/Manure pasteurization
National legislation/recommendation	
References	https://greengeneration.ie/what-we-do/
Additional information and comments	
Editor of the template	Robert Ludgate / MTU

3.4 Anaerobic digestion WR

P4

Practice summary	
Short title	Anaerobic digestion
Short summary for stakeholders	Anaerobic digestion is the fermentation process of organic matter in the absence of oxygen. Feedstocks are manure, crop residues or any other form of organic matter. The product of anaerobic digestion is biogas (CH_4). Biogas needs to be upgraded to be able to use it in our gas network. The biogas can also directly be burned and used as heat. Anaerobic digestion happens at different levels, from farm to regional levels, to even small scale with kitchen scraps. The technique is widely used and it's even more interesting in recent light, with rising gas and energy prices. The main advantage for farmers is the production of biogas. The digestate (the residual slurry after digestion) is still rich in nutrients and can be directly spread onto the field. It can also be separated into a liquid and a solid fraction, so the nutrients can be applied to the field more precise.
Practice details	
Practice full title	Anaerobic Digestion
Practice objective and context	There are mainly two different methods for digestion shortly, mono and co digestion. With mono digestion, manure (e.g. cattle or pig) is the sole input stream into the digester. Co-digestion is the digestion of both manure in combination with other input streams like crop residues or grass. In both system, the aim is to produce biogas (60% methane, 35% CO_2, 5% other gasses) and digestate. Biogas can be used to produce energy by burning it directly (heat) or in a combined heat and power device (heat and electricity combined). It is possible that the biogas is not suitable for grid purposes (such as in the Netherlands). In these cases, the biogas has to be upgraded to grid gas quality. Digestate can be used as fertilizer since it contains nutrients such as N, P and K. Digestion of manure has a positive environmental effect (de Vries, 2014). Digestion was and still is in case of low gas prices subsidized by the Dutch government to boost the development of mono and co digestion. The recent high gas prices might spark a new wave of digesters.

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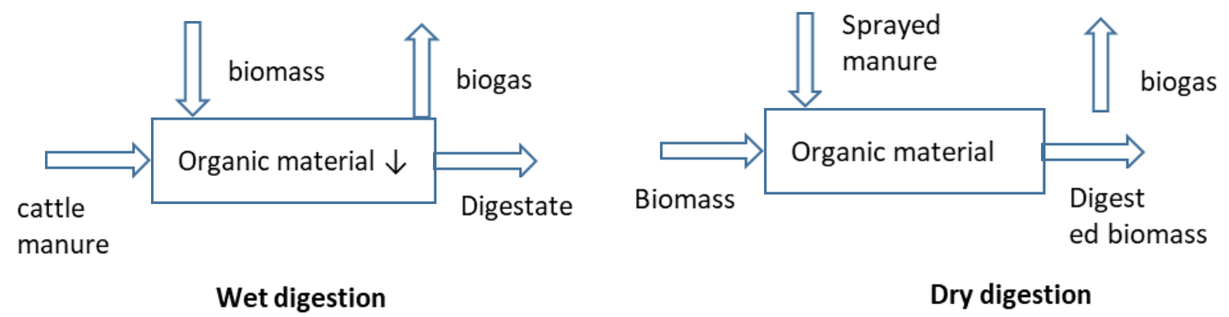
Practice description	During the process of anaerobic digestion cattle manure is mixed with biomass. Bacteria in the manure convert organic material (such as sugars, fats and cellulose) into biogas (methane and CO_2). The biogas consists of about 60% methane, 35% CO_2 and 5% of other gasses, such as H_2S, NH_3 and others. There are basically two subtypes of digestion (next to the already mentioned main types, co and mono digestion): namely wet and dry. Wet digestion means that a big basin with a stirring mechanism (mixing the slurry) is filled with a liquid mixture of manure and possibly biomass. Dry digestion is suitable for fibrous/stalky materials, that are difficult to digest in a slurry. An example of a feedstock suitable for dry digestion is grass or straw. Dry digestion is done by an air tight device/container with a sprinkler in the roof. Biomass is placed on the floor and liquid manure is sprayed over the biomass. The liquid manure seeps through the biomass to the floor, which is permeable for the liquid manure. In the floor, the liquid manure is collected and pumped to the sprinklers again. Most common in the market are wet digestors and these widely commercially available. Dry digestors are still more in development but there are some available on the market. Most digestors are mesofile digestors, that run on temperatures between 37°C and 40°C. In these digestors the manure is kept for about 15 to 40 days. There are also thermofile digestors, that are kept at a temperature of around 55°C. In these digestors the manure is kept for about 10 to 20 days. The time that manure is kept in a digestor is depending on the speed of the digestion process and on the ingredients of the product that is digested.
General diagram	
Input components	Animal slurry, liquid manure, digestate, biomass
Biomass type	All. Dedicated (possible for dry digestion), or Waste (most common for wet digestion)
Final products and their use	Fertilizer / Acidified slurry or digestate used to crop fertilization, digested biomass

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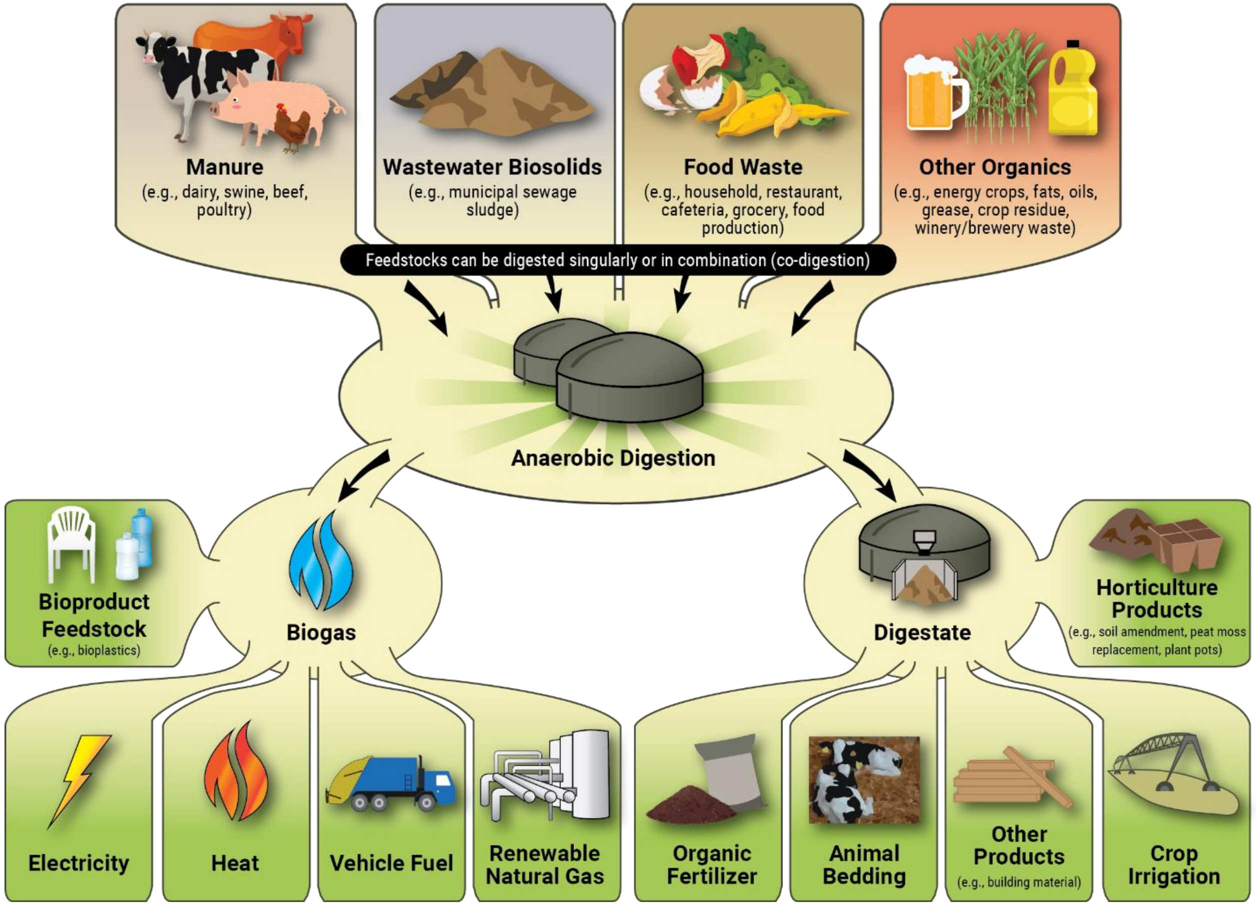
Visual examples of final product	
Spatial coverage	Farm, local or regional
Practice mobility	Static
Level of complexity	Medium
Replication potential	High

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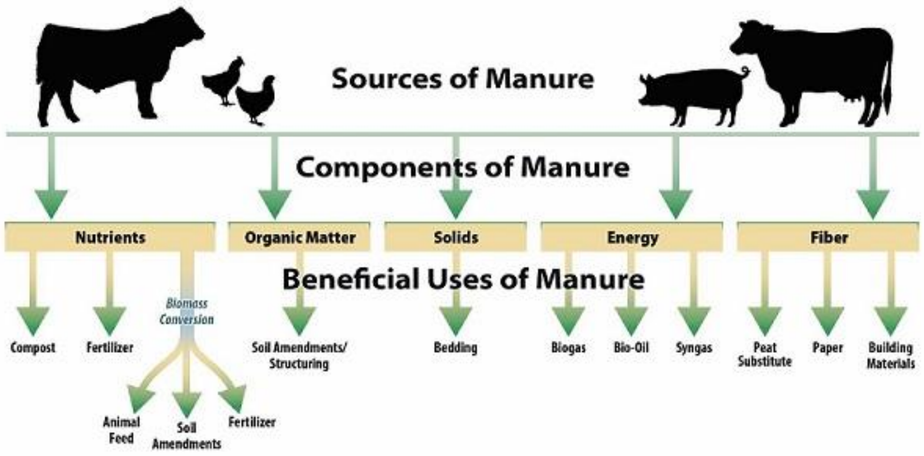
Innovation stage	Commercially available (wet digestion), Commercially available to Under development (dry digestion)
Country / Region of implementation	EU
Statistical location	
Practice implementation	There are several real scale wet digestors. These are widely commercially available in Europe. Dry digestors are less common. There are some real scale sites, but this scale is rare.
Environmental effects	If manure is just used as fertilizer than the methane emissions on the field are higher than when the manure is first used for mono-digestion. If biomass waste streams are left on site than the greenhouse gas emissions into the atmosphere are higher than when digested.
Limitations	With co-digestion there is the amount of material classified as manure is more after digestion than before digestion.
Relevant stakeholders	Producers of digstors as for example Host, bioelectric, companies with digesters https://www.vertogas.nl/producenten/overzicht-producenten (vertogas organization delivering green gas certificates in the Netherlands) organizations https://biogasbranche.nl/over-biogas/ https://platformgroengas.nl/
EU legislation/recommendation	
National legislation/recommendation	https://www.rvo.nl/onderwerpen/bio-energie/wet-en-regelgeving
References	Karki, R., Chuenchart, W., Surendra, K. C., Shrestha, S., Raskin, L., Sung, S., ... & Khanal, S. K. (2021). Anaerobic co-digestion: Current status and perspectives. *Bioresource Technology*, *330*, 125001.
	De vries, J.W. (2014) From animals to crops : environmental consequences of current and future strategies for manure management PHD dissertation https://edepot.wur.nl/287471
Additional information and comments	
Editor of the template	WUR (ACRRES)

3.5 Appropriate manure application

P5

Practice summary	
Short title	Appropriate manure application
Short summary for stakeholders	Animal manure is a good source of nutrients for crops, including nitrogen (N), phosphorus (P), and potassium (K). The proportion of the nutrients in manure are typically not the same as needed by the crops, however. Manure application based on one nutrient may over- or under apply other required crop nutrients. Nitrogen is required in the largest quantities by non-legume crops. Applying manure to meet crop N needs will likely over apply P, and possibly K, for a crop such as corn. On the other hand, using manure to meet P needs of the crop will likely result in a lower application rate and will under apply N and possibly K. Commercial fertilizers will then be needed to balance out N and K needs. Consider the pros and cons of these two options when choosing a manure application rate. When compared to more conventional fertilizer, manure properly applied to land has the potential to provide environmental benefits including: (1) Increased soil carbon and reduced atmospheric carbon levels; (2) Reduced soil erosion and runoff; (3) Reduced nitrate leaching and Reduced energy demands for natural gas-intensive nitrogen(N) fertilizers.
Practice details	
Practice full title	Appropriate manure application
Practice objective and context	Animal manure is a good source of nutrients for crops, including nitrogen (N), phosphorus (P), and potassium (K). The proportion of the nutrients in manure are typically not the same as needed by the crops, however. Manure application based on one nutrient may over- or under apply other required crop nutrients. Nitrogen is required in the largest quantities by non-legume crops. Applying manure to meet crop N needs will likely over apply P, and possibly K, for a crop such as corn. On the other hand, using manure to meet P needs of the crop will likely result in a lower application rate and will under apply N and possibly K. Commercial fertilizers will then be needed to balance out N and K needs. Consider the pros and cons of these two options when choosing a manure application rate. When compared to more conventional fertilizer, manure properly applied to land has the potential to provide environmental benefits including: (1) Increased soil carbon and reduced atmospheric carbon

	levels; (2) Reduced soil erosion and runoff; (3) Reduced nitrate leaching and Reduced energy demands for natural gas-intensive nitrogen(N) fertilizers.
Practice description	There are several methods for appropriate manure application as follow: (A) Broadcast - Broadcasting can be used for the application of solid, slurry and liquid manure. Application techniques include box spreaders, tank wagons, tow hoses, and irrigation systems. Broadcasting requires the least amount of energy and time, and results in a uniform application pattern. However, surface broadcasting promotes loss of nitrogen to the atmosphere, and the organic fraction decays slowly on the soil surface. The manure could also be mechanically incorporated; (B) Band spread - is the placement of fertilizer in a concentrated layer or location (band) in the soil, commonly 8-15 cm below the surface. Fertilizer bands can be placed with the seed, below the seed, or both. Surface banding requires half the power of injection units to pull around the field. Also, there is no root pruning with banding, unlike with injectors. Placing manure on the soil surface where it is exposed to sun and air may also reduce pathogens. (C) Trailing hose - Slurry is discharged at ground level to grass or arable land through a series of flexible hoses. Application between the rows of a growing crop is feasible; (D) Trailing shoe - Slurry is normally discharged through rigid pipes which terminate in metal "shoes" designed to ride along the soil surface, parting the crop so that slurry is applied directly to the soil surface and below the crop canopy. Some types of trailing shoes are designed to cut a shallow slit in the soil to aid infiltration. (E) Injection of manure - are beneficial as they place liquid manure below the soil surface, eliminating both surface runoffs on sloping soils, and volatilization of ammonia from the manure on any soil. It also reduces odor.
General diagram Graphic diagram of the practice showing the key elements and processes	

Input components	Manure
Biomass type	Manure
Final products and their use	Organic fertilizers
Visual examples of final product	
Spatial coverage	Farm
Practice mobility	Static
Level of complexity	Low
Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	Denmark, Estonia, Finland, Latvia, Lithuania, Germany, Netherlands, Poland, Spain, Sweden, Bulgaria, Romania
Statistical location	
Practice implementation	
Environmental effects	Manure contains most elements required for plant growth including N, P, potassium, and micronutrients (Manure as a Source of Crop Nutrients and Soil Amendment). However, it is manure's organic carbon that provides its potential environmental value. Soil organic matter is considered nature's signature of a productive soil. Organic carbon from manure provides the energy source for the active, healthy soil microbial environment that both stabilizes nutrient sources and makes those nutrients available to crops. Several long-term manure application studies have illustrated its ability to slow or reverse declining soil organic levels of cropland: (1) Manure and Soil Quality; (2) Building Soil Organic Matter with Manure. The ability of manure to maintain or build soil organic matter levels has a direct impact on enhancing the amount of carbon sequestration in cropped soils. Manure organic matter contributes to improved soil structure, resulting in improved water infiltration and greater water-

	holding capacity leading to decreased crop water stress, soil erosion, and increased nutrient retention. In addition, surface application of manure behaves similarly to crop residue. Crop residue significantly decreases soil erosion by reducing raindrop impact which detaches soil particles and allows them to move offsite with water runoff. In addition, organic N (manure N tied to organic compounds) is more stable than N applied as commercial fertilizer. A significant fraction of manure N is stored in an organic form that is slowly released as soils warm and as crops require N. Recycling of manure nutrients in a cropping system as opposed to manufacturing or mining of a new nutrient resource also provides energy benefits.
Limitations	The basic limitations are: (1) It is difficult to collect enough animal dropping if the animals are scattered; (2) Requires a lot of labor to collect the dung; (3) Farm yard manure has a bad smell which is not good if the farmer wants to offer touristic services
Relevant stakeholders	Farmers, advisers, researchers, manure providers, the state also the costumers
EU legislation/recommendation	Framework Water Directive (2000/60/WE), The National Emission Ceilings (NEC) Directive (EU 2016/2284)
National legislation/recommendation	REGULATION No 2 of 13.09.2007 on the protection of water against nitrate pollution from agricultural sources Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources Order No. RD09-565/16.07.2020 on approval of Rules for Good Agricultural Practice for the protection of water from nitrate pollution from agricultural sources
References	Hou, Y. 92018. Stakeholder perceptions of manure treatment technologies in Denmark, Italy, the Netherlands and Spain. https://geographypoint.com/2022/09/advantages-and-disadvantages-of-farm-yard-manure/ https://lpelc.org/environmental-benefits-of-manure-application/ https://extension.umn.edu/manure-management/manure-application-rates https://www.frontiersin.org/articles/10.3389/fsufs.2019.00029/full
Additional information and comments	
Editor of the template	

3.6 Appropriate manure storage

P6

Practice summary	
Short title	Appropriate manure storage
Short summary for stakeholders	Appropriate manure storages allowed the nutrients contained in manure to be applied to crop fields at the right times during the growing cycle. Proper solid manure storing is a treatment used to reduce NH_3 emissions and uncontrolled leakage of nutrients from manure storage areas. The size and proper construction of manure storage structure are its main characteristics, which depends on local regulations, type and number of animals. Manure storage should have floors and walls made of impermeable materials. An additional option to reduce the loss of ingredients is the use of covers for the storages. Covers can be permanent or temporary structures over the prism or tanks. These treatments allows to reduce ammonia emissions during manure storage by about 40-100% for liquid manures and by 20-60% for solid manure.
Practice details	
Practice full title	Appropriate manure storage
Practice objective and context	Every animal farm requires a manure store. Storage allows the nutrients contained in manure to be applied to crop fields at the right times during the growing cycle. It allows to store manure when fields are frozen or covered with snow and application is not allowed and can cause runoff that contaminates surface waters. Proper solid manure storing is a treatment used to reduce NH_3 emissions and uncontrolled leakage of nutrients from manure storage areas. It helps farmers to meet the requirements of national and EU legislation.

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Practice description	Appropriately sized manure storage facilities allowed to adjust manure application to growing season, and reduces the nutrient loss. The size and proper construction of manure storage structure are its main characteristics, which depends on local regulations, type and number of animals. Solid manure storage should have floors and walls made of impermeable materials. Slopes should be directed towards the inside of the storage to prevent leachate from escaping to the outside of storage. Leachates should be collected in a tank located nearby. Liquid manure should be stored in lagoons lined with impermeable material resistant to slurry or in cylindrical concrete tanks. An additional option to reduce the loss of ingredients is the use of covers for storages. Covers can be permanent roof structures over the prism or tanks. The heap can be covered with plastic foil or a layer of peat, phosphogypsum or zeolites. For liquid manure is also recommended to use temporary covers such as floating foil or plastic bodies or even natural crust. Slurry can be also stored in flexible tanks made of technical fabrics, so-called slurry bags. These treatments reduce ammonia emissions during manure storage. According to UNECE, the use of such solutions allows to reduce ammonia emissions during manure storage by about 40-100% for liquid manures and by 20-60% for solid manure.
General diagram	  Source: Sutton, M. A., Howard, C. M., Mason, K. E., Brownlie, W. J., Cordovil, C. (2022). Nitrogen opportunities for agriculture, food & environment. UNECE guidance document on integrated sustainable nitrogen management. ISBN: 978-1-906698-78-2
Input components	Manure

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Biomass type	Manure
Final products and their use	Organic fertilizes
Visual examples of final product	
Spatial coverage	Farm
Practice mobility	Static
Level of complexity	Low
Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	Denmark, Estonia, Finland, Latvia, Lithuania, Germany, Netherlands, Poland, Spain, Sweden
Statistical location	
Practice implementation	In Poland, manure must be stored in storages with concrete floors and walls made or lined with impermeable material. The capacity of solid manure storages must be sufficient to store 5 months of manure production and for liquid manures should allowed to store 6 month production.
Environmental effects	Appropriate solid manure storages allowed the nutrients contained in manure to be applied to crop fields at the right times during the growing cycle. Proper solid manure storing is a treatment used to reduce NH_3 emissions and uncontrolled leakage of nutrients from manure storage areas.
Limitations	
Relevant stakeholders	Farmers
EU legislation/recommendation	Framework Water Directive (2000/60/WE), The National Emission Ceilings (NEC) Directive (EU 2016/2284)
National legislation/recommendation	PL: Prawo wodne (Water low), Program Azotanowy (Nitrate Programme)

References	Chadwick D.R. 2005. Emissions of ammonia, nitrous oxide and methane from cat-tle manure heaps: effect of compaction and covering. Atmospheric Environment, Volume 39, Issue 4, s. 787-799. https://doi.org/10.1016/j.atmosenv.2004.10.012 UN, 2014. Guidance document on preventing and abating ammonia emissions from agricultural sources. Economic Commission for Europe, document nr ECE/ EB.AIR/120. Sutton, M. A., Howard, C. M., Mason, K. E., Brownlie, W. J., Cordovil, C. (2022). Nitrogen opportunities for agriculture, food & environment. UNECE guidance document on integrated sustainable nitrogen management. ISBN: 978-1-906698-78-2 U N E C E: Framework Code for Good Agricultural Practice for Reducing Ammonia Emissions. Published by the European Commission, Directorate-General Environment on behalf of the Task Force on Reactive Nitrogen of the UNECE Convention on Long-range Transboundary Air Pollution, 2015, http://www.unece.org/index.php?id=41358.
Additional information and comments	
Editor of the template	

3.7 Ash recycling

P7

Practice summary	
Short title	Ash recycling
Short summary for stakeholders	According to the Swedish Forest Agency there are rules and recommendations throughout Sweden when forest fuels such as e.g., GROT (treetops and branches) are removed from the forest. This is important as the removal of GROT will also remove important nutrients. Therefore, after the forest fuel is burned, the nutrients, apart from nitrogen, remaining in the ash must be recycled to compensate for the extraction of nutrients such as phosphorous, calcium, magnesium, and potassium, that occurred during the extraction of forest fuel. Thus, the long-term production capacity is then secured, and insurance is prevented. Moreover, all ash returns must be reported to the Swedish Forest Agency for consultation at least six weeks before you plan to carry out the measure. Also, the ash is always controlled by the agency in means of nutrient and heavy metal content before being spread out and the reactivity of the ash is controlled as it cannot be spread out if reactive. In the region of middle and upper Norrland. As for streams in the region of middle and upper Norrland for ash recycling, there is little or no activity in the region. It is only Jämtkraft in Östersund that has returned ash regularly, that is fly ash from a CFB boiler. In Västerbotten, Umeå Energi has carried out some small tests with ash recycling. Last autumn, an ash return was carried out by helicopter in northern Västerbotten with ash from Holmen's sawmill in Bygdsiljum. It was ash from their roasting pan. Moreover, in Norrbotten, ash from Stenvalls Trä's sawmill in Sikfors has been returned with some regularity. There are also ashes from the roasting pan.
Practice details	
Practice full title	Ash recycling
Practice objective and context	The removal of nutrients from the forest in means of forest fuel has to be returned back to the forest soil to secure long-term capacity and growth in the forest.
Practice description	Forest fuels such as e.g., GROT (treetops and branches) that are removed from the forest to be used as fuel. When this practice is performed in an extension, a lot of the forests nutrients are being missed. Therefore, after the forest fuel is burned, the nutrients, apart from nitrogen, remaining in the ash must be recycled to compensate for the extraction of nutrients such as phosphorous, calcium, magnesium,

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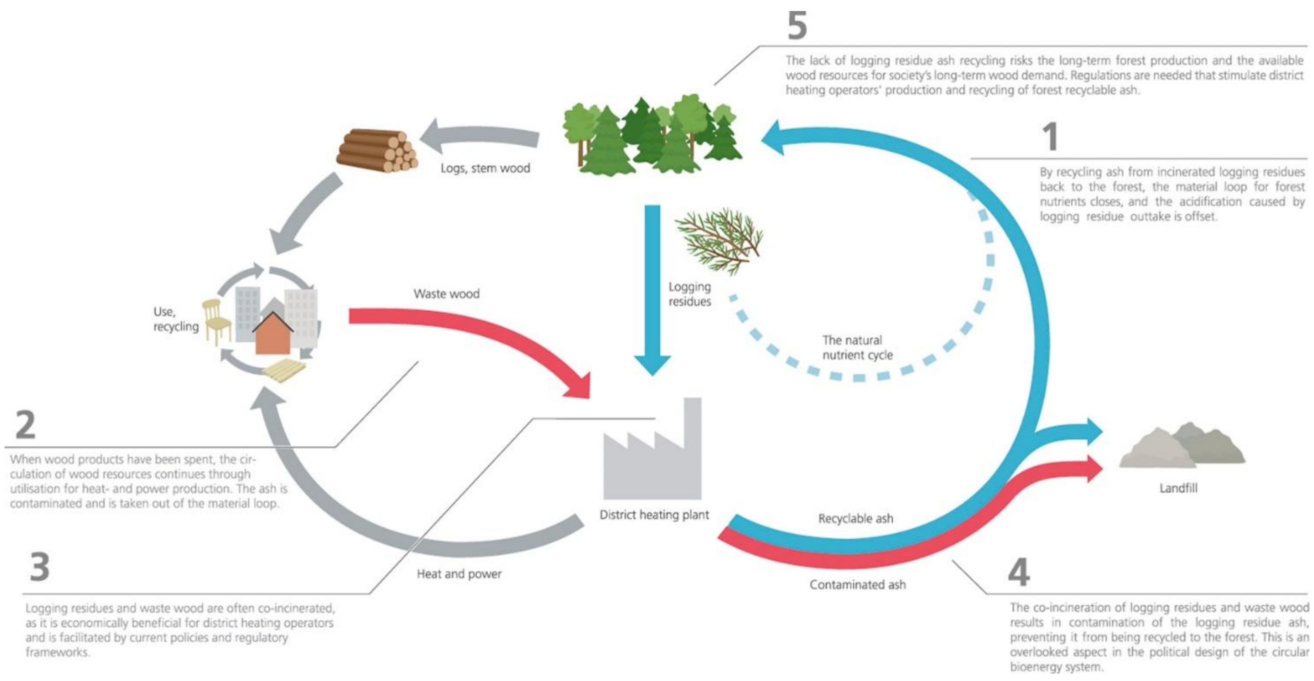
	and potassium, that occurred during the extraction of forest fuel. Thus, the long-term production capacity is then secured, and insurance is prevented.
General diagram	
Input components	GROT (tree tops and branches)
Biomass type	Co-product
Final products and their use	Ash from forest fuels, recycled to the soil of the forest. Consist mainly of phosphorous, calcium, magnesium and potassium
Visual examples of final product	https://www.skogforsk.se/Large/cd_20190114162531/contentassets/b473c9426961409d9996672e8694b06e/askaterforing-och-tillvaxt.jpg
Spatial coverage	National in Sweden and also in Finland. Started to be used in Germany. Not commonly used practice in other EU countries.
Practice mobility	Mobile. The combined heat and power plants are static practices, however, the retrieval practice of GROT and the recycling practice of ash is mobile

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Level of complexity	Medium
Replication potential	Medium. GROT for recycling is only taken out on spruce dominated area
Innovation stage	Commercially available
Country / Region of implementation	Sweden
Statistical location	Region (Middle Norrland, NUTS2: SE32 and upper Norrland, NUTS2: SE33, Sweden)
Practice implementation	The practice is legislated and mandatory to perform throughout the whole country (Sweden) if GROT is taken out
Environmental effects	The practice is relevant from an environmental point of view as nutrients that are very important for the sustainable growth is being returned the soil. Risks: Ash should not be spread when there is a risk of leaching into ditches, lakes or waterways. For example, one should avoid spreading ashes on snow or during heavy rain. This is especially true if the land ends at lakes and streams.
Limitations	Economically the practice is not beneficial every time as the demand for GROT differs and the cost of transportation of GROT and recycling of ash also differs in different regions.
Relevant stakeholders	Forest industries, forest owners, combined heat and power plants and private actors
EU legislation/recommendation	
National legislation/recommendation	Forest Protection act (1979:429): According to section 14 §, it is the owner of the productive forest land who is responsible for notifying the Swedish Forestry Agency of, among other things, felling and removal of forest fuel that is to take place on his or her land. Forest Protection act (1979:429): According to section 14 §, it is the owner of the productive forest land who is responsible for notifying the Swedish Forestry Agency of, among other things, felling and removal of forest fuel that is to take place on his or her land. Forest Protection Ordinance (1993:1096): According to section 15 §, the owner of forest land is responsible for notifying the Swedish Forest Agency of removal of forest fuels on his or her land. Regulations and General Advice (SKSFS 2011:7): According to section 15 § Extraction of forest fuel may begin no earlier than six weeks after the measure has been notified to the Swedish Forestry Agency.

	Regulations and General Advice (SKSFS 2011:7): According to chapter 7 section 27 §, Supply of mineral nutrition, for example ash, should be done as compensation when withdrawal of tree parts in addition to stem wood, corresponding to more than half a ton of pure dry matter unhardened ash, per hectare and rotation time. Regulations and General Advice (SKSFS 2011:7): According to chapter 7, section 27 §, extraction should not take place on strongly acidified land or on peatland that is used for forest production without the supply of mineral nutrition.
References	https://www.skogsstyrelsen.se/bruka-skog/godsling/askaterforing/
Additional information and comments	
Editor of the template	Johanna Källman, RISE Processum; Zozan Tunc, RISE Processum

3.8 Catch crops

P8

Practice summary	
Short title	Catch crops
Short summary for stakeholders	Catch crops are used as a tool to reduce nitrogen leaching. In Denmark, at present, there are several different sets of rules, where catch crops are included as means of action. There are different catch crop schemes with different opportunities to apply such as compulsory catch crops, livestock catch crops, targeted catch crops and mandatory targeted catch crops. Catch crops are essential for reducing nitrate leaching from fields not covered with crops. This has the benefit of reducing eutrophication in coastal waters as well as lakes and inlets. This will in turn reduce the risk of losing life and diversity in the water environment. The main factors and obstacles preventing the widespread implementation of catch crops is the economic aspects for farmers and the need for farmers to change their crop choice and rotation type. When catch crops were first introduced, the limited species of catch crops available meant, that it had a big impact on e.g., the feed production from cereals. For a widespread acceptance of catch crops, it is therefore important with a variety of alternatives suitable for different types of farmers.
Practice details	
Practice full title	Catch crops

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Practice objective and context	Catch crops are used as a tool to reduce nitrogen leaching. In Denmark, at present, there are several different sets of rules, where catch crops are included as means of action. In 2023, there are four different catch crop schemes with different opportunities: 1. Compulsory catch crops. The purpose of compulsory catch crops is to reduce nitrogen leaching from the time the main crop is harvested and until a new crop is established the following spring. The mandatory catch crops contribute to Denmark's compliance with the Nitrates Directive. 2. Livestock catch crops. The purpose of the livestock catch crops is to compensate for the additional leaching of nitrogen from organic fertilizers in special areas. 3. Targeted catch crops. The purpose of targeted nitrogen regulation is to ensure that the environmental condition of our coastal waters is improved through the establishment of catch crops. Subsidies can be applied for through the scheme for the establishment of follow-on crops and alternatives within the coastal catchments where there is a need to reduce nitrogen leaching. 4. Mandatory targeted follow-on crops. If not enough catch crops or alternatives are laid out under the voluntary part of targeted nitrogen regulation, to meet the need for efforts in the individual coastal water catchment, a requirement for the establishment of mandatory targeted catch-up crops may be introduced. This will be announced in the early summer of 2023.
Practice description	For compulsory catch crops, it is required to establish catch crops on 10.7 or 14.7 percent of catch crop plot area depending on how much organic fertilizer is applied. Compulsory catch crops can be replaced with alternatives, e.g., fallow and early sowing of winter crops. Nitrogen quota can be reduced instead of sowing catch crops, or extra catch crops can be established, which can be used to full fill the requirement in later planning periods. There is a requirement to establish livestock catch crops for farms that apply organic fertilizer and have areas in specially designated catchments. If more than 30 kg of N per ha is applied from animal manure or other organic fertilizers, and if the production is not organic, it is required to lay out livestock catch crops. This applies if the agricultural land is placed in specially designated areas, where there is an increasing use of organic fertilizers. Livestock catch crops can be replaced by same alternatives as applies for compulsory. For the targeted nitrogen regulation, subsidies for establishing catch crops and a number of alternatives can be applied in 2023. Subsidies cannot be applied for, if the alternative 'reduced nitrogen quota' has been chosen or if the production is organic. The subsidy rate is about €67 per ha catch crops and subsidies only accounts for fields, that lies within a coastal catchment and where an effort is required.

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	Alternative nitrogen-reducing approaches can also be established. However, the alternatives do not have the same nitrogen-reducing effect per ha as catch crops, and therefore conversion factors apply. E.g., if you choose to register a reduced nitrogen quota, the conversion factor depends on how much organic fertilizer is used on the farm.
General diagram	https://www.seges.tv/video/69694731/efterafgroder-inspiration-og-tips https://lbst.dk/#:~:text=Kravet%20om%20udl%C3%A6g%20af%205,samt%20minimere%20risiko%20for%20kv%C3%A6lstofudvaskning
Input components	Maps, location of fields, list of approved catch crops.
Biomass type	The co-product is an increase in retained nitrogen by catch crops in the soil.
Final products and their use	The final product is an increase in cover in fields with catch crops to reduce leaching of nutrients.
Visual examples of final product	https://lbst.dk/fileadmin/user_upload/NaturErhverv/Filer/Landbrug/Efterafgroeder_og_jordbearbejdning/Faktaark_-_efterafgroedeordninger_2023.pdf
Spatial coverage	Farms at national level. Compulsory to have at least 10-14%
Practice mobility	Static, permanent, mandatory
Level of complexity	Low
Replication potential	Medium, require background info
Innovation stage	Commercially available, mandatory
Country / Region of implementation	Denmark
Statistical location	
Practice implementation	Mandatory for all professional farmers

Environmental effects	Catch crops are essential for reducing nitrate leaching from fields not covered with crops. This has the benefit of reducing eutrophication in coastal waters as well as lakes and inlets. This will in turn reduce the risk of losing life and diversity in the water environment. There are no environmental risks associated with cover crops. There are however farming risks, as some of the catch crop species may act as weeds in the crop rotation or participate in the spread of diseases like club root in crucifers like oil seed rape. This in turn has an impact of the possible crops that farmers can grow.
Limitations	The main factors and obstacles preventing the widespread implementation of catch crops is the economic aspects for farmers and the need for farmers to change their crop choice and rotation type. When catch crops were first introduced, the limited species of catch crops available meant, that it had a big impact on e.g., the feed production from cereals. For a widespread acceptance of catch crops, it is therefore important with a variety of alternatives suitable for different types of farmers.
Relevant stakeholders	Danish Agricultural Agency
EU legislation/recommendation	https://eur-lex.europa.eu/legal-content/DA/TXT/?uri=CELEX%3A32000L0060
	https://environment.ec.europa.eu/all-publications_en
National legislation/recommendation	https://lbst.dk/landbrug/efterafgroeder-og-jordbearbejdning/efterafgroeder/pligtige-efterafgroeder/#:~:text=Pligtige%20efterafgr%C3%B8der%20skal%20v%C3%A6re%20etableret,frem%20til%20og%20med%207. https://www.landbrugsinfo.dk/public/9/d/9/danmarks_undtagelse_nitratdirektiv_forlanget
References	https://lbst.dk/landbrug/efterafgroeder-og-jordbearbejdning/efterafgroeder/
	https://www.landbrugsinfo.dk/public/9/4/9/miljotiltag_efterafgroeder#:~:text=Efterafgr%C3%B8der%20er%20et%20af%20de,%2C%20korsblomstrede%2C%20honningurt%20og%20cikorie https://lbst.dk/fileadmin/user_upload/NaturErhverv/Filer/Landbrug/Efterafgroeder_og_jordbearbejdning/Faktaark_-_efterafgroedeordninger_2023.pdf
Additional information and comments	
Editor of the template	Liselotte Puggaard, Food & Bio Cluster, Denmark

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3.9 Combustion/Incineration

P9

Practice summary	
Short title	Combustion/Incineration
Short summary for stakeholders	Using thermochemical and biochemical conversion processes, biomass may be turned into energy (heat or electricity) or energy carriers (charcoal, oil, or gas). Because of its cheap prices and great dependability, combustion is the most developed and widely used technique for solid biomass fuels. However, in order to compete with alternative possibilities, combustion technologies require constant attention from engineers. It already supplies over 90% of the energy generated from biomass globally, a large portion of which is used for cooking and heating. This is especially true in developing nations, where biomass combustion supplies basic energy for cooking and heating rural families, as well as process heat in a range of traditional businesses. However, many of these conventional applications are inefficient, resulting in high indoor air pollution and unsustainable forest usage. Beside classic biomass combustion, biomass co-firing (or co-combustion) involves “supplementing existing fossil-based (mostly pulverized coal) power plants with biomass feedstock”. Biomass fuels are often regarded to contain both residues and energy crops and span from woody to grassland and straw-derived materials. The fuel qualities of biomass differ greatly from those of coal, as do the fuel properties of different forms of biomass. Ash levels, a usually high moisture content, possibly high chlorine content, relatively low heating value, and low bulk density distinguish biomass from coal. One advantage of biomass co-firing is that it reduces greenhouse gas (GHG) emissions from coal-fired power plants while also enabling biomass power generation at the high efficiency achieved in modern, large-scale coal-fired power plants, which is much higher than the efficiency of dedicated, 100% biomass power plants. If biomass co-firing occurs in combined heat and power (CHP) facilities, total energy efficiency may be boosted even more. Another benefit of biomass co-firing is that the extra investment for burning biomass in coal-fired power plants is far cheaper than the cost of dedicated biomass generation.
Practice details	
Practice full title	Combustion/Incineration

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Practice objective and context	The following factors are driving global interest in utilizing biomass for energy: - political advantages include less reliance on foreign oil. - employment generation – biomass fuels provide up to 20 times more jobs than coal and oil. - environmental advantages such as reduced greenhouse gas emissions, acid rain reduction, and soil improvement. Already, the burning of biomass fuels, which range from wood to animal by products and black liquor, generates around 12% of the total energy needs. A wide range of gadgets are used to convert biomass into usable energy. In developing nations, biomass accounts for around 35% of total energy consumption, however the majority of this is for non-commercial usage in traditional uses (such as cooking). The entire contribution of biomass to the primary energy mix in developed nations is only 3%. This mostly entails the use of commercial biomass fuels in contemporary equipment, such as woodchip-fired co-generation facilities for heat and power. Domestic space heating and cooking, industrial heat delivery, and large-scale power production in coal-fired facilities are some of the other applications.
Practice description	In various types of combustion reactors, biomass such as wood, crop leftovers, and animal dung are burnt. What remains are a variety of gases, pieces of partly oxidized hydrocarbons, and water vapor. During combustion, the biomass loses moisture initially at temperatures of up to 100°C, utilizing heat from other particles that release their heat value. Solid biomass must be burned in order to be transformed into usable heat energy. Although there are several combustion methods available, the basic idea of biomass combustion is the same for all. The combustion process is divided into three stages: Drying - All biomass contains moisture, which must be removed before burning can occur. The heat for drying is supplied by radiation from flames and heat stored in the combustion unit's body. Pyrolysis - The volatile gases are generated when the temperature of the dry biomass rises between 200°C and 350°C. Carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and high molecular weight compounds (tar) are pyrolysis products that condense to liquid when cooled. These gases react with the oxygen in the air to produce a yellow flame. The heat from the burning gases is utilized to dry the fresh fuel and release additional volatile gases, making this process self-sustaining. To keep this stage of the combustion process going, oxygen must be supplied. Char is the substance that remains after all of the volatiles have been burnt away. Oxidation - The char oxidizes or burns at around 800°C. Again, oxygen is required, both at the fire bed for carbon oxidation and above the fire bed, where it combines with carbon monoxide to generate carbon dioxide, which is released into the atmosphere. A long residence time for fuel in a combustor allows for complete consumption of the fuel. It is important to remember that any of the aforementioned stages can occur simultaneously within a fire.

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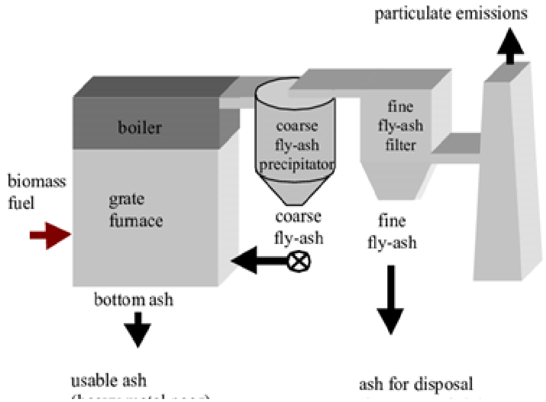
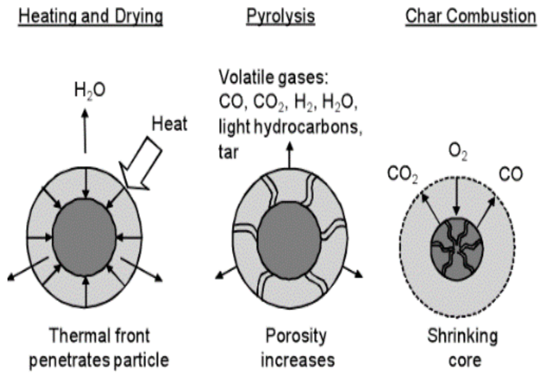
<table>
<tr><td>General diagram</td><td>




</td></tr>
<tr><td>Input components</td><td>Materials high in hydrogen and carbon make good combustion fuels. Biomass feedstock e.g. agricultural wastes and municipal solid refuse are examples of such fuels. In an ideal world, all hydrogen and carbon would split off and react with oxygen in the air to form water vapor, carbon dioxide, and heat.
Biomass is divided into three major components: cellulose, hemicellulose, and lignin, as well as three minor components: proteins, sugars and aliphatic acids, and lipids.
They have varied burning tendencies and degradation patterns, and they release varying amounts of energy depending on the kind of biomass and its content.</td></tr>
<tr><td>Biomass type</td><td>Waste - The chemical composition of biomass combustion ash varies depending on biomass qualities and incineration settings.
Such trash is often disposed of in landfills or piles. It may also be kept, although under the wrong conditions, it will lose its quality.
According to Jacobson et al., diverting biomass ash from landfills is an environmental blunder since valuable components may be returned to the environment and utilized to fertilize plants and enhance soil qualities.
As a result, it appears logical to employ ash from biomass combustion in applications such as agriculture, land remediation, environmental protection, zeolite synthesis, rare earth metal recovery, and plastic manufacture. However, its use is dependent on the physicochemical properties of the ash itself.</td></tr>
<tr><td>Final products and their use</td><td>All biomass may be burnt directly to heat buildings and water, as well as to generate power in steam turbines.</td></tr>
</table>

Visual examples of final product	https://www.researchgate.net/figure/Schematic-outline-of-the-new-biomass-combustion-technology-with-integrated-fractionated_fig2_237544804
Spatial coverage	Small-scale appliances for farm or house heating: The use of biomass for heating in homes and farms is becoming more popular. Heat storage stoves, pellet stoves and burners, and even central heating furnaces are examples of domestic biomass-burning appliances. Large-scale combustion: for industrial reasons, many biomass combustion systems are available. They are classified as fixed-bed combustion, fluidized bed combustion, and dust combustion. At this level, biomass combustion can be used for both heating and electricity generation.
Practice mobility	The transportability of biomass combustion setups is mostly determined by the application size. Because they are mostly portable burners of modest size, the equipment may be transported in tiny applications. Large-scale biomass combustion systems, on the other hand, are more difficult to move since they not only have a separate ventilation system, but their installation is also tailored to the space for which they are designed.
Level of complexity	Depending on the scale of the application, the biomass combustion complexity can range from low to moderate. Factors such as the management of ash residues or the transfer of the produced heat and its final utilization can increase the complexity.
Replication potential	Biomass combustion process replication potential lays between medium-low. With the use of the appropriate equipment and the correct study, the process of biomass combustion can be repeated in places, but each time with results that depend on factors such as the biomass feedstock used
Innovation stage	Biomass combustion technology are already on the market. These technical advancements can be developed further to lower total expenses of heat and/or power produced while also maximizing safety and ease of operation. The need to burn novel biomass fuels, such as energy crops, scrap wood, and agricultural leftovers, drives the need for innovation. Computational Fluid Dynamics modelling, rather than expensive and time-consuming test runs, is increasingly being used to calculate flow, temperature, and residence time distributions, as well as two-phase flows (flue gas and ash particles) in biomass furnaces and boilers, and to evaluate the impact of design on combustion quality and emissions. Technical issues associated to ash, including as particle production, deposit formation, corrosion, and slagging, necessitate constant research and development. To decrease maintenance and repair costs and maximize installation availability, the processes causing difficulties, as well as relevant primary and secondary preventive actions, must be properly understood.

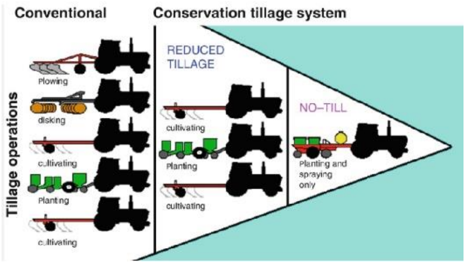
Country / Region of implementation	In nations such as Belgium, Finland, Ireland, Portugal, Sweden, and Slovakia, the use of heat provided by biomass combustion in the industrial sector is very important. Denmark, Lithuania, and Sweden have the highest percentage of bio heat consumption via district heating, with more than 30%.
Statistical location	
Practice implementation	Small-scale biomass combustion is gaining popularity as a way of rural electricity in developing countries where extending the national grid would be prohibitively expensive. The technology utilized to generate electricity from vegetable oil (e.g., diesel generators) is well-known and requires little or no change. Direct biomass co-firing in large-scale contemporary coal plants is the most cost-effective use of biomass for power generation in industrial applications today. If the biomass is not too wet and has been pre-milled to a sufficient size, this method requires relatively little expenditure to change handling and feeding equipment without impacting boiler performance considerably. Furthermore, electric efficiencies for the biomass section range from 35% to 45%, which is greater than the efficiency of biomass specialized plants in general.
Environmental effects	Emission reduction solutions for biomass combustion are available for almost all hazardous emission components; whether or not the emission reduction measures are adopted is mostly determined by emission restrictions and cost-effectiveness. Though scale effects mean that big facilities (such as coal power plants) may be equipped with flue gas cleaning at a lower cost, local biomass fuel supply and transportation costs will typically be a limiting factor for size. In general, NO_X and SO_X emissions from biomass combustion applications are lower than those from coal combustion, and secondary reduction techniques are rarely required to full fill emission limitations. NO_X emissions from biomass combustion applications are primarily caused by the nitrogen component of the fuel, as opposed to fossil fuel combustion applications, where nitrogen in the air also contributes to the NO_X emission level. In most circumstances, primary emission reduction techniques may dramatically reduce NO_X emissions, which can then be further reduced by applying secondary emission reduction measures.
Limitations	A high combustion quality, defined as maximum combustion of the burning gases, is critical for low emission levels. It is primarily determined by the combustion chamber temperature, the turbulence of the burning gases, the residence period, and the oxygen excess. These characteristics are regulated by a number of technical aspects such as: - combustion technology (e.g. combustion chamber design, process control technology)

	- combustion settings (e.g. primary and secondary air ratio, distribution of the air nozzles) - the load situation (full- or part-load)
Relevant stakeholders	Rural actors (e.g. feedstock & biomass providers, farmers), agriculture companies & SMEs, equipment manufacturers & suppliers, industry, environmental organizations & NGOs, general public
EU legislation/recommendation	*DIRECTIVE (EU) 2015/2193 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (25 November 2015) on the limitation of emissions of certain pollutants into the air from medium combustion plants* *EU Biomass Legal Case Main Arguments* This legal document provides the key arguments in the EU Biomass Legal Case, in which the applicants seek to overturn the Renewable Energy Directive 2018's inclusion of "forest biomass" - essentially trees, including stems, stumps, branches, and bark - as a renewable fuel.
National legislation/recommendation	
References	"Biomass combustion and Co-firing: an overview", IEA Bioenergy "Biomass Combustion", Agriculture and Natural Resources, Samy Sadaka & Donald M. Johnson "Utilization of Ashes from Biomass Combustion", Joanna Irena Odzijewicz, ElzbietaWołejko et al., Energies 2023, 15, 9653. https://doi.org/10.3390/en15249653 "Health, energy, and greenhouse-gas impacts of biomass combustion in household stoves", Kirk R. Smith, East-West Center, Honolulu, Hawaii 96848, USA "A Combined Overview of Combustion, Pyrolysis, and Gasification of Biomass", Ali Akhtar, doi: 10.1021/acs.energyfuels.8b01678D58 https://www.ctc-n.org/technologies/biomass-combustion-and-co-firing-electricty-and-heat
Additional information and comments	
Editor of the template	Anastasios Galatsopoulos, White Research

3.10 Conservation tillage

P10

Practice summary	
Short title	Conservation tillage
Short summary for stakeholders	Conservation tillage is an umbrella or generic term used to describe tillage systems that have the potential to conserve soil and water by reducing their loss relative to some form of conventional tillage. Conservation Tillage Impact on Soil Organic Carbon Sequestration (SOCS). Conservation tillage practices have been shown to promote SOC sequestration, most notably, in the shallow surface soil. Another important benefit of conservation tillage in reducing GWP in addition to removing CO_2 from the atmosphere by sequestering soil C is reducing fossil fuel use through reduced tractor passes and other equipment needs. Early studies comparing conservation tillage with tilled soils reported that tilled or disturbed soils released large amounts of CO_2 compared with no-till soils. One of the conservation tillage farming advantages is effective erosion control, especially when compared to chemical technologies. Thus, the system contributes to water conservation in semi-arid and sub-humid regions. Other benefits include maintaining high organic matter levels and economic productivity.
Practice details	
Practice full title	Conservation tillage
Practice objective and context	Like other tillage technologies, these methods have their advantages and disadvantages. It depends on the crop grown type, the area characteristics, and climatic conditions. It is no coincidence that this type of land cultivation is popular today. It has a lot of advantages, among which the following can be distinguished: (1) increases the soil's ability to store carbon; (2) improves the resistance of the ground top layer to the emission of harmful particles in the air and wind erosion; (3) facilitates the moisture penetration into the soil; (4) reduces the leaching of nutrients due to the preservation of a large amount of organic matter; (5) lowers the moisture evaporation from the ground, which saves the harvest in dry years; (6) helps to retain pesticides and other valuable chemicals in the soil; (7) requires less land cultivation. In addition to agricultural benefits, the last point also has environmental and economic advantages. Farmers use conservation tillage to reduce fuel costs and lower air emissions. Despite the apparent conservation tillage environmental benefits, these methods also have disadvantages. First of all, they are associated with creating special conditions that are not suitable

	for all manufacturers. There is also a specific negative impact on the environment. Consider some drawbacks: (1) conservation tillage requires expensive equipment or a lot of manual labor if we are talking about small producers; (2) unlike traditional methods of weed and pest control, it demands more pesticides and herbicides; (3) the first positive results of conservation tillage are visible only in long-run; (4) the method contributes to greenhouse gases emission (CH_4 and N_2O).
Practice description	Soil cultivation's different depths characterize the method. It can be minimum, strip-, ridge-, mulch-, or zero-tillage. The choice of a conservation tillage system depends on the favorable field environment for particular plants: (1) No-Till (Zero-Till) - Among all methods of conservation tillage, this one minimally disrupts the topsoil through single-pass seeding and fertilization. Farmers make only shallow seedbeds and cover them with mulch from plant residues. Accordingly, the fertilizer quality is of prime importance for conserving soil and water. This type of conservation tillage, in particular, is used in northern Tanzania for the processing of wheat and coffee plantations; (2) Strip-Tillage - this type is also known as zonal tillage. The principle's essence is to divide a field into two parts: seedling and soil management. The first is processed mechanically to optimize the ground and microclimate. You shouldn't process the second one, just treat it with cover crops for conservation tillage systems. Additionally, rows can be made for better water penetration; (3) Ridge-Till - this kind of conservation tillage planting is characterized by creating beds with the special equipment's help; this process is called "scalping." It is suitable for spring crops, which is why it is gaining popularity in the farm community. The major problem with conservation tillage is the high cost of technology. Cultivators used for loosening should be heavy and sturdy enough and cost more than 1,500 euro per row. (4) Mulch-Till - covers the ground with a layer of residues, which are cultivated with cultivators, sweeps, and chisels to mix with the soil partially. In this case, the mulch should cover one-third of the surface at least.
General diagram	
Input components	Biomass

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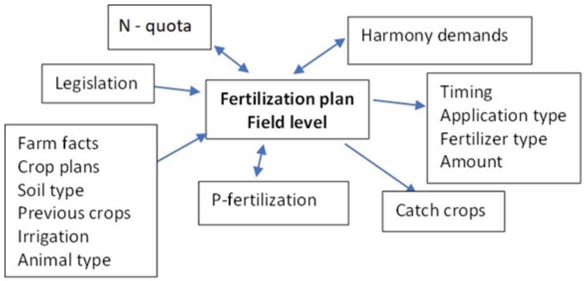
Biomass type	Crop residues
Final products and their use	Mulch
Visual examples of final product	
Spatial coverage	Farm
Practice mobility	Static
Level of complexity	Low
Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	South central region of Bulgaria
Statistical location	NUTS2
Practice implementation	
Environmental effects	The practice contributes to water conservation in semi-arid and sub-humid regions. Other benefits include maintaining high organic matter levels in soil. Increasing soil C is an important component of increasing soil productivity and in reversing the positive global warming potential (GWP) of agricultural systems.
Limitations	Conservation tillage requires expensive equipment or a lot of manual labor if we are talking about small producers
Relevant stakeholders	
EU legislation/recommendation	The National Emission Ceilings (NEC) Directive (EU 2016/2284)
National legislation/recommendation	Manual of good agricultural practices

References	William R. Horwath. Chapter Three - The Potential for Soils to Mitigate Climate Change Through Carbon Sequestration. Developments in Soil Science, vol. 35, 2018, https://www.sciencedirect.com/science/article/pii/B978044463865600003X M.R. Carter. Encyclopedia of Soils in the Environment 2005, Pages 306-311
Additional information and comments	
Editor of the template	

3.11 Fertilization plan

P11

Practice summary	
Short title	Fertilization plan
Short summary for stakeholders	A fertilizer plan (fertilizer quota calculation) is a tool to describe, plan and calculate the distribution of organic and inorganic fertilizer. The purpose is to minimize the risk of nutrient pollution and at the same time optimize the utilization of nutrients on farm level. This improves production and simultaneously protects the environment and water environment. Everyone who is registered in the Register for Fertilizer Accounting must report a fertilizer plan. The plan is based on Guidelines for fertilization and harmony rules. Every year, the Danish Agency for Agriculture prepares an updated guidance on rules regarding allocation of nitrogen, phosphorus, and harmony. The practice is mandatory for all professional farmers and is therefore an essential part of everyday farming in order to have the 'license to produce'.
Practice details	
Practice full title	Fertilization plan
Practice objective and context	A fertilizer plan (fertilizer quota calculation) is a tool used to plan, describe and calculate the distribution of organic and inorganic fertilizer to minimize the risk of nutrient pollution and at the same time optimize the utilization of nutrients on a farm level, and improves production and simultaneously protects the environment and water environment.
Practice description	Everyone who is registered in the Register for Fertilizer Accounting must provide and report a fertilizer plan. The plan is based on Guidelines for fertilization and harmony rules. Every year, the Danish Agency for Agriculture prepares guidance on the rules regarding allocation of nitrogen, phosphorus, and harmony. Accordingly, a fertilizer account is a statement of the amount of fertilizer that is used on the company's land. The fertilizer account is a statement of how fertilizer is used during a planning period. The accounting is reported online to Danish Agricultural Agency. The Danish Agency for Agriculture checks that no more fertilizer than the permitted amount has been used. The fertilizer account is a tool for carrying out this control. The reported fertilizer accounts are checked partly administratively and partly physically. A physical check means that one of the inspectors visits the farm to see if the

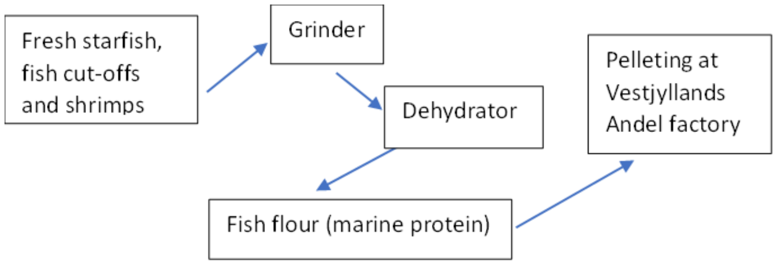
	fertilizer account matches the actual conditions. When the case processing is completed, the fertilizer accounts are, with certain exceptions, published on the Internet.
General diagram	Fertilization plan is reported online by using digital tools. 
Input components	Farm facts, farm size, herd size and type of animals, types of crops, soil type, N - quota, P-quota, fertilizer type and application procedure.
Biomass type	Not as such, but many factors are influencing the main goal i.e., reducing the negative impact of nutrients on environment, and optimizing the use of nutrients for crop production. Farm management, supplier of manure to biogas and hence the use of degassed fertilizer, catch crops, wetlands taken out of crop rotation, established mini wetlands to catch nutrients, establishment of energy crops etc. are also factors affecting the farms impact on environment and possibility to reduce but also the risk of allocating excess nutrients into the environment.
Final products and their use	A fertilization plan for the farmer and an account for ensuring that rules are kept.
Visual examples of final product	
Spatial coverage	Farm, local, Regional, National
Practice mobility	Mobile
Level of complexity	Low
Replication potential	Generally available, mandatory for professional farmers.

Innovation stage	(Commercially) available open access, but is often connected with other farm tools with fees or advisory services.
Country / Region of implementation	Denmark
Statistical location	
Practice implementation	Mandatory for professional farmers.
Environmental effects	Fertilization plan is a plan that describes and calculates the distribution of organic and inorganic fertilizer to minimize the risk of nutrient pollution and at the same time optimize the utilization of nutrients on a farm level for crop production. Fertilization plan and account is a tool to help the farmer comply with rules for fertilizer allocation and is therefore a crucial protection tool for the environment and water environment.
Limitations	
Relevant stakeholders	Danish Agency for agriculture. Environmental Protection Agency
EU legislation/recommendation	https://www.retsinformation.dk/eli/lta/2022/1142 https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/new-cap-2023-27_en#:~:text=On%202%20December%2C%202021%2C%20the,and%20more%20performance%2Dbased%20CAP.
National legislation/recommendation	https://lbst.dk/nyheder/nyhed/nyhed/se-den-nye-goedskningsbekendtgoerelse-for-planperioden-20212022/ https://mst.dk/natur-vand/natur/international-naturbeskyttelse/eu-direktiver/eus-vandrammedirektiv/ https://www.seges.dk/software/plante/cropmanager
References	https://denstoredanske.lex.dk/kv%C3%A6lstofkredsl%C3%B8b https://denstoredanske.lex.dk/kv%C3%A6lstofkredsl%C3%B8b https://lf.dk/-/media/lf/aktuelt/nyheder/2017/juni/fakta-om-kvaelstof.pdf
Additional information	
Editor of the template	Liselotte Puggaard, Food & Bio Cluster Denmark

3.12 Fish meal production

P12

Practice summary	
Short title	Fish meal production
Short summary for stakeholders	Danish Marine Protein in Greenlab Skive is the first facility in the world that is producing protein for animal feed based on starfish harvested in the Limfjord. Starfish are very high in protein content, and is growing problem in the Limfjord, as they eat and hereby removes the Limfjord's blue-mussel production and aquaculture. Thus, starfish are posing a threat to the blue-mussels both from an environmental perspective but also business. At Danish Marine protein, there is an opportunity to create a locally based production of sustainable protein and solve a local problem at the same time. Marine protein is produced from fresh whole starfish and/or fresh fish cut-offs. The Starfish are caught locally in the Limfjord, and fish cut-off are used to supplement the protein production. The flour is produced by dehydrating the biomass and is distributed to Vestjyllands Andel, the company that established Danish Marine protein. At the feed factory, the flour is included in the production of pellets for pig and poultry feed. The production supports the company's ambition of producing more local types of protein and to reduce the import of soya for feeding animals. At the same time, the harvest of starfish benefits the aquaculture by giving blue-mussels better conditions to produce and serve as filters of the Danish Fjords.
Practice details	
Practice full title	Fish flour production (marine protein)
Practice objective and context	Protein originating from fish for feeding animals is a common and widely established practice in Denmark, but a practice based on starfish is a new approach. Danish Marine Protein (DMP) in Greenlab Skive is the first facility in the world that is producing protein from starfish harvested in the Limfjord, where they pose a growing problem to this low inland fjord's blue-mussel production and aquaculture. Starfish are posing a threat to the blue-mussels both from an environmental perspective but also business. Starfish have a very high content of protein and is very suitable for animal protein. Marine protein is established by the regional grain and feed company Vestjyllands Andel, and the company is also working with solutions to reduce import of soya. On top of that, there is a directly

	benefit from the industrial symbiosis at Greenlab Skive, using excess heat from other production processes in our dehydration.
Practice description	At Danish Marine protein, there is an opportunity to create a locally based production of sustainable protein and solve a local problem at the same time. Marine protein is produced from fresh whole starfish and/or fresh fish cut-offs. The Starfish are caught in the Limfjord, that is very close to the facility. The fish cut-off (residues from filleting) is transported to the facility. All biomasses are fed to a large grinder. The fish is transformed into a consistency of pate, that is transported to the heating/drying facility making the final product by dehydrating the processed biomass. The flour is collected in bags, that are distributed to Vestjyllands Andel, where it is included in the production of pellets for pig and poultry feed.
General diagram	
Input components	Starfish, fish cut-offs and residues from shrimp production.
Biomass type	All biomass is converted to the primary product, but the facility can also be used to dry and produce green protein delivered from biorefine facility.
Final products and their use	Fish flour and protein made from starfish at Danish marine protein. The product is used as ingredient in feed for fish, poultry and pigs.
Visual examples of final product	
Spatial coverage	Industry
Practice mobility	The facility is static, but the product is highly mobile.

Level of complexity	The level of complexity is low as the process is mainly mechanical and thermal. However, in order to reduce odor and requirement for reducing noise and distance to neighbors, adjustments are still being developed.
Replication potential	High
Innovation stage	Commercial available
Country / Region of implementation	Denmark
Statistical location	
Practice implementation	Commonly used
Environmental effects	The use of starfish for protein is having environmental benefits as the starfish eats blue-mussels and threatens the fishing industry of blue-mussels. The population of blue-mussels in the Limfjord is crucial for filtrating the fjord, and is therefore a directly link to reducing the nutrient content in Danish water.
Limitations	The biggest obstacle is the access to starfish, as they are responding to temperature in the fjord. It the temperature is too high, they will not enter the fjord, where fishing possibility exist. The biomass resource is therefore shifted to consist more of fish cut offs and side streams such as residues from shrimp production.
Relevant stakeholders	Vestjyllands Andel, Greenlab Skive, Ministry of Food, Agriculture and Fisheries of Denmark, Danish Veterinary and Food Administration.
EU legislation/recommendation	It was necessary to change the legislation in EU to include production of fish flour from starfish. This took two years and was performed by chef consultant for animal health at Danish Veterinary and Food Administration.
	https://www.foedevarestyrelsen.dk/Selvbetjening/lovstof/Sider/Foder--og-foderstofomr%C3%A5det-.aspx
National legislation/recommendation	https://www.retsinformation.dk/eli/lta/2018/1000 https://www.retsinformation.dk/eli/lta/2021/2227 https://www.retsinformation.dk/eli/lta/2021/2101
References	https://foodnationdenmark.com/news/denmark-gets-the-worlds-first-starfish-plant/ https://www.greenlab.dk/knowledge/worlds-first-starfish-plant-under-way-at-greenlab-skive-denmark/ https://fvm.dk/ministeriet/i-nationens-tjeneste/lobbyarbejde-i-eu

	https://ffskagen.dk/media/2151/produktbrochure_dk.pdf https://ffskagen.dk/media/2151/produktbrochure_dk.pdf
Additional information and comments	
Editor of the template	Liselotte Puggaard, Food & Bio Cluster Denmark

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3.13 Gasification

P13

Practice summary	
Short title	Small scale gasification units for agricultural and agro-food industry secondary solid biomass streams (BIO2CHP)
Short summary for stakeholders	Gasification is one of the main processes that can be applied at small or large scale for thermochemical conversion of biomass. In this process, agricultural solid organic residues are partially oxidized by heating at high temperatures (<1000ºC), with syngas being the primary product to be used for energy production and solids (biochar). Biochar produced is normally a fine-grained, highly porous material, with a large fraction of carbon (C) content. Biochar quantity and properties may significantly vary in its chemical and physical properties depending on the process parameters and the feedstock used. Its application as soil amendment constitutes one promising practice to sustainably sequester atmospheric CO_2. There exist small-scale, compact, mobile and modular gasification technologies, operational with a variety of solid waste streams from agro-industry, that seem promising regarding the possibility to combine an efficient bioenergy production with an organic soil amendment at a low cost to the user.
Practice details	
Practice full title	Small scale gasification units for agricultural and agro-food industry secondary solid biomass streams (BIO2CHP)
Practice objective and context	Biomass gasification couples the possibility of co-producing heat, electricity and biochar by valuably utilizing agricultural solid waste streams. Gasification biochar contains a considerable amount of minerals and recalcitrant carbon and is considered as an attractive product for soil amendment due to its fertilizer and carbon sequestration potential. The application of biochar improves soil fertility through two mechanisms: adding nutrients to the soil (such as K, to a limited extent P, and many micronutrients) or retaining nutrients from other sources, including nutrients from the soil itself. Its addition increases soil pH, electric conductivity, organic matter and total nitrogen
Practice description	A fluidizing bed gasifier is coupled with a hot gas filtration system and a gas engine-based combined heat and power generator. Organic residues with moisture <50% can be directly fed to the gasifier. Ideal moisture content is 10-20%. The gasifier has a limitation in moisture (<50%) and in particle size (<2 cm), thus, a limited pre-processing is necessary. In addition, the ash content of the fuel should be lower than 25% to avoid additional maintenance of the unit. Part of the thermal energy produced

	is used for feedstock drying as an integrated part of the feeding system of the unit. Additional already existing equipment (e.g. crusher) may be required depending on the state and type of the waste stream. Potential uses are in wineries, chicken processing factories, cotton industry, rice industry, paper industry, breweries, olive mills, wood processing and fruit processing (jams, juices, etc.).
General diagram	https://www.bio2chp.com/chp.html
Input components	Solid biomass waste streams from wineries, breweries, cotton ginning and rice industries, seed-oil mills (olive, sunflower, cotton etc.), chicken and animal farms and fruit processing units (jam, juice production).
Biomass type	Waste
Final products and their use	Bioenergy (electricity, heat), biochar
Visual examples of final product	https://www.google.com/imgres?imgurl=https%3A%2F%2Fwww.farm2energy.com%2Fwp-content%2Fuploads%2F2018%2F03%2FBiochar.jpg&imgrefurl=https%3A%2F%2Fwww.farm2energy.com%2Fproducts%2Fbio-char&tbnid=_qvBgzEcQL9PiM&vet=12ahUKEwiKh6Dkwt38AhVZw7sIHagdAZwQxiAoCHoECAAQGw..i&docid=XWpQg7gFbpzacM&w=1440&h=960&itg=1&q=biochar%20from%20gasification&ved=2ahUKEwiKh6Dkwt38AhVZw7sIHagdAZwQxiAoCHoECAAQGw
Spatial coverage	Farm, Local
Practice mobility	Mobile
Level of complexity	Low
Replication potential	High
Innovation stage	TRL 7
Country / Region of implementation	Greece
Statistical location	

Practice implementation	A working prototype has been developed which has worked under real life conditions with 4 different types of biomass residue: grape seeds, olive kernels, peach kernels and almond shells. A first pre-commercial pilot is installed and demonstrated at the facilities of a winery in northern Greece.
Environmental effects	Environmental benefits: gasification biochar application as soil amendment constitutes one promising practice to sustainably sequester atmospheric CO_2.Gasification produce significantly lower quantities of air pollutants. The process reduces the environmental impact of waste disposal because it allows for the use of waste products as a feedstock. Gasification plants also use less water than traditional coal-based power plants. Environmental considerations: During gasification, tars, heavy metals, halogens and alkaline compounds are released within the product gas and can cause environmental and operational problems.
Limitations	
Relevant stakeholders	Farmers, farmers' associations, agro-food industry
EU legislation/recommendation	EBC. European Biochar Certificate: Guidelines for a Sustainable Production of Biochar; European Biochar Foundation (EBC): Arbaz, Switzerland, 2015. [Google Scholar]
	IBI. Standardized Product Definition and Product Testing Guidelines for Biochar that Issued in Soil; The International Biochar Initiative (IBI): Philadelphia, PA, USA, 2012. [Google Scholar]
	https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12136-Fertilising-products-pyrolysis-and-gasification-materials_en
National legislation/recommendation	
References	https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.12028
	https://www.mdpi.com/2077-0472/5/4/1076 https://www.bio4africa.eu/technologies/bio2chp/
Additional information and comments	
Editor of the template	Evangelia Tsagaraki (QPLAN International)

3.14 Hydrothermal carbonization

P14

Practice summary	
Short title	Hydrothermal carbonization
Short summary for stakeholders	Hydrothermal carbonization (HTC) is a thermochemical process of converting organic feedstock into a high carbon rich solid product. This process is performed at the temperature range of 180-260ºC during which the biomass is submerged in water and is heated under pressure for 5 to 240 minutes. The HTC process results in producing three main end products: solid (hydrochar), liquid (bio-oil mixed with water) and small fractions of gases (mainly CO_2). The process conditions, including reaction time, temperature and reaction temperature, strongly influence the properties and percentage distribution of the final products, from which hydrochar is the most desired one. Hydrochar is characterized by its affinity for the water and when it is used on the soil it can increase its water retention capacity. Also, it can substitute wooden charcoal or it can be used as a means for carbon sequestration. There exist small-scale, compact and modular HTC technologies, operational with a variety of feedstock with low or high moisture content, that seem promising regarding the possibility to combine an efficient bioenergy production with an organic soil amendment at a low cost to the user.
Practice details	
Practice full title	Hydrothermal carbonization
Practice objective and context	Hydrothermal carbonization attracts interest as a possible way to transform organic waste into a stable, solid, sterile and valuable product. The HTC process results in the formation of three products: hydrochar, bio-oil mixed with water and small fractions of gases. Particularly, Hydrochar can be used as a soil improving material in agricultural field. When it is added to soil, it increases the crop yield, water retention and soil stability. It also contributes to carbon sequestration as it releases carbon much more slowly than biomass left on the field. The high conversion efficiency, elimination of pre-drying requirement, and relatively low operating temperature among other pre- treatments make HTC a perfectly suitable conversion technique for the production of hydrochar, especially from wet biomass feedstock.

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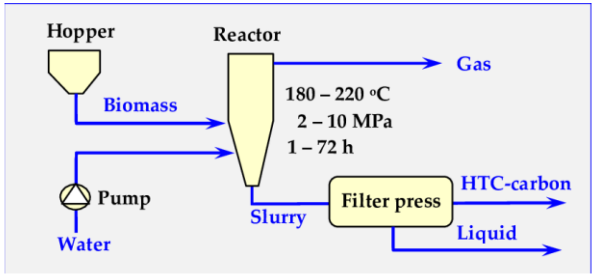
Practice description	Hydrothermal carbonization (HTC) is a thermochemical process of converting organic feedstock into a high carbon rich solid product. During the HTC process, the biomass is submerged in water into a reactor and heated to approximately 200ºC for several hours. The water is kept in a liquid phase by keeping the mixture under saturated pressure in the reactor, allowing the pressure to rise to roughly 20 bar. Both oxygen and hydrogen of the initial feedstock decrease, while the C content increases. When leaving the HTC process, hydrochar is wet and in the form of slurry, therefore it passes through mechanical dewatering (compressing), filtering, and solar/thermal drying before it can be used. Since an HTC process removes a fraction of the oxygen from feedstock via reactions, the moisture content can be achieved to a value of less than 50% just by compression, ultimately reducing the energy and time consumption.
General diagram	https://www.researchgate.net/figure/Scheme-of-the-Hydrothermal-carbonization-process-HTC-167-168_fig7_341017549 
Input components	Feedstock, reaction time, temperature, reaction temperature
Biomass type	Waste
Final products and their use	Solid (Hydrochar), liquid (bio-oil mixed with water), gases
Visual examples of final product	https://www.nature.com/articles/s41598-022-05943-z/figures/2
Spatial coverage	Farm, Local, Regional, National, Industry
Practice mobility	Static

Level of complexity	Low to Medium
Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	German, Ireland
Statistical location	
Practice implementation	These solutions are characterized by high cost and high-tech requirements and they are feasible only for industrialized countries. Given the numerous advantages of HTC, there are efforts on exploring the potential of an adapted HTC system for bio waste and faecal sludge treatment that is suitable for developing countries.
Environmental effects	Benefits: HTC process convers raw biomass to a coal-like material with improved physicochemical properties, which can be used as an alternate to coal. Furthermore, HTC products can be used as a means for carbon sequestration. Risks: During the process, CO_2 gases are generated. Hydrochar additions may affect the ecology of soil and the functionality of inhabiting microorganisms.
Limitations	High cost for this technology. Roughly a third of the total cost is for the security certificates required for pressure-vessels. There is not enough information about hydrochar and its application for soil amendment. Researchers observed that hydrochar has negative effects for some plants, when it is used on soil.
Relevant stakeholders	Agro-food industry, farmers' associations
EU legislation/recommendation	Hydrochar: A Promising Step Towards Achieving a Circular Economy and Sustainable Development Goals https://doi.org/10.3389/fceng.2022.867228
National legislation/recommendation	
References	A comparative review of biochar and hydrochar in terms of production, physico-chemical properties and applications http://dx.doi.org/10.1016/j.rser.2015.01.050
	Hydrothermal Carbonization (HTC): A Pressure Cooker for Biowaste

Additional information and comments	
Editor of the template	Georgios Spyridopoulos (Q PLAN INTERNATIONAL)

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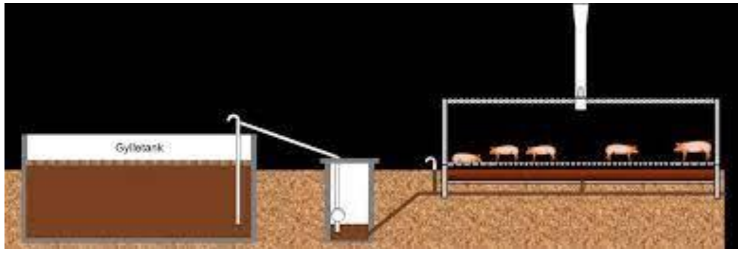
3.15 Increased outtake of slurry from pig stables

P15

Practice summary	
Short title	Increased outtake of slurry from pig stables
Short summary for stakeholders	There is a high potential in reducing methane emission from pig barns by applying a practice with increased frequency of slurry outtake. Hence, from January 2023, it is required to remove slurry from the stables every 7th day. The aim is to reduce methane emissions from the manure in the barn. Research from SEGES Innovation shows that weekly discharge rather than monthly discharge reduces the methane release from the slurry by approximately 45 percent. Frequent outtake has several additionally benefits is less time consuming because the system can be full automatically, online monitoring and management also for relevant authorities, improves working environment, as amount of the gases ammonia and hydrogen sulphide are reduced and heavy lifting of manual manure removal is avoided, less smell and no incorrectly inserted slurry plugs. Thus, automatic outtake, by vacuum release controlled by a gate located outside the barn, is controlled digitally, and logging of outtake is done automatically, and the mechanics are located outside the barn. The workload is very low in this system, and all data are maintained.
Practice details	
Practice full title	Increased outtake of slurry from pig stables
Practice objective and context	At present, Danish agriculture accounts for 25 per cent. of Denmark's total greenhouse gas emissions. Apart from CO_2, the most important greenhouse gases from livestock production are methane and nitrous oxide. Around 2,5 percent of Denmark's total greenhouse gas emissions originate from methane emissions from piggery. Approximately 77 per cent of this methane is formed in the manure, and the last 23 per cent. of the methane is formed via fermentation in the large intestine of the pigs. With traditional manure handling, manure is discharged every 4-5 weeks. This means that the manure stays in the barn for many days at a temperature of 18-20°C, which provides good growth conditions for the methane-producing bacteria. Therefore, increased, or frequent outtake of slurry has a lot of great potentials. The most important ones are the reduction of emission of methane and CO_2 and improvement of the value as a biogas biomass. Methane is a potent greenhouse gas that is 25 times

	more powerful than CO_2, and therefore it is an important climate measure to reduce methane emissions. Moreover, frequent outtake is less time consuming because the system can be full automatically, online monitoring and management also for relevant authorities, improves working environment, as amount of the gases ammonia and hydrogen sulfide are reduced and heavy lifting of manual manure removal is avoided, less smell and no incorrectly inserted slurry plugs. Thus, automatic outtake, by vacuum release controlled by a gate located outside the barn, is controlled digitally, and logging of outtake is done automatically, and the mechanics are located outside the barn. The workload is very low in this system, and all data are maintained.
Practice description	It is expected that the requirements will include outtake of manure to be practiced at least every 7 days from all pig pens and must be documented with a logbook. New barns planned after January 1st 2023 must practice outtake at least every 7 days. For larger barns requirements for automatic outtake, with a logging system, must be expected for all types of barns and animal groups. Even though automatic outtake of slurry is becoming a widespread technology with many advantages, frequent outtake can be practiced in many different housing systems. A line winch system for outtake of the manure under the floors in the stables moves manure directly to the tank outside the stables. Unlike the traditional plug system, the line system can handle straw, which is used in this housing system. Measurements carried out by SEGES Innovation show that daily discharge with a line winch system reduces the methane emission from the slurry by approximately 90 percent. The traditional system is to 'pull plugs' for taking manure out from the stables. However, when integrating this task in the daily routine and combine the process with simultaneously collection of manure by biogas company, the manure also has a higher dry matter content, which gives a better quality for the biogas production. Thus, this fresh manure has approximately 10 percent higher gas content than traditionally discharged manure.
General diagram	
Input components	Slurry, technology, mechanical solutions.

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Biomass type	The slurry has an improved quality for the use in e.g., biogas. The farmer can strategically deliver to biogas simultaneously with practicing frequent outtake of slurry.
Final products and their use	A higher quality of biomass for biogas production, and a reduction in GHG emission.
Visual examples of final product	https://www.youtube.com/watch?v=PZL4zMR4DmU
Spatial coverage	Farm, National
Practice mobility	Static
Level of complexity	Medium
Replication potential	Low, the practice is possible to practice in most barns. However, automatically approached are giving some advantages.
Innovation stage	Commercially available
Country / Region of implementation	Denmark
Statistical location	
Practice implementation	As the practice is a requirement, the practice and associated technology is getting more common. Another factor that should be considered in relation to the use of frequent outtake is the number and location of exit points in the stables. If the outfall site covers a larger number of paths, there will be risk of accumulation of manure in the areas furthest away from the discharge point. Is this in this case, it may be necessary to have a longer time between the discharges in order to achieve an effective shut-off. On the other hand, frequent emptying may prevent the settling of particles in slurry, but this has not been further investigated.
Environmental effects	Due to the high potential in reducing methane emission, it is stated, that from 1st of January 2023, there will be a requirement for frequent removal of manure from Danish pig barns. The aim is to reduce methane emissions from the manure in the barn. Research from SEGES Innovation shows that weekly discharge rather than monthly discharge reduces the methane release from the slurry by approximately 45 percent.
Limitations	With this practice, it appears that the loss of methane in the pig barn is reduced by up to 45 percent. But the 45 percent is not the final reduction. The manure that is pushed out into the manure storage has a relatively higher emission of methane in the manure tank than normal. Therefore, it is estimated

	that the total loss of methane in the barn and manure tank will be reduced by approximately 16 percent when the manure is removed every 7 days.
Relevant stakeholders	Environmental Protection Agency SEGES Innovation Danish Agriculture & Food Council, sector for pig research The Danish Agricultural Agency Aarhus University - Danish Centre for food and agriculture Agrifarm Landia
EU legislation/recommendation	https://eur-lex.europa.eu/legal-content/DA/TXT/PDF/?uri=CELEX:32016L2284&from=DE
National legislation/recommendation	https://mst.dk/erhverv/landbrug/miljoeteknologi-og-bat/teknologilisten/gaa-til-teknologilisten/staldindretning/vilkaarsforslag-hyppig-gylleudslusning/ https://eur-lex.europa.eu/legal-content/DA/TXT/PDF/?uri=CELEX:32016L2284&from=DE https://www.retsinformation.dk/eli/lta/2019/520 https://svineproduktion.dk/Viden/Paa-kontoret/Love-_regler-og-standarder/Husdyrlov
References	https://svineproduktion.dk/aktuelt/nyheder/2022/11/301122_gylleudslusning https://svineproduktion.dk/aktuelt/nyheder/2022/12/151222_hyppig_udslusning_bekendtgoerelse https://agrifarm.dk/en/ https://pure.au.dk/portal/files/207749759/Metanproduktion_og_hyppig_udslusning_af_gylle_i_stalde_120121.pdf
Additional information and comments	
Editor of the template	Liselotte Puggaard, Food & Bio Cluster Denmark

3.16 Integrated pest management

P16

Practice summary	
Short title	Integrated pest management (IPM)
Short summary for stakeholders	Integrated Pest Management (IPM) is an effective and environmentally sensitive strategy to protect plants and manage pest. The strategy relies on common-sense practices and is the cornerstone of the EU framework directive on the sustainable use of pesticides (dir. 2009/128/EC). All EU member states are obliged to ensure that everyone who uses pesticides in a commercial context follows the IPM principles. A healthy crop rotation prevents challenges with weeds, fungi and pests. A more sustainable plant production with less harmful impact on the aquatic environment, biodiversity and public health. But also a stable and robust yield is a valuable outcome of implementing IPM. The ultimate benefits of implementing IPM is the protection of the general environment against harmful damage from chemical crop protection. More specific, the implementation of IPM leads to protection of biodiversity and to the protection of ground waters and surface waters from pollution of chemical crop protection products. This without compromising the level of crop protection needed to manage a sustainable crop production. As the IPM principles does not exclude the use of chemical crop protection agents, there is still a risk of environmental damage from these agents.
Practice details	
Practice full title	Integrated pest management (IPM)
Practice objective and context	Integrated Pest Management (IPM) is an effective and environmentally sensitive strategy to protect plants and manage pest. The strategy relies on common-sense practices and is the cornerstone of the EU framework directive on the sustainable use of pesticides (dir. 2009/128/EC). All EU member states are obliged to ensure that everyone who uses pesticides in a commercial context follows the IPM principles. The diagram illustrates that the preventative actions are the foundation of IPM together with a healthy crop rotation. A healthy crop rotation prevents challenges with weeds, fungi and pests. The EU's framework directive for the sustainable use of pesticides contains an annex with 8 principles for integrated plant protection (IPM), stated in 'Practice description'. The implementation

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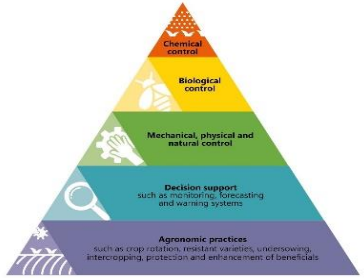
	of these 8 principles has been the responsibility of each EU member state. In Denmark, the Danish EPA translated, interpreted, and disseminated the principles in collaboration with national crop protection advisors from the largest farm advisory network DLBR (Danish farm advisors), in order to ensure that the principles reached farmers and were implemented.
Practice description	The IPM principles: 1. Prevent and/or fight weeds, diseases and pests using several methods, in particular by: - Practicing a varied and healthy crop rotation and appropriate cultivation methods (good and timely establishment, appropriate seed quantity, etc.) - Using resistant or tolerant varieties, when possible, preferably in combination with high quality seed material - Fertilizing, liming, irrigating, and draining in a way so the spread of weeds, diseases and pests is prevented (careful cleaning of machines, etc.) - Protecting and increasing the number of beneficial organisms in and around the cultivated area 2. Know and follow the pests in the crops, use alerts and forecasts and seek advice from qualified and impartial advisers. 3. Include notifications, forecasts, and thresholds when we make decisions about crop protection. We also take regional and climatic conditions into account. 4. Choose non-chemical methods (biological, mechanical, thermal, etc.) against the pests if the methods have sufficient effect. 5. Choose the pesticides that best suit the task and offer the least risk of side effects on human health, on other organisms in nature and on the environment. 6. Choose the correct dosage, where possible reduced dosages. Treat as few times as possible, spot sprays etc. At the same time, we prevent the pests from developing resistance to the agents. 7. If there is a risk of resistance developing, try to replace some of the treatments with agents with other mechanisms of action, or mix agents with different mechanisms of action. 8. Follow up on the effect of the applied crop protection strategy. The starting point is continuous monitoring of pests in the field and the registrations in the spraying journal, on maps etc.

General diagram	  https://planteinspektion.dk/ukrudtskort https://effektivtlandbrug.landbrugnet.dk/artikler/plantevaern/69155/nu-kan-bekaempelse-af-rapsjordlopper-begynde.aspx
Input components	A well formulated local translation of the IPM-principles, written in a practical and understandable language, so farmers can see the benefits of implementing them. This of course should be combined with appropriate legislation or other incentives, to further increase the motivation of adopting the principles.
Biomass type	A more sustainable plant production with less harmful impact on the aquatic environment, biodiversity and public health. But also a stable and robust yield is a valuable outcome of implementing IPM.
Final products and their use	Well written and locally adapted IPM-principles that are possible for farmers to understand, implement and further develop upon, if needed.
Visual examples of final product	
Spatial coverage	National
Practice mobility	Mobile
Level of complexity	High, requires extensive knowledge in areas such as biology and the interactions between factors like: climate, soil type, crop choice, crop rotation, chosen IPM strategy and much more.
Replication potential	High, as long as it is adapted to local conditions.
Innovation stage	Commercially available

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Country / Region of implementation	Denmark
Statistical location	
Practice implementation	As it is required by law, the principles are used by all professionals practicing crop protection
Environmental effects	The ultimate benefits of implementing IPM is the protection of the general environment against harmful damage from chemical crop protection. More specific, the implementation of IPM leads to protection of biodiversity and to the protection of ground waters and surface waters from pollution of chemical crop protection products. This without compromising the level of crop protection needed to manage a sustainable crop production. As the IPM principles does not exclude the use of chemical crop protection agents, there is still a risk of environmental damage from these agents.
Limitations	The success of the implementation in Denmark is associated with the strong independent farm advisory network, combined with a long history of initiatives to protect ground water resources from chemicals. If farm advises are coming from e.g., chemical companies or others with commercial interest, the implementation may be affected. Also, if the EPA is not naturally focused on adapting the regulations and forcing farmers habits in a more sustainable direction, the implementation of IPM principles may also be less successful. Finally, a major barrier for IPM is the mind-set of farmers. If they, as an example, perceive IPM as an increased risk to their production, they will be less willing to adopt them.
Relevant stakeholders	The Danish Environmental Protection Agency (EPA) SEGES Innovation
EU legislation/recommendation	https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:da:PDF
National legislation/recommendation	https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:da:PDF https://mst.dk/kemi/pesticider/anvendelse-af-pesticider/brugere-professionel-brug/ipm-integreret-plantebeskyttelse/regler-om-udfyldelse-af-ipm-skema/ https://mst.dk/kemi/pesticider/strategier-og-regler/handlingsplaner-og-eu/
References	https://mst.dk/kemi/pesticider/anvendelse-af-pesticider/brugere-professionel-brug/ipm-integreret-plantebeskyttelse/
Additional information and comments	
Editor of the template	Liselotte Puggaard, Food & Biocluster Denmark.

3.17 Manure Composting

P17

Practice summary	
Short title	Manure Composting
Short summary for stakeholders	Composting "..the biological decomposition and stabilization of organic substrates under conditions that allow development of thermophilic temperatures as a result of biologically produced heat.." Aim: "..to produce a final product that is stable, free of pathogens and weed seeds. The resulting compost that is used by the ether the farmer or the horticulturist is they get a biologically sourced fertilizer that also provides the soil with numerous benefits including improvements to soil improvements both in structure and nutritional qualities.
Practice details	
Practice full title	Manure Composting
Practice objective and context	Reduced moisture, weight, and volume of stored manure. An efficient recycling method for crop residues. Reduced fly, weed and odor problems in manure. More stable form of nitrogen and other nutrients. For Soil Improvement: Physical characteristics. Infiltration rate. Water holding capacity & tilt, soil aggregation. Increase population and diversity of soil microbial community. For fertilizer: For specific nutrients e.g., nitrogen, phosphorus, potassium, and micronutrients. To increase humus content of soil.
Practice description	Microorganisms consume greater than 90% of the available organic matter. The organic matter is broken down into: CO_2, H_2O, heat and compost. The composting process proceeds through three phases: • Mesophilic 10-45°C • Thermophilic 45-70°C

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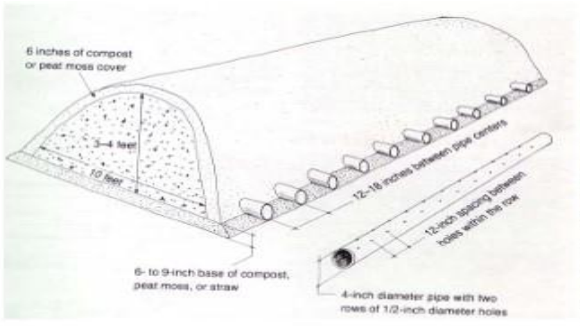
	• Maturation (curing)
General diagram	 
Input components	Poultry Manure, Sheep / Pig Manure, Horse Manure, Cow Manure, Wheat Straw, Sawdust, Grass Clippings, Vegetable Waste, Potato Tops, Leaves
Biomass type	All - waste
Final products and their use	Agri compost
Visual examples of final product	
Spatial coverage	Farm, Local, Regional, National
Practice mobility	Static
Level of complexity	Low - mainly mechanical and/or thermal processes are involved with minimum engineering skills.
Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	Ireland

Statistical location	
Practice implementation	Common use, used by Agriculture, but more by Horticulture.
Environmental effects	Improves aeration of heavy soil, improves water holding capacity of light soil-can reduce flooding, saving on agricultural chemicals – less plant disease, saving on fertilizer application.
Limitations	
Relevant stakeholders	Agriculture & Horticulture
EU legislation/recommendation	Plastic Separation Legislation
National legislation/recommendation	https://www.teagasc.ie/media/website/publications/2000/MunooPrasad.pdf
References	
Additional information and comments	
Editor of the template	Robert Ludgate / MTU

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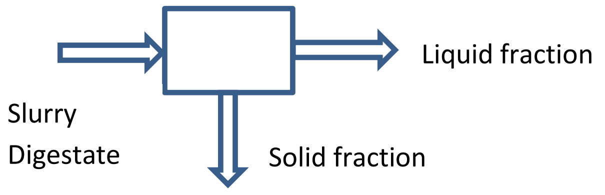
3.18 Mechanical Solid-liquid separation

P18

Practice summary	
Short title	Mechanical Solid-liquid separation
Short summary for stakeholders	High slurry dry matter results in crust formation on the slurry surface and solid parts sedimentation on the bottom of the tank. In order to achieve an even distribution of nutrients in the slurry, it must be mixed and homogenized prior to application. Homogenizing slurry with high dry matter content is energy-consuming and increases NH_3 emissions. After the application of dense slurry, NH_3 emissions are also significant and increase with high dry matter content, due to slower infiltration through the soil profile. Mechanical Solid-liquid separation is a cost-effective method, where, during the slurry or digestate separation process, solids, and liquids are mechanically separated into a liquid and a solid fraction. In the liquid fraction, dry matter content is reduced by 40–45 %, carbon content is reduced by 45–50 %, and the C/N ratio decreases from about 10:1 to about 5:1. Mechanical separation results in the increased concentration of N and K in the liquid fraction, and the increasing concentration of P and organic material in the solid fraction. The liquid N-rich fraction can be used on arable land/grassland on the farm to reduce the use of mineral fertilizer. The solid fraction contains a high concentration of P and is mainly used in regions with low P-soils and/or with a high demand for OM, reducing problems derived from nutrient surplus elsewhere. Separation can increase the efficiency and flexibility of handling and transporting manures and help in more accurate management of nutrients in the farm. The solid slurry fractions may become a significant source of NH_3 and CH_3 emissions, and the practice's maximum environmental effectiveness also requires appropriate storage of the solid fraction under a covering, its direct incorporation into the soil, or using it as a feedstock for anaerobic digestion with nutrient recovery. Slurry separation meets most requirements of appropriate manure management.
Practice details	
Practice full title	Mechanical Solid-liquid separation

Practice objective and context	Reduce the loss of nitrogen from animal manures, which may be easily lost via gaseous emissions (NH_3, N_2O, NO_x, N_2) and leaching of nitrate (NO_3^-) and other N compounds. Besides nitrogen losses, animal and manure emissions of methane (CH_4) to the atmosphere must be reduced, to limit climate change impacts. High slurry dry matter results in crust formation on the slurry surface and solid parts sedimentation on the bottom of the tank. In order to achieve an even distribution of nutrients in the slurry, it must be mixed and homogenized prior to application. Homogenizing slurry with high dry matter content is energy-consuming and increases NH_3 emissions, as a larger part of the slurry comes into close contact with the atmosphere. Environmentally friendly slurry application in the field requires application near or below the soil surface. It is much more complicated when the slurry has a higher dry matter content, causing a higher viscosity and less easy flow through application equipment. After application of dense slurry, NH_3 emissions are significant and increase with high dry matter content, due to slower infiltration through the soil profile. The N availability to plants is difficult to evaluate for slurry with the high dry matter, as a result of intensive microbial-induced immobilization right after application. Simultaneous high soil N content has the potential to increase rates of nitrification and denitrification, increasing subsequent N_2O, NO_x, and N_2 losses. Separation can increase the efficiency and flexibility of handling and transporting manure and help in more accurate management of nutrients in the farm.
Practice description	Mechanical Solid-liquid separation includes various technologies, using a screw press, belt press, centrifuge, grid, sieves filters, or a screener. Separators are efficient in producing a solid fraction with high dry matter content on a relatively cost-effective basis. During slurry or digestate separation, solids, and liquids are mechanically separated into a liquid and a solid fraction. Energy consumption for separation is relatively low but depends on the technology used for separation. Dry matter content in the liquid fraction is reduced by 40–45 %, and simultaneously increases for the solid fraction. Carbon content in the liquid is reduced by 45–50 %, with the C/N ratio decreasing from about 10:1 to about 5:1. As a result of carbon removed from the liquid, microbial degradation of organic matter during storage is reduced. The opposite may be the case for the solid fraction, depending on storage conditions. The removal of solids reduces crust formation and sedimentation of the liquid fraction, thus, less intensive mixing is required to homogenize the slurry prior to application. Mechanical separation results in the increase concentration of N and K in the liquid fraction, and the increase concentration of P and organic material in the solid fraction. The liquid N-rich fraction, can be used on arable land/grassland on the farm to reduce the use of mineral fertilizer. The solid fraction contains a high concentration of P and is mainly used in regions with low P-soils and/or with a high demand of OM. The most efficient solid–liquid mechanical separators for the removal of DM, P and, to some extent, total N and NH_4^+, can be ranked in the order: centrifuge > sedimentation > filtration without pressure > filtration with pressure.

General diagram Graphic diagram of the practice showing the key elements and processes	
Input components	Slurry, liquid manure, semi-solid manure, digestate
Biomass type	Waste
Final products and their use	Liquid slurry fraction, solid slurry fraction
Visual examples of final product	Slurry separation https://www.youtube.com/embed/j3tVzZmXBho?autoplay=1  https://www.agrometer.dk/assets/Uploads/_resampled/FitWyIxMDAwIiwiODAwIl0/IMG-0223-1.jpg
Spatial coverage	Farm, regional, industry
Practice mobility	Static and mobile
Level of complexity	Low to medium
Replication potential	Medium

Innovation stage	Commercially available
Country / Region of implementation	Denmark, Netherlands, Spain, Belgium, Poland
Statistical location	
Practice implementation	Slurry separation meets most requirements of appropriate manure management. Costs of implementation could be reduced if the technology were more widespread and more separators were on the market and available to farmers. The choice of technique depends on the type of manure, the desired end product, the volume that needs to be separated, the investment- and operational costs, etc.
Environmental effects	The liquid slurry fraction has a narrow C/N ratio, which reduces the potential of microbial N immobilization in the soil and N_2O emissions. It has a low denitrification rate and stable N content, which makes it more predictable in the context of N availability for crops and high fertilization efficiency. In order to reduce NH_3 emissions from the liquid fraction, mitigation measures such as tank covering, acidification, and low-emission application techniques should be used. The solid slurry fractions may become a significant source of NH_3 and CH_3 emissions if not properly treated. The maximum environmental effectiveness of the practice also requires appropriate storage of the solid fraction under covering, its direct incorporation into the soil, or using it as a feedstock for anaerobic digestion with nutrient recovery. Solid fraction can be exported at lower costs to areas with low livestock density, reducing problems derived from nutrient surplus, whereas liquid fractions can be used closer or further processed in situ. Separation does not affect pathogens or other contaminants, but they are separated to solid and liquid fractions according to their solubility. Separation can increase the efficiency and flexibility of manure handling and transport and assist in more precise management of manure nutrients. Solid fractions can be more easily exported to areas with low livestock density, reducing problems derived from nutrient surplus, whereas liquid fractions can be used or further processed in situ.
Limitations	To implement a solid-liquid separation practice, a whole-system approach is important with pre-treatments of the components and post-treatments of the final products. Solid-liquid separation technologies require investment in expensive equipment with a limited life span, periodic maintenance, and an external power supply. These extra costs should be balanced against e.g. the reduction in investment in and cost of slurry transportation between animal houses, slurry storage facilities, and fields. Just as in any industrial farm operation, it is also very important to balance investment, running, and labor costs against product-added value, environmental impact, and process complexity.

Relevant stakeholders	Farmers, Advisors, SME, Local administration.
EU legislation/recommendation	Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants.
	Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).
	European Commission, Joint Research Centre. 2017. Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs (BREF) – BAT 16, 21, 23, 30, European Commission. 2017. Commission Implementing Decision (EU) 2017/302 of 15 February 2017 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for the intensive rearing of poultry or pigs. The Nitrates Directive, Council Directive 91/676/EEC of 12 December 1991
National legislation/recommendation	PL: Ustawa o nawozach i nawożeniu (The act on fertilizers and fertilization) z dnia 10 lipca 2007 r. (Dz.U. 2007 nr 147 poz. 1033) PL: Rozporządzenie Rady Ministrów z dnia 31 lutego 2023 r. w sprawie przyjęcia „Programu działań mających na celu zmniejszenie zanieczyszczenia wód azotanami pochodzącymi ze źródeł rolniczych oraz zapobieganie dalszemu zanieczyszczeniu", (Regulation of the Council of Ministers of February 12, 2020 on the adoption of the "Action Program to reduce water pollution with nitrates from agricultural sources and to prevent further pollution") (Journal of Laws of 2020, item 243) (Dz.U. 2023 poz. 244) PL: Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 16 kwietnia 2008 r. w sprawie szczegółowego sposobu stosowania nawozów oraz prowadzenia szkoleń z zakresu ich stosowania (Regulation of the Minister of Agriculture and Rural Development on the detailed method of applying fertilizers and conducting training in the field of their use) (Dz. U. 2018 poz. 1438) PL: Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska, (Environmental Protection Law) (Dz.U. 2001 nr 62 poz. 627) PL: Biełka I., Pietruszka A. 2017. Wytyczne dotyczące praktycznego zastosowania Konkluzji BAT w zakresie intensywnego chowu drobiu i świń, część 2 Instalacje do chowu świń, Ministerstwo Środowiska, (Guidelines for the practical application of the BAT Conclusions for the intensive rearing of poultry and pigs, part 2 Installations for rearing pigs, Ministry of the Environment). https://www.ekoportal.gov.pl/fileadmin/user_upload/Wytyczne_dotyczace_praktycznego_zastosowania_Konkluzji_BAT_w_zakresie_intesywnego_chowu_drobiu_i_swin_-_Czesc_II_Instalacje_do_chowu_swin.pdf
	Hjorth M., Christensen K.V., Christensen M.L., Sommer S.G. 2010. Solid-liquid separation of animal slurry in theory and practice. A review. Agron. Sust. Devel. 30, 153-180. DOI: 10.1051/agro/2009010.

References	Flotats, X., Foged, H.L., Bonmati Blasi, A., Palatsi, J., Magri, A. & Schelde, K.M. 2011. Manure processing technologies. Technical Report No. II concerning "Manure Processing Activities in Europe" to the European Commission, Directorate-General Environment. 184 pp. https://www.agrotechnologyatlas.eu/docs/21010_technical_report_II_manure_processing_technologies.pdf
Additional information and comments	
Editor of the template	Piotr Skowron, IUNG

3.19 Pelletizing/granulation

P19

Practice summary	
Short title	Pelletizing/granulation
Short summary for stakeholders	Biomass is described as wood and agricultural residues from the wood industry, crop fields, and forests. Some drawbacks of biomass include: irregular size and shape, low bulk and energy density, and high moisture content. To address these challenges, biomass is pelletized into cylindrical pellets that may be utilized for both domestic (diameter 6mm) and industrial (diameter 8mm) heat and power applications. The pelletizing process is defined as compression of the feedstock (in this example, biomass). The friction between the biomass and the press channel creates a force that compresses the biomass, causing the final product, pellets, to retain their form and density due to bonding that happens between the particles under high pressure inside the press channels. Several benefits / opportunities from pellet production and use can be identified: - Environmental friendly: Biomass pellets are carbon-neutral and emit no harmful gases into the atmosphere. - High efficiency: Depending on moisture content, biomass wood pellets can be your highly effective fuel - Easy-to-use: Because biomass pellets are uniform in size, they are simple to store and transport. - Renewable & sustainable: Biomass pellets are renewable since farm and forest waste are abundant and generated year after year. - Independent pricing: Biomass pellets pricing can be produced on individual and independent levels, and hence the pricing is independent.
Practice details	
Practice full title	Pelletizing/granulation
Practice objective and context	Pelletizing biomass improves its use performance as a solid biofuel by reducing moisture content, increasing calorific value and bulk density, and, perhaps most crucially, achieving consistent shape, size, and density.

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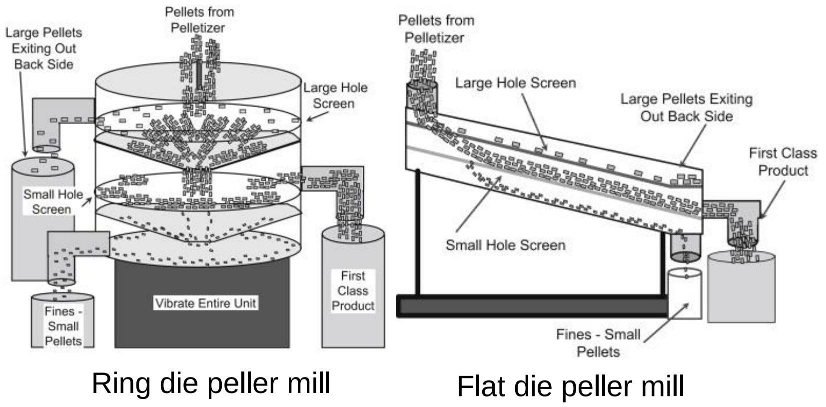
	These, in general, more stable and constant qualities, offer reduced consumption costs in terms of transit, storage, and ultimate use - feeding residential or industrial boilers, and finally, combustion. Moreover, the homogeneous size allows for automatic or semi-automatic treatment, overcoming the drawbacks of traditional home biomass utilization. The use of densified pellet biofuels significantly lowers the expenses of handling, storage, and transportation.
Practice description	The pellet mill is in control of this procedure. Ring or flat die pellet mills are commonly used by large-scale companies, with ring die mills being the most popular. The die and rollers are always the major sections of the mill, with rollers driving the material through the bore-holes of the die, creating an unending string of pelletized material, breaking up into random bits, or being chopped into required length by knives. Within the published literature, there are several interpretations and definitions of the pelletizing process. In summary, the pelletizing process is based on forcing the raw material through the die holes. It is also a kneading, compressing, heating, and shaping process that causes rheological alterations in the material, as well as a high agglomeration process. During the mechanical process of compressing biomass into pellets, pressure is applied to the biomass to crush its cellular structure, increasing its density. Raw material species, particular plant parts/components utilized, moisture content, and particle size are key criteria influencing the cost, method, and dynamics of the process itself, as well as the quality of the final product (biomass pellets). Furthermore, temperature and pelletizing pressure, as well as the kind of pellet mill and die specifications, all play a vital part in the pelletizing process, influencing each other directly or indirectly to create a pellet of a given grade.

General diagram	 Source: Handbook of Thermoplastic Elastomers (Second Edition), 2014
Input components	There are two types of feedstock as input component for pelletizing: forestry/woody and agricultural/herbaceous. Specific forest trees and agricultural crops within two feedstock types are referred to as species. Hardwood and softwood are the two broad categories of forestry and wood industry feedstock species. Different species have different energy needs for pelletizing, which has a direct influence on cost and manufacturing capacity. Hardwoods such as European beech took more energy to process than softwood Scots pine while yielding pellets with higher mechanical qualities (strongest). If additional conditions, such as acceptable moisture content, are fulfilled, agricultural feedstock can have satisfactory pelletizing qualities. Furthermore, including softwood (pine) with agricultural (straw) feedstock might increase the mechanical qualities of pellets generated.
Biomass type	Apart from the biomass powder produced during the milling process, no other by-product or waste can be identified in biomass pelletizing.
Final products and their use	Pellets are a type of solid biomass fuel made mostly from wood waste, but also from agricultural by products such as straw. They are cylindrical in shape and have a diameter of 6 - 12 mm. We distinguish between wood pellets and agro pellets in the context of energy based on the feedstock utilized. Pellets are now mostly made from wood scraps, while the volume of pellets made from agricultural by products such as straw, husks of sunflower seeds, stalks and leaves of corn, and so on is rising.

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	Pellets are used in pellet stoves and pellet boilers for household heating, as well as for the creation of heat, steam, and electricity in the service sector, manufacturing, and power generation.
Visual examples of final product	 Pellets produced from different kind of biomass feedstock Source: https://bestonmachinery.com/biomass-pellet-making-machine/
Spatial coverage	Pelletizing can be carried out on a local, regional, or global scale, depending on the specific treatment process being used and the needs and circumstances of the area being served.
Practice mobility	Mobile - the practice can be done in mobile or temporary installation.
Level of complexity	The pelletizing process's complexity ranges from low to medium, depending on the operations that take place to generate the best result. Complexity is noted during pelletizing mostly during the biomass drying stage, when biomass is dried to reach a low moisture percentage. Steam dryers, for example, have unique operating characteristics that may affect process's complexity.
Replication potential	Pelletizing replication potential lays between medium-high. The use of the same biomass and the precise application of the drying process so that the pellets have a low moisture coefficient are essential aspects for the development of a pellet product with specified qualities. The pelletizing process may be simply reproduced in another location as long as these requirements are satisfied.

Innovation stage	The pellet industry is already highly mature, with considerable evidence of development and progress in recent years. The energy crisis and the development of sustainability policies have all had a substantial impact on the market position. According to a recent study submitted with the USDA Foreign Agricultural Service's Global Agricultural Information Network, the European Union consumed a record 23.1 million metric tons of wood pellets in 2021. This year, demand is predicted to increase to 24.3 million metric tons. According to the analysis, the record-breaking 2021 consumption is mostly due to rising residential usage in Germany and coffering of wood pellets with coal in the Netherlands. Consumption is likely to rise this year as a consequence of the development of EU residential markets, particularly in Germany and France, aided by assistance programs for the installation of biomass boilers and the high price of fossil fuels.
Country / Region of implementation	Germany, Sweden, Latvia, Estonia, France, Russia, Austria, Poland, Portugal, Romania
Statistical location	
Practice implementation	With 16,6 million tons of pellets produced in 2016, the EU was the world's largest producer, accounting for approximately 57% of worldwide output (EU28 accounted for 48%, with 14,0 million tons). After years of uninterrupted development, actual European output halted in 2016 with a 1% increase (the EU28 had a 0.4% dip). Because the bulk of European pellet output is used in the heating market, the demand contraction caused by the mild winter of 2015.2016 and the fall in heating equipment sales has had a significant influence. The utilization of pellets in the industrial market was also lower than expected in 2016, exacerbating the dilemma of European pellet manufacturers' overcapacity and excess.
Environmental effects	Environmental Benefits: - Biomass pellet-fueled stoves and boilers emit very little CO2. - Biomass pellets are carbon beneficial, lowering greenhouse gas emissions significantly when compared to fossil fuels. - Wood pellets are also lower in sulphur, chlorine, nitrogen, and trace elements such as mercury, arsenic, beryllium, cadmium, and lead than coal. When wood pellets are used instead of coal, considerably less of these components are released into the environment. As a result, they have reduced the generation of greenhouse gases and its related negative environmental impacts, such as acid rain, increased temperatures, and rising sea levels.

<table>
<tr><td>Limitations</td><td></td></tr>
<tr><td>Relevant stakeholders</td><td>Rural actors (e.g. feedstock & biomass providers, farmers), agriculture companies & SMEs, equipment manufacturers & suppliers, environmental organizations & NGOs, general public</td></tr>
<tr><td>EU legislation/recommendation</td><td>Many European countries have created quality, storage, transportation, and combustion criteria for densified biomass fuels.
Particle and bulk density, moisture content, crushing resistance or hardness, particle number, particle size (length and diameter), chemical composition, ash content, and heating value are among the metrics and recommendations covered.
As international trading becomes increasingly common, worldwide rules for the acquisition and selling of biomass fuels must be developed.
As a result, the European Commission mandated the European Committee for Standardization, CEN, to produce standards for solid biofuels through the Technical Committee (TC) 335 Solid Biofuel.
European standard committee CEN/TC 335
European Standardization Committee
CEN/TC 335 is the technical committee that created the draft standard to characterize all types of solid biofuel in Europe, including wood chips, pellets and briquettes, logs, sawdust, and straw bales.
As a result, the experimental technical specification CEN/TS 14588:2004 for solid biofuels was developed, which incorporates and specifies the pertinent terminology, definitions, and descriptions.
<table>
<tr><td>Size (diameter and length) (mm)</td><td>D06: $D \leq 6 \pm 0.5$ and $L \leq 5D$
D08: $D \leq 8 \pm 0.5$ and $L \leq 4D$
D10: $D \leq 10 \pm 0.5$ and $L \leq 4D$
D12: $D \leq 12 \pm 1.0$ and $L \leq 4D$
D25: $D \leq 25 \pm 1.0$ and $L \leq 4D$</td></tr>
<tr><td>Moisture content (%)</td><td>M10: ≤10%
M15: ≤15%
M20: ≤20%</td></tr>
<tr><td>Ash content (%)</td><td>A0.7: ≤0.7%
A1.5: ≤1.5%
A3.0: ≤3%
A6.0: ≤6%
A6.0+: >6%</td></tr>
<tr><td>N (%)</td><td>N0.3: ≤0.3%
N0.5: ≤0.5%
N1.0: ≤1%
N3.0: ≤3%
N3.0+: >3%</td></tr>
<tr><td>S (%)</td><td>N0.05: ≤0.05%
N0.08: ≤0.08%
N0.1: ≤0.1%
N0.2+: >0.2%</td></tr>
<tr><td>Cl (%)</td><td>CL0.03: ≤0.03
CL0.07: ≤0.07
CL0.1: ≤0.1
CL0.1+: >0.1</td></tr>
<tr><td>Durability[a]</td><td>DU97.5: ≥97.5
DU95.0: ≥95
DU90: ≥90</td></tr>
<tr><td>Fines content (%<3.15 mm)</td><td>F1.0: ≤1%
F2.0: ≤2%
F2.0 +: >2%</td></tr>
<tr><td>Bulk density (kg/m³)</td><td>Recommended value should be included by manufacturer</td></tr>
<tr><td>Heating value (kcal/kg)</td><td>Recommended value should be included by manufacturer</td></tr>
<tr><td>Additives</td><td>Binding materials and ash inhibitory should be included in the label</td></tr>
</table>
[a] Durability has been defined in terms of the percentage of whole pellets after testing.</td></tr>
<tr><td>National legislation/recommendation</td><td>Austrian standard: ÖNORM M 7135</td></tr>
</table>

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The NORM M 7135 Austrian standard for energy pellets defines standards and test specifications for compressed wood or compressed bark in its natural condition - pellets and briquettes.
It also covers non-wood biomass pellet requirements (M7139 for energy grains, C 4000 for Miscanthus pellets, and C 4002 for straw pellets).

Parameter		Limit values
Physical	Diameter (mm)	4–10
	Length (mm)	<5D
	Particle density (kg/dm³)	<1.12
Mechanical	Durability (%)[a]	<2.3
Chemical	Moisture content (%)	<10
	Ash content (%)	<0.5
	Heating value (kcal/kg)	>4302
	N (%)	<0.3
	S (%)	<0.04
	Cl (%)	<0.02
	Additives (%)	<2

[a] Durability has been defined in terms of the percentage of fines after testing.

Swedish specifications: SS 187120
Sweden was among the first to set pellet quality criteria in its SS 187120.
Depending on the parameter limit values examined, this standard divides pellet quality into three groups.

Parameter		Pellet category		
		Group 1	Group 2	Group 3
Physical	Diameter (mm)	<25	<25	<25
	Length (mm)	<4D	<5D	<5D
	Bulk density (kg/dm³)	>600	>500	>500
	Moisture content (%)	<10	<10	<10
Mechanical	Durability (%)[a]	<0.8	<1.5	<1.5
Chemical	Ash content (%)	<0.7	<1.5	<1.5
	Heating value (kcal/kg)	>4039	>4039	>3609
	S (%)	<0.08	<0.08	–
	Cl (%)	<0.03	<0.03	–

[a] Durability has been defined in terms of the percentage of fines after testing.

German standards: DIN 51731 and DIN EN 15270
Germany has two standards for pellets and briquettes: DIN 51731 [10] and DIN EN 15270 [11] for high-quality pellets. In 1996, Germany adopted the first compressed wood standard.

	Parameter	DIN 51731	DINEN 15270
Physical	Diameter (mm)	4–10	–
	Length (mm)	<5D	<5D
	Particle density (kg/dm³)	<1.2	<1.2
Mechanical	Durability (%)[a]	–	<2.3
Chemical	Moisture content (%)	<12	<10
	Ash content (%)	<1.5	<0.5
	Heating value (kcal/kg)	3705–4661	>4302
	N (%)	<0.3	<0.3
	S (%)	<0.08	<0.04
	Cl (%)	<0.03	<0.02
	Additives (%)	–	<2
	As (mg/kg)	<0.8	<0.8
	Cd (mg/kg)	<0.5	<0.5
	Cr (mg/kg)	<8	<8
	Cu (mg/kg)	<5	<5
	Hg (mg/kg)	<0.05	<0.05
	Pb (mg/kg)	<10	<10
	Zn (mg/kg)	<100	<100

[a] Durability has been defined in terms of the percentage of fines after testing.

Italian standard: CTI-R04/05

The Italian standard CTI-R04/05 defines quality standards for biomass energy pellets [12]. Pellets are classified into three types based on their composition: A.1. Deciduous and conifer tree trunks without bark; untreated wood from the wood-yielding business; used untreated wood and wood without bark; a blend of these commodities; A.2 Unprocessed herbaceous biomass; a combination of these ingredients; A.3. Raw materials that do not fall within category A.2.

Parameter		Pellet category		
		A.1	A.2	A.3
Physical	Diameter (mm)	6 ± 0.5–8 ± 0.5	6 ± 0.5–8 ± 0.5	10 ± 0.5–25 ± 1.0
	Length (mm)	–	<5D	–
	Bulk density (kg/dm³)	620–720	600–720	≥550
Mechanical	Dust emission (%)	≤1	≤1	–
Chemical	Moisture content (%)	≤10	<10	≤15
	Ash content (%)	≤0.7	<1.5	–
	Heating value (kcal/kg)	>4039	>3870	–
	N (%)	≤0.3	≤0.3	–
	S (%)	≤0.5	≤0.5	–
	Cl (%)	≤0.03	–	–
	Additives (%)	banned	–	–

French recommendation: ITEBE

Despite the fact that there is no formal standard for wood pellets in France, the government has created specific quality standards (ITEBE) that classify pellets based on their usage context (stove, boiler, large boiler, and incinerator).

	(table below)

Parameter		Type of combustion installation			
		Stove	Boiler	Large boiler	Incinerator
Physical	Diameter (mm)	6 ± 1	8–10 ± 1	>16	>16
	Length (mm)	10–30	10–15	>16	>16
	Bulk density (kg/dm³)	>650	>650	>580	>580
	Particle density (kg/dm³)	1.2–1.4	1.2–1.4	–	–
Chemical	Moisture content (%)	<10	<10	–	–
	Ash content (%)	<10	<10	–	–
	Heating value (kcal/kg)	>4052	>4052	–	–
	N (%)	<0.3	<0.3	–	–
	S (%)	<0.08	<0.08	–	–
	Cl (%)	<0.3	–	–	–
	Na (ppm)	<300	–	–	–

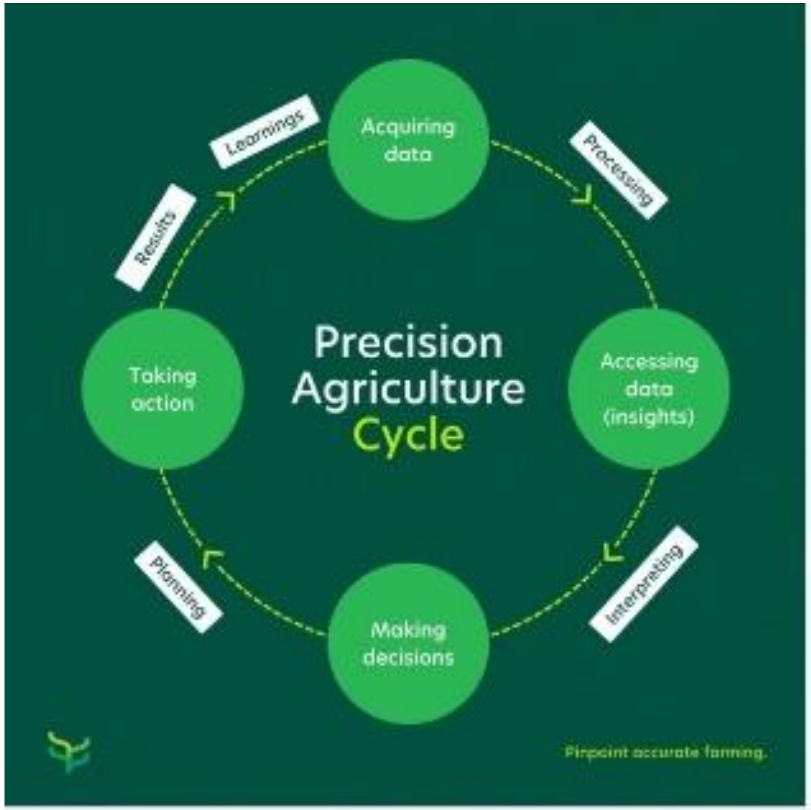
References	"Biomass Pelletization Process", Angela Garcia-Maraver & Manuel Carpio, doi:10.2495/978-1-84566-062-8/004 "Pellets – a fast growing energy carrier", WBA fact sheet "Pellet market overview", AEBIOM Statistical Report 2017, European Bioenergy Outlook "Biomass Pelletizing Process: A Review", Marin Dujmović et al., https://doi.org/10.5552/drvind.2022.2139 "A review of European standards for pellet quality", A. García-Maraver et al.,doi:10.1016/j.renene.2011.05.013 https://www.bioenergyconsult.com/biomass-pelletization/ https://www.renewableenergyworld.com/baseload/whats-biomass-pellet-and-biopellets-species/#gref https://biomassmagazine.com/articles/19198/eu-wood-pellet-demand-to-set-a-new-record-in-2022 https://bestonmachinery.com/biomass-pellet-making-machine/
Additional information and comments	
Editor of the template	Anastasios Galatsopoulos, White Research

3.20 Propagation technology/precision farming

P20

Practice summary	
Short title	Propagation technology/precision farming
Short summary for stakeholders	Precision farming is an integrated farming system, based on the use of digital information, designed to increase the long-term efficiency of whole-farm production, as well as its productivity and profitability while minimizing negative environmental impacts. There is a range of evidence from research that shows that environmental degradation is reduced when precision farming methods are applied, including increasing the fuel efficiency of farm machinery, leading to a reduction in the carbon footprint of farming in nature. Some other examples of the successful application of precision agriculture methods are minimizing nitrate amounts in agricultural systems, reducing groundwater contamination, and reducing erosion when the proper tillage treatments are done at the right time on farms. Precision farming can also generate benefits that make the social and working conditions in agriculture easier and more attractive for those employed in the sector. For example, automatic control systems integrated into various tractor models can make work less tiring for the operator.
Practice details	
Practice full title	Propagation technology/precision farming

Practice objective and context	The digitalization of agriculture allows the widespread use of precision farming methods, which undoubtedly lead to great benefits in optimizing production efficiency, increasing the quality of production, and minimizing the impact and pressure on the environment. Precision farming is seen as an ecological system solution that optimizes the quality and quantity of agricultural products while minimizing costs, human intervention, and variations caused by unpredictable nature. The application of precision agriculture is made possible by the development of sensor technologies combined with standardized procedures for linking mapped variables to appropriate algorithms for managing agronomic interventions such as cultivation, seeding, fertilization, herbicide application, and harvesting. The ultra-competitive agricultural market where there are multiple players is characterized by declining gross margins and profitability for each new entrant. Farm owners are therefore motivated to seek technologies that allow them to reduce costs without cutting production volumes. These market conditions lead to the intensive application of precision farming on farms located in the EU. However, it can be said that market conditions are not the only factor in the widespread introduction of precision farming. In fact, the application of precision farming in large agricultural areas in some EU countries aims first and foremost to increase production, only then to seek the economic and environmental benefits of the application of the approach.
Practice description	Precision farming is an integrated farming system, based on the use of digital information, designed to increase the long-term efficiency of whole-farm production, as well as its productivity and profitability while minimizing negative environmental impacts.

General diagram	
Input components	
Biomass type	Biomass
Final products and their use	Crop residues
Visual examples of final product	

Spatial coverage	Farm
Practice mobility	Static and mobile
Level of complexity	High
Replication potential	Low
Innovation stage	Commercially available
Country / Region of implementation	EU regions
Statistical location	NUTS2
Practice implementation	The application of precision agriculture requires the use of sensor technologies combined with standardized procedures to link mapped variables with appropriate algorithms to manage agronomic activities such as cultivation, seeding, fertilization, herbicide application and harvesting
Environmental effects	Precision farming plays an important role in farmland management. Through this method, fertilizer use is optimized, starting with the three main fertilizer substances - nitrogen, phosphorus, and potassium. In conventional farming, these fertilizers are applied evenly to fields at certain times of the year. This leads to over-application in some places and under-application in other places in production plots. The environmental costs are directly related to the over-application of fertilizers and chemicals to crops, allowing significant amounts of nitrogen and phosphorus to leach from the field into groundwater and surface water. With the use of precision farming methods, fertilizers are applied in more precise amounts in fewer applications, with a spatial and temporal component to optimize these applications.
Limitations	The use of precision farming in farm management requires large-scale investments to purchase the machinery and equipment to implement this type of technology. In addition to these investments, farmers need to be trained to acquire the knowledge and skills to handle the machinery and technology for the application of precision farming, which is one of the main reasons for the slow uptake of the technology in poorer regions of the EU.
Relevant stakeholders	IT providers, farmers, cooperatives and consumers
EU legislation/recommendation	According to the CAP legal requirements, each Member State has established an Integrated Administration and Control System (IACS), including an identification system for agricultural parcels,

	known as the Land Parcel Identification System (LPIS), as the spatial component. Using computerized geographical information system techniques for the identification system for agricultural parcels is in fact a legal obligation prescribed under Council Regulation 73/2009. By localizing, identifying and quantifying agricultural land eligible for EU support via very detailed geospatial data, IACS has become the most important system for the management and (administrative and on-the-spot) control of payments to farmers made by the Member States in application of the Common Agricultural Policy. It enables a set of comprehensive administrative and on-the-spot checks on subsidy applications, which is managed by the Member States and provides for a uniform basis for controls and on-the-spot checks performed by national authorities.
National legislation/recommendation	
References	Kritikos, M. (2017). Precision agriculture in Europe. Legal, social and ethical considerations. European Parliamentary Research Service - EPRS, November, 2017 - PE 603.207;
	Nikolov, D., Iv. Boevski, P. Borisov (2022). Digitalization in agriculture - competitiveness and business models. Publishing Institute of Agricultural Economics - Sofia, ISBN 978-954-8612-40-1
Additional information and comments	
Editor of the template	

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3.21 Pyrolysis

P21

Practice details	
Practice full title	Pyrolysis
Practice objective and context	Pyrolysis of biomass is a process in which solid (biochar), liquid (bio-oil) and gas (syngas) products are produced. The high porosity of biochar and its high content in energy, make it an appropriate material for its usage as soil additive for the restoration of polluted land and water, for the mitigation of climate change as well as the production of energy. Specifically for agriculture, biochar improves soil aeration and provides an asylum to the beneficial soil organisms which aids the supply of minerals and water, and guards crops against infections by root pathogens. Although biochar is highly hydrophobic in nature, when it is mixed with wet soil and exposed to O_2, it becomes hydro-philic with time and enhances the cation exchange capacity (CEC), nutrient retention on capacity (NRT) and water holding capacity (WHC) of soil. All these features considerably improve soil health and increase crop productivity. The liquid product of the pyrolysis of biomass is bio-oil whose production is maximized with the process of fast pyrolysis. Bio-oil, as a product ,has important biochemical applications and can be used as fuel, however, in order to be used in the field of transportation it is necessary its qualities to be improved, which is feasible with the implementation of various upgrading techniques. Syngas is a mixture whose main components are H_2, CO, CO_2 and CH4 and due to its high thermochemical value could stand as alternative gas fuel in the industrial scale. The increasing energy demand, the depletion of oil resources as well as the environmental pollution require the finding of alternative resources and technology for the replacement of fossil fuel, consequently, the pyrolysis of biomass is a technology that can contribute to this direction.
Practice description	Pyrolysis is a thermochemical decomposition process during which biomass is heated at elevated temperature in the absence of oxygen. The process results in the formation of three main products: carbon-rich solid product (biochar), a volatile matter which can further be partially condensed to liquid phase (bio-oil), and the remaining so-called “non-condensable” gases, like CO, CO_2, CH_4, and H_2. Depending upon the reaction time, temperature ,and heating rate the pyrolysis process is sub- divided to four categories :slow, fast, flash, and intermediate pyrolysis. Before the pyrolysis, biomass is dried and ground, if necessary. The slow-pyrolysis reactions are carried out in a reactor which is slowly

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	heated at a rate of 10-30ºC/min. The reactor is continuously swept with nitrogen to remove the produced gases and tars produced during pyrolysis. The temperature of biomass is elevated until the maximum temperature is reached, which range between 300 and 650ºC depending on the desired physicochemical properties of biochar. The slow heating process lasts from a few minutes up to several hours (5 min - 12 h). Once the high temperature is reached, the reactor is kept at this temperature for a specific duration, before the heating device is shut-off and the reactor ambiently cooled. During the cooling phase, the nitrogen flow is continued to purge the reactor of any remaining pyrolysis gases and to prevent any oxygen exposure to the char while it is still above ignition. Low operating temperatures and slow heating rate favor high solid product yield, where the high operating temperatures and high heating rate show significant influence on the carbon percentage, HHV, and BET-surface area of biochar.
General diagram	https://www.researchgate.net/figure/General-layout-of-pyrolysis-process_fig5_351482640
Input components	Feedstock, Max Temperature, Duration (Residence Time), Heating rate, Gaseous atmosphere, Desired Solid yield
Biomass type	Waste
Final products and their use	Biochar, Bio-oil, non-condensable gases
Visual examples of final product	https://www.google.com/imgres?imgurl=https%3A%2F%2Fwww.farm2energy.com%2Fwp-content%2Fuploads%2F2018%2F03%2FBiochar.jpg&imgrefurl=https%3A%2F%2Fwww.farm2energy.com%2Fproducts%2Fbio-char&tbnid=_qvBgzEcQL9PiM&vet=12ahUKEwiKh6Dkwt38AhVZw7sIHagdAZwQxiAoCHoECAAQGw..i&docid=XWpQg7gFbpzacM&w=1440&h=960&itg=1&q=biochar%20from%20gasification&ved=2ahUKEwiKh6Dkwt38AhVZw7sIHagdAZwQxiAoCHoECAAQGw
Spatial coverage	Farm, Local
Practice mobility	Static and Mobile
Level of complexity	Low to Medium

Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	Germany, Denmark, UK, Hungary, Estonia and other countries
Statistical location	
Practice implementation	Pyrolysis is widely used, especially in industrial countries, while researchers are exploring different pyrolysis processes and parameters (e.g. feedstock, temperatures etc.) to improve the properties of the generated end products.
Environmental effects	Benefits: Pyrolysis produce products which contributes to the restoration of polluted land and water, the mitigation of climate change and the replacement of fossil fuels for energy production. Risks: During pyrolysis, tars and gases are released and can cause environmental problems.
Limitations	Wet biomass needs to be dried and ground before the pyrolysis reaction and that may increase the overall cost of the process and reduce the profit of its implementation.
Relevant stakeholders	Farmers, farmers' associations, agro-food industry
EU legislation/recommendation	EBC. European Biochar Certificate: Guidelines for a Sustainable Production of Biochar; European Biochar Foundation (EBC): Arbaz, Switzerland, 2015. [Google Scholar]
	https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12136-Fertilising-products-pyrolysis-and-gasification-materials_en
	IBI. Standardized Product Definition and Product Testing Guidelines for Biochar that Issued in Soil; The International Biochar Initiative (IBI): Philadelphia, PA, USA, 2012. [Google Scholar]
National legislation/recommendation	

References	Production and characterization of slow pyrolysis biochar: influence of feedstock type and pyrolysis conditions https://doi.org/10.1111/gcbb.12018
	A comparative review of biochar and hydrochar in terms of production, physico-chemical properties and applications http://dx.doi.org/10.1016/j.rser.2015.01.050
Additional information and comments	
Editor of the template	Georgios Spyridopoulos' (Q PLAN INTERNATIONAL)

3.22 Sewage Sludge Treatment MTU

P22

Practice summary	
Short title	Sewage Sludge Treatment
Short summary for stakeholders	Sludge processes can be generally divided into the following main categories: Sludge volume, reduction, Sludge quantity reduction, Sludge biosolids production. These categories are not mutually exclusive, e.g., thermal drying substantially reduces sludge volume by evaporation of water and produces a microbiologically safe and stable biosolid by heat treatment of the organic solids. Wastewater Sludge should stop be looked at as waste and start looked as a valuable resource. If we change that mindset from waste treatment to protecting a valuable resource, i.e. just treating organic waste just enough to use it as a ground fill cover. We have all the valuable organic waste that are in people homes and businesses and how do we protect that material, separate it correctly and use it to produce good quality compost. How do we look as a valuable resource and not as a waste, this will drive use and acceptance.
Practice details	
Practice full title	Sewage Sludge treatment
Practice objective and context	First there are several barriers existing for wastewater sludge. There are a number of barriers i.e., the grain growers association that automatically say if you use wastewater sludge that a farmers product will not be certified. Barriers like these need to be changed so that it is not source dependent but rather quality dependent. If we look at a particular sludge, then it should be tested and measured and if that sludge is below a particular level of contaminants, then it should certify that it acceptable for use in an agricultural setting. The new EU fertilizer regulations set out what a fertilizer should with regards to nutrient content, contaminants etc. and if these standards were fully accepted by organizations for fertilizers that originate from wastewater etc. then the acceptance levels would rise dramatically. Looking at the quality of the material is key.

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Practice description	Sludge processes can be generally divided into the following main categories: Sludge volume reduction Sludge quantity reduction Sludge biosolids production. These categories are not mutually exclusive, e.g., thermal drying substantially reduces sludge volume by evaporation of water and produces a microbiologically safe and stable biosolid by heat treatment of the organic solids.

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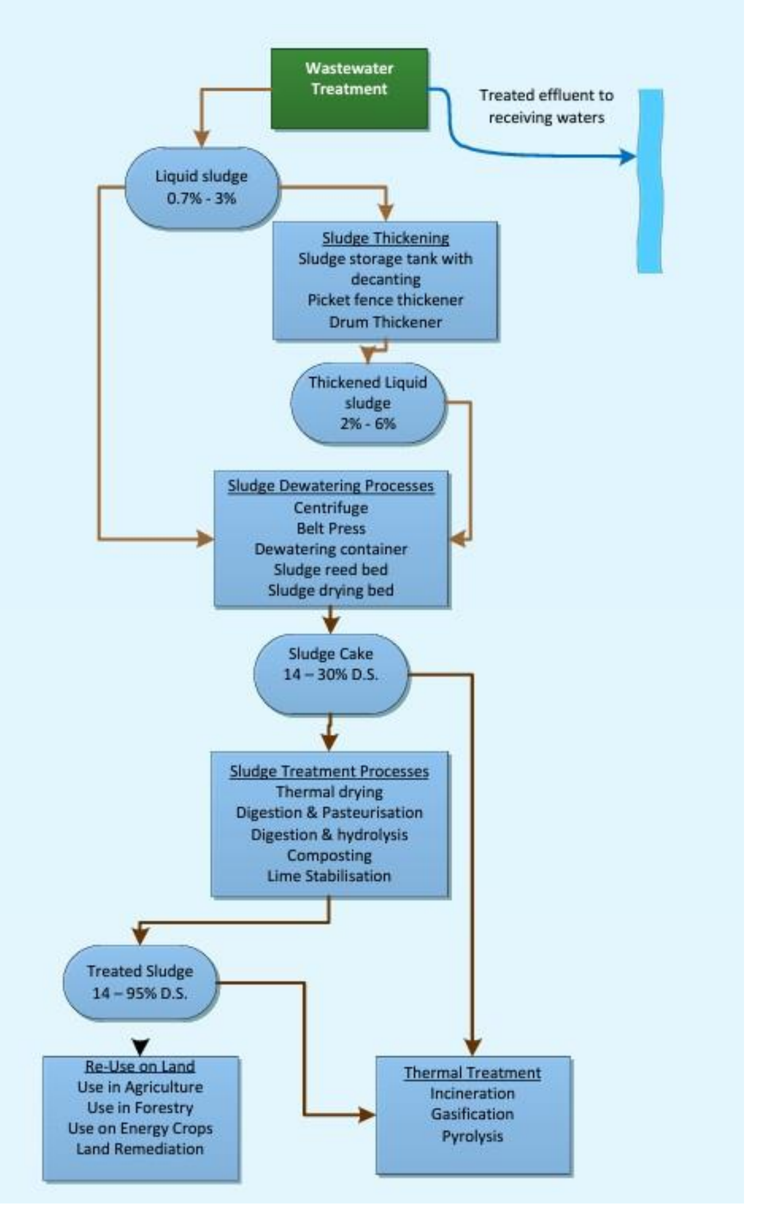
General diagram	

Input components	Waste Water
Biomass type	Waste - low quality biomass of null or negative values
Final products and their use	Treated Sludge 14 – 95% D.S. Re-Use on Land Use in Agriculture Use in Forestry Use on Energy Crops Land Remediation
Visual examples of final product	
Spatial coverage	Farm & Forestry - Local, Regional, National
Practice mobility	Static
Level of complexity	Medium
Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	Ireland
Statistical location	
Practice implementation	Biological sludge is produced at approximately 80% of wastewater treatment plants accounting for over 94% of the population equivalent treated. Biological treatment is most commonly by way of the activated sludge process but other processes including biological filters, rotating biological contactors and trickling filters are also utilized. The quantity of sludge produced decreases as the sludge age increases.
Environmental effects	Wastewater sludge is not as clear if the resulting product is safer or not, In Ireland long term storage is acceptable to make it safer however it is not clear if this is in fact affective. An alkaline stabilization process or an anaerobic digestion process is affective at making sludge safer. It depends on the process that the sledge undergoes to weather it is safer or not.
Limitations	Regulatory limitations : We should stop looking at this material as waste and start looking at it as a valuable resource. If we change that mindset from waste treatment to protecting a valuable resource, i.e. just treating organic waste just enough to use it as a ground fill cover. We have all the valuable

	organic waste that are in people homes and businesses and how do we protect that material, separate it correctly and use it to produce good quality compost. How do we look as a valuable resource and not as a waste, this will drive use and acceptance.
Relevant stakeholders	Irish water primarily & local authorities
EU legislation/recommendation	CEN/TR 13097:2010 : Characterization of sludges - Good practice for sludge utilization in agriculture 2010-06-02 CEN/TS 13714:2013: Characterization of sludges - Sludge management in relation to use or disposal 2013-07-24 CR 13846:2000 : Recommendations to preserve and extend sludge utilization and disposal routes 2000-03-22 CEN/TR 15584:2007 : Characterization of sludges - Guide to risk assessment especially in relation to use and disposal of sludges 2007-07-25 CEN/TR 15809:2008 : Characterization of sludges - Hygienic aspects - Treatments 2008-11-26.
National legislation/recommendation	
References	https://doi.org/10.1016/j.wasman.2012.01.012 https://www.water.ie/docs/Final-NWSMP.pdf
Additional information and comments	
Editor of the template	Robert Ludgate / MTU

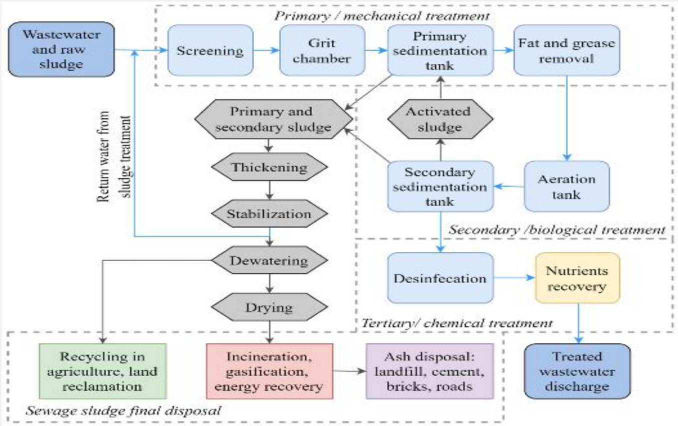
3.23 Sewage sludge Treatment WHITE

P23

Practice summary	
Short title	Sewage Sludge Treatment
Short summary for stakeholders	The process of managing and disposing of the solid by-product generated during wastewater treatment is referred to as sewage sludge treatment. Treatment options for sewage sludge include anaerobic digestion, composting, and landfilling. The primary goal of sewage sludge treatment is to reduce the volume and toxicity of the sludge while recovering valuable resources like energy, nutrients, and organic matter. Cost savings, resource recovery, and sustainability are the primary advantages of implementing sewage sludge treatment practices. Municipalities can reduce the amount of waste that must be landfilled by treating sewage sludge, saving money on disposal costs. Furthermore, recovering resources such as energy and nutrients can generate revenue while reducing the need for resource extraction. Sewage sludge treatment can help to reduce greenhouse gas emissions and protect the environment from a sustainability standpoint. There are several values and benefits for end users: - Cost savings: By treating sewage sludge, municipalities can reduce the amount of waste that must be landfilled, saving money on disposal. Furthermore, recovering resources such as energy and nutrients can generate revenue. -Resource recovery: Treatment of sewage sludge can aid in the recovery of valuable resources such as energy, nutrients, and organic matter. These resources can be used for a variety of purposes, including the production of biogas and fertilizers. -Sustainability: Sewage sludge treatment can aid in the reduction of greenhouse gas emissions and the protection of the environment. The risk of pollution and negative effects on public health and the environment can be reduced by treating sewage sludge. Stakeholders, such as wastewater treatment facilities and governments, can use the results of sewage sludge treatment to inform their waste management decisions and investments. Then they can select the best approach for their specific needs and goals by weighing the cost, efficiency, and sustainability of various sewage sludge treatment options.

Practice details	
Practice full title	Sewage sludge treatment
Practice objective and context	Several factors have contributed to the development of sewage sludge treatment practices: - Environmental regulations: There are laws and regulations in many countries that specify how sewage sludge must be treated before it can be disposed of or reused. These rules are intended to protect the environment and public health by lowering the risk of pollution and disease spread. - Concerns for public health: Proper sewage sludge treatment is critical for public health because untreated sludge can contain harmful pathogens that can cause illness if not properly treated. - Resource recovery: By treating sewage sludge, valuable resources such as nutrients, organic matter, and energy that can be reused or sold can be recovered. - Waste reduction: Proper sewage sludge treatment can reduce waste generation and help to reduce the environmental impact of waste disposal. - Economic considerations: Proper sewage sludge treatment can also save money by reducing the need for landfill disposal and allowing valuable resources to be recovered. Reference: Environmental, economic and social impacts of the use of sewage sludge on land, Part I: Overview Report, Link: https://ec.europa.eu/environment/archives/waste/sludge/pdf/part_i_report.pdf
Practice description	Sewage sludge treatment is the process of removing contaminants from sewage sludge so that it can be reused or disposed of safely. Sewage sludge is a product of the wastewater treatment process that is composed of solid and semi-solid materials removed from sewage during treatment. Treatment of sewage sludge can be accomplished through a variety of methods, including: - Thickening: This process involves removing water from the sludge to increase its solids content. This can be accomplished through gravity thickening, in which the sludge is allowed to settle in a tank, or mechanical thickening, in which the sludge is mechanically dewatered using equipment such as a belt press. - Stabilization and/or disinfection involving biological processes such as anaerobic and aerobic digestion. Anaerobic digestion: Anaerobic bacteria break down organic matter in sludge, producing methane as a product. Methane can be captured and used as a renewable energy source. Aerobic digestion: This process is similar to anaerobic digestion, but it uses oxygen to break down the organic matter in the sludge. - Conditioning: Sewage sludge conditioning is a process that improves the physical and chemical properties of sewage sludge, making it more suitable for further treatment and disposal.

<table>
<tr>
<td></td>
<td>The goal of sewage sludge conditioning is to improve sludge thickening or dewatering.
- Thermal drying: In this process, the sludge is heated to evaporate the water content, leaving a dry, solid material that can be disposed of or used as a soil amendment.



</td>
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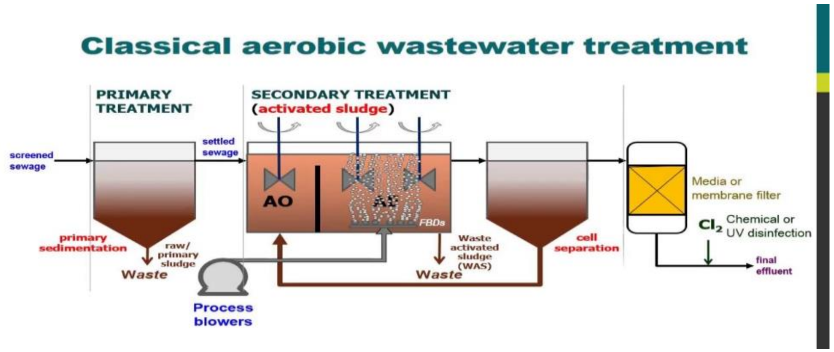
<tr>
<td>General diagram</td>
<td>

Source: https://www.sludgeprocessing.com/aerobic-digestion/aerobic-digestion/</td>
</tr>
<tr>
<td>Input components</td>
<td>The raw materials used in the treatment process are the input components of sewage sludge treatment. These include both the sewage sludge itself and any chemicals or other additives used in the treatment process.
Some common sewage sludge treatment input components include:
- Raw sewage sludge: This is the sludge produced as a product of the wastewater treatment process. It is made up of solid and semi-solid materials extracted from sewage during treatment.</td>
</tr>
</table>

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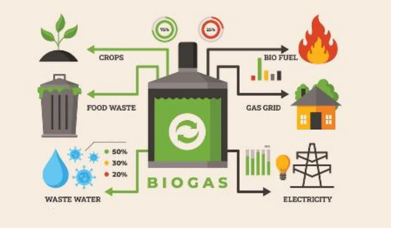
	- Chemicals: To improve the efficiency or effectiveness of the treatment process, various chemicals may be added to the sludge for example, to adjust the pH of the sludge or to provide nutrients to the microorganisms used in the treatment process. - Additives: Additional additives may be added to the sludge to improve its quality or make it more suitable for reuse or disposal. For example, additives may be used to stabilize the sludge, reduce odors, or improve its consistency. References: 1) The presence of contaminations in sewage sludge – The current situation, Krzysztof Fijalkowski et al. (2017), Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7115761/ 2) Application of activated sludge for odor control in wastewater treatment plants: Approaches, advances and outlooks, Fuqiang Fan (2020), Link: https://www.sciencedirect.com/science/article/abs/pii/S0043135420304528
Biomass type	Depending on the specific treatment process used, all three types of biomass - co-product, waste, and dedicated - can potentially be obtained during sludge wastewater treatment. References: https://sswm.info/sites/default/files/reference_attachments/RULKENS%202007%20Sewage%20Sludge%20as%20a%20Biomass%20Resource.pdf
Final products and their use	Dried sludge is a solid material formed after the sludge's water content has been evaporated. It is frequently used as a soil amendment and may contain nutrients like nitrogen, phosphorus, and potassium. - Compost: This is a material created by aerobic digestion of sewage sludge. It is usually used as a soil amendment and may contain nutrients like nitrogen, phosphorus, and potassium. - Biogas: A gas produced by the anaerobic digestion of sewage sludge. It is frequently used as a source of renewable energy. References: 1) Sustainable Sewage Sludge Management Technologies Selection Based on Techno-Economic-Environmental Criteria: Case Study of Croatia, Dinko Durdevic et al. (2022), Link: https://www.mdpi.com/1996-1073/15/11/3941

Visual examples of final product	 ***Dried sludge*** *Source: https://www.dorset.nu/sewage-sludge-dryer-for-8-years-in-operation/*  ***Compost*** *Source: https://www.groworganic.com/blogs/articles/how-to-make-your-own-high-quality-compost-for-compost-tea*  ***Biogas*** *https://www.techquintal.com/biogas/*
Spatial coverage	Depending on the specific treatment process used and the needs and circumstances of the area served, sewage sludge treatment can be done on a local, regional, or global scale.
Practice mobility	Depending on the treatment process, they can be either static or mobile.
Level of complexity	Depending on the specific treatment goals and the characteristics of the sludge being treated, sewage sludge treatment can range from simple, low-tech processes to highly complex, high-tech processes. The type and amount of contaminants present in the sludge, the desired end product, and the available resources are all factors that can influence the level of complexity of sewage sludge treatment (equipment, facilities, etc.)
Replication potential	The replication potential of sewage sludge treatment is difficult to generalize because it varies greatly depending on the specific treatment process and the location where it is replicated. Because of their simplicity, low cost, and ease of implementation, some sewage sludge treatment processes may have a high replication potential. These processes may be applicable in a variety of settings and circumstances. Other treatment processes may have limited replication potential due to their complexity, high cost, or reliance on specialized equipment or conditions. These processes may be more difficult to replicate in different places or situations.
Innovation stage	Commercially available and constantly evolving, as new technologies and approaches emerge. Many of the basic treatment processes, such as thickening, digestion, and drying, have been in use for decades in sewage sludge treatment. These processes have been refined and improved over time, and they are now considered mature technologies. Simultaneously, research and development in the field of sewage sludge treatment is ongoing, and new technologies and approaches are being

	investigated. Overall, the innovation stage of sewage sludge treatment is likely to be a mix of well-established technologies and emerging, cutting-edge approaches. Reference: Available Technologies for Wastewater Treatment, Ifeanyi Michael Smarte Anekwe et al. (2022), Link: https://www.intechopen.com/chapters/81315
Country / Region of implementation	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Norway
Statistical location	
Practice implementation	Sewage sludge treatment is widely used in Europe, and it is an important part of many countries' wastewater treatment processes. According to the European Environment Agency (EEA), approximately 11.1 million tons of sewage sludge were produced in 2018, with 94% of that amount being disposed of. The specific treatment processes used, as well as the management approach, can differ from country to country. According to the European Environment Agency, Estonia, Ireland, and Spain had the highest rates of using treated sludge for agricultural purposes in 2018, while Greece, Cyprus, and Portugal had the lowest rates for agricultural use but higher rates for incineration/composting. Overall, the implementation stage of sewage sludge treatment in Europe is likely to be well-developed, with many countries having well-established systems.
Environmental effects	Environmental benefits: - Reduced Pollution: Treatment of sewage sludge can help to reduce the amount of pollutants and contaminants released into the environment. This has the potential to improve air and water quality while also protecting public health and the environment. - Resource conservation: Treatment of sewage sludge can aid in the recovery of valuable resources such as water, energy, and nutrients that can be used or reused rather than being wasted. - GHG reduction: Some treatment processes, such as anaerobic digestion, can produce methane as a product, which is a potent greenhouse gas. Capturing and utilizing methane as a renewable energy source can aid in the reduction of greenhouse gas emissions. Environmental dangers: - Pollution: If sewage sludge is not properly treated, it can pollute the environment and endanger the public health. - Odors: Some treatment processes can emit odors that are both unpleasant and potentially harmful to human health.

	- Landfill leachate: When treated sludge is disposed of in a landfill, it can generate leachate, a liquid produced when water passes through the landfill and comes into contact with the waste. This leachate must be properly treated before being released into the environment, as it poses a pollution risk.
Limitations	The cost of implementing and operating sewage sludge treatment systems can be prohibitively expensive, especially for smaller communities or countries with limited resources. - Technological barriers: Some sewage sludge treatment technologies are complex or require specialized equipment, which can make implementation difficult in some cases. - Limited treatment capacity: In some cases, a given region may have limited treatment capacity, which can stymie the implementation of new treatment systems. - Regulatory barriers: In some cases, such as the need for permits or compliance with specific regulations, there may be regulatory barriers to the implementation of sewage sludge treatment systems. - Public perception: In some cases, there may be public concern or opposition to the implementation of sewage sludge treatment systems. References: 1) Barriers in Implementation of Wastewater Reuse: Identifying the Way Forward in Closing the Loop J.C. Morris et al. (2021), Link: https://link.springer.com/content/pdf/10.1007/s43615-021-00018-z.pdf?pdf=button 2) Environmental, economic and social impacts of the use of sewage sludge on land, Part I: Overview Report, Link: https://ec.europa.eu/environment/archives/waste/sludge/pdf/part_i_report.pdf
Relevant stakeholders	The following stakeholders may be involved in the performance and implementation of sewage sludge treatment: - All levels of government (federal, state, local), Utility companies and service providers (such as water and wastewater utilities), Operators of treatment facilities, Manufacturers and suppliers of equipment, Companies that manage sludge, industry (e.g., agriculture), environmental groups/organizations, and local governments
EU legislation/recommendation	Existing: 1) The Sewage Sludge Directive (Directive 86/278/EEC), 2) The Urban Waste Water Treatment Directive (UWWTD), 3) The Industrial Emissions Directive (IED), 4) The Waste Framework Directive (Waste FD)
National legislation/recommendation	Ireland: S.I. No. 148/1998 - Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 Reference: https://www.irishstatutebook.ie/eli/1998/si/148/made/en/print
References	Included in each of the sections already.

Additional information and comments	Further actions suggested: 1) Investigate the potential reuse and recycling of by-products from sewage sludge treatment 2) Investigate the environmental effects of various sewage sludge treatment options. 3) Assess the efficacy of various treatment options for various types of sewage sludge. 4) Development of strategies for the safe and long-term management of sewage sludge.
Editor of the template	Sofia Michopoulou/White Research

3.24 Slurry acidification

P24

Practice summary	
Short title	Slurry acidification
Short summary for stakeholders	Slurry acidification is a treatment used to reduce NH_3 emissions to allow farms to comply with national or EU legislation. The reduction in pH decreases ammonia emissions because the proportion of ammoniacal N that is present as NH_3 is reduced. When the pH is decreased from typically around 7.5 to 5.5, the gaseous acid-base compound concentration of NH_3 decreases from 1.8% to 0.02%. The slurry can be acidified at different stages in the manure handling chain. Acidification in the animal house involves pumping acidified slurry into the storage area beneath the slatted floors. Acidifying the slurry at the start of the manure management chain means that emissions are reduced in animal housing, in slurry storage, and after field application. Ammonia emissions from pig housing were reduced by up to 70% when slurry was acidified from pH 7.5 to pH 6 and by 67% following subsequent field application by band-spreading. Another approach is to add the acid in the slurry storage tank just before the slurry is applied to fields or the acid can be applied in-line on the slurry tanker during field application. This approach is cheaper than in-house acidification as less equipment and sulphuric acid are needed for decreasing the pH of the slurry. Ammonia emissions were reduced by 58% during field application when the pH was decreased from 7.8 to 6.8. However, field acidification only reduces NH_3 emissions in the field and does not reduce emissions from animal housing or manure storage. The improved fertilizer value of nitrogen (N) is another advantage of slurry acidification. Lower NH_3 losses following acidification mean more slurry total-N and plant-available N remains in the slurry applied to fields, resulting in an increased mineral N fertilizer equivalent (MFE) value compared to the untreated slurry.
Practice details	
Practice full title	Slurry acidification
Practice objective and context	Reduce the loss of nitrogen from animal manures, which may be easily lost via gaseous emissions (NH_3, N_2O, NO_x, N_2) and leaching of nitrate (NO_3^-) and other N compounds. Besides nitrogen losses, animal and manure emissions of methane (CH_4) to the atmosphere must be reduced, to limit climate change impacts. Slurry contains nitrogen in the form of organic nitrogen and ammoniacal nitrogen. In

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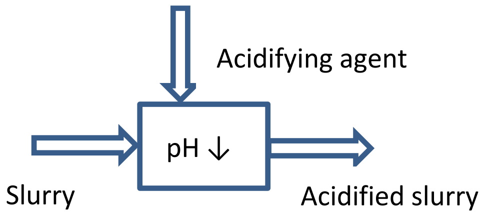
	liquid solutions ammoniacal nitrogen existing as a both ammonia (NH_3) and ammonium (NH_4^+) form. The equilibrium between these forms are largely dependent on solution pH. Ammonia is a gas that easily vaporizes whereas ammonium is stabile in solution. NH_3 emissions are a significant environmental problem impacting human and animal welfare. 80% of the total NH_3 emissions from agricultural activities are from slurry storage and its application to soil. It even accounts for more than 50% of the N used in slurry fertilization. Slurry acidification is a simple treatment used to reduce NH_3 emissions to allow farms to comply with national or EU legislation (BAT conclusion, NEC directive).
Practice description	The addition of acids aids the protonation of ammonia, shifting the equilibrium towards ammonium thus reducing the possibility of nitrogen loss through ammonia evaporation and increasing the nitrogen content of the slurry in effect. When sulfuric acid is used for acidification, then the sulfur content of the slurry is also increased. There are commercially available technologies to acidify slurry in the animal house, before the slurry is pumped to storage, or just before or during spreading. All systems use sulfuric acid for acidification. The acidified slurry is stored or spread with regular equipment. The acidified slurry has characteristics with significantly different buffering capacities, N and P speciation, and electrical conductivity. Slurry acidification can lead to significant CO_2 emissions during the process as well as H_2S emissions during storage. Acidification in the animal house involves pumping acidified slurry into the storage area beneath the slatted floors. Another approach is to add the acid in the slurry storage tank just before the slurry is applied to fields or the acid can be applied in-line on the slurry tanker during field application. This approach is cheaper than in-house acidification as less equipment and sulphuric acid are needed for decreasing the pH of the slurry. However, field acidification only reduces NH_3 emissions in the field and does not reduce emissions from animal housing or manure storage. The improved fertilizer value of nitrogen (N) is another advantage of slurry acidification. Lower NH_3 losses following acidification mean more slurry total-N and plant-available N remains in the slurry applied to fields, resulting in an increased mineral N fertilizer equivalent (MFE) value compared to the untreated slurry.
General diagram	
Input components	Animal slurry, liquid manure, digestate, separated liquid fraction of manure

Biomass type	Co-product, or Waste
Final products and their use	Fertilizer / Acidified slurry or digestate used to crop fertilization
Visual examples of final product	Baltic slurry acidification project YouTube channel https://www.youtube.com/channel/UC1W0TdVuzREXROIsYC6uKaQ 
Spatial coverage	Farm
Practice mobility	Static, Mobile
Level of complexity	Medium to High
Replication potential	Low to Medium
Innovation stage	Commercially available
Country / Region of implementation	Denmark, Estonia, Finland, Latvia, Lithuania, Germany, Netherlands, Poland, Spain, Sweden
Statistical location	

Practice implementation	In Poland, there is one modified in-house system installed on a pig farm where the separated liquid fraction is acidified before it is sent to a storage lagoon. There is also one in-storage system.
Environmental effects	Acidification decreases ammonia emissions from manure and digestate by 50–70%. When the pH is decreased from typically around 7.5 to 5.5, the gaseous acid-base compound concentration of NH_3 decreases from 1.8% to 0.02%. Ammonia emissions from pig housing were reduced by up to 70% when slurry was acidified from pH 7.5 to pH 6 and by 67% following subsequent field application by band-spreading. If slurry is acidified during the storage period, it will also reduce methane emissions by +90% during storage. Some studies suggest that acidification can reduce nitrous oxide emissions but there is not consensus on this in scientific literature
Limitations	The fear of farmers relative to the handling of concentrated acids (mainly sulfuric acid) Operation has to be performed by trained staff and implies, in most cases, to rely on contractors
Relevant stakeholders	Farmers, Advisors, SME, Local administration.
EU legislation/recommendation	Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants.
	Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).
	European Commission, Joint Research Centre. 2017. Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs (BREF) – BAT 16, 21, 23, 30, European Commission. 2017. Commission Implementing Decision (EU) 2017/302 of 15 February 2017 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for the intensive rearing of poultry or pigs. The Nitrates Directive, Council Directive 91/676/EEC of 12 December 1991
National legislation/recommendation	PL: Ustawa o nawozach i nawożeniu (The act on fertilisers and fertilisation) z dnia 10 lipca 2007 r. (Dz.U. 2007 nr 147 poz. 1033) PL: Rozporządzenie Rady Ministrów z dnia 31 lutego 2023 r. w sprawie przyjęcia „Programu działań mających na celu zmniejszenie zanieczyszczenia wód azotanami pochodzącymi ze źródeł rolniczych oraz zapobieganie dalszemu zanieczyszczeniu", (Regulation of the Council of Ministers of February 12, 2020 on the adoption of the "Action Program to reduce water pollution with nitrates from agricultural sources and to prevent further pollution") (Journal of Laws of 2020, item 243) (Dz.U. 2023 poz. 244) PL: Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 16 kwietnia 2008 r. w sprawie szczegółowego sposobu stosowania nawozów oraz prowadzenia szkoleń z zakresu ich stosowania

	(Regulation of the Minister of Agriculture and Rural Development on the detailed method of applying fertilizers and conducting training in the field of their use) (Dz. U. 2018 poz. 1438) PL: Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska, (Environmental Protection Law) (Dz.U. 2001 nr 62 poz. 627) PL: Biełka I., Pietruszka A. 2017. Wytyczne dotyczące praktycznego zastosowania Konkluzji BAT w zakresie intensywnego chowu drobiu i świń, część 2 Instalacje do chowu świń, Ministerstwo Środowiska, (Guidelines for the practical application of the BAT Conclusions for the intensive rearing of poultry and pigs, part 2 Installations for rearing pigs, Ministry of the Environment). https://www.ekoportal.gov.pl/fileadmin/user_upload/Wytyczne_dotyczace_praktycznego_zastosowania_Konkluzji_BAT_w_zakresie_intesywnego_chowu_drobiu_i_swin_-_Czesc_II_Instalacje_do_chowu_swin.pdf
References	Mazur, K. & Sindhoj, E. 2017. Description of slurry acidification techniques (SATs) and how they are practiced. In: Possibilities and Bottlenecks for implementing SATs in the Baltic Sea Region. www.balticslurry.eu
	Fangueiro, D., Hjorth, M. & Gioelli, F. 2015. Acidification of animal slurry – a review. Journal of Environmental Management 149: 46–56.
Additional information and comments	
Editor of the template	Piotr Skowron, Damian Wach /IUNG

3.25 Small-scale green biorefining

P25

Practice summary	
Short title	Small-scale green biorefining
Short summary for stakeholders	Small-scale green biorefineries are low-cost operating units operated independently at farm or community level. Feedstocks used are fresh grasses and other protein-rich biomass such as leguminous crops, green leaves, sugar beet leaves, beet, carrot, green leaf crops waste (lettuce, spinach, cabbage, cassava, rice, palm tree etc.), fresh pruning waste from horticulture etc. A suite of co-products is resulting including an optimized cattle fodder silage, protein concentrate feed for monogastrics, high value prebiotic sugars for animal and human nutritional health and a nutrient-rich fertilizer, applying a zero-waste biorefinery ethos, ensuring that all components of the grass are utilized in a circular manner. The application of grass whey as a fertilizer would be particularly suitable in small-scale mobile biorefinery systems where processing is taking place directly across multiple farms. Additionally, by depositing animal manure to crops, the nutrient loop of closes at farm level as nitrogen, phosphorus and potassium are recycled back to land, diminishing the need of fertilizing. Results from Feeney et al. (2020) found that application of grass whey, as a sole source of fertilizer to grass plots, yield similar grass yields to slurry. In particular, previous research has showed that there is some potential to concentrate this whey into a potassium-rich concentrate, due to their high potassium concentration, which would be suitable for using on potassium deficient soils (Ravindran et al., 2022) The integration of green biorefinery with anaerobic digestion, wherein, whey is used as a biogas substrate, further improves the suitability of the whey, in the form of biogas digestate, to be used as a fertilizer source.
Practice details	
Practice full title	Small-scale green biorefining
Practice objective and context	Grass whey is the residual stream obtained from a green biorefinery fed by fresh grass, following removal of a press cake fiber fraction and protein concentrate. The residual whey stream, after high value components have been extracted, can be used as a nutrient fertilizer to fields supplying the grass to be used as feedstock for the green biorefinery. In relevant projects, it has been proved that grass whey supported grass growth and performed comparably with slurry across the demonstration

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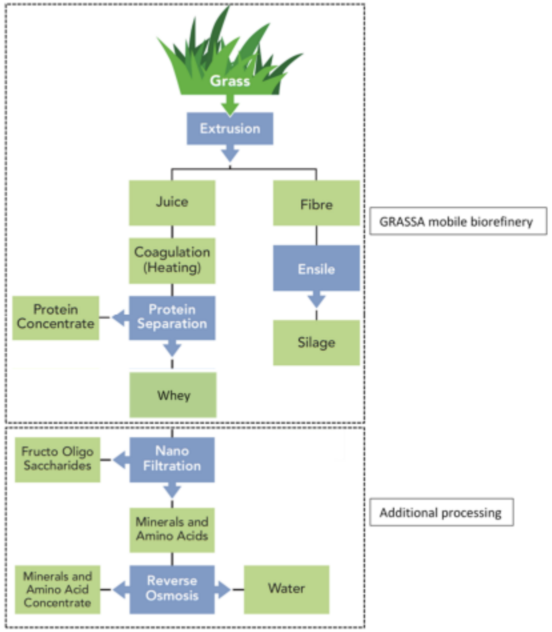
	farms. The application of grass whey as a fertilizer would be particularly suitable in small-scale mobile biorefinery systems where processing is taking place directly across multiple farms.
Practice description	A small, mobile, compact refiner that fits on a trailer and can process between 300-600 kg/h. The technology used is based on the combination of successive steps of grinding, pressing, heating, precipitating, ultrafiltration and reverse osmosis to reduce grass moisture content, separate and concentrate the valuable components in different streams. Apart from grass, several other kinds of fresh green biomass can be used as feedstock such as alfalfa, green leaf crops waste (lettuce, spinach, cabbage etc.), fresh pruning waste from horticulture and aquatic plants. Outputs: (i) ensiled fiber to be used as animal feed (cattle, pigs, chicken), containing resistant proteins and dietary fibers, (ii) protein concentrate that can serve as animal feed/ rape meal substitute and soya meal replacement (non-ruminant livestock) (iii) phosphate concentrate, to be used as biofertilizer, (iv) nano filtration concentrate, rich in sugars, polyvalent ions and minerals that can be used as feedstock for bio-based industry to retreat valuable sugar compounds, (v) mineral concentrate, rich in potassium and amino acids to be used as biofertilizer, (vi) water
General diagram	 Source: https://biorefineryglas.eu/wp-content/uploads/2021/03/Biorefinery-Glas-D1.3.pdf

Input components	Fresh green biomass can be used as feedstock such as alfalfa, green leaf crops waste (lettuce, spinach, cabbage etc.), fresh pruning waste from horticulture and aquatic plants
Biomass type	Dedicated
Final products and their use	Grass whey based biofertilizer (high K concentration, low P concentration)
Visual examples of final product	
Spatial coverage	Farm, local
Practice mobility	Mobile
Level of complexity	Medium
Replication potential	High
Innovation stage	Prior to market introduction
Country / Region of implementation	Ireland, Netherlands
Statistical location	
Practice implementation	TRL 7
Environmental effects	Using grass whey as a biofertilizer that the nutrient value of grass biorefinery residue can be retained and recycled ensuring a more circular use of nutrients. Combined with the grass biorefinery it helps to realize a more optimum use of nitrogen and other macronutrients in grass
Limitations	
Relevant stakeholders	Farmers, technology providers
EU legislation/recommendation	

National legislation/recommendation	
References	https://biorefineryglas.eu/wp-content/uploads/2021/03/Biorefinery-Glas-D2.6.pdf https://www.youtube.com/watch?v=Z1UFHU-rt9s
Additional information and comments	
Editor of the template	Evangelia Tsagaraki (Q-PLAN INTERNATIONAL)

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3.26 Smart combined stable system

P26

Practice summary	
Short title	Smart combined stable system - Lely Sphere
Short summary for stakeholders	Lely Sphere is a circular barn system to separate mineral streams and valorize emissions. The system separates manure and urine, besides it transforms nitrogen emissions to valuable fertilizers which can be used within precision fertilization. To be more precise the manure is split into three different mineral streams: the urine containing potassium, the solid fraction of the manure with organic nitrogen and phosphorus and a acidified solution coming from the filter systems containing mineral nitrogen of artificial fertilizer quality.
Practice details	
Practice full title	Smart combined stable system - Lely Sphere
Practice objective and context	Lely Sphere is a smart stable system that reduces emissions in the stables by a couple of connected systems. On 1-okt-2021 the Lely Sphere barn system is officially taken up in the RAV-list (Dutch regulation ammonia in livestock farming). On this list emission reducing flooring systems and intelligent low emission systems are present. The RAV-list systems are proven to reduce ammonia emissions within the barn. The Lely Sphere system is on the list with a value of 3.6 kg ammonia per animal housing place per year. A regular traditional raster flooring system has a score of 13.0 kg ammonia per animal housing place per year, in other words a 70% emission reduction takes place using the Lely Sphere system
Practice description	The Lely Sphere separation floor has separation strips on it which closes the regular raster flooring. The stainless steel strips contain holes via which urine and air can float towards the vault. Manure will stay on the floor. Due to this separation the manure and urine are not mixed as much as normally which reduces the ammonia emissions. The Lely discovery 120 collector is not a manure scraper but a manure vacuum cleaner (only possible on closed floors like the lely sphere separation floor) which provides a cleaner floor and cleaner feet of the cows. Besides the lely Sphere N-capture provides an negative pressure which creates an suction effect of air and manure gasses both on top and below

	the Lely Sphere separation floor. The air flows through an air scraper in the N-Capture device which collects the nitrogen.
General diagram	https://www.youtube.com/watch?v=d9T1_WfOM10
Input components	Manure, urine, air
Biomass type	Co-product. Cow manure and urine
Final products and their use	Separated urine, separated manure, mineral nitrogen concentrate
Visual examples of final product	https://www.lely.com/nl/oplossingen/huisvesting-en-verzorging/sphere/
Spatial coverage	Farm
Practice mobility	Static
Level of complexity	Medium
Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	Netherlands
Statistical location	a.o. Firma Nescio (Bleskensgraaf, the Netherlands) https://www.facebook.com/farmnescio/
Practice implementation	Multiple farmers work already with the system.
Environmental effects	Lower ammonia emissions due to the direct separation of manure and urine and the negative pressure system including air stripper
Limitations	The barn flooring should be adjustable
Relevant stakeholders	Lely and the individual farmers

EU legislation/recommendation	
National legislation/recommendation	Is on the RAV list for approved methods for less N emission from stables
References	https://research.wur.nl/en/publications/protocol-voor-meting-van-ammoniakemissie-uit-huisvestingssystemen-2 https://www.youtube.com/watch?v=UfxkKpZtag8
Additional information and comments	
Editor of the template	WUR (ACRRES)

3.27 Struvite precipitation

P27

Practice summary	
Short title	Struvite precipitation
Short summary for stakeholders	The practice aims to recover phosphorus and ammonium nitrogen from the liquid fraction of digestate based on animal manure or slurry. The product obtained is a solid fertilizer (slow N release fertilizer) - struvite (magnesium nitrogen-phosphate salt). Precipitation and formation (crystallization) of struvite is chemical reaction between magnesium, ammonium and phosphate in equal stoichiometric proportions. Struvite precipitation is forced by adding magnesium ions to slurry or liquid fraction of digestate. The process requires pH adjustment in the range of 8.3-10 (e.g. with addition of NaOH). The effect of struvite precipitation is removal 80–90% of soluble P in the processed liquid fraction and 10–40% of NH_4-N. Reduction of the nutrient concentration in input components can enhance the capability of slurry management in areas with nitrogen/phosphorus surplus.

Practice details	
Practice full title	Struvite precipitation
Practice objective and context	The practice aims to recover phosphorus and ammonium nitrogen from the liquid fraction of digestate based on animal manure or slurry. The product obtained is a solid fertilizer - struvite (magnesium nitrogen-phosphate salt). The use of practice allows to reduce ammonia emissions, storage space and application. Reduction of the nutrient concentration in input components can enhance the capability of slurry management in areas with nitrogen/phosphorus surplus.
Practice description	Precipitation and formation (crystallization) of struvite is chemical reaction between magnesium, ammonium and phosphate in equal stoichiometric proportions. Struvite precipitation is forced by adding magnesium ions to slurry or liquid fraction of digestate. The process requires pH adjustment in the range of 8.3-10 (e.g. with addition of NaOH). The major limitation of the process is the P concentration and N/P molar equivalence in liquid slurries/manures. The effect of struvite precipitation is removal 80–90% of soluble P in the processed liquid fraction and 10–40% of NH_4-N.

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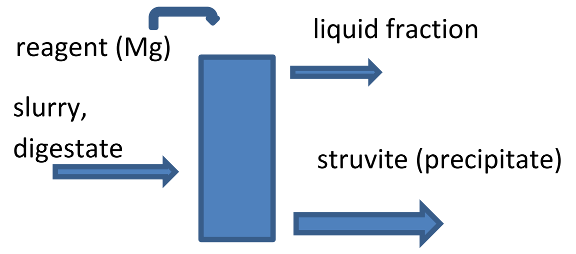
General diagram	
Input components	Slurry, liquid fraction of digestate
Biomass type	Co-product, waste
Final products and their use	Slow N release fertilizer, ($MgNH_4PO_4 * 6H_2O$)
Visual examples of final product	https://doi.org/10.1016/j.arabjc.2013.10.007
Spatial coverage	Farm, local
Practice mobility	Static, (mobile)
Level of complexity	Medium
Replication potential	Medium
Innovation stage	Commercially available
Country / Region of implementation	
Statistical location	
Practice implementation	

Environmental effects	There are no emissions from the reactors, but with elevated pH and strong agitation there is a risk of ammonia volatilization.
Limitations	
Relevant stakeholders	Farmers, biogas plants
EU legislation/recommendation	Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
National legislation/recommendation	
References	Jaffer, Y., Clark, T.A:, Pearce, P., Parsons, S.A. (2002). Potential phosphorus recovery by struvite formation. Water Research 34, 18341842. Zarebska, A., Nieto, D.R., Christensen, K.V., Søtoft, L.F. & Norddahl, B. 2015. Ammonium fertilizers production from manure: A critical review. Critical Reviews in Environmental Science & Technology 45: 1469–1521
Additional information and comments	
Editor of the template	Damian Wach, IUNG

3.28 Thermal drying

P28

Practice summary	
Short title	Thermal drying
Short summary for stakeholders	Thermal drying of solid manure or the separated solid fraction from liquid manure/digestate is aimed at reducing its total weight, increasing the concentration of nutrients and stabilizing and sanitizing the final product. Ammonia losses during drying can be reduced by using a scrubber or by acidifying the substrate. Practice allows to improve the storage and transport of the final product and to meet the requirements for large agricultural producers in the BAT conclusions. Thermal drying can be carried out using the following technologies: contact/convection technologies, conductive technologies, infrared drying. Solar, freeze-drying and superheated steam drying technologies are available for sewage sludge. Dried product can be pelletized for easier transport and field application.
Practice details	
Practice full title	Thermal drying
Practice objective and context	Thermal drying of solid manure or the separated solid fraction from liquid manure/digestate is aimed at reducing its total weight, increasing the concentration of nutrients and stabilizing and sanitizing the final product. However, this practice is quite challenging due to high investment cost, high energy requirement and potential nitrogen loss. Ammonia losses during drying can be reduced by using a scrubber or by acidifying the substrate. Practice allows to improve the storage and transport of the final product and to meet the requirements for large agricultural producers in the BAT conclusions.
Practice description	High moisture manure can lead to higher transport costs, faster reproduction of pathogens/bacteria and flies, and the generation of odors. Furthermore, wet manure tends to lose a higher ratio of nitrogen (N) as moisture plays a key role in the generation and emissions of ammonia (NH_3) especially from poultry manure. Thermal drying can be carried out using the following technologies: contact/convection technologies, conductive technologies, infrared drying. Solar, freeze-drying and superheated steam drying technologies are available for sewage sludge. Dried product can be pelletized for easier transport and field application.

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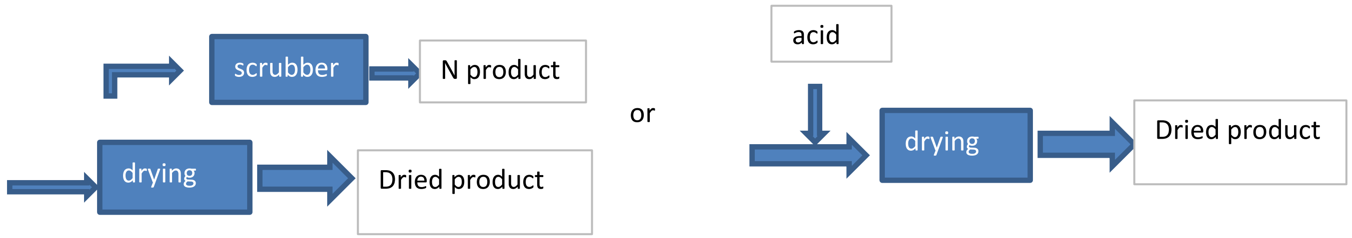
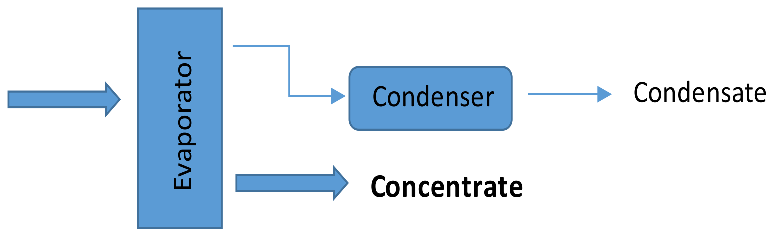
General diagram	
Input components	Manure, separated solid fraction from liquid manure/digestate, sewage sludges
Biomass type	Co-product, waste
Final products and their use	Fertilizer with high P and N content
Visual examples of final product	https://sustainablesales.com/heat-treated/6-2-2/
Spatial coverage	Farm, local
Practice mobility	Static
Level of complexity	Medium
Replication potential	Medium
Innovation stage	Commercially available
Country / Region of implementation	
Statistical location	
Practice implementation	

Environmental effects	Potential risk of air pollutant emissions. Acidification at the beginning of the process or scrubbing/filtration air from dryer is necessary to avoiding ammonia (NH_3) or organic volatiles (VOC) emissions.
Limitations	High cost equipment, high energy consumption
Relevant stakeholders	
EU legislation/recommendation	BAT Conclusion, NEC Directive
National legislation/recommendation	
References	Aboltins A., Kic P. 2015. Forced convection in drying of poultry manure. Agronomy Research. 13 (1), 215–22. Bolzonella, D., Fatone, F., Gottardo, M. & Frison, N. 2018. Nutrients recovery from anaerobic digestate of agro-waste: Techno-economic assessment of full scale applications. Journal of Environmental Management 216: 111–119.
Additional information and comments	
Editor of the template	Damian Wach, IUNG

3.29 Vacuum evaporation

P29

Practice summary	
Short title	Vacuum evaporation
Short summary for stakeholders	The aim of the practice is to remove water and increase the concentration of nutrients contained in the concentrate. Vacuum evaporation is carried out at negative pressure in a closed vessel (evaporator). The processed liquid is sprayed on the inner surface of the evaporator. Vacuum conditions allow you to lower the boiling point of water to 40-75. Evaporation allows to recover 80–99% of N and 85–100% of P from the treated liquid fraction. The side product, condensate can be used as process water or be treated with RO to produce clean water.
Practice details	
Practice full title	Vacuum evaporation
Practice objective and context	The aim of the practice is to remove water and increase the concentration of nutrients contained in the concentrate. The end product of the process is a concentrate that contains 80-99% nitrogen and 85-100% phosphorus from the treated liquid fraction. Reduced volume requires less storage space. Additionally, the condensate (side product) formed in the process can be used as process water
Practice description	Vacuum evaporation is carried out at negative pressure in a closed vessel (evaporator). The processed liquid is sprayed on the inner surface of the evaporator. Vacuum conditions allow you to lower the boiling point of water to 40-75. Evaporation allows to recover 80–99% of N and 85–100% of P from the treated liquid fraction. The side product, condensate can be used as process water or be treated with RO to produce clean water.
General diagram	

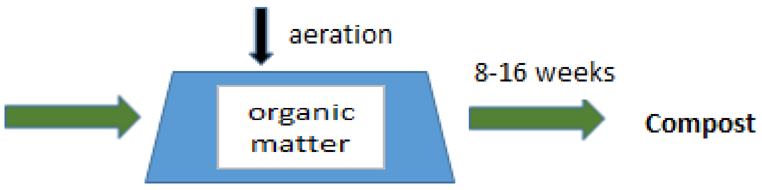
Input components	Liqud fraction
Biomass type	Co-product
Final products and their use	Concentrate, liquid NPK fertilizer
Visual examples of final product	
Spatial coverage	Regional, industry
Practice mobility	Static
Level of complexity	High
Replication potential	Low/medium
Innovation stage	Commercially available
Country / Region of implementation	
Statistical location	
Practice implementation	
Environmental effects	No negative effects, since evaporated flow is recovered as a condensate.
Limitations	
Relevant stakeholders	
EU legislation/recommendation	Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products

	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
National legislation/recommendation	
References	Guercini S., Castelli G., Rumor C. (2014). Vacuum evaporation treatment of digestate: full exploitation of cogeneration heat to process the whole digestate production. Water Science and Technology, 70(3), 479–485. doi:10.2166/wst.2014.247
	Bonmatí A, Flotats X. Pig slurry concentration by vacuum evaporation: influence of previous mesophilic anaerobic digestion process. J Air Waste Manag Assoc. 2003 Jan;53(1):21-31. doi: 10.1080/10473289.2003.10466112.
Additional information and comments	
Editor of the template	Damian Wach, IUNG

3.30 Waste composting/hygienization

P30

Practice summary	
Short title	Waste composting/hygienization
Short summary for stakeholders	Composting is a sustainable waste management practice that converts any volume of accumulated organic waste into a usable product. When organic wastes are broken down by microorganisms in a heat-generating environment, waste volume is reduced, many harmful organisms are destroyed, and a useful, potentially marketable, product is produced. The first stage of composting is decomposition of organic matter, which is result of exothermic reactions causing the temperature of the compost matrix to increase to above 50°C. These reactions require oxygen and it is need to conduct aeration in this phase. In a second stage, curing is produced. While organic compounds are degraded and humic acids are produced, temperature slowly decreases. Composting lasts between 8 to 16 weeks. The effectiveness of the composting process is influenced by factors such as temperature 40–65°C), oxygen supply (i.e. aeration), moisture content (40–65%), pH, C/N ratio (25–35), particle size and degree of compaction.
Practice details	
Practice full title	Waste composting/hygienization
Practice objective and context	Composting is a sustainable waste management practice that converts any volume of accumulated organic waste into a usable product. When organic wastes are broken down by microorganisms in a heat-generating environment, waste volume is reduced, many harmful organisms are destroyed, and a useful, potentially marketable, product is produced. Organic wastes may include manure from livestock operations, animal bedding, yard wastes, such as leaves and grass clippings, and even kitchen scraps. Composting is a spontaneous, aerobic and thermophilic process (40-65°C), which causes mineralization and partial humification of organic matter. The main purpose of composting is to reduce the cost of transporting nutrients by reducing weight and stabilizing the material, resulting in an odorless, weed-free and low-pathogenic soil amendment.

Practice description	The first stage of composting is decomposition of organic matter, which is result of exothermic reactions causing the temperature of the compost matrix to increase to above 50°C. These reactions require oxygen and it is need to conduct aeration in this phase. In a second stage, curing is produced. While organic compounds are degraded and humic acids are produced, temperature slowly decreases. Composting lasts between 8 to 16 weeks. The effectiveness of the composting process is influenced by factors such as temperature 40–65°C), oxygen supply (i.e. aeration), moisture content (40–65%), pH, C/N ratio (25–35), particle size and degree of compaction. The microorganisms which degrade organic wastes use carbon for energy, and nitrogen for protein. Organic matter contains carbon and nitrogen in varying amounts and ratios. A Carbon : Nitrogen (C:N) ratio of 30:1 is considered ideal for composting. Too much carbon or very large particle size slows the process down. When too much N is present, the compost may become too hot, killing the composting organisms.
General diagram	
Input components	Leaves and grass clippings, kitchen scraps, animal bedding, yard waste
Biomass type	Waste
Final products and their use	Compost
Visual examples of final product	https://www.agrifarming.in/organic-compost
Spatial coverage	Farm, local
Practice mobility	Mobile
Level of complexity	Low to medium

Replication potential	High
Innovation stage	Commercially available
Country / Region of implementation	
Statistical location	
Practice implementation	This practice is commercially available. Process is widely used by city cleaning companies and by farmers.
Environmental effects	Composting stabilizes organic matter, however, it is associated with GHG emissions. The carbon lost is in the forms of CO_2 and CH_4. Emission of N_2O is relatively low.
Limitations	
Relevant stakeholders	
EU legislation/recommendation	Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
National legislation/recommendation	PL: Ustawa o nawozach i nawożeniu (The act on fertilisers and fertilisation) z dnia 10 lipca 2007 r. (Dz.U. 2007 nr 147 poz. 1033) PL: Rozporządzenie Rady Ministrów z dnia 31 lutego 2023 r. w sprawie przyjęcia „Programu działań mających na celu zmniejszenie zanieczyszczenia wód azotanami pochodzącymi ze źródeł rolniczych oraz zapobieganie dalszemu zanieczyszczeniu”, (Regulation of the Council of Ministers of February 12, 2020 on the adoption of the "Action Program to reduce water pollution with nitrates from agricultural sources and to prevent further pollution") (Journal of Laws of 2020, item 243) (Dz.U. 2023 poz. 244)

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	PL: Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 16 kwietnia 2008 r. w sprawie szczegółowego sposobu stosowania nawozów oraz prowadzenia szkoleń z zakresu ich stosowania (Regulation of the Minister of Agriculture and Rural Development on the detailed method of applying fertilizers and conducting training in the field of their use) (Dz. U. 2018 poz. 1438)
References	Ayilara, M.S. Olanrewaju, O.S. Babalola, O.O. Odeyemi, O. Waste Management through Composting: Challenges and Potentials. Sustainability 2020, 12, 4456. https://doi.org/10.3390/su12114456 Chukwudi O. Onwosi, Victor C. Igbokwe, Joyce N. Odimba, Ifeanyichukwu E. Eke, Mary O. Nwankwoala, Ikemdinachi N. Iroh, Lewis I. Ezeogu, Composting technology in waste stabilization: On the methods, challenges and future prospects, 2017, Journal of Environmental Management, 190, 140-157 https://doi.org/10.1016/j.jenvman.2016.12.051.
Additional information and comments	
Editor of the template	Damian Wach, IUNG

3.31 Wetlands

P31

Practice summary	
Short title	Wetlands (collection of nutrients)
Short summary for stakeholders	Like nitrogen, phosphorus can lead to an increased growth of algae, which makes the water cloudy. This has a negative effect on the lake's other animal and plant life. The deteriorated conditions cause the lake to become out of balance, so that the good ecological condition cannot be maintained. Wetlands and mini wetlands aims to remove nitrogen from the water that ends up in the Danish fjords and coastal waters, where nitrogen is a problem. A wetland can be created either by closing drains in order to irrigate the area with drainage water from the surrounding areas, establishing a shallow lake, or by raising the streambed and re-winding the course so that the areas close to the stream are periodically flooded. Regardless of how a wetland is established, a wetland contributes to nitrogen reduction by bacteria in the wet soils breaking down nitrates in the water and thereby releasing gaseous nitrogen. In addition, the cessation of cultivation of the agricultural land contributes to reducing nitrogen emissions. A mini-wetland consists of a wetland and a sedimentation basin. The wetland area is designed with several basins which clean the drainage water from the drainage catchment(s) that drains into the mini-wetland area. In connection with the wetland, a sedimentation basin will be established, where sediment and particle-bound phosphorus will settle. Nitrogen removal takes place primarily by biological conversion of nitrate into free gaseous nitrogen via microbial denitrification. Denitrification is an anaerobic process and takes place primarily in the oxygen-free bottom sediment, while the water phase in mini-wetlands with surface flow is always oxygenated. The plants in the mini-wetland area are important as they contribute to supplying the bacteria with carbon for use in microbial denitrification.
Practice details	
Practice full title	Wetlands (collection of nutrients)

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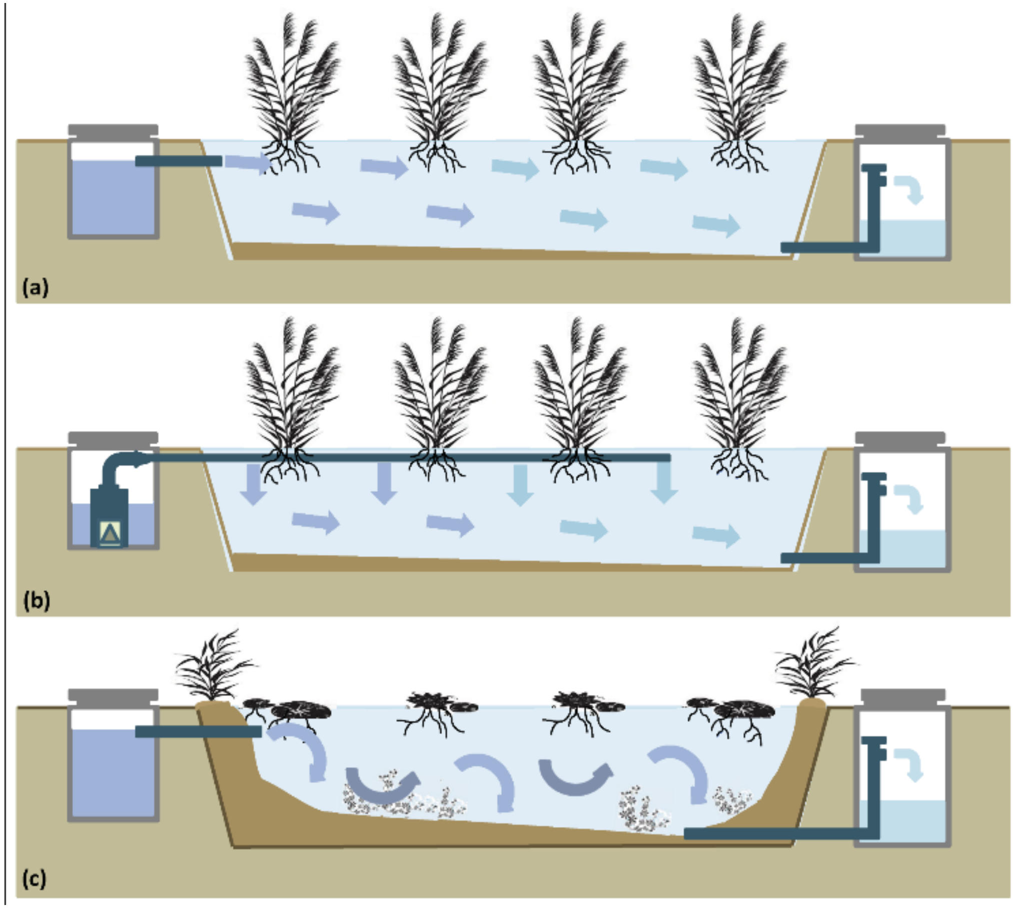
Practice objective and context	Supplying nitrogen to the fields is a prerequisite for food production. Denmark is an agricultural country with a good climate prerequisite for agricultural production, and we produce food enough to feed three times the number of people living in Denmark. Nitrogen is added to the soil when we fertilize with livestock and commercial manure, when leguminous plants bind nitrogen from the air and to a smaller extent, with precipitation and air. Too much nitrogen and phosphorus change the balance between plants and animals in lakes and coastal areas. This can result in cloudy water, fewer large plants, and oxygen loss. However, the loss of nitrogen to the aquatic environment has more than halved since the 1980s because of a large research and advisory effort, political regulation and skilled Danish farmers who have adapted to new production conditions. The EU has adopted the Water Framework Directive, which is the starting point to set the limits for the discharge of nitrogen into inlets etc., which is administered after today in Denmark. Wetlands (and mini wetlands) is a valuable tool to reduce the amount of nitrogen and phosphorus discharge to the Danish coastal waters, inlets and lakes, where the nutrients create environmental problems. In this practice the residence time for surface and drainage water between fields and coastal waters is increased, and by the nitrate-containing water during transport meets organic material. These are the mechanisms that are put into play by re-establishing lakes and wetlands or create mini wetlands. And by very small measures on the individual property where the farmer cuts off some drains and lets the water run down over grass areas that are no longer used.
Practice description	Wetlands can be divided into three main types: 1. Areas flooded by stream water. It happens by re-establish the stream with natural meanders and raise the bottom of the stream, so that the current speed in the stream is lowered and the areas close to streams are periodically flooded. 2. Areas through which groundwater flows. It happens by drains or ditches are looped on the low-lying areas so that the water flows naturally as groundwater or surface water 3. Areas that are irrigated with drainage and/or ditch water. It happens by diverting water from the higher lying areas to the wetland through ditches or drains that are interrupted at the edge of the wetland. The water is distributed in the wetland by infiltration or irrigation. The goal is for the soil to be waterlogged or flooded during the winter months, when the greatest runoff of nutrients from the catchment area going. The speed of the water is lowered and thus the residence time of the water in it is increased the wetland. This creates the best conditions for denitrification and deposition of nutrients. All these conditions result in a high N effect in the wetlands. A mini wetland consists of a wetland and a sedimentation basin. The wetland area is designed with several basins which clean the drainage water from the drainage catchment(s) that drains into the mini-wetland area. In connection with the wetland, a sedimentation basin will be established, where sediment and particle-bound phosphorus will settle.

General diagram	
Input components	Water, drain from agricultural land.
Biomass type	Phosphorus is retained in the sediment pool, as it is bound to particles, and can be used as a fertilizer.
Final products and their use	Improved water quality in lakes and inlets
Visual examples of final product	https://oplandskonsulenterne.dk/minivaadomraader/

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Spatial coverage	Farm, local, regional, national
Practice mobility	Static
Level of complexity	Low but requires some preparation and planning.
Replication potential	Medium, requires some specific conditions to have the optimal effect. Wetlands are applicable in natural wet areas, with low soil fields. Mini wetlands are most applicable in clay soils.
Innovation stage	Commercial, allocated subsidies.
Country / Region of implementation	Denmark
Statistical location	
Practice implementation	There is a high potential in converting farmland to wetland and to establish mini wetlands. Since Water Environment Plan II was adopted in 1998, 182 have been implemented wetland projects around Denmark. Before the end of the water area plans' second planning period in 2021 collective nitrogen efforts must be carried out for a total of approx. 2,500 tons N. Wetlands alone must remove 1,250 tons. That's why it's a lot important that as many environmental efforts as possible are established in Denmark in the coming years. Among the possible means of action can be mentioned mini-wetlands, afforestation, wetlands, and low-lying projects.
Environmental effects	Wetlands- and mini-wetlands are effective filters in the landscape that clean drainage water of nitrogen and phosphorus. Nitrogen removal takes place primarily by biological conversion of nitrate into free gaseous nitrogen via microbial denitrification. Denitrification is an anaerobic process and takes place primarily in the oxygen-free bottom sediment, while the water phase in mini-wetlands with surface flow is always oxygenated. The plants in the mini-wetland area are important as they contribute to supplying the bacteria with carbon for use in microbial denitrification. The mini-flood area must be placed in connection with a drainage catchment and adapted to the slope of the terrain to avoid back-up or backflow in drainage pipes. The mini-wetland works by diverting the drainage water into open basins, where sedimentation and microbial processes reduce the discharge of nitrate and phosphorus. Mini-wetland areas contributes to maintaining good fertilizer standards, ensures a lasting nitrogen effect with virtually no maintenance, creates life and variety with open pools of water and is a visible proof of concern for the environment.

Limitations	Financial loss from reduced production and transparency of subsidies may cause restraints from farmers in establishing wet- and mini wetlands. At the present, wetland subsidy schemes are accessible to restore natural water conditions in the places in the landscape that are suitable for this. Wetlands have good and safe effects on the environment and nature, and there can be good economics in participating in a larger wetland project. However, the mindset and support from both landowners and neighbors. Wet- and mini-wetlands also have a very positive impact on nature restoration and biodiversity and can be of benefit for both wildlife and people living and resides in the area.
Relevant stakeholders	Danish Agricultural Agency. Environmental Protection Agency
EU legislation/recommendation	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32000L0060 https://lbst.dk/tvaergaaende/eu-reformer/landbrugsreformen-2014-2022/landdistriktsprogrammet-2014-2022 https://lbst.dk/tvaergaaende/eu-reformer/landbrugsreformen-2014-2022/landdistriktsprogrammet-2014-2022
National legislation/recommendation	https://www.retsinformation.dk/eli/lta/2022/236 https://mst.dk/natur-vand/vandmiljoe/tilskud-til-vand-og-klimaprojekter/kvaelstof-og-fosforvaadomraader/ https://mst.dk/media/115012/ny-aftale-17-21-end.pdf https://mst.dk/media/180503/bilag-1-b-ekspropriation-rev-003.pdf https://www.retsinformation.dk/eli/lta/2017/126
References	https://www.retsinformation.dk/eli/lta/2017/126 https://lbst.dk/tilskudsguide/kvaelstof-og-fosforvaadomraader-forundersoegelses-og-etableringsprojekter https://oplandskonsulenterne.dk/miljoeeffekter/
Additional information and comments	The re-establishment of a wetland will most often take place by looping drains or ditches in the wetland, so that the water flows out naturally as groundwater or surface water. Water from the higher lying areas is led to the wetland through ditches or drains that are interrupted at the edge of the wetland and the water is distributed over the wetland. The stream can also be re-established with natural meanders, so that the current speed is lowered. The quantity of nutrients from the drainage water of the fields is reduced by denitrification, sedimentation of clay particles and uptake by plants and grazing by livestock, so that lakes and fjords receive fewer nutrients.
Editor of the template	Liselotte Puggaard, Food & Bio Cluster Denmark

4. Collection of interviews

Table 3: Interview questionnaire content.

Note: Write down your notes in a way that ensures that information is recorded in a comprehensive and understandable way. Always make sure that the answer provided by the interviewee, fully responds to the respective question. Please, include interesting quotations, if possible.

Interviewee: [First Name] [Last Name] Title:

Date: [Date]

Interviewer: [First Name] [Last Name]

Interview language: [language]

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organisations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: ______________________

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
- What are the sources of biomass for these practices?
- Who applies these practices?
- What fertilizing products are created in these practices?
- What is the market for these processed fertilising products?

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How would you classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

1. What makes you consider a specific nutrient recycling practice safe/unsafe?
2. What makes you consider a specific fertilizer product safe/unsafe?
3. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- Do you think that existing legislation or recommendations ensure public and environmental safety?
- Are relevant regulations missing?
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- Are specific practices also applied in other regions of your country?
- Is it possible to implement these practices in other regions/countries?

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?

- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight.
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.1 AUP

4.1.1

Interviewee: [SS]

Title: agricultural producer – walnut orchids and soybean

Date: [09.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - <u>Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)</u>
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ________________________

Question 2:

- Your region: Dimitrovgrad, Haskovo

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - <u>Bachelor's degree or equivalent</u>
    - Master's degree or equivalent
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - Appropriate solid manure storage;
    - Conservation tillage
- What are the sources of biomass for these practices?
    - ***last year's crop residues***
- Who applies these practices?
    - Large –scaled farms (grain producers)
- What fertilizing products are created in these practices?
    - ***extracting the maximum amount of mulch***

- What is the market for these processed fertilizing products?
    - the mulch is not for sale, it is used as organic manure and protect the upper layer from evaporation of moisture.

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
    - ***Acceptable if the benefits are realized by the farmers themselves***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
    - ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied in the farms***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***The conservation tillage is safe agricultural practice free of any chemicals.***

4. What makes you consider a specific nutrient recycling practice safe/unsafe?
5. What makes you consider a specific fertilizer product safe/unsafe?
6. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- Do you think that existing legislation or recommendations ensure public and environmental safety?
    - ***May be, sure***
- Are relevant regulations missing?
    - ***Not at all***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

   - ***Conservation tillage (no tillage) are very popular in the region of Haskovo. Farmers prefer it because this approach of cultivation reduce the costs and in is subsidized as "green practice" by the government!***

- Are specific practices also applied in other regions of your country?

I do not know!

- Is it possible to implement these practices in other regions/countries?

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
   - ***I am not familiar! No idea!***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
   - ***No idea!***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
   - ***No***
- Anything you consider important to highlight.
   - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.1.2

Interviewee: [GI] Title: agricultural producer – green houses – tomatoes and cucumbers

Date: [07.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify _______________________

Question 2:

- Your region: Hissara, Karlovo

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  - ***Integrated pest management;***
  - ***Solarization***
- What are the sources of biomass for these practices?

- Who applies these practices?
  - Green house producers
- What fertilizing products are created in these practices?
  - ***Decrease the input of chemical fertilizers in greenhouses***

- What is the market for these processed fertilizing products?
  - ***N/A***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable – cheap and easy to imply***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied in the greenhouses***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

  - ***Integrated pest management is safe, because is bases on agricultural practice reducing the chemicals in soil!***

7. What makes you consider a specific nutrient recycling practice safe/unsafe?
   - ***Unknown origin of products/practice like GMOs used in greenhouse production!***
8. What makes you consider a specific fertilizer product safe/unsafe?
9. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

  - ***Should be regulated but the control is missing on the field!***
- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***YES!***
- Are relevant regulations missing?
  - ***No!***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
  - ***I do not know!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Pest management and solarisation is common practice in greenhouse production, especially in regions specialized in such agricultural production!***

- Are specific practices also applied in other regions of your country?

Maybe

- Is it possible to implement these practices in other regions/countries?
  - ***It is possible, because these practises do not need extra investments***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***Vegetables growing***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***N/A***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***No idea!***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***No***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.1.3

Interviewee: [TK] Title: executive director – farmers association

Date: [01.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - <u>Civil Society (non-governmental organizations, consumer associations, etc.)</u>
    - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - <u>Master's degree or equivalent</u>
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - ***Integrated pest management;***
    - ***Solarization;***
    - ***Gasification;***
    - ***Thermal drying.***
- What are the sources of biomass for these practices?

- ***agricultural residues***

- Who applies these practices?

- ***Green house producers***

- What fertilizing products are created in these practices?
  - ***Decrease the input of chemical fertilizers in greenhouses***
- What is the market for these processed fertilizing products?
  - ***Free access***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable – cheap and easy to imply***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied in the greenhouses***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Integrated pest management is safe, because is bases on agricultural practice reducing the chemicals in soil!***

10. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***If it tested in the experimental field by researchers – it is safe!***
11. What makes you consider a specific fertilizer product safe/unsafe?
    - ***If it tested in the experimental field by researchers – it is safe!***
12. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***YES!***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Should be regulated but the control is missing on the field!***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***Yes!***
- Are relevant regulations missing?
  - ***No!***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
  - ***I do not know!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Pest management, solarisation and gasification is common practice in greenhouse production, especially in regions specialized in such agricultural production!***

- Are specific practices also applied in other regions of your country?

Maybe

- Is it possible to implement these practices in other regions/countries?
  - ***It is possible, because these practices do not need extra investments (except gasification)***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***Vegetables growing***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***N/A***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***No idea!***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***Should have more info campaigns about benefits of these practices***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.4

Interviewee: [SK] Title: business – renewable electricity, logistics – food and agricultural products

Date: [01.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - Master's degree or equivalent
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - ***Small-scale biorefining***
- What are the sources of biomass for these practices?

- ***agricultural residues;***
- *wood residues;*
- *grass*

- Who applies these practices?
    - ***Can be applied by farmers, small sized business***
- What fertilizing products are created in these practices?

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- ***N/A***

- What is the market for these processed fertilizing products?
    - ***N/A***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
    - ***Acceptable because the price for electricity is very high and any investment in reducing the electricity costs is a good idea***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
    - ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied in t***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Safe if they do not harm the human health!***

13. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Scientific proof for that***
14. What makes you consider a specific fertilizer product safe/unsafe?
    - ***Scientific proof for that***
15. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***YES!***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Should be regulated !***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
    - ***Yes!***
- Are relevant regulations missing?
    - ***No!***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
    - ***I do not know!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

<u>The availability of the practice in your region and the possibility of its dissemination</u>

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Small-scale bio refining is not popular in region of Plovdiv***

- Are specific practices also applied in other regions of your country?

Maybe

- Is it possible to implement these practices in other regions/countries?
    - ***It is possible, if there is subsidies***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***pellet production;***
- ***logistics;***
- ***packaging***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
    - ***N/A***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
    - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
    - ***No***
- Anything you consider important to highlight.
    - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.5

Interviewee: [GP] Title: business – farmer

Date: [02.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - Master's degree or equivalent
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - ***Follow-up crops***
    - ***Conservation tillage***
- What are the sources of biomass for these practices?

- ***agricultural residues;***

- Who applies these practices?
    - ***Farmers, agricultural producers***
- What fertilizing products are created in these practices?

- ***N/A***

- What is the market for these processed fertilizing products?
    - ***N/A***

<u>Social acceptance of nutrient recycling practices</u>

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
    - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
- ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

<u>Awareness of the safety of nutrient recycling practices</u>

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Safe if they do not harm the human health and environment***

16. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Other farmers who are adopters of these practices***
17. What makes you consider a specific fertilizer product safe/unsafe?
18. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes***

<u>Legislation related to nutrient recycling practices</u>

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Should be regulated!***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
    - ***Yes!***
- Are relevant regulations missing?
    - ***No!***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
    - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

<u>The availability of the practice in your region and the possibility of its dissemination</u>

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage is very popular in North Bulgaria, where the grain production is situated.***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
    - ***It is possible, if there are subsidies***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***Manure providers***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
    - ***No***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
    - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
    - ***No***
- Anything you consider important to highlight.
    - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.6

Interviewee: [MT] Title: farmer – orchids, hazelnuts - organic

Date: [03.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  - ***Follow-up crops***
  - ***Conservation tillage***
  - ***IPM***
- What are the sources of biomass for these practices?

- ***agricultural residues;***

- Who applies these practices?
  - ***Farmers, agricultural producers and cooperatives***

- What fertilizing products are created in these practices?
    - ***Natural bio-fertilizers***
- What is the market for these processed fertilizing products?
    - ***Competitive***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
    - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
    - ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Safe if they do not harm the human health and environment***

19. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Regulation – national and European***
20. What makes you consider a specific fertilizer product safe/unsafe?
21. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes, I believe***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Should be regulated!***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
    - ***Yes!***
- Are relevant regulations missing?
    - ***No at the moment!***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
    - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

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<u>The availability of the practice in your region and the possibility of its dissemination</u>

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage is very popular***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
  - ***It is possible, if there are subsidies***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***Fertilizer providers***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***No***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***No***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.7

Interviewee: [KK] Title: assoc. prof, PhD

Date: [04.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  - ***Follow-up crops;***
  - ***Conservation tillage;***
  - ***IPM;***
  - ***Gasification***
- What are the sources of biomass for these practices?

- ***agricultural residues;***
- ***wood residues***

- Who applies these practices?
    - ***Farmers, agricultural producers and cooperatives, wood holdings***
- What fertilizing products are created in these practices?
    - ***bio-fertilizers***

- What is the market for these processed fertilizing products?
    - ***Competitive and very dynamic***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
    - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
    - ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied by farmers.***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Safe if they do not harm the human health and environment***

22. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Results from test in research institutes and universities***
23. What makes you consider a specific fertilizer product safe/unsafe?
24. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes, I believe***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Should be regulated!***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
    - ***Yes!***
- Are relevant regulations missing?
    - ***No at the moment!***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
    - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage is very popular***
- ***Gasification of greenhouses***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
  - ***It is possible, if there are subsidies***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***N/A***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***No***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***No***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.8

Interviewee: [GA] Title: executive director

Date: [08.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - <u>Civil Society (non-governmental organizations, consumer associations, etc.)</u>
    - Other, specify ______________________

Question 2:

- Your region: Karlovo

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - <u>Master's degree or equivalent</u>
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - ***Conservation tillage;***
- What are the sources of biomass for these practices?

- ***agricultural residues;***
- ***IPM***

- Who applies these practices?
    - ***Farmers, agricultural producers and cooperatives, rose growers***
- What fertilizing products are created in these practices?
    - ***bio-fertilizers***

- What is the market for these processed fertilizing products?
  - ***Underdeveloped***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable but there is a lack of information about benefits***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***Main reasons are related with the economic and environmental value. If this practice lead to better economic efficiency, and do not harm the environment it will be applied by farmers.***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Safe if they do not harm the human health and environment***

25. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Regulations and control on good practices***
26. What makes you consider a specific fertilizer product safe/unsafe?
    - ***Same!***
27. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes, I believe***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Should be regulated!***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***Yes!***
- Are relevant regulations missing?
  - ***No at the moment!***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
  - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage is very popular***
- ***IPM, also is very popular good practice***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
  - ***It is possible, if there are subsidies***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***N/A***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***No***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***No***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.9

Interviewee: [NI] Title: ecology expert

Date: [08.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45’ – 60’

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - <u>Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)</u>
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor’s degree or equivalent
  - <u>Master’s degree or equivalent</u>
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  - ***Conservation tillage;***
  - ***Manure local exchange;***
  - ***Appropriate solid manure storage***

- What are the sources of biomass for these practices?

- ***animal residues;***
- ***agricultural residues***

- Who applies these practices?

- ***Farmers***

- What fertilizing products are created in these practices?
  - ***N/A***

- What is the market for these processed fertilizing products?
  - ***N/A***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***N/A***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Safe if they do not harm the human health***

28. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Regulations and control on good practices***
29. What makes you consider a specific fertilizer product safe/unsafe?
30. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Should be regulated!***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***Yes!***
- Are relevant regulations missing?
  - ***Not familiar***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
  - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

Funded by the European Union

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage is very popular***
- ***IPM***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
  - ***It is possible***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***N/A***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***No***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***No***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.10

Interviewee: [SB] Title: business

Date: [10.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45’ – 60’

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - <u>Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)</u>
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor’s degree or equivalent
    - <u>Master’s degree or equivalent</u>
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - ***Conservation tillage;***
    - ***Manure local exchange;***
    - ***Pelletizing***

- What are the sources of biomass for these practices?

- ***biomass residues;***
- ***agricultural residues***
- ***wood residues***

- Who applies these practices?
  - ***Farmers, producers of pellets, producers of organic fertilizers***
- What fertilizing products are created in these practices?
  - ***Organic fertilizers***

- What is the market for these processed fertilizing products?
  - ***Very competitive***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***N/A***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?
  - ***N/A***

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***There are Safe based on organic elements and components***

31. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Regulations and control on good practices***
32. What makes you consider a specific fertilizer product safe/unsafe?
33. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Yes***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***Yes!***
- Are relevant regulations missing?
  - ***Not familiar***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

- ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Using bio fertilizers like manure local exchange***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
    - ***It is possible***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***N/A***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
    - ***No***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
    - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
    - ***No***
- Anything you consider important to highlight.
    - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.
    - ***N/A***

4.1.11

Interviewee: [SS] Title: policy maker

Date: [10.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45’ – 60’

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - <u>Government/policy-maker/public authority</u>
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor’s degree or equivalent
    - Master’s degree or equivalent
    - <u>Doctorate or equivalent</u>

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - ***Conservation tillage;***

- What are the sources of biomass for these practices?

- agricultural residues

- Who applies these practices?
    - ***Farmers and cooperatives***
- What fertilizing products are created in these practices?

- ***Organic fertilizers***

- What is the market for these processed fertilizing products?
    - ***Competitive***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
    - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
    - ***N/A***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?
    - ***N/A***

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***There are safe***

34. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Regulations and control by the government***
35. What makes you consider a specific fertilizer product safe/unsafe?
36. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Yes***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
    - ***Yes!***
- Are relevant regulations missing?
    - ***No***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
    - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
  - ***Yes***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***N/A***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***N/A***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***No***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.
  - ***N/A***

4.1.12

Interviewee: [TR] Title: prof.

Date: [10.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - <u>Academic/Researcher (experts, researchers, etc.)</u>
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - Master's degree or equivalent
    - <u>Doctorate or equivalent</u>

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
    - ***Appropriate manure storage;***
    - ***Thermal drying;***
    - ***Gasification***

- What are the sources of biomass for these practices?

- Agricultural residues

- Who applies these practices?

- ***Farmers***

- What fertilizing products are created in these practices?
  - ***Organic fertilizers***

- What is the market for these processed fertilizing products?
  - ***Competitive***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***N/A***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?
  - ***N/A***

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Maybe***

37. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Regulations***
38. What makes you consider a specific fertilizer product safe/unsafe?
39. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Yes***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***Yes!***
- Are relevant regulations missing?
  - ***No***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
  - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
  - ***Yes***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***N/A***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - ***N/A***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  - ***No***
- Anything you consider important to highlight.
  - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.13

Interviewee: [AY] Title: farmer

Date: [14.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - <u>Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)</u>
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: Ygodovo, Plovdiv

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - <u>Secondary school</u>
  - Bachelor's degree or equivalent
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  - ***Conservation tillage***

- What are the sources of biomass for these practices?

- Agricultural residues

- Who applies these practices?
  - ***Farmers***
- What fertilizing products are created in these practices?

- ***N/A***

- What is the market for these processed fertilizing products?
  - ***N/A***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***N/A***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?
  - ***N/A***

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***Maybe***

40. What makes you consider a specific nutrient recycling practice safe/unsafe?
    - ***Regulations and control***
41. What makes you consider a specific fertilizer product safe/unsafe?
    - ***Regulation and control by the state***
42. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    - ***Yes***

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- ***Yes***

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***Yes!***
- Are relevant regulations missing?
  - ***No***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
  - ***No!***

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage***

- Are specific practices also applied in other regions of your country?

Yes

- Is it possible to implement these practices in other regions/countries?
    - ***Yes***

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- ***N/A***

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
    - ***N/A***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
    - ***N/A***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
    - ***No***
- Anything you consider important to highlight.
    - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

N/A

4.1.14

Interviewee: [HB] Title: PhD

Date: Feb. 8, 2023

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

Which of the following stakeholder groups do you associate with?

Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)

Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)

<u>Academic/Researcher (experts, researchers, etc.)</u>

Government/policy-maker/public authority

Civil Society (non-governmental organizations, consumer associations, etc.)

Other, specify _______________________

Question 2:

Your region: Plovdiv

Question 3:

What is your highest educational level achieved?

Primary school

Secondary school

Bachelor's degree or equivalent

Master's degree or equivalent

<u>Doctorate or equivalent</u>

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Nutrient recycling refers to the employment of movement and recycling of nutrients in the environment involving both living and non-living components.

Most used method in the region is nutrient cycling used in the farm.

Exports are mainly in the form of crops and animal products.

Question 4:

Can you identify the most common nutrient recycling practices in your region?

Crops and animal products. On the whole, a great number of nutrients are exported off the farm in vegetation

List the most important nutrient recycling practices in your region.

Agricultural intensification using mineral fertilizers to boost farm production.

What are the sources of biomass for these practices?

Plants, wood, and waste.

Who applies these practices?

Local farms.

What fertilizing products are created in these practices?

Phosphorus fertilizers

What is the market for these processed fertilizing products?

Still, relatively small to other E.U. countries.

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

Yes, to a large extend.

How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection

Acceptable by all segments of the general public and authorities as well.

What are the main reasons for the level of acceptance of specific nutrient recycling practices?

The search for optimization and environmentally friendly initiatives.

In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

Not much, a common standard is needed.

What makes you consider a specific nutrient recycling practice safe/unsafe?

Only after official approvals after checks performed on the spot.

What makes you consider a specific fertilizer product safe/unsafe?

Official approval by the authorities.

Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Yes, most likely.

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

Yes, partly.

Do you think that existing legislation or recommendations ensure public and environmental safety?

Needs improvements.

Are relevant regulations missing?

Yes, partly.

Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

No.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

Yes, almost the same around the country.

Are specific practices also applied in other regions of your country?

Yes.

Is it possible to implement these practices in other regions/countries?

Yes.

Regional nutrient recycling practices in value chains

Yes.

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

No.

Do you know of specific nutrient recycling practices in your region that connect different types of value chains?

No.

Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?

Yes, it is into a rising path.

Part 5: Final Thoughts

Question 10:

Would you like to share any final thoughts?

Anything you consider important to highlight.

Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.1.15

Interviewee: [CM] Title: agricultural producer – business

Date: [14.02.2023]

Interviewer: [Petar] [Borisov]

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - <u>Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)</u>
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: Plovdiv

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - <u>Bachelor's degree or equivalent</u>
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  - ***Conservation tillage***
- What are the sources of biomass for these practices?
  - ***last year's crop residues***
- Who applies these practices?
  - Mainly grain producers
- What fertilizing products are created in these practices?
  - ***extracting the maximum amount of mulch***
- What is the market for these processed fertilising products?

- ***N/A***

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  - ***Acceptable if the benefits are realized by the farmers themselves***
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  - ***Main reasons are related with the economic value. If this practice lead to better economic efficiency, it will be applied in the farms***
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

- ***The conservation tillage is safe agricultural practice free of any chemicals.***

43. What makes you consider a specific nutrient recycling practice safe/unsafe?
44. What makes you consider a specific fertilizer product safe/unsafe?
45. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - ***May be, sure***
- Are relevant regulations missing?
  - ***Not at all***
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- ***Conservation tillage (no tillage) are very popular in the region of Haskovo. Farmers prefer it because this approach of cultivation reduce the costs and in is subsidized as "green practice" by the government!***

- Are specific practices also applied in other regions of your country?

I do not know!

- Is it possible to implement these practices in other regions/countries?

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
    - ***I am not familiar! No idea!***
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
    - ***No idea!***

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
    - ***No***
- Anything you consider important to highlight.
    - ***No***
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.1.16

Interviewee: [SD] Title: farmer

Date: 06.2.2023

Interviewer: Peter Borisov

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - <u>Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)</u>
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: ___Plovdiv___________________

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - <u>Bachelor's degree or equivalent</u>
    - Master's degree or equivalent
    - Doctorate or equivalent
    -

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region. **plant residues**
- What are the sources of biomass for these practices? **same**
- Who applies these practices? **Poultry farmers, stock breeders**.
- What fertilizing products are created in these practices? **granular feed**
- What is the market for these processed fertilizing products?

<u>Social acceptance of nutrient recycling practices</u>

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region? **they are sparsely represented**

- How you would classify the acceptance level of each practice into the following categories (acceptable, **neutral,** not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices? **poor awareness**
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved? **more information and good practices Part 3: Safety and legislation for nutrient recycling practices and fertilizer products**

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe? **yes**

46. What makes you consider a specific nutrient recycling practice safe/unsafe?
47. What makes you consider a specific fertilizer product safe/unsafe? **we can get them at a much lower cost by using raw materials that are easily available near the household, the farm**
48. **we can offer the birds 100% healthy food, which we know for sure what ingredients it contains, compared to store-bought feed**
49. **birds consume food with pleasure (due to its optimal shape) and grow healthy and uniform**
50. **excellent absorption of nutrients is achieved**
51. **does not require the addition of additives or chemicals**
52.
53. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue? **yes.**

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region? **yes**

- Do you think that existing legislation or recommendations ensure public and environmental safety? **yes**
- Are relevant regulations missing? **no**
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread? **Part 4: Nutrient recycling practice spread, replication potential and value chains involvement**

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country? **maybe**

- Are specific practices also applied in other regions of your country? **not sure**
- Is it possible to implement these practices in other regions/countries? **yes**

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains? **no**

- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **I cannot answer**

Part 5: Final Thoughts
Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight.

Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.1.17

Interviewee: [SI] Title: farmer

Date: 08.02.2023

Interviewer: Peter Borisov

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: ____Plovdiv Region__________________

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region. **Usage of different types of natural fertilizers from cow and other animal waste.**
- What are the sources of biomass for these practices? **Mostly cows.**
- Who applies these practices? **Small farmers.**
- What fertilizing products are created in these practices? **Fertilize only**
- What is the market for these processed fertilizing products? **There are no market, the farmers made it for themselves, with their own help, or with the help of other cattle breeders.**

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region? **Most of them yes.**

- How you would classify the acceptance level of each practice into the following categories (acceptable**,** **neutral**, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved? **Small number of companies, which want to develop this type of fertilizers. Most of Bulgarian companies are only traders of conventional fertilizers.**

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe? **yes**

54. What makes you consider a specific nutrient recycling practice safe/unsafe? **Because it is natural**
55. What makes you consider a specific fertilizer product safe/unsafe? **Mostly my practice,**
56. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue? **I do not know.**

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region? **I think there is a lot work to be done**

- Do you think that existing legislation or recommendations ensure public and environmental safety? **I am not sure**
- Are relevant regulations missing? **I think so**
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread? **Yes.**

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country? **no**

- Are specific practices also applied in other regions of your country? **Not much**
- Is it possible to implement these practices in other regions/countries? **yes**

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains? **yes**
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **Yes**

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts**? There are a lot of things that can be done. First to educate people, more experimental fields where you can see the results.**
- Anything you consider important to highlight.
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.1.18

Interviewee: [HP] Title: Farmer

Date: 5.02.2023

Interviewer: Petar Borisov

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - **Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)**
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: **Plovdiv**

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - **Master's degree or equivalent**
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region. **Animal manure recycling**
- What are the sources of biomass for these practices? **Animal waste**
- Who applies these practices? **Small and medium farmers**
- What fertilizing products are created in these practices? **Organic fertilizer**
- What is the market for these processed fertilizing products? **Not very big**

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region? **Yes**

- How you would classify the acceptance level of each practice into the following categories (**acceptable,** neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices? **It's cheap, organic and safe**
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe? **Yes**

- What makes you consider a specific nutrient recycling practice safe/unsafe? **If it comes from healthy animals it's safe**
- What makes you consider a specific fertilizer product safe/unsafe? **If I buy it from local producers I know and they have good reviews**
- Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue? **Yes**

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region? **No**

- Do you think that existing legislation or recommendations ensure public and environmental safety? **In papers yes, but in practice- we don't know**
- Are relevant regulations missing? **Yes**
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread? **Yes, it should be promoted more by the authorities**

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country? **No**

Are specific practices also applied in other regions of your country? **Yes**

- Is it possible to implement these practices in other regions/countries? **Yes**
- Regional nutrient recycling practices in value chains **Not familiar**

Question 9:

Can you list the value chains in which nutrient recycling practices operate? **Production of bio and organic foods**

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains? **Yes, agri-food producers**
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **Yes, for sure**

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight. **Organic farming is the future**

Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc. **There should be more and more organic food producers and farmers and the legal authorities should encourage them to produce safe and clean food**

4.1.19

Interviewee: [DG] Title: Farmer

Date: 11.02.2023

Interviewer: Petar Borisov

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - **Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)**
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: **Plovdiv**

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - **Bachelor's degree or equivalent**
    - Master's degree or equivalent
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region. **Compost**
- What are the sources of biomass for these practices? **Organic waste**
- Who applies these practices? **Small and organic farmers**
- What fertilizing products are created in these practices? **Bio compost**
- What is the market for these processed fertilizing products? **Limited**

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region? **Yes**

- How you would classify the acceptance level of each practice into the following categories (**acceptable,** neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices? **It's clean, safe and organic**
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe? **Yes**

- What makes you consider a specific nutrient recycling practice safe/unsafe? **If it comes from organic material it's safe**
- What makes you consider a specific fertilizer product safe/unsafe? **If I produce it myself or it comes from people I know**
- Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue? **Maybe yes**

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region? **No**

- Do you think that existing legislation or recommendations ensure public and environmental safety? **It's not specifically regulated**
- Are relevant regulations missing? **Yes**
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread? **Yes, it should be officially legislated and communicated with all the stakeholders**

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country? **Not so wide-spread but they are used**

- Are specific practices also applied in other regions of your country? **Yes**
- Is it possible to implement these practices in other regions/countries? **Yes**
- Regional nutrient recycling practices in value chains **Not familiar**

Question 9:
Can you list the value chains in which nutrient recycling practices operate? **Organic farming**

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains? **Not familiar**
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **Not informed**

Part 5: Final Thoughts
Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight. **Organic fertilizers from biological waste should be more popular and the use of it- more supported**

Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc. **There should be more local producers of organic fertilizers**

4.1.20

Interviewee: [GA] Title: Farmer

Date: 7.02.2023

Interviewer: Petar Borisov

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - **Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)**
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: **Plovdiv**

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - **Bachelor's degree or equivalent**
  - Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region- **recycling animal manure**
- What are the sources of biomass for these practices? – **chicken manure**
- Who applies these practices?- **farmers**
- What fertilizing products are created in these practices? - **fertilizers**
- What is the market for these processed fertilizing products?- **farmers, greenhouses**

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region? **Yes**

- How you would classify the acceptance level of each practice into the following categories (**acceptable**, neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices? **Cheaper, cleaner and efficient recycled product**
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe? **Yes**

57. What makes you consider a specific nutrient recycling practice safe/unsafe? **The organic origin of the nutrient**

58. What makes you consider a specific fertilizer product safe/unsafe**? The previous harvests were good and this practice is traditionally used for many years**

59. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue? **Yes**

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region? **Yes**

- Do you think that existing legislation or recommendations ensure public and environmental safety? **Yes**
- Are relevant regulations missing? **Yes**
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread? **Yes. The legislation for recycling and processing all kinds of biomass would widen the field of activities and would create new opportunities**

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country? They are spread but not widely

- Are specific practices also applied in other regions of your country? **Yes, but they are not so diverse**
- Is it possible to implement these practices in other regions/countries? **Yes**

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains? **No, only soil fertilizer production**
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **No**

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight. **Biomass recycling should be more developed**
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc. **The government should implement a bio waste recycling and processing strategy**

4.1.21

Interviewee: [SM] Title: Farmer

Date: 29.01.2023

Interviewer: Petar Borisov

Interview language: Bulgarian

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - **Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)**
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: **Plovdiv**

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - **Master's degree or equivalent**
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance
Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region- **recycling animal manure**
- What are the sources of biomass for these practices? – **cow manure**
- Who applies these practices?- **farmers**
- What fertilizing products are created in these practices? - **fertilizers**
- What is the market for these processed fertilizing products? - **farmers**

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region? **Yes**

- How you would classify the acceptance level of each practice into the following categories (**acceptable**, neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices? **Cheaper, cleaner and efficient recycled product**
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe? **Yes**

60. What makes you consider a specific nutrient recycling practice safe/unsafe? **The organic origin of the nutrient**

61. What makes you consider a specific fertilizer product safe/unsafe**? The origin is from animals that are clean and healthy**

62. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue? **Yes**

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region? **Yes**

- Do you think that existing legislation or recommendations ensure public and environmental safety? **Yes**
- Are relevant regulations missing? **Yes**
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread? **Yes. The legislation for recycling and processing all kinds of biomass would widen the field of activities and would create new opportunities**

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country? They are spread but not widely

- Are specific practices also applied in other regions of your country? **Yes, but they are not so diverse**
- Is it possible to implement these practices in other regions/countries? **Yes**

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains? **No, only soil fertilizer production**
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **No**

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight. **Biomass recycling should be more developed**

Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc. **The government should implement a bio waste recycling and processing strategy**

4.2 FBCD

4.2.1

Interviewee: KT Title: Environmental Advisor

Date: 15th February 2023

Interviewer: Liselotte Puggaard

Interview language: Danish

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - o Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - o Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - X Academic/Researcher (experts, researchers, etc.)
    - o Government/policy-maker/public authority
    - o Civil Society (non-governmental organizations, consumer associations, etc.)
    - o Other, specify ______________________

Question 2:

- Your region: __Denmark________________

Question 3:

- What is your highest educational level achieved?
    - o Primary school
    - o Secondary school
    - o Bachelor's degree or equivalent
    - X Master's degree or equivalent
    - o Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region. Recycling of nitrogen and phosphorus, establishment of wet- and mini-wetlands to remove nutrients from farmland to avoid entry into lakes, coastal waters and inlets.
- What are the sources of biomass for these practices? Organic manure from agriculture, inorganic fertilizer
- Who applies these practices? Farmers
- What fertilizing products are created in these practices? None

Funded by the European Union

- What is the market for these processed fertilizing products? None

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection different from place to place, smell and mosquitoes, challenges with flooded gardens
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

63. What makes you consider a specific nutrient recycling practice safe/unsafe?
64. What makes you consider a specific fertilizer product safe/unsafe?
65. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- Do you think that existing legislation or recommendations ensure public and environmental safety? EU Water Framework and agricultural board reform
- Are relevant regulations missing? Paragraft 3 arealer naturbestykkelses
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- Are specific practices also applied in other regions of your country? Mest ler på ler
- Is it possible to implement these practices in other regions/countries?

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains? **Recreational areas combined with wetlands and mini-wetlands to create biodiversity.**
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **No**

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight.
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

4.2.2

Interviewee: RTP Title: Teacher at agricultural college

Date: 16/2-2023

Interviewer: Liselotte Puggaard

Interview language: Danish

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - X Other, specify _**Teacher in agricultural subjects such as general plant production, sustainability, organic production, biology and more**

Question 2:

- Your region: **Denmark – central region**

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - **X** Master's degree or equivalent
  - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  - **All waste is recycled from households – controlled by the municipalities. Organic waste, e.g. food waste is turned into soil improvement agents, composts etc.**
  - **Sewage water from households is treated in central cleaning facilities. Here is biogas produced and the residues are sold/delivered/distributed to farmers as manure.**
  - **Slurry and bedding from animal production is recycled as fertilizer on farmers fields, to improve yields for e.g., feed production and bedding – and then the cycle repeats itself.**
  - **Some of the organic waste from animal production is treated in biogas facilities as a supplement to green energy.**

    - **Nutrients (mainly nitrogen and phosphorus that are at risk of leaching are collected either using catch crops, plant cover or wetlands.**
    - **Incorporation of straw in fields, leave straw for improving content of organic content in the soil.**
- What are the sources of biomass for these practices?
    - **Organic waste from households or farming practices – mainly animal production.**
- Who applies these practices?
    - **Farmers, municipalities, and private companies investing in green products.**
- What fertilizing products are created in these practices?
    - **Biogas slurry**
    - **Slurry from treating sewage water (high in phosphorus**
    - **Compost**
    - **Biochar (in the near future)**
- What is the market for these processed fertilizing products?
    - **As the price on inorganic fertilizers has exploded, these alternatives are becoming increasingly attractive.**

<u>Social acceptance of nutrient recycling practices</u>

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
    - **I believe that there is a wide acceptance of all the practices in the community. So, the answer to all the practices is “acceptable”. I justify the selection by:**
        - **Biogas slurry: It gives the community a rather cheap and reliable energy supply. For the farmer it still serves as a good fertilizer**
        - **Slurry from treating sewage water: There is a lot of it! And in the old days it was simply dumped in lakes and streams, polluting our water environment. This is not the case anymore. And the community likes when pollution is stopped.**
        - **Compost: Until recently, each member of the community could go to the nearest recycling facility and pick up compost for free. This has increased the acceptance of this practice.**
        - **Biochar: If the initial results of biochar production holds, it will be a valuable input to both farmers and local communities. So, I don’t see why it should not be accepted as well.**
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
    - **That they contribute to the common good of the whole community on several levels: Energy supply, food production and environmental security.**
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

<u>Awareness of the safety of nutrient recycling practices</u>

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

Yes.

66. What makes you consider a specific nutrient recycling practice safe/unsafe?
    1. **It is safe if it does not harm me, my community, or the environment. And harm is of course both a physical and mental thing. It could be the smell of a biogas plant or the outlook of having a plant as your neighbour.**
67. What makes you consider a specific fertilizer product safe/unsafe?
    1. **In addition to the above, the nutrients in fertilizers must not leach to the surface or groundwater. The water environment in Denmark is of high quality and one of the major risks is nutrient pollution.**
68. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue? **I don't really understand the difference between a fertilizer product obtained from the nutrient recycling practice and the processed residue? Is the process of making a fertilizer (in this case) not the same as processing a residue..? So the short answer is, that they are equally safe..**

<u>Legislation related to nutrient recycling practices</u>

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region? **To my knowledge, yes they are.**

- Do you think that existing legislation or recommendations ensure public and environmental safety? **I do not have reason to believe otherwise. Sometimes it feels like the legislation is actually inhibiting the adaptation of new practices.**
- Are relevant regulations missing? **I think that more research is needed before new regulations are required.**
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread? **When it comes to nutrient recycling, I think that it is not the legislation that inhibits the wider adoption. I think, as soon as this source of nutrients becomes the cheaper alternative to other types of fertilizer, it will sustain itself. In the future, nutrient recycling will be crucial for stable food production.**

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

<u>The availability of the practice in your region and the possibility of its dissemination</u>

Question 8:

Are specific practices in your region wide-spread in your country? **In general, yes.**

- Are specific practices also applied in other regions of your country?
    - **Yes, with some variations, as animal production e.g. is concentrated more in the western part of the country.**
    - **And when it comes to the newer practices such as biochar, it is still in the development phase, and therefore not present I the entire country.**
- Is it possible to implement these practices in other regions/countries?
    - **Yes**

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate? **Well, to some extent, the value chains become shorter when recycling nutrients, as farmers become more the fertilizer producer as well as user. But other than that, nutrient recycling practices operate in the value chains of food and energy production. With fertilizer production companies, importers, distributors, farmers, wholesale, sale, and consumers being the main actors along with adjacent industries.**

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
    - **Not specifically.. Maybe when farmers have their own biogas production facilities. Then the energy and food production chains are connected.**
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains? **Indirectly yes… When a fertilizer e.g., is being made by recycling organic waste through a biogas plant, the biogas has a value and the degassed waste has a value. So, the same waste is producing value twice but only once as fertilizer.**

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
    - **Nope, think that's it.**
- Anything you consider important to highlight.
    - **That nutrient recycling is a difficult discipline with many complex systems to take into careful consideration before praising them as the practices to save the world.**
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.
    - **At this specific time, no.**

4.3 IUNG

4.3.1

Interviewee: [First Name] [Last Name] MK Title: Mr

Date: [Date] 13.02.2023

Interviewer: [First Name] [Last Name]

Interview language: English

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify **extension service**

Question 2:

- Your region: Mazovia, Poland

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - Master's degree or equivalent
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
- What are the sources of biomass for these practices?
- Who applies these practices?
- What fertilizing products are created in these practices?
- What is the market for these processed fertilizing products?

The most popular recycling practices are:

1. Municipal sewage sludge mostly used in plant production farm nearby cities and towns with treatment plants
2. Composts from agricultural waste - some vegetable farms sell dried and/or pelleted compost. Vermicomposts are also produced.
3. Substrates for mushrooms and vegetables from greenhouses and polytunnels – usually in dried form in big bags or in bulk transport
4. Sludge from the food processing industry (fruit, vegetables), - wholesale transport to short distances
5. Sludge from distilleries- wholesale transport to short distances
6. Digestate from biogas plants- wholesale transport to short distances.
7. Ready, dried/pelleted manure, including imported manure, is a new phenomenon. Mainly from poultry production, granulated or pelleted. Also dried and granulated cow manure intended for vegetable production and for allotment owners.
8. Also fertilizers obtained from the processing of organic fertilizers - humus extracts, etc. Processed organic fertilizer products containing humic acids, for floriculture, vegetable growing
9. Organic - calcium fertilizers, produced from animal bones,
10. Lake chalk with bottom silt (so-called black chalk), lime after sugar beet production.
11. Dolomitic limes, which are a waste from the production of road crushed stone
12. Processing fear, hair etc. animal byproducts

<u>Social acceptance of nutrient recycling practices</u>
Question 5:
Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

1. Municipal sewage sludge – neutral/not acceptable
2. Composts from agricultural waste - acceptable
3. Substrates for mushrooms and vegetables from greenhouses and polytunnels – acceptable
4. Sludge from the food processing industry (fruit, vegetables), - acceptable/neutral
5. Sludge from distilleries- acceptable
6. Digestate from biogas plants- acceptable
7. Ready, dried/pelleted manure, including imported manure - neutral/acceptable(not acceptable from imported manures)
8. Fertilizers obtained from the processing of organic fertilizers - acceptable
9. Organic - calcium fertilizers, produced from animal bones, not acceptable/neutral
10. Lake chalk with bottom silt (so-called black chalk) and lime after sugar beet production - acceptable
11. Dolomitic limes, acceptable
12. Processing fear, hair etc. animal byproducts- not acceptable/neutral

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

<u>Awareness of the safety of nutrient recycling practices</u>

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

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69. What makes you consider a specific nutrient recycling practice safe/unsafe?
70. What makes you consider a specific fertilizer product safe/unsafe?
71. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Processed natural plant residues, vegetable or mushroom substrates are considered safe. Also, most manures that are processed are considered safe. Animal production waste and sewage of various origins - municipal and industrial - are usually considered potentially dangerous. Farmers are afraid of heavy metals that can permanently contaminate the soil. Similarly, biological hazards, bacteria and viruses that can contaminate crops are considered dangerous. Surprisingly, they are not afraid of plant diseases transmitted with processed plant residues, recognizing that the processing process renders them harmless. Similarly, they do not consider that pesticide residues (plant residues) or antibiotics (animal waste) may pose a threat to production.

Plant waste (composts, etc.), cow manure, and bird manure are considered safe for the environment. Animal products (e.g. bone lime, feather meal, etc.) are considered less safe to prepare and use, and post-production waste is considered less safe for humans and the environment.

The biggest fear is biological threat - coli bacteria, salmonella, parasites. In the case of minerals, the listed content of heavy metals raises suspicion (even if there are less of them than in manure).

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- Do you think that existing legislation or recommendations ensure public and environmental safety?
- Are relevant regulations missing?
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

In Poland main legislation is ordinance of the Minister of the Environment of January 20, 2015 on the R10 recovery process) The Regulation defines the recovery conditions in the recovery process R10 (surface treatment yielding benefits for agriculture or improvement of the environment and types of waste allowed for such recovery) Conditions for recovery in a recovery operation R10 - surface treatment with benefits for agriculture or improvement of the environment and the types of waste allowed for such recovery are set out in the Annex to the Regulation.

Farmers believe that some regulations are even overly restrictive - this applies to, for example, vegetable or mushroom substrates that must not contain harmful biological pollutants, pesticides or heavy metals, and are subject to general waste regulations.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- Are specific practices also applied in other regions of your country?
- Is it possible to implement these practices in other regions/countries?

Regional nutrient recycling practices in value chains

Granulated manures are widely appreciated in the production of vegetables and ornamental plants, as well as in home gardens.

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?

Additional income obtained from the processing of poultry manure - although it concerns rather wealthier farms - is a significant additional source of income. Also residues from alcohol distillation. Several farms produce earthworm compost - the extra income is the sale of earthworms as bait for fish. **Part 5: Final Thoughts**

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight.
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

Recycling of by-products is not very popular - it requires a good understanding of the market and establishing marketing contacts. The next stage is investments in waste processing, storage and packaging. Farmers are afraid of legal regulations - including unfavorable tax regulations - in Poland agricultural tax (land rent depends on the quality of land) and farmers' social insurance (special, separated Agricultural Social Insurance Fund) are small. Starting processing on a larger scale is associated with a multiple increase in tax burdens.

A similar problem existed in small-scale processing of agricultural products - earlier regulations did not allow farmers to process and sell processed products (that is, the farmer had to be subject to all restrictive regulations of the food processing industry). The introduction of three new regulations, with a mild tax scale and simplified sanitary requirements, made it possible to start the process of identifying groups of farms processing their agricultural raw materials into food and introducing them to the market.

4.3.2

Interviewee: JK Title: MSc Eng.

Date: 24.02.2023 r.

Interviewer: Piotr Jurga, IUNG-PIB

Interview language: Polish

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - **Biomass producer** (**farmers**, **forestry**, aquaculture, **unions, associations**, etc.)
    - **Business** (**agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing**, etc.)
    - **Academic/Researcher (experts, researchers**, etc.)
    - **Government/policy-maker/public authority**
    - **Civil Society (non-governmental organizations, consumer associations**, etc.)
    - Other, specify ______________________

Question 2:

- Your region: The highest contact with stakeholders from Świetokrzyskie Region.

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - **Master's degree or equivalent**
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance
<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
- What are the sources of biomass for these practices?
- Who applies these practices?
- What fertilizing products are created in these practices?
- What is the market for these processed fertilizing products?

Okay, then let's focus immediately on municipal sewage sludge and let's say other biodegradable waste and you have so R10 or R3. What I mean by R10 - that is the use of the waste directly on the ground. Introducing them and getting them out into the soil.

R10 issues are being obstructed. See two years ago someone came up with the idea of cutting off the possibility of using municipal sewage sludge in the tenth, so that they have to have a sufficiently low organic matter content. This is a problem on such a basis that take a kick in the head guys. Let's see, in Poland we don't even have enough installations like composting plants to take it all in. To whom do we want to pour this bath? I mean, how many cars do we want to appear at sewage treatment plants, because normally there will be nowhere to store this sludge. Transport it to the composting plant. The construction of the composting plant itself is, let's say, a few months, and obtaining permits is 3 to 4 years with today's conditions. What do we want to do? After all, there is nowhere to house this waste. Let's give them to R10. Farmers have long since proven that they can manage municipal sludge. Treatment plants have also proven it, so what are we talking about. From the other side what of course we can say that biodegradable waste, sorry from municipal wastewater treatment plants clear that there are bacteria. Any amount of heavy metals there. Sure there are, but see from the other side. Let's say, I don't know, a piggery can dump as much manure as it wants into the field, a dustman can go into the field in practically any amount. Only 170 kg of the pure nitrogen component must be observed. So let's see why I'm talking about manure and chicken manure - you have so many parasite eggs that it's like the world hasn't seen at all. Yes, in chicken salmonella is very high0 Yes, but you can pound the field in any amount, and sewage sludge not because there is salmonella as well as parasites, but let's agree or we say hard stop and you cannot give up. This amendment is political correctness.

Continuing to list techniques. Okay that's right R10, that is the use of waste directly - putting into the soil directly, I understand without first processing or passing it through a plant that somehow processes it or changes it into a composition. Another way is the processing of waste into, say, compost other than we say broadly soil conditioners, or fertilizers. Now an important group is composting plants, which operate in such a way that biodegradable waste is mixed and let's say averaged, aerated in some way. This reduces the volume. This is our waste, that is, the weight of the compost is always less than the weight of the waste it formed. There are, of course, not only waste, because unfortunately already used valuable biomass type straw, woodchip type to improve the quality of the material, but the sum total of it all turns into some organic matter that goes into the soil, so it's nice in the sense that the material is good to have. In general, it is good when there is less organic matter in the soil rather than more. Generally we have a little less organic matter in the soils than let's say we had years ago, because it is said that we fertilize with it, and the organic matter in the soil mineralizes, so it is good if we return it there. That is, composting, that's one way of processing waste, but very important and gaining in importance is the process of converting waste into products in situ. I mean in situ - let's say a wastewater treatment plant at home. A technology is being installed that allows municipal sewage sludge to be turned into a soil product. And here, surprisingly, technologies based on sludge liming are used more often. The Świętokrzyskie Region has a nice thing going because there is greater availability of lime processing products, or whatever it is to be called now. Our sludge with lime causes an increase in PH, possibly an increase in temperature, and if there is a particular type of lime there. The mixture of sludge with lime has significantly different properties from those of the sludge itself - it is stylized, that is, there is no more salmonella there no more parasites, such hygienization - it as organic-mineral matter can go into the soil, farmers are happy, the treatment plant is happy because it has solved the waste problem and there is a lot and more of this. That is, to sum up. either you go with the waste directly to the farmer without changing the status to something that is not waste, or you go with the waste to an installation that processes this waste into compost or broadly defined soil improvers and then as improvers, that is, products no longer waste will go to the farmer, or the 3rd group. I think that these are more and more installations, which at home directly without taking the waste away, turn this waste into products and after that as products already go to the farmer.

The scale of this is large and growing. I'm just looking after myself. See, in 2021 I think the Minister of Agriculture issued less than 70 decisions for Soil Improvers. In 2022, I think there were more than 120 of those. This year I don't know how many there will be, but we'll see in Microbiotech we're running at the moment in addition to the 17 or 18 projects we've already obtained, I think, in parallel, you know, 17 projects.

Funded by the European Union

Compared to let's say the 120 that the minister issued last year, that's some significant part of the market and I think the trend is upward.

Waste comes from all industries.

Let's start with municipal waste, because if we have municipal sewage sludge in the identical name municipal this municipal component is obviously not municipal in the sense of municipal from separate collection and only municipal arising at the installation. After all, treating municipal sewage is yes it's us residents who produce it and that's the main source for sure it's the one I deal with the main source.

Another are non-specialized fertilizers and similar agents. In general, these agents are richer in organic matter than classic NPK. Yes, it rather looks that way. I'll tell you that it's rare to come across a soil conditioner that would have more like 3% nitrogen in dry matter. Where let's say and in general there is probably less than 50% dry matter in these agents, so as you can see the sheer amount is even less. It's not some powerful proposition for the farmer it's more of an add-on "if you're buying fertilizers anyway, then apply a little less fertilizer."

That or they were buying, and that there is organic matter at the same time, the soil will be, let's say, more uplifted. That's the main value. That is, unspoiled, unspecialized fertilizer products with a focus more on improvement. Lord of the soil properties and this is primarily in terms of organic matter content now. Usually it will be grain agriculture, rather larger areas. We certainly don't work with vegetable growers and certainly not with fruit growers for the reason that it's difficult to get approval to use products arising between them. That is, municipal sewage sludge for use in vegetable growing or fruit growing. Yes on the other hand if they are field crops for example cereal. Let it be rapeseed, something that is not intended for direct consumption. In that case, it's a lot easier, and it's more likely to cause someone who already has a little more than that average 10 hectare farm, or what the average is now, to be interested in this.

<u>Social acceptance of nutrient recycling practices</u>

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

To answer this question for you accurately it is necessary to divide society into at least such 2 groups. One group is the bourgeoisie, that is us, and the other group is actually users, that is farmers. Yes among users the acceptance is very high.

Farmers are eager to use this type of product. Hardly, farmers are also eager to use the waste, if it is approved for use in R10. Acceptance is very high. Hardly, now with these rising fertilizer prices there is more of a queue of farmers at the treatment plants than a problem for the treatment plants to find a farmer.

The undisputed problem is the rest of society, which has a rather negative attitude. I can't tell how much of the public resistance is due to real objections to the fact that it "stinks," and how much is due to the fact that we can protest, we will protest.

A humorous saying in the industry is that the manager of a wastewater treatment plant says he hasn't managed to open the gate yet, and already they're calling that the stench is coming from him. You know the point. People are what they are, and let you hit the 1% of the population that has nothing to do today, so they will "attach" themselves to anything, because if people have the right to "attach" then they will do it, and there will be a problem from that.

And I think it's so that it's hard to put any statistics to it - what the public acceptance actually is, and it is. The whole analysis is in a very heavily distorted mirror, because it depends on how much this 1% screams, who don't like it, and how much is accepted by 99% of the public, who don't really give a damn, because they don't notice it in the main. On the other hand, I think that in general the understanding of the awareness that waste is something that must be used in agriculture is growing.

That would be an interesting analysis. Yes to how much does society accept it versus how much it doesn't? How much is shouted by some small percentage of the public that accepts it the least.

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

72. What makes you consider a specific nutrient recycling practice safe/unsafe?
73. What makes you consider a specific fertilizer product safe/unsafe?
74. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

I have this general thought. You know, it is necessary to speak frankly. A trial batch of the product can be prepared. Anyone can be prepared. You can prepare whatever you want for the first tests. Then there is still the question of whether this product will ultimately be produced in the way that the trial batch was produced? That's what I think, and now PIORIN, or the State Plant Protection and Fertilization Inspectorate, probably has less control than it would like. I am able to imagine a whole lot of manufacturers of fertilizers or improvers. To maybe fly under the radar, yes this also results in a very strong emphasis on verifying the producer before he even enters the game as a producer, so somewhere there is a search. And where does that success come from? And where did that pole and so on come from. Where I think a little bit is not the way to go. I think it's the current quality control that will answer whether the product is safe or not, but again it's still a question of which factors we consider to be the demarcation between safe and unsafe again or the fact of occurrence. Let's say, does the fact that heavy metals are present in a product in some concentration mean that it is safe or unsafe? Does it? Well someone will say; heavy metals - we don't want to, because it's dangerous, but someone on the other side will say - look at the amount of heavy metals in this product. Also look at the amount of this product you introduce per hectare and see, the amount of heavy metals. Even at the highest concentration introduced with a small amount of this product, it will have virtually no measurable effect on the amount of heavy metals that have appeared in the environment. Well, the question is whether it's safe or not safe, whether we're talking more about merit, or whether we're talking about having heard that heavy metals are dangerous. That's what I'm going to shout loudly now and everyone will think I'm smart. So ongoing quality control, but before that, have we definitely collected good parameters to assess whether something is safe or not. The waste will either go to a plant that processes this waste into improvers, and that will be, let's say, point B. And from there it will go to a farmer and that will be our point C. This is such a classic path - treatment plant -> waste treatment plant -> farmer. Now the law allows such a configuration that the treatment plant will transfer the waste to the farmer without turning this waste into an improver, that is, here the composting plant will not be and another variant. This is that the treatment plant for itself is a waste processing plant and it markets to the farmer no more waste, and the soil improver yes, so these are the variants such 3 paths I think cover us 100% of the market.

Legislation related to nutrient recycling practices

Question 7:

Funded by the European Union

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- Do you think that existing legislation or recommendations ensure public and environmental safety?
- Are relevant regulations missing?
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

I have the general thought. Yes, that thinking should have long gone with us in the direction of what to do so that there is less regulation than what to do so that there is more regulation. I think that if we think about the future of waste management, fertilizer management, and we think that we will introduce regulations that will take us to some kind of bright future. Then no, we will not introduce such regulation. We need to remove regulations and the free market will get us there on its own And that's my conclusion.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- Are specific practices also applied in other regions of your country?
- Is it possible to implement these practices in other regions/countries?

Yes, I have such an example that takes into account the whole value chain. I like it a lot, and I think there should be more of it and there will be more of it. See, a wastewater treatment plant produces municipal sludge, these can be digested with the separation of biogas. Yes, that means we have fermentation, we have biogas. This biogas is a cool energy carrier, and now yes the same wastewater treatment plant can upgrade this entire biogas production line so as to feed the digesters with waste accepted externally. For example, from the food industry, such a dairy industry gives back a lot of fatty waste that is very caloric.

The capacity to gasify them so are and as waste from the food industry, for example, from the vegetable and fruit industry. Different kinds of fats and a whole bunch of things that can be loaded into digesters, generate biogas, generate electricity, generate heat, at the end get after the ferment, which can go directly to the farmer, or this ferment can be turned into non-waste fertilizer or soil improvers and introduced in this form, and then around this point, and next to the sewage treatment plant there will be a whole bunch of waste suppliers, and it all makes energy sense then. Also of importance are fertilizers and the closed-loop economy. That is, we can summarize that the value of the fertilizer product will increase if we combine more of these practices, more of these value ends, that it is kind of obvious.

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight.
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

Thank you sincerely the day may come that I will ask you for support, but for now let's focus on getting from me the knowledge you need and expect. I am at your disposal for further action.

4.4 MTU

4.4.1

Interviewee: NP Title: Lecturer & Researcher

Date: 15/12/22

Interviewer: Robert Ludgate

Interview language: English

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - **Academic/Researcher (experts, researchers, etc.) ☑**
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify _______________________

Question 2:

- Your region: Ireland, South & South West

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor's degree or equivalent
  - Master's degree or equivalent
  - **Doctorate or equivalent ☑**

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

- **Can you identify the most common nutrient recycling practices in your region?**

Agricultural slurry and manure.

Digestate from Anaerobic digestion.

Composted organic material.

Household nutrients, sludges, and wastewater sludges.

- **List the most important nutrient recycling practices in your region.**

Slurry and manure from the dairy industry is the most used in the region. Most of it in Ireland is used by farmers and recycled back onto the land and acceptance is high. However, when it comes to other types, acceptance is a great deal lower. Research has shown acceptance of household nutrients, sludges and wastewater sludges drops does not have anywhere near the support amongst farmers.

- **What are the sources of biomass for these practices?**

As previously mentioned, the main source for slurry and manure is the agricultural sector, must more specifically most of it comes from the dairy industry.

- **Who applies these practices?**

For agricultural manure, farmers are very happy to apply the nutrients themselves, so most farmers (Dairy) would have their own supply from their own livestock. However, other farmers (tillage) would not and would have to import the manure from another neighboring farm. About other types of nutrients like wastewater sludges, farmers would get in contact with a local organization who is involved in processing these sludges, also with composted nutrients the onus is on the farmer. If a farmer is interested in applying these nutrients to his farm, then they usually source and apply themselves.

- **What fertilizing products are created in these practices?**

In Ireland the most common is raw slurry and manure, it is collected throughout the winter whilst the livestock are indoors and then spread directly onto the farm.

Digestate from Anaerobic digestion is not nearly as common but there are a number of facilities within the south and southwest region. Most of that will have gone through a pasteurization process due to regulatory requirements. Relatively small quantities of composted material that can be used in an agricultural setting.

- **What is the market for these processed fertilizing products?**

For digestate most farmers are happy to take it, but they don’t want to pay for it. Farmers are happy to pay for mineral fertilizers, as there is a sense of a proven, measurable track record. Recent price rises in mineral fertilizer has shown interest grown in digestate from anaerobic digestion facilities within the region. The composting industry’s main competitor is cheap imported peat-based products but that is more of a result from the size of the composting industry in Ireland and they focus on horticulture rather than agriculture.

<u>**Social acceptance of nutrient recycling practices**</u>

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- **How would you classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection**

Slurry and manure are very acceptable in the agricultural sector. Research has shown that across the region (and Europe) farmers are very accepting. Composted materials it depends on where you are using it. In private gardens and horticulture, it is becoming more acceptable as people understand the larger issue with peat-based composts. With regards to wastewater sludges etc. it is not acceptable, as farmers are just not interested.

- **What are the main reasons for the level of acceptance of specific nutrient recycling practices?**

As mentioned previously, those reasons are true here. In general manure is very acceptable, again according to research there are concerns and fears of contaminants such as heavy metal, plastics and other contaminants will carry through onto the farm and into the food chain.

- **In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?**

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A few issues to it. First there are several barriers existing for wastewater sludge. There are a number of barriers i.e., the grain growers association that automatically say if you use wastewater sludge that a farmers product will not be certified. Barriers like these need to be changed so that it is not source dependent but rather quality dependent. If we look at a particular sludge, then it should be tested and measured and if that sludge is below a particular level of contaminants, then it should certify that it acceptable for use in an agricultural setting. The new EU fertilizer regulations set out what a fertilizer should with regards to nutrient content, contaminants etc. and if these standards were fully accepted by organizations for fertilizers that originate from wastewater etc. then the acceptance levels would rise dramatically. Looking at the quality of the material is key.

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

75. **What makes you consider a specific nutrient recycling practice safe/unsafe?**
76. **What makes you consider a specific fertilizer product safe/unsafe?**

That's a very big issue. All practices a have the potential to safe or unsafe as mentioned in the previous section. It's important that safe good quality inputs are used and thus you will have safe good quality outputs coming out the other side of the process, that's just the reality of it. It is important that you have source segregated waste (which we have a big issue within Ireland, and this gives rise to contaminate concerns that we previously mentioned). The EPA in Ireland did a survey in 2018 and they found that the lowest level of contamination came from the organic household brown bins. If best practice standards are adhered to then a good quality product will come out. This ethos will apply to all nutrient recycling technologies. Research has shown that farmers want a reliable and dependable classification system so they can rely on the biobased product like that can the mineral based one. Often it gets confused with the issue of heavy metals and what a lot of end users of fertilizers don't realize is that a lot of mineral fertilizers have a certain level of heavy metals in them and often it's a lot higher than those levels in wastewater sludge. It's just that are regulated and certified and there is an existing acceptance of mineral fertilizers.

77. **Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?**

It depends, for example digestate is better than the raw material/input. The feedstock has gone through a process that involves pasteurization i.e., the temperature has raised to above 70 degrees that inherently safer. In-vessel composting likewise raises the temperature of the input feedstock and during this process the rise in temperature leads to weed die off and seed deactivation lowering continuation issues. Wastewater sludge is not as clear, In Ireland long term storage is acceptable to make it safer however it is not clear if this is in fact affective. An alkaline stabilization process or an anaerobic digestion process is affective at making sludge safer. It depends on the process that the sledge undergoes to weather it is safer or not.

Legislation related to nutrient recycling practices.

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- **Do you think that existing legislation or recommendations ensure public and environmental safety?**

Yes, however, there is a lot of barriers put in place when it comes to recycling nutrients. Speaking to an anaerobic digestor operator and new regulations have resulted in their lagoons being redesigned. These

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designs are accepted in other regions and suddenly after a few years after opening the facility that design isn't acceptable. There seems to be a worrying number of unnecessary roadblocks being put in place. It's inconsistency that's the issue , slurry in a tank doesn't face the same regulations as digestate in a tank.

Other nutrient recycling practices like composting, the standards are let slip, i.e., incomplete source separation and allowing comb mixing of organic material and calling it composting just isn't true. Use of organic material in this way is just a waste, the waste framework directive for the end waste criteria states that it should have a common use and be useable. Allowing this to happen and only be used as landfill cover isn't a common use and thus shouldn't be classified as compost according to the directive.

- **Are relevant regulations missing?**

Certain legislation that exists isn't implemented and that should be addressed first. For example, the household and commercial legislation in place, and the legislation talk about all households having a brown bin, where in fact that many houses don't have a brown bin in place. So perhaps it's that the legislation isn't missing in some instances but isn't fully enacted and properly enforced.

End of waste criteria they should be responded to in a timely fashion and by the time the waste has been processed it's too late to do anything about it.

- **Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?**

Yes, it is. Mentioned earlier, the grain growers association won't accept waste from a certain area i.e. wastewater sludge and if this criterion was based on quality and not source then nutrient recycling processes like those involved with wastewater sludge would become more accepted and widespread.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement.

<u>The availability of the practice in your region and the possibility of its dissemination</u>

Question 8:

Are specific practices in your region widespread in your country?

- **Are specific practices also applied in other regions of your country?**

Yes. Manure slurry spreading is widespread within the agriculture industry. Most farmers will spread their own material and they don't even realize that they are recycling nutrients as culturally it's engrained in their day-to-day practices. Research has shown that Irish farmers have a lower rate of previous use of recycled material compared to their European counterparts, 20% of Irish farmers have used materials other than slurry on their farms.

- **Is it possible to implement these practices in other regions/countries?**

Regional nutrient recycling practices in value chains

Regarding implementing practices that are more widely used across Europe in Ireland -Yes, other countries have more experience than we do in Ireland and in Ireland we tend to take a more cautious approach, which is good from a safety approach.

There are barriers in place in Ireland that don't seem to be in place in other regions within Europe and those roadblocks need to be overcome. For example, if a farmer is in derogation they cannot import material from other sources, they aren't allowed to take in material from sources of manure, anaerobic digestion etc. yet they are allowed to use mineral fertilizer which makes little sense.

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- **Do you know of specific nutrient recycling practices in your region that connect different types of value chains?**

Pig slurry for example, most farmers have a land bank they must spread it out on, and this would be contracted to surrounding farms/farmers. Similarly Agri food companies would have a similar requirements for use of their waste water and they are finding it increasingly difficult to find land to spread this waste water out on due to regulations. These links that are not able to happen could stop industry growing as they cannot get rid of their waste in a responsible sustainable safe way. That as mentioned previously in the interview happens because of waste being classified from source and not from quality.

- **Does the value of the fertilizer product increase because of these specific practices that connect different types of value chains?**

No, farmers pay a lot of value for their mineral fertilizers and as a result put a lot of value in it. However when it comes to fertilizers from natural sources they see it as a waste product and don't see that should be paying for it. Their isn't the realization within the agricultural community that this waste has to be treated and it all costs money and they don't put an economic value in it.

Agri industry have a legal requirement to remove nutrients before expelling the waste and whether the end of the value chain (farmer) values it economically is irrelevant as there is a legal requirement to process the waste stream.

Part 5: Final Thoughts

Question 10:

- **Would you like to share any final thoughts?**
- **Anything you consider important to highlight.**

We should stop looking at this material as waste and start looking at it as a valuable resource. If we change that mindset from waste treatment to protecting a valuable resource, i.e. just treating organic waste just enough to use it as a ground fill cover. We have all the valuable organic waste that are in people homes and businesses and how do we protect that material, separate it correctly and use it to produce good quality compost. How do we look as a valuable resource and not as a waste, this will drive use and acceptance.

4.4.2

Interviewee: PF Title: Senior Research Officer

Date: 18/1/2023

Interviewer: Robert Ludgate

Interview language: English

Total Estimated duration: 45’ – 60’

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - **Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.) ☑**
  - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - **Academic/Researcher (experts, researchers, etc.) ☑**
  - Government/policy-maker/public authority
  - Civil Society (non-governmental organizations, consumer associations, etc.)
  - Other, specify ______________________

Question 2:

- Your region: Ireland

Question 3:

- What is your highest educational level achieved?
  - Primary school
  - Secondary school
  - Bachelor’s degree or equivalent
  - Master’s degree or equivalent
  - **Doctorate or equivalent ☑**

Part 2: Recycling practices recognition and social acceptance

Most important nutrient recycling practices in your region

Question 4:

- **Can you identify the most common nutrient recycling practices in your region?**
- **List the most important nutrient recycling practices in your region.**

Primary – recycling of organic material on farms i.e., Slurry / Manure practices. It is long established and has improved over time in retention of nutrients within the system.

Nutrients that are being recycling from Dairy industry in the form of sludge being recycled back onto farms.

Another example is the likes of spent mushroom compost being recycled back and poultry manure might also be further processed (i.e., dried) and returned to the soil.

- **What are the sources of biomass for these practices?**

As previously mentioned, the dairy sector at a farm level the nutrients are collected by the farmer and spread in the form of slurry and at a processing level organic sludge from processing.

Spent compost from horticulture i.e., mushroom growers and the poultry industry in some cases processes livestock manure for use.

- **Who applies these practices?**

Farmers, advisors, processors of agricultural products, horticulturists.

- **What fertilizing products are created in these practices?**

Examples: dried / pelletized poultry manures, struvite processed from waste facilities, digestate from the Anaerobic digestion sector (still relatively small in Ireland) – which have a variety of inputs. Dairy sludges are being looked at (more at an EU level however) for further processing. Some ash material is also coming on stream although at low levels.

- **What is the market for these processed fertilizing products?**

There is a large market, in Ireland we are importing in the region of 343,000 tons of nitrogen nutrient, so there is an opportunity to displace some of the market that exists for mineral/synthetic based fertilizers. The current geopolitical situation has led to higher costs on this and restrictions on the quantities available. **Social acceptance of nutrient recycling practices**

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- **How would you classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection**

There is a spectrum of products that are recycled and used on farms. The one that is most acceptable and most widely used is slurry/manure however at the other end of the spectrum is sludge coming from wastewater / effluent . Even when treated there still are outstanding issues that act as barriers to use and can stand in the way of certification of the crops used. Identifying when this kind of waste stops being a waste and becomes a fertilizer needs to be addressed to raise acceptance and develop the area of biobased fertilizers.

- **What are the main reasons for the level of acceptance of specific nutrient recycling practices?**

Re: Sludge – is the most challenging to raise acceptance. The first and primary challenge is certification by the likes of Bord Bia (Irish Food Board), what needs to be looked at is the separation between the resulting fertilizers being used in the food chain and human consumption, i.e., if the nutrient is used on grain that is fed to animals that will be consumed there is a longer gap than if the grain was used for products for human consumption or fertilizing in horticulture i.e., lettuce and regulations need to address this in the raise acceptance.

- **In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?**

Struvite – a phosphorus fertilizer can be processed from sewage sludge, there is very low acceptance when this is obtained from 'human' effluent, and these are valuable nutrients that are being wasted and there could be work done on improving acceptance. The biosecurity area of it is important, what metrics regarding existing metals etc. and this needs to be addressed at end of waste status legislation and the CE marking that is used for the product.

Key areas:

- End of waste status – metrics / parameters
- Assurance type schemes – lie Bord Bia, that they engage with developing these parameters so the likes of products from wastewater sludge can be used.

- Consumers – a conversation needs to be had on the practicality and safety of fertilizers derived from human waste and how this can lead to a nutrient security as Ireland & EU do rely heaving on mineral-based imports.

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

78. What makes you consider a specific nutrient recycling practice safe/unsafe?
79. What makes you consider a specific fertilizer product safe/unsafe?
There is a wide spectrum of potential products and a great deal of them are very safe, and are very similar to traditional fertilizers, Ammonia fertilizers can also be derived from waste streams and is very safe. The question arises again what category it falls into is it still manure or its now an anomia sulphate fertilizer. There are challenges around other materials and heavy metal content and is that safe? If material is being incinerated and does that affect the heavy metal content and how is this certified for use in soil?

- **Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?**

In most cases, biorefining aspect will affect the safety of the material. In the case of struvite from wastewater you are taking out a phosphorus fertilizer and that is safe, however it can be envisioned that you could taking out an unsafe material. However, in general it is safer.

Legislation related to nutrient recycling practices.

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- **Do you think that existing legislation or recommendations ensure public and environmental safety?**

There is legislation to ensure safety for sure. The legislation surrounding the area of biorefining needs to be improved so that they are being categorized correctly so that they are not falling between stools. However existing legislation, the existing legislation is not set up to deal with these evolving technologies and this can act as a barrier.

- **Are relevant regulations missing?**

There is a need at an EU level – that will filter down to national level, particularly end of waste status.

- **Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?**

Yes, not helping the status particularly within the categorization area.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement.

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region widespread in your country?

- **Are specific practices also applied in other regions of your country?**

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Some practices are, like Slurry spreading, but at the other level nutrient recovery from wastewater and the production of struvite is very limited and there is scope for more. The area of anaerobic digestion is getting more attention and the production of digestate and is expanding and becoming more common.

- **Is it possible to implement these practices in other regions/countries?**

Regional nutrient recycling practices in value chains

For many of these practices they are already in place to a greater extent across other regions in Europe and its fact that Ireland could and should adapt them more here.

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- **Do you know of specific nutrient recycling practices in your region that connect different types of value chains?**

Wastewater stream is discharged to a water body as long it meets a specific water quality. Effective capture of nutrients from this waste stream would go a long way in helping wastewater meet and exceed these water quality targets and create a value chain surrounding the capture of these nutrients.

A more complex example would be those explored in the biorefinery Glas project (https://biorefineryglas.eu/) , there are value chains that can be obtained through further biorefining of grass.

- **Does the value of the fertilizer product increase because of these specific practices that connect different types of value chains?**

i.e., Biorefinery Glas - the resulting fertilizer would create a new value chain so that's a yes. However, these fertilizers would have to compete head on with synthetic fertilizers and has to show additional benefits which I think is the case.

Part 5: Final Thoughts

Question 10:

- **Would you like to share any final thoughts?**
- **Anything you consider important to highlight.**

It the context of the farm to fork strategy, nutrient security, environmental challenges, and organic farming. This is an area that we should be putting or efforts into developing and opening the pathways for it. At a regulatory level, at an assurance scheme level there is room for EU/national/Industry to work together to develop regulations and take down barriers and work on how these nutrients are classified correctly and when does something stop being organic waste and start becoming a fertilizer and how is that process facilitated.

The area of acceptance and inclusion of these fertilizers into assurance schemes on a sustainability basis and into the organic farming standards.

4.4.3

Interviewee: SN

Title: Field Research Lead　　　　　　　　　　　　　　　　　　　　Date: 15/12/2022

Interviewer: Robert Ludgate

Interview language: English

Total Estimated duration: 45’ – 60’

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.) ☑
    - **Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.) ☑**
    - **Academic/Researcher (experts, researchers, etc.) ☑**
    - Government/policymaker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: Ireland

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor’s degree or equivalent
    - Master’s degree or equivalent
    - **Doctorate or equivalent ☑**

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

- **Can you identify the most common nutrient recycling practices in your region?**
- **List the most important nutrient recycling practices in your region.**
- **What are the sources of biomass for these practices?**

The Green Generation Anaerobic Digestion plants processes 23,000 tons of food waste a year and this is processed along with slurry from pigs which is used to produce biogas. The leftovers from that or digestate is used as an organic fertilizer. This digestate consists of around 6/7 kg nitrogen, 1/2kg phosphorus, 2/3 kg potassium per cubic meter along with some sulphur and organic matter which is good for restoring soil health. They supply local farmers who have been using that and some have even replaced chemical fertilizer.

- **Who applies these practices?**

Local farmers have been using the digestate for a while now as previously mentioned and several of them have decided to replace their chemical fertilizers exclusively with the digestate.

- **What fertilizing products are created in these practices?**

It's a digestate, as outlined previously and the approximate nutrient content. It has around 6-8% solids and it's spread using traditional slurry spreading equipment due to the high-water content. There are conversations around drying it or pelletizing it however in reality you need a high capital expenditure to set up production facilities for that and at present the return doesn't exist to warrant that level of investment.

- **What is the market for these processed fertilizing products?**

This is a common conversation now, the very best we can hope for is that farmers will take it for free and hand over their maps for nitrates essentially. The current EU limit for nitrates is 170 kg per hectare for organic fertilizer, and there is a game of brinksmanship presently as farmers know that producers want the maps for their data and exchange that for supply of the organic fertilizer. One of the biggest costs for an Anaerobic Digestate facility is shipping out the digestate and if a facility can get that to a no cost scenario, then that's seen as a positive.

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- **How would you classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection**

The only pushback we have at the facility is around odor. If farmers are applying the fertilizer when it's appropriate to do so, and not on hot days where the ammonia can cause strong odours then no issue exists.

- **What are the main reasons for the level of acceptance of specific nutrient recycling practices?**

We're surrounded by farmers at the anaerobic digestion facility, so the local benefits from things like employment for people spreading the digestate to getting free fertilizer so for the most the community benefits and so this drives general acceptance of it in the area.

- **In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?**

Using low emission spreading techniques help with this and as they are becoming compulsory the odor issue is dealt with. Education of the local community is crucial, letting them know who we are and what we do and the benefits and value that an Anaerobic Digestion facility can bring to a community. The most complaints they tend to receive seem to be form people that have moved to the area recently and agricultural in their background.

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

80. What makes you consider a specific nutrient recycling practice safe/unsafe?

The facility must adhere Department of Agriculture regulations or more specifically EU regulations on pasteurization. As they take in animal biproducts there is a risk of pathogen transfer and so everything must be pasteurized and heated to above 70 degrees for more than one hour and this is effective at killing off any existing pathogens. EPA regulations must also be followed on covered storage of the digestate to mitigate against emissions to the wider environment. Other regulations around nitrates which are also set by the EU must adhered to, that is 170kg per hectare means there is less risk of runoff to local bodies of water.

81. What makes you consider a specific fertilizer product safe/unsafe?

82. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

If it's from a plant that has followed the rules as laid out in the previous question, then there is no reason why the resulting fertilizer wouldn't be safe. A particular frustration is that there are 40 million tons of slurry being spread every year in Ireland without any treatment and that is full of pathogens and is far more unsafe than digestate and ideally every bit of slurry should be processed through anaerobic digestion because even without pasteurization reduces the pathogen load. The steps involved in anaerobic digestion make the feedstock far safer.

<u>Legislation related to nutrient recycling practices.</u>

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- **Do you think that existing legislation or recommendations ensure public and environmental safety?**

Yes, they do, I would say the lack of regulation for chemical fertilizers is more of an issue due to that with current regulations i.e., the nitrate regulations we previously spoke about then this creates a barrier to use. If it's harder or more restrictive to use an organic based fertilizer, then naturally farmers will continue to use the chemically based one.

- **Are relevant regulations missing?**

Regulations around the area of spreading unprocessed slurry should be looked at and how it should be treated to some degree before being spread to reduce the pathogen load.

- **Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?**

There is one rule for slurry, and that is that if you take in more than 5000 tons from one farm then you must pasteurize everything and that rule by itself is stopping the development of a lot of anaerobic digestion plants. If you are pasteurizing, you are going to use 40% of your produced energy to just heat it up post anaerobic digestion.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement.

<u>The availability of the practice in your region and the possibility of its dissemination</u>

Question 8:

Are specific practices in your region widespread in your country?

- **Are specific practices also applied in other regions of your country?**

There are eight operational anaerobic digestion plants currently in the country processing waste or residues of some description so it's not widespread for sure. Industrial composting is a massively energy intensive process and the resulting compost is not relatively valuable compared to the amount of processing that going into it and using the same feedstocks with anaerobic digestion would be more effective economically.

- **Is it possible to implement these practices in other regions/countries?**

Regional nutrient recycling practices in value chains

We're way behind the rest with Anaerobic Digestion compared to the rest of Europe. Italy, France, and Germany would be the main ones and Sweden and the Netherlands are also pretty well developed and it's those that Ireland should be looking to replicate when developing Anaerobic Digestion.

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- **Do you know of specific nutrient recycling practices in your region that connect different types of value chains?**

At Green Generation they take in food processing waste right the way from meat processing to residues from food processing and retail waste and repackage and food waste from brown bins in canteens and processes it through the facility.

- **Does the value of the fertilizer product increase because of these specific practices that connect different types of value chains?**

No, no matter where you get your feedstock as previously outlined – the value of the methane produced or digestate (which is virtually zero as previously mentioned) is consistent. However, the possibility do exist to lower the value due to contamination like plastic and would make the product less desirable.

Part 5: Final Thoughts

Question 10:

- **Would you like to share any final thoughts?**
- **Anything you consider important to highlight.**

The contamination issue is perhaps the biggest challenge, from an Anaerobic Digestion point of view feedstocks can be very highly contaminated and this absorbs resources. Educating people and companies on correct separation would help a great deal. This needs to be addressed and regulated for the industry to develop.

4.5 PROC

4.5.1

Interviewee: EB Title: Innovations- och processledare

Date: 1/3 - 2023

Interviewer: Amelie Karlsson

Interview language: English

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - **Academic/Researcher (experts, researchers, etc.)**
    - Government/policy-maker/public authority
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ________________________

Question 2:

- Your region: __________**Västerbotten**______________

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - Bachelor's degree or equivalent
    - Master's degree or equivalent
    - **Doctorate or equivalent**

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

Return of animal manure and Ash return (Not done on a large scale, Ash that is bio-classified may be returned to the forest but it must meet all requirements for it to be sent back to the forest)

- List the most important nutrient recycling practices in your region.

Arginine fertilizer

- What are the sources of biomass for these practices?

Residual biomass (GROT Bark, wood chips, animal droppings mixed with sawdust, straw, and peat.

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- Who applies these practices?

Farmers and forest owners

- What fertilizing products are created in these practices?

Decomposed animal droppings mixed with sawdust and peat (Horse manure) Hardened bio ash

- What is the market for these processed fertilizing products?

There is no requirement to return ashes, but there is an interest in returning them. Research is currently being done on the effects of returning ash depending on forest land and growth phase.

For fertilizer there is no organized market.

<u>Social acceptance of nutrient recycling practices</u>

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?
People are positive about returning manure and ash to nature.

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection

  Fertilizer – Acceptable
  Ash – Acceptable

- What are the main reasons for the level of acceptance of specific nutrient recycling practices?

  Contains nothing dangerous for nature and you want to return nutrients.

- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

  X

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

<u>Awareness of the safety of nutrient recycling practices</u>

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

Yes

83. What makes you consider a specific nutrient recycling practice safe/unsafe?

    You do not return more and more dangerous substances, but the level remains stable. They do not run off with rain and do not contribute to eutrophication.

84. What makes you consider a specific fertilizer product safe/unsafe?

They do not contain too high levels of dangerous metals, they are stable and bioavailable forms (does not corrode)

85. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
Yes

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

Yes, but there could be a requirement to do so, but the rules that exist for what it can contain are good.

- Do you think that existing legislation or recommendations ensure public and environmental safety?

  Yes

- Are relevant regulations missing?

  There should be rules around that it should be done.

- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

Yes

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

Ash is returned to a greater extent in other regions than in our region. Fertilizer looks the same nationally (possibly more spread of fertilizer in southern Sweden).

Are specific practices also applied in other regions of your country?

No

- Is it possible to implement these practices in other regions/countries?

Yes

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

Animal manure nutrient circularity, Forestry residual valorization

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?

No

- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?

Not applicable

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight.
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.
  Askåterföring - Skogskunskap
  Askåterföring - Skogsstyrelsen

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the European Union

4.5.2

Interviewee: [ZT] Title: Research and Development engineer

Date: [2023-02-14]

Interviewer: [Stefan] [Anderson]

Interview language: English

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
    - Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
    - Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
    - Academic/Researcher (experts, researchers, etc.)
    - **Government/policy-maker/public authority**
    - Civil Society (non-governmental organizations, consumer associations, etc.)
    - Other, specify ______________________

Question 2:

- Your region: Upper and Middle Norrland

Question 3:

- What is your highest educational level achieved?
    - Primary school
    - Secondary school
    - **Bachelor's degree or equivalent**
    - Master's degree or equivalent
    - Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
- What are the sources of biomass for these practices?
- Who applies these practices?
- What fertilizing products are created in these practices?
- What is the market for these processed fertilizing products?

<u>Answer:</u>

The only nutrient recycling practice in our region is ash recycling. We have fertilization of course but that is not seen as a recycling procedure. The sources of biomass for ash recycling are pure wood fuels such as GROT, wood chips, stem wood chips, bark sawdust, white reclaimed wood (untreated wood) etc. These wood fuels are mixed according to recipes to fit into the regulations with limits on the various nutrients and heavy metals. The Swedish Forest Industry supervises forest return values such as ash to check that it is correct and not cheated. This is checked before distribution of ash to the forest lands.

The most common way of practicing the ash recycling in that the producer of the ash, for instance the thermal power plant, Jämtkraft in Östersund, hires a contractor who takes care of the ash, which is then spread out in the forest. In this case, Jämtkraft oversees the work. Otherwise, it is also very common for the thermal power plants to receive quotes for someone who takes care of the ash return, who then is fully responsible for the spreading and return of ash.

The most common fertilizing agents that are created in this process is the same fertilizing agents that are present in wood, except from nitrogen that is converted to nitric oxide in the combustion. These fertilizing products are for instance phosphorus, potassium, calcium, magnesium, and zinc. Moreover, heavy metals are also present in the ash.

The market is predominantly the recycling of the ash in means of nutrients back to the forest. Ash recycling to the forest is required for nutrient balance

<u>Social acceptance of nutrient recycling practices</u>

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?

<u>Answer:</u>

Ash recycling is ensured for long-term measures of the forest. You usually see no results in the short term. The acceptance of ash recycling is a little slower in our region compared to, for example, South of Sweden. In Norrland, nitrogen fertilizers are preferred as the ash recycling usually leads to acidification, which is not what we are used to here. Acidification is thus less common and less accepted in northern Sweden. Therefore, the withdrawal of GROT from the forest is almost non-existent, as the ash recycling is also unwanted. Moreover, the prices of GROT used to be higher due to the high demand if it. This in turn lead to a search for other fuels to be used in the thermal power plants and thus the demand for GROT decreased and so did the price of it.

It is important to take out more GROT as the energy demand is very high in Sweden right now. This is a very complex issue in our region, GROT withdrawal from the forest in our region out is almost non-existent as they don't want to burn and recycle the ashes. Moreover, this is also an economical issue as the areal of the forest in the north are very big and sparse and therefore the volume that is needed to be economically beneficial isn’t as the transportation distances are so long. In comparison, the same amount of volume of GROT in South of Sweden can be collected in much smaller areas and with les transportation costs.

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

<u>Awareness of the safety of nutrient recycling practices</u>

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

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MAINSTREAM BIO

86. What makes you consider a specific nutrient recycling practice safe/unsafe?
87. What makes you consider a specific fertilizer product safe/unsafe?
88. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?

Answer:

The safety of the procedure of spreading the ashes is regulated according to a different legislation than the one that the Swedish Forest Agency oversees. It is difficult to know as different actors perform this. However, it is assumed that the legislation says something about the safety and preservation of the forest when driving around during the spreading of the ashes.

When it comes to the safety of the fertilizers, meaning the ashes that are recycled back to the forest, all ashes in means of analysis is controlled by the Swedish Forest Agency. Before the ash is approved to be spread, it must be analyzed, and the analysis results must be within the framework and legislation of how much nutrient and heavy metals it contains. Also, the ashes cannot be reactive, and this is analyzed by checking the conductivity.

Alternatives to process residues could be granulated ash or pellets of ash. These two procedures mean that it is very homogeneous and easy to spread out in the forest. However, this does not occur very often as it is an extra step in the process and costs too much. Does not work financially. The common ash that is spread out today is faster produced and cheaper. However, it is not as homogeneous as the mentioned examples and not as easy to spread. However, the chemical content of ash in powder form, granules or pellets is the same.

Legislation related to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

- Do you think that existing legislation or recommendations ensure public and environmental safety?
- Are relevant regulations missing?
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?

Answer:

Yes, there is legislations in our region. The Forest Protection Act legislates this. In addition to this, we have produced recommendations, guidance, and rules. Examples of this can be found in report 2019:4 of the Swedish Forest Agency to control spreading of ashes, and the recycling of ash is controlled according to Environmental Code 12:6. In addition to this, there is an obligation to report ash return no later than 6 weeks before spreading to the Swedish Forest Agency.

No, no relevant regulations are missing.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

The availability of the practice in your region and the possibility of its dissemination

Question 8:

Are specific practices in your region wide-spread in your country?

- Are specific practices also applied in other regions of your country?
- Is it possible to implement these practices in other regions/countries?

Regional nutrient recycling practices in value chains

Answer:

Yes, the ash recycling is actually very important and popular practice in the south of Sweden. This is the opposite to our region in Norrland. The practice is the same throughout whole of Sweden.

Yes, Finland recycles even more ashes than Sweden does. Also, the Baltic countries and Germany are trying to implement these practices with Swedish recommendations and legislations as an example.

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?

Answer:

No, in our region I don't know of any other recycling practices than the ash recycling as mentioned.

In the south of Sweden, I know that forest fuel such as GROT for instance and its ashes has been spread out in farming lands mostly due to the rich amount of phosphorus that is needed in the lands.**Part 5: Final Thoughts**

Question 10:

- Would you like to share any final thoughts?
- Anything you consider important to highlight.
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.

Answer:

No.

4.6 WR

4.6.1

Interviewee: WG Title: ing.

Date: 15-2-2023

Interviewer: Rommie van der Weide

Interview language: Dutch

Total Estimated duration: 45' – 60'

Part 1: Background Information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - ○ Biomass producer (farmers, forestry, aquaculture, unions, associations, etc.)
  - ○ Business (agri-food & bio-based industry, rural entrepreneurs, tech providers, logistics, financing, etc.)
  - • Academic/Researcher (experts, researchers, etc.)
  - ○ Government/policy-maker/public authority
  - ○ Civil Society (non-governmental organizations, consumer associations, etc.)
  - ○ Other, specify ______________________

Question 2:

- Your region: provinces Flevoland and Friesland

Question 3:

- What is your highest educational level achieved?
  - ○ Primary school
  - ○ Secondary school
  - • Bachelor's degree or equivalent
  - ○ Master's degree or equivalent
  - ○ Doctorate or equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Most important nutrient recycling practices in your region</u>

Question 4:

Can you identify the most common nutrient recycling practices in your region?

- List the most important nutrient recycling practices in your region.
  a. Use of manure (most cattle slurry and pig slurry) and processing of manure which produces different fertilizer products or soil improvers.
  b. Composting of organic household waste, including grass clippings and pruning waste from private gardens and use of the compost as soil improver (VFG-compost (vegetable, fruit and garden waste)).
  c. Composting of clippings of roadside grass, grass and pruning from nature reserves and public gardens and use of the compost as soil improver (green compost)

d. Fermentation (digestion) of manure, vegetal side products of food production or waste of the food processing industry for biogas production. The residue that is left (digestate) is use as a fertilizer.
e. Air scrubbers in, for example, intensive livestock barns that remove ammonium from the air that can then be used as a nitrogen fertilizer (mostly in the form of ammonium sulphate).
f. Use in agriculture of residual flows that contain valuable nutrients for plants, that are generated during sugar extraction from sugar beets or starch extraction from starch potatoes (beet vinasse, spent lime, protamylasse).
g. Extraction of struvite from sewage treatment and use as a fertilizer.

- What are the sources of biomass for these practices?
  a. Livestock farms
  b. Households
  c. Public green areas and nature areas
  d. Livestock farms, food processing industry and others
  e. Intensive livestock farms and composting sheds
  f. Sugar industry and potato starch industry
  g. Sewage water purification companies and purification of industrial waste water by companies
- Who applies these practices?
  It is applied by different companies or civil society organizations

- What fertilizing products are created in these practices?
  - Different liquid fertilizers that have various compositions and that contain nutrients for plants (N, P, K and meso and micronutrients) and organic matter.
  - Some solid products that contain nutrients and organic matter, for example manure pellets.
  - Compost that is used for supplying stable organic matter to the soil but that also contains nutrients for plants.
  - Struvite as a P-fertilizer.
- What is the market for these processed fertilizing products?
  Manure and the different liquid product are mainly used in field crops.

  The market for manure pellets is small. They are sometimes used in field crops and further sold on the consumer market for use in gardens. Much of it is exported abroad as fertilizer / soil improver.

  Compost is used on agricultural land and in gardens.

  Struvite is hardly used by farmers. Some fertilizer producers use struvite as a resource and upgrade it to a P-fertilizer.

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices, which are performed in your region?

- How you would classify the acceptance level of each practice into the following categories (acceptable, neutral, not acceptable)? Please justify your selection
  Manure and other above describes liquid fertilizer product are highly accepted by farmers. They like to use them as they are a cheap source of nutrients and organic matter (for manure). Especially last year, when the price of chemical fertilizers was high, the demand for some of these products exceeded the supply.

  Farmers know the value of manure pellets, but the acceptance is low due to the relatively high price of it.

Compost is partly accepted. Farmers endorse its value as a soil improver, especially because of its organic matter supply, but the price may keep some of them from applying it. VFG-compost is not always accepted, due to contaminations with glass and plastic particles.

The acceptance of P-fertilizers made out of struvite is neutral.

- What are the main reasons for the level of acceptance of specific nutrient recycling practices?
  The price of the products and its value for crop and soil, compared to other products.

- In case of neutral/not acceptable: How should the acceptance level of specific nutrient recycling practice be improved?
  Manure pellets: lower price

  VFG-compost: total removal of contaminants (which however, seems to be almost impossible)

  P-fertilizers derived from struvite: will be accepted when the price can compete with chemical P-fertilizers derived from rock phosphate and when the fertilizing value for crops is equal.

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

<u>Awareness of the safety of nutrient recycling practices</u>

Question 6:

Do you consider individual nutrient recycling practices and their products as safe?

Yes

89. What makes you consider a specific nutrient recycling practice safe/unsafe?
    It is safe due to legislation that must guarantee safety.

90. What makes you consider a specific fertilizer product safe/unsafe?
    They are safe too due to legislation or other regulations for the use of it that must guarantee safety.

91. Is the fertilizer product obtained from the nutrient recycling practice safer than the processed residue?
    This is hard to say. It depends on the type of product.

<u>Legislation related to nutrient recycling practices</u>

Question 7:

Are nutrient recycling practices regulated by the appropriate types of legislation and/or national/regional recommendation in your region?

Yes

- Do you think that existing legislation or recommendations ensure public and environmental safety?
  - Yes
- Are relevant regulations missing?
  - Not as far as I know.
- Does the lack of appropriate legislation limit the wider adoption of nutrient recycling practices? If so, what change would make such practices more widespread?
  - Not as far as I know.

Part 4: Nutrient recycling practice spread, replication potential and value chains involvement

<u>The availability of the practice in your region and the possibility of its dissemination</u>

Question 8:

Are specific practices in your region wide-spread in your country?

- Are specific practices also applied in other regions of your country?
  Yes

- Is it possible to implement these practices in other regions/countries?
  - In other parts of my country: yes. In other countries: that depends on the local infrastructure of these countries and their legislation.

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
  - Fermentation of manure and organic wastes and side products for biogas production and the use of the digestate as a fertilizer in agriculture.
  - Sewage treatment as a social service, by which also nutrients are recycled that can be reprocessed into fertilizers.
- Does the value of the fertilizer product increase as a result of these specific practices that connect different types of value chains?
  - The value of the fertilizer products itself does not increase. They are mostly by-products or residues from other production chains. When they can be marketed as fertilizer, this is an economical benefit that compensates for the productions costs of the main product of the chain.

Part 5: Final Thoughts

Question 10:

- Would you like to share any final thoughts?
  The use of nutrient recycling products must be stimulated by the government, not only in The Netherlands but throughout the European Union and even further. The use of chemical fertilizers should be reduced, especially the use of P-fertilizers derived from rock phosphate, as this is a finite resource. P for plant nutrition cannot be replaced by an alternative nutrient. A lack of P in the world will lead to starvation, enormous social and political tensions and eventually war. This will not occur in the near future, but we have a responsibility to future generations.

  Many nutrients still get lost by human consumption. Human urine and faeces are legally not allowed to use as a fertilizer yet, due to the presence of drug residues and hormones. Techniques to remove this contaminations should be stimulated and if necessary subsidized by the government. There is already for several years interest in using human urine, but it is still not allowed. This takes too long.

- Anything you consider important to highlight.
  - In general nutrient recycling products have a better CO_2 foot print than chemical fertilizers.
  -
- Any references to (practical or scientific) information about nutrient recycling practices, legislation, etc.
  - Commissie Deskundigen Meststoffenwet (2016). Protocol beoordeling stoffen Meststoffenwet. Versie 3.2. WOt-technical report 71. Wageningen University & Research. https://edepot.wur.nl/394876

This report is a protocol (in Dutch) for the judgement of waste and residues as a fertilizer or as feedstock for fertilizer production. The judgement includes the agricultural significance and the risk for environmental pollution by the products.

- Annex Aa of the Dutch Fertilizer Act Implementation Regulations. This annex contains a list of all waste and residue streams which are approved as fertilizer or soil improver.

4.6.2

Interviewee: PV

Title: Programme manager circularity

Date: 23-02-2023

Interviewer: Kimberly Wevers

Interview language: English

Total estimated duration: 45' – 60'

Part 1: Background information

Question 1:

- Which of the following stakeholder groups do you associate with?
  - Biomass producer (farmers, forestry, aquaculture, trade unions, associations, etc.)
  - Business (agri-food and bio-based industry, rural entrepreneurs, technology suppliers, logistics, financing, etc.)
  - Academic/Researcher (experts, researchers, etc.)
  - Government/policymaker/government agency
  - Civil society (non-governmental organisations, consumer organisations, etc.)
  - Other, specify ______

Question 2:

- Your region: Friesland

Question 3:

- What is your highest level of education?
  - Primary school
  - Secondary school
  - Bachelor's degree of equivalent
  - Master's degree of equivalent
  - PhD of equivalent

Part 2: Recycling practices recognition and social acceptance

<u>Key andkey recycling practices in your area</u>

Question 4:

Can you identify the most common nutrient recycling practices in your area?

- Make a list of the top nutrient recycling practices in your area.

  The most important nutrient practice for Pieter is what is currently being done with compost, this is important because this is the first step. You work in steps, if we do this well we can use agriculture as the basis of the circular society. In fact, everything that is produced ecologically can be processed by agriculture, on the soil. That has a lot of value, just think of the energetic value of the nutrients.
  If you were to assess residual flows, you would see that you can bring everything (meaning nutrients) back to the soil. Especially when keeping in mind the right quantity and the right composition for each area. **That is the ultimate nutrient processing scheme.**

- What are the sources of biomass for these practices?

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Grass, reed and roadside grass are the products which are often used now. Everything is composted on the farms, decentralized. Why decentralized? Because it puts the farmers in a great position. The farmers are able to negotiate, they basically 'bully' the big composter companies because they are actually hijacking their market share. Composting on the farm fits perfectly into a farmer's activity plan. A farmer is perfectly allowed to compost himself, it is an agricultural activity.
Farmers are allowed to add green residual flows originating from up to 10 km of the farm, to the compost, up to 600 cubic metres. Remains of natural clippings, reeds, roadside grasses, ditch clippings and all those kinds of products.

- Who applies these practices?

Agricycling. Agricycling 120 farmers, scale up to 6 municipalities, South Holland, present at ministry

New proposition, soil is the best and only place for recycling of nutrients. Farmers can do this! Farmers should not only receive money for their output (vegetables/crops which they produce on their lands) but also get paid for processing nutrients.

Please look for more info about this refreshing concept on the following website;

https://www.agricycling.nl/

- What fertilization products are made in these practices?
Compost which is returned to the soil. The addition of the compost to the different lands and soil types is tailored, to have an optimal working soil and balanced nutrient application.

The composting result of this system is better than 'traditional' composting.

- What is the market for these processed fertilizers?

They are now having talks with OMRIN, who process about 15% of the total organic waste of the Netherlands. They are working on a PFAS and microplastic-free factory, which will be located in Groningen. They want green compost from organic waste. Tailoring compost at soil level is an interesting different concept. Positively received. Comment of Pieter; If you know how to build relevance, you will become important which puts you in a better position than as when you are a farmer standing alone. A corporation gives farmers strength but also guaranteed purchase.

How would you describe the market? He now describes the compost market as the mafia. The BVOR that has been colored by a number of very large composters in our country. So they are actually controlling their own market. So the farmers intervened now, via a different route, which the big composting lobby did not expect.

Social acceptance of nutrient recycling practices

Question 5:

Does your community accept the specific nutrient recycling practices that are being implemented in your area?

The first to step this new collaboration between farmers were the municipalities. They are competent authorities regarding compost. Not the state or the provinces. Which means you need the municipalities to be on board. Several more municipalities have already joined the programme.

As a society, we have made nutrient loss almost like a sport. Every nutrient you can keep in the cycle and not go to waste is a win. Suppose 80 'nutrient units' remain in the cycle, which you would normally have burned in the regular recycling practice. Suppose the efficiency of those 80 units is only 20%. Then you still have extra efficiency on your field, that you would otherwise have burned. So that's just having a different view to it. As they learn, they want to keep testing efficiency.

Funded by the European Union

The trick to community acceptance is simply presenting the project in the right way, everything has to be put into perspective. If a farmer can save money on fertilizer use, he is interested. It is also important to form a sense of cohesion between the farmers, they are trying to find a solution for the nutrient problems in the Netherlands, together.

Part 3: Safety and legislation for nutrient recycling practices and fertilizer products

Awareness of the safety of nutrient recycling practices

Question 6:

Do you consider individual recycling practices of nutrients and their products to be safe?

Safety
In the process (composting) they have been working very me. They have mitigated risks in 2 ways. They look carefully at which residual flows go in, roadsides where cycling past school-age children are skipped, for example, because there is more junk in them. Within the laws and regulations, compost is very clearly defined. They have set up an organization that does the planning and the organization and the composting in the farmer's yard. This way you guarantee the quality. They also certify the final product by CMC methodology. Is of course also checked for fertilizing values

What makes you consider a specific nutrient recycling practice to be safe/unsafe? Question is skipped

92. What makes you consider a specific fertilizer product to be safe/unsafe ? Question is skipped
93. Is the fertilizer product obtained from nutrient recycling practice safer than the processed residue? Question is skipped

Legislation relating to nutrient recycling practices

Question 7:

Are nutrient recycling practices regulated by the right types of legislation and/or national/regional recommendations in your area?

Do you think there is any legislation in the way of allowing products or putting products/methods on the market?

Ha! 1 example, then he stops talking about it because this can easily be talked about for 2 hours.

Laws and regulations have always been about removing as many components as possible from a residual stream. A circular idea does not fit in this picture at all. First, Pieter (agricylcing) has first been busy figuring out who has authority over a residual flow, such as roadside grass, or about the compost product. After a while they have found out that these are the municipalities. This was extremely difficult to dig up, the municipalities did not even know it themselves. So no one seems to know who has authority over which feedstocks or organic end products, which makes it very difficult to look for opportunities and different methods of processing. It's not even about changing the law, but more about who is responsible for which product? This example shows that our entire Dutch system is not set up for a circular approach.

Part 4: Dissemination of nutrient recycling practices, replication potential and value chain involvement

The availability of the practice in your region and the possibility of its dissemination

Are there methods orproducts that are common in Friesland and not in other parts of the Netherlands?

Friesland is at the forefront of thenew system, but it is being rolled out across several provinces in the Netherlands now.

Question 8:

Are specific practices in your region widespread in your country?

- Are specific practices also applied in other regions of your country?
- Is it possible to implement these practices in other regions/countries?

Regional nutrient recycling practices in value chains

Question 9:

Can you list the value chains in which nutrient recycling practices operate?

Question is skipped with respect to time

- Do you know of specific nutrient recycling practices in your region that connect different types of value chains?
- Is the value of the fertilizer product increasing as a result of these specific practices that connect different types of value chains?

Part 5: Final Thoughts

Question 10:

- Want to share one last thought?

It is important to careabout the socio-economic context, because who gets money for what? The farmer should not pay for all the changes made in a system.

Secondly, provide context for the assignments we have to do and challenges we face. If we adapt our system, what are the clear results of those changes? What do we gain in terms of carbon fixation, water holding capacity and nitrogen content in the soil?

- Everything you find important to emphasize.
- All references to (practical or scientific) information on nutrient recycling practices, legislation, etc.

The project

MainstreamBIO is a Horizon Europe EU funded project, which sets out to get small-scale bio-based solutions into mainstream practice across rural Europe, providing a broader range of rural actors with the opportunity to engage in and speed up the development of the bioeconomy. Recognizing the paramount importance of bioeconomy for addressing key global environmental and societal challenges, MainstreamBIO develops regional Multi-actor Innovation Platforms in 7 EU countries (PL, DK, SE, BG, ES, IE & NL). The project aims to enhance cooperation among key rural players towards co-creating sustainable business model pathways in line with regional potentials and policy initiatives. MainstreamBIO supports 35 multiactor partnerships to overcome barriers and get bio-based innovations to market with hands-on innovation support, accelerating the development of over 70 marketable bio-based products and services. Furthermore, the project develops and employs a digital toolkit to better match bio-based technologies, social innovations and good nutrient recycling practices with available biomass and market trends as well as to enhance understanding of the bioeconomy with a suite of educational resources building on existing research results and tools. To achieve these targets, MainstreamBIO involves 10 partners across Europe, coming from various fields. Thus, all partners combine their knowledge and experience to promote the growth of bioeconomy in a sustainable and inclusive manner.

Coordinator: **Q-PLAN INTERNATIONAL ADVISORS PC (Q-PLAN)**

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	STICHTING WAGENINGEN RESEARCH	WR
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	RISE PROCESSUM AB	PROC
	AGRAREN UNIVERSITET - PLOVDIV	AUP
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