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Nutri2Cycle

D.1.6 Report on the effects of the current legal framework on CNP in main farming systems in Europe

Deliverable:	Report on the effects of the current legal framework on CNP flows in main farming systems in Europe
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List of abbreviations

AD	Anaerobic Digestion
C	Carbon
CAP	Common Agricultural Policy
CE	Circular Economy
CECs	Contaminants of emerging concern
Cu	Copper
EC	European Commission
ILUC	Indirect Land Use Change
FPR	Fertilising Product Regulation
GHGs	Greenhouse gases
Hg	Mercury
N	Nitrogen
ND	Nitrates Directive
NECD	National Emission Ceilings Directive
NRR	Nutrient recovery and reuse
P	Phosphorus
RDP	Rural Development Program
RENURE	REcovered Nitrogen from manURE
TOC	Total organic carbon
Zn	Zinc

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Executive Summary

Activities such as the use, handling and storage of manure and streams of nutrient-containing substances of biological origin, and technologies like anaerobic digestion and composting for energy recovery, nutrient recovery and reuse from manure and other biological streams in Europe, impact nutrient streams in European societies, and in agriculture in particular. These activities provide considerable opportunities to increase the efficiency of our farming systems, potentially providing European farmers with a competitive edge in the world's economy. Furthermore Europe's dependency on imported goods, energy and nutrients has led to an increased attention for nutrient cycling of and energy recovery from biological streams that flow through our society. Moreover, there is an increased awareness that accumulation of or high concentrations of nutrients can have undesirable effects on human health, wildlife and biodiversity on a local scale, and that human activities are altering the biogeochemical cycles on a global scale, with the risk of generating large-scale abrupt or irreversible environmental changes. It is therefore not surprising that the Commission, the Council and the Parliament have initiated several European policies, regulations, directives and actions to influence the flows of carbon, nitrogen[1] and the critical raw material phosphorus (CNP) in farming systems in Europe.

The Nutri2Cycle project aims to help close nutrient loops in European farming systems. Partners from 12 European countries were brought together with the common challenge of improving CNP flows between crop production and animal husbandry and by linking these two pillars to agro-processing. Literature already provides reviews on the influence of policy and regulations on nutrient streams in agriculture, often with a focus on certain technologies, nutrients, regions or policies. The current report provides a complementary assessment of the legal framework on CNP flows in place in EU agriculture and includes animal husbandry and plant production. The report considers carbon, nitrogen and phosphorus, with a strong focus on legislation that was developed after publication of Hermann & Hermann (2018). Whereas chapter 2 of this report focuses on European legislation, chapter 3 shifts its attention to the national level. Where applicable, we highlighted the link between the national implementation of European legislation.

Chapter 2 of this report reviews and analyses the available literature on the effects of (changes in) the Common Agricultural Policy (CAP), including the Rural Development Program (RDP), the Water Framework Directive, including the underlying Groundwater Directive and the Nitrates Directive (ND), the Clean Air Package, including the underlying Revised Emission Ceilings Directive and the Medium Combustion Plant Directive, the Biofuels Directive, the Climate and Energy package, and the Circular Economy strategy, including the revised Fertilising Product Regulation (FPR), the Waste Framework Directive and the Landfill Directive on CNP flows in EU farming systems. Measures in the legal framework with impacts on CNP flows are identified and described. Assessment reports of policy evaluations were scrutinized for information on CNP flows.

Chapter 3 of this report assesses the effects of the legal framework at the national level on activities such as the use, handling and storage of manure and streams of nutrients of biological origin, and

[1] The main industrial procedure for the production of ammonia today is artificial nitrogen-fixation from N2, using the century-old Haber-Bosch process. Global energy use for, and CO2-emmissions that come from NH_3-synthesis are estimated to be in the order of 1%

technologies like anaerobic digestion (AD) and composting for energy recovery, nutrient recovery and reuse (NRR) from manure and other biological streams in Europe. To reach this goal, a set of technologies was put forward by each project partner. A questionnaire (in annex) was sent out to all involved partners to identify the possible legal roadblocks pertaining to their shortlisted technologies and in which they were able to rate the positive or negative effect of the national legislation (ranging from -3 to +3) on the proposed CNP innovations. The focus of the questionnaire was on national legislation for each involved partner with the aim to provide the reader with an overview and to highlight the main trends which emerge from the questionnaire results. More detailed information for each technology and country is available in the original questionnaire annexed to this document.

It was concluded that the CAP, over the course of its lifespan since 1962, has been a driver for increased fluxes of N and P in agricultural systems, for a net loss of C out of agro-ecological systems and for an accumulation of N and P into natural environments in Europe. Successive reforms of the CAP are addressing these negative effects and new policies and legislation have been introduced to tackle some of the challenges of European agriculture.

The Water Framework Directive, the Groundwater Directive and the Nitrates Directive contributed to reducing water pollution from agricultural sources, mainly by limiting the use of fertilisers. The ND also decreased gaseous emissions of NO_x, NH_3 and N_2O to the atmosphere. The questionnaire showed that the implementation of the Nitrates Directive especially is moving towards stricter monitoring and higher fines. Despite this positive overall trend, nitrates pollution and eutrophication continue to cause problems in many Member States and although the Nitrates Directive is generally well accepted on the national level, the questionnaire showed that current limitations on livestock manure products are perceived as weighing down on the development of nutrient products recovered from manure. Therefore the assessment by the JRC of RENURE products and the possible revision of the Nitrates Directive are being welcomed.

The targets under the 2020 Climate and Energy Package and 2030 Climate & Energy framework are likely to decrease the flux of C in agricultural systems in Europe. The revised NECD and the Medium Combustion Plant Directive under the Clean Air Package will decrease agricultural emissions of NH_3 and NO_x to the air. The Biofuel Directive could potentially reduce emissions from agriculture by reducing ILUC emissions.

Under the CE package, the revised Landfill Directive, the revised Waste Framework Directive and the new FPR especially opening up the European single market, are expected to bring about a shift for bio-waste streams currently ending up in landfills to become available as fertilising products on agricultural land. The recovery and reuse of nutrients from bio-waste streams, through e.g. composting and anaerobic digestion, could effectively create a carbon and nutrient loop in our society and is perceived as crucial to successfully carry and promote innovations.

1. Introduction

The greatest transition in food production took place in the 19th and 20th centuries, along with a very impressive demographic transition from one to seven billion people in just 120 years. This became possible, in great part thanks to private ownership (e.g. of land). Private ownership, still heavily debated in 17th and 18th century England, is now regarded as a fundamental right and generally interpreted in absolute terms. Private property makes economies of scale possible, among others for the agro-industry: more and more our food chain is being concentrated in fewer hands (Kuhk, Holemans, & Van den Broeck, 2018; Platteau, Van Gijseghem, Van Bogaert, & Vuylsteke, 2016).

The changes in the food system had already begun with industrialisation (Steel, 2013): the emergence of railways, along with inventions such as canning (from the beginning of the 1800's and further developed thereafter) and freezing (quick freezing from 1924 on), allowed cities to thrive more or less everywhere, supplied by far-off food production. During the period 1870-1930, food became cheaper and could support cheap labour. During the following few decades of 1950-1970, food became a tradeable bulk commodity produced by an agro-industry and strongly relying on chemical fertilizers and cheap fossil energy, causing heavy environmental damages such as a massive loss of biodiversity, a destructive exploitation of soil (McMichael, 2013), chemical pollution and increasing the magnitude and speed of biogeochemical cycles of minerals and materials, especially nitrogen and phosphorus (Rockström, et al., 2009).

It is important to keep in mind that it that the European legal framework legislation has emerged within this historical context. Starting with the Common Agricultural Policy in 1962, the European Economic Community and later the European Union, have assisted this agricultural transition in Europe, with the aim to ensure food security and a viable agricultural sector. Adjustments to negative effects of this agricultural transition and with a focus on the environmental challenges, were tackled through reforms of the Common Agricultural Policy starting in the early 1990's. New legislation was also introduced to deal with specific issues that were partially a consequence of this agricultural transition, such as decline in biodiversity, the mass extraction, conversion and use of resources leading to the depletion of natural resources and nutrient losses to the environment. Therefore, this report analyses the relevant European legislative framework (chapter 1) and identifies, within each partner country, the implementation of this legislation to gauge whether this legislation is providing a supportive legal framework – thus acting as an incentive for new ecological technology – or, on the contrary, if the legal framework is hampering the development of a given technology (chapter 3).

In light of the Nutri2Cycle project, the report will focus on the technologies for the use, handling and storage of manure and streams of nutrient-containing substances of biological origin, like anaerobic digestion (AD) and composting for energy recovery, nutrient recovery and reuse from manure and other biological streams in Europe.

For the analysis on a national level, a set of technologies was put forward by each project partner and each project partner filled in a questionnaire (see Annexes) where he was able to report the perceived legal roadblocks and/or opportunities pertaining to his respective set of technologies. In the questionnaire, each partner was also given the possibility to rate the effects of national legislation on the CNP innovations (from -3 being very negative, to +3 being very positive). The introduction of this rating system was meant as an additional means to classify and quantify the feedback received in the questionnaires.

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However, the analysis in chapter 3 does not aim to be an exhaustive review of the questionnaire: for further information, the unabridged input for each technology and country can be found in the original questionnaire annexed to this report. The present report is rather meant as an overview of the emerging trends based on a literature study and the questionnaire results. To provide an easily digestible summary, chapter 2 focused on the most impactful pieces of national legislation, i.e. those that received very positive ratings (ranging from +2 or +3), and those that received a negative rating (-1 to -3).

After each chapter, an synthesis is provided with the main conclusions. A synthesis of the whole report can be read in the Executive Summary.

We would like to take the opportunity to thank all Nutri2Cycle partners for sharing their expertise, for providing insights on national or regional legislation and for kindly giving us their feedback on the draft report. A special Thanks goes out to our work package partners from Ghent University, Wageningen University and Research, the European Biogas Association and United Experts.

2. European Legal Framework

2.1. Common Agricultural Policy

2.1.1. Introduction

The CAP is a common policy for all EU countries since 1962. It is managed and funded at European level from the resources of the EU's budget and is the most important driver of agricultural management and sustainability in the European Union. Its objectives of economic and social kind have remained unchanged since the Treaty of Rome of 1957 (art. 33) that established the common market in 1958 (European Parliament, 2019):

a) To increase agricultural productivity by promoting technical progress and ensuring the optimum use of the factors of production, in particular labour;

b) To ensure a fair standard of living for farmers;

c) To stabilise markets;

d) To ensure the availability of supplies;

e) To ensure reasonable prices for consumers.

The EU supported farmers with EUR 58.82 billion in 2018; 41.8 billion through income support, 14.4 billion through rural development and 2.7 billion through market related measures (European Commission, 2019). The CAP now has a direct impact on 14 million farmers, with a further 4 million people working in the food sector (Mosquera-Losada, et al., 2018; European Commission, 2019).

2.1.2. CAP in history

Productivity gains and stable markets were seen as spearheads of food security and the CAP created the conditions for a single market within the European Economic Community and the protection of European products. It introduced a restriction on imports and an incentive for exports. Protein crops such as soya and other basic products for animal feed are an exception to this, which explains why there is landless intensive pig farming around European ports (Holemans, 2016). After establishment of the CAP in 1962 among the 6 countries of the European Economic Community, Europe shifted to being an exporter in the 1970's. The CAP led to a surplus production and had budgetary problems due to the unlimited buying guarantee. On environmental level, the CAP has been blamed for the far-reaching encouragement of environmentally damaging intensive farming (Jeffery, 2003) (Senet, 2019), especially in its first years up until the 1970's, and it has profoundly transformed the European landscapes (CAPeye, 2017). E.g. reparcelling, accentuated with the CAP, has led to the destruction of hedges and trees, especially between 1962 and 1991, causing a decline in ecological corridors, leading to a general decline in biodiversity and abundance of wildlife that can provide benefits such as balancing between crop pests and their predators, and decreasing the resilience of fields against erosion from wind and water (CAPeye, 2017).

Agriculture in the EU has become highly intensive over that period, heavily relying on pesticides, fertilizers and heavy machinery (Oenema, 2011) (CAPeye, 2017). The promotion of new techniques allowed for a considerable population growth, but in return has heavily increased the magnitude and speed of nutrient (and energy) fluxes through society, through agricultural systems and soils, and decreased the carbon and nutrient stocks in and on European soils. These external inputs have required a high use of energy and non-renewable resources and come at a heavy environmental cost.

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Both agriculture and wild biodiversity have been heavily affected. The Less Favoured Areas directive (Council of the EU, 1975) was an exception to this trend. Although devoid of defined environmental objectives, this directive had certain positive effects on biodiversity.

Food production after the 1980's has seen the development of the bio-industry and greater control of biophysical processes, is dominated by corporate and financial power and is focused on a global circulation of food (McMichael, 2013). Coinciding with the Rio Earth Summit, the MacSharry reforms in 1992 were introduced to limit overproduction and to respond to societal demands to tackle the CAP's negative environmental effects. Price support was scaled down and replaced with direct payments per hectare, shifting from market to producer support. In practice, subsidies that were "decoupled" and from then on based on the surface of land owned by farmers, decreased the intensification of production but incentivised farmers to grow in size and destroy landscape features. Measures were also introduced to stimulate land withdrawal from production; limit stocking levels, afforestation, farmers' retirement and the obligation to leave part of the land with cereals, oilseed and protein crops to lie fallow. Although rather introduced to limit overproduction, these measures had positive effects on biodiversity and decreased the use of agricultural inputs. However, despite the policy of "set aside", overproduction persisted (Jeffery, 2003).

The flagship measures of the CAP were the Agro-environment measures: all member states had to financially compensate farmers that voluntarily introduced more environmentally respectful practices. This was built out further in the Agenda 2000. The CAP was divided in 2 pillars: a 'first pillar' that provided production support based on single farm payments, and a 'second pillar' focusing on rural development and environmental measures. Agri-environment schemes became compulsory for EU member states under Pillar 2, and were co-financed by them, representing 15% of the CAP budget in 2001.

The 2003 fundamental reform was based on a complete "decoupling" of support, completely cutting the links between subsidies and production. Farmers now received an income support on a per-hectare basis. As explained before, this decoupling, although not introduced for environmental reasons, helped to limit intensification and thus had a positive environmental impact. The CAP, through its income support or "single farm payments" (pillar 1) pushed forward "cross-compliance" conditions by which farmers that received payments, were required to meet other relevant European Community legislation relating to environmental, food safety, animal and plant health and animal welfare standards. Concretely, farmers had to comply with several European directives, among others the ND, Habitat Directive and Birds Directive. Farmers receiving support had to also respect the good agricultural and environmental condition of land (GAEC) that were defined at national level. These were measures that specifically took the environment into account. They had a positive impact on environmental level, but were only applicable to the CAP-beneficiaries and showed relatively low efficiency due to the limited control measures in place.

2.1.3. CAP 2014-2020

The legal basis for the CAP 2014-2020 is established in the treaty on the functioning of the European Union (European Union, 2016). The following 4 regulations set out the different elements of the CAP 2014-2020 (European Commission, 2019):

f) Rules for direct payments to farmers (European Parliament & Council of the EU, 2013)

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g) A common organisation of the markets in agricultural products (European Parliament & Council of the EU, 2013)

Support for rural development (European Parliament & Council of the EU, 2013)

Financing, management and monitoring of the CAP (European Parliament & Council of the EU, 2013)

In 2013, the last big CAP-reform outlined the CAP for 2014-2020 to strengthen the competitiveness of the sector, promote sustainable farming and innovation, to support jobs and growth in rural areas and to move financial assistance towards the productive use of land. The decoupled aid system from 2003 that provided generic income support, was once again converted into a system in which instruments are coupled to specific objectives or functions. Single farm payments under pillar 1 were replaced by a system of payments in stages or strata, comprising seven components:

Compulsory support schemes for EU countries:

a) A basic payment;

    1. Per hectare support for each “active farmer”

b) A greening payment (European Commission, 2019);

    2. EU countries have to allocate 30% of their income support to greening.

    3. Paid if farmers comply with:

        a. Crop diversification: farms with more than 10 ha of arable land have to grow at least two crops, while at least three crops are required on farms with more than 30 ha;

        b. Maintaining permanent grassland to support carbon sequestration and protect biodiversity. The ratio of permanent grassland to agricultural land is set by EU countries at national or regional level (with a 5% margin of flexibility). Moreover, EU countries designate areas of environmentally sensitive permanent grassland. Farmers cannot plough or convert permanent grassland in these areas;

        c. Ecological Focus Areas (EFA): farmers with arable land exceeding 15 ha must ensure that at least 5% of their arable land is an EFA, for example cash crops, cover crops, trees, hedges or land left fallow. The reasoning is that EFA’s would improve diversity and habitat.

c) Payment for young farmers;

    1. Max 2% of budget allocation

    2. For farmers no more than 40 years old, setting up for the first time as head of their farm, up to 5 years before claiming support; this payment is available for up to 5 years.

Under the optional support schemes, EU countries can choose:

d) A ‘redistributive payment’ (optional, applied by 8 member states)

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1. additional support for the first hectares of farmland;

e) Additional income support in areas with specific natural constraints (optional);

f) Limited amounts of aid coupled to production ('coupled support' — payments linked to specific crops or types of livestock) to help agricultural sectors in their own country which are in difficulty;

g) A simplified system for small farmers (implemented by 15 States) – an annual payment up to EUR 1.250.

Since recent data on environmental indicators is scarce and environmental impacts are often long-term processes, it remains difficult to establish a direct link between the CAP intervention and its actual result on the environment. Agricultural GHG emissions declined by more than 20 % since 1990 to 12 % of total EU GHG emissions in 2016, thanks to reduced nitrous oxide emissions from agricultural soil management (mainly due to a decline in use of nitrogenous fertilisers) and reduced enteric fermentation emissions due to an overall reduction in livestock numbers. However, the rate of decline has levelled out in the past 10 years and emissions in 2016 fluctuated around 490 million t of CO2 equivalent. Contrary to the common belief, emissions from grassland and cropland are still positive, albeit on a declining trend (-15% between 2006 and 2016). Main reasons are conversion of land to cropland and grassland management practices, but large differences between Member states are noted. In addition, ammonia emissions from agriculture increased during the last two years (+10%) (European Commission, 2018).

Scientists, environmental organisations and even the European Court of Auditors have strongly criticised the greening payment. While the EU spends €12 billion per year on the new green payment, representing 30% of all CAP direct payments and almost 8% of the whole EU budget, European Court of Auditors concluded that greening, as currently implemented, is unlikely to enhance the environmental and climate performance of the CAP, mainly due the low level of requirements, which largely reflect the normal farming practice. It was found that the budget allocated to greening remained the same all through subsequent rounds of the legislative process that was adopted by the European Commission, starting with a scientific impact analysis, followed by legislative proposals and finally to the adopted legislation. However, the ambitious initial reform proposals were weakened down during each subsequent step of that legislative process (European Court of Auditors, 2017) (CAPeye, 2017). Moreover, conditions are too similar to AEM´s and GAEC´s that were already in place, resulting in a greening payment that pays farmers to do what they already were doing under another framework (CAPeye, 2017). Greening, therefore, remains essentially an income support scheme (European Court of Auditors, 2017). It is estimated that greening has led to a change in farming practice on only around 5 % of all EU farmland (European Court of Auditors, 2017), partly because only 27% of European useful agricultural land and 77% of agricultural enterprises are not submitted to greening measures, mainly due to their size or other exception measures (CAPeye, 2017).

In 2015, the most frequently declared EFA types were the field-wide interventions that mostly follow an annual cycle: nitrogen-fixing crops (39.13%), land lying fallow (38.52%) and catch crops (14.87%). These were followed by the more (semi-)permanent linear or point measures : landscape features (4.80%), buffer strips (1.49%), followed by the rather permanent measure of afforestation (0.97%). Strips along forests (0.13), short rotation coppice (0.08%), terraces (0.00) and agroforestry (0.00%), were the least favoured EFA areas (European Commission, 2017). The low success rate of e.g.

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agroforestry, a potentially highly remunerating form of agriculture, could be partially explained by the fact that the EU currently indicates that arable land, and therefore agroforestry on such land, is not eligible for direct payments if it contains more than 100 trees per hectare, as established by Regulation 640/2014 (Mosquera-Losada, et al., 2016).

Soil carbon sequestration is directly dependent on soil biodiversity and is related with a healthy soil that better holds nutrients. This highlights the links and possible synergies between improving biodiversity on farms and climate change mitigation (due to carbon sequestration), which is directly related to all three mandatory practices under greening. Unfortunately, scientists from all EU Member States and beyond are observing the catastrophic decline in the populations of birds, mammals, reptiles, amphibians, insects and plants across Europe, due to harmful agricultural practices (European Ornithologists Union; European Mammal Foundation; Societas Europaea Herpetologica; Societas Europaea Lepidopterologica; Butterfly Conservation Europe; European Bird Census Council, 2019). Leguminous crops, one of the most frequently used EFA's, can result in displacement of nitrogen fertiliser with nitrogen fixation. However, literature shows that, under the current EFA rules and conventional farming practices, it is unlikely that most of the widely adapted nitrogen-fixing crops and catch and cover crops grown on EFA's, provide significant benefits for farmland biodiversity. In contrast, the EFA options of land lying fallow and landscape features such as hedges and field margins generally have the potential under typical management to provide much greater, more diverse and more reliable benefits on biodiversity and ecosystem services (European Commission, 2017) (Underwood & Tucker, 2016). Landscape features also potentially reduce soil loss, increase the soil's capacity to store nutrients or to decompose pollutants such as pesticides, and reduce runoff erosion and flooding of downstream land. This potential erosion reduction by landscape features is again linked to healthy soil that can sequester more carbon and better holds nutrients (EIP AGRI Focus Group on Ecological Focus Areas, 2016). Grassy strips can also benefit nutrient management in that they can become raised banks because they are not ploughed regularly, so the soil is not washed away. These banks can filter water, slow its movement and allow the reabsorption of some nutrients by the soil, especially organic phosphorus. Nutrient uptake by hedgerows, especially during the early spring, encourages them to grow. The recycling of nutrients when the leaves fall to the ground then keeps the resource within the system (EIP AGRI Focus Group on Ecological Focus Areas, 2016).

Six EU Rural Development Policy priorities provide the basis for rolling out support from the European Agricultural Fund for Rural Development (EAFRD) to rural areas. The prerequisites for farmers to receive payments from Pillar II are established by each Member State based on their own interests from a productive and environmental point of view (Nègre, 2019); and too fragmented (Mosquera-Losada, et al., 2018). EU Member States and regions need to address at least four of these priorities when designing their Rural Development Programmes (RDPs). These broader policy priorities are broken down into specific areas of intervention, known as Focus Areas (FAs). The RDPs set out quantified targets against the selected Focus Areas and outline the programme Measures and their allocated funding that will be used to reach the targets (European Network for Rural Development, 2017). Priority 4 and 5 are the most relevant for Nutri2Cycle. These priorities and their FAs are:

Priority 4: Restoring, Preserving and Enhancing Ecosystems

a) FA 4A: Restoring, preserving and enhancing biodiversity;

b) FA 4B: Improving water management;

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c) FA 4C: Preventing soil erosion and improving soil management.

Priority 5 focuses on a resource-efficient, climate-resilient economy.

a) FA 5A: Increasing efficiency in water use by agriculture;

b) FA 5B: Increasing efficiency in energy use in agriculture and food processing;

c) FA 5C: Facilitating the supply and use of renewable sources of energy;

d) FA 5D: Reducing greenhouse gas and ammonia emissions from agriculture;

e) FA 5E: Fostering carbon conservation and sequestration in agriculture and forestry.

FA 4C and FAs 5B to 5E are most directly linked to CNP stocks and flows in agriculture; but also the other FAs under priorities 4 and 5 influence CNP flows and stocks in agriculture.

2.1.4. CAP post-2020

Drawing lessons from greening during the CAP 2014-2020 period has led to several conclusions by several civil society groups (CAPeye, 2017):

a) The lack of results obtained by greening, although being a step in the right direction;

b) Measures need to be tailored to local needs rather than uniform across the EU;

c) The importance of results-based measures and a long-term horizon rather than basing financing on commitments and permanently subjecting farmers to CAP reforms;

d) The possible role of new technologies in agriculture;

e) A debate on the agricultural models and their environmental impact, questioning if an intensive industrial agriculture can be at the same time environmentally friendly, or if the re-emergence of a peasant and agro-ecological model be promoted.

Following this, the European Commission has proposed “The new delivery model” (NDM) which has been described by Commissioner Hogan as representing a shift from a compliance-based to a performance-based or results-based governance system for the CAP. The key instrument designed to underpin the NDM will be the requirement for each Member State to draw up a Strategic Plan setting out its assessment of needs, the specific CAP objectives it intends to address, its intervention strategy including the targets it intends to achieve with respect to these objectives, and the interventions it plans to use, thereby adapting to the logic of results-based payments and reducing administrative charges. (Matthews, 2018; CAPeye, 2017; European Commission, 2018)

Reforms of CAP post-2020 will take place during the Nutri2Cycle project period between 01/10/2018 – 30/09/2022. The Commission proposal for the multiannual financial framework (MFF) 2021-2027 includes €365 billion for the CAP (in current prices). This corresponds to an average share of 28.5% of the overall EU budget for the period 2021-2027. Out of this amount for the CAP, €265.2 billion is for direct payments, €20 billion for market support measures under pillar 1 (EAGF) and €78.8 billion is for rural development (EAFRD) under pillar 2. An additional €10 billion will be available through the EU's Horizon Europe research programme to support specific research and innovation in food, agriculture, rural development and the bio-economy (European Commission, 2018). In order to allow Member States to better adapt the policy to their farming sector’s priorities, they will have the option to

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transfer up to 15% of their CAP allocations between direct payments and rural development. Member States will also have the flexibility to transfer an additional 15% from pillar 1 to pillar 2 for environmental and climate measures without co-financing. 40% of the CAP's overall budget is expected to contribute to climate action and at least 30% of pillar 2 funding will be spent on climate and environmental measures (European Commission, 2018).

In what follows, measures of the CAP post-2020 are mentioned, with relation to the objectives of Nutri2Cycle they relate to.

The CAP post-2020 presents changes in the set of criteria to subsidy allocation. Hectare-based payments without both ceilings and conditionality upon strong and effective socio-ecological criteria will no longer be acceptable. (Directorate-General Agriculture and Rural Development, 2019)

Three of the nine future CAP objectives aim to enhance and improve environmental and climate change actions and ambitions by the European Commission (Directorate-General Agriculture and Rural Development, 2019):

a) Contributing to climate change mitigation and adaptation, as well as sustainable energy;

b) Fostering sustainable development and efficient management of natural resources such as water, soil and air;

c) Contributing to the protection of biodiversity, enhanced ecosystem services and preservation of our habitats and landscapes.

Of the CAP post-2020, especially higher environment and climate action objectives (e.g. preserving carbon rich soils such as wetlands, bigger focus on nutrient management with an obligatory farm nutrient management tool (Farm Sustainability Tool for Nutrients to improve water quality, reduce ammonia and nitrous oxide levels), crop rotation instead of crop diversification) (Fertilizers Europe, 2018) may potentially influence CNP focus and positively influence CNP in soils. This links to the Nutri-2-Cycle's focus on nutrient management: SL1 to SL7; reducing ammonia and NO_x: SL1 & 2 and crop rotation vs diversification: potential positive impact - SL 1 & 2 objectives.

Conditionality is still an integral part of the future CAP framework. It links income support (and other area- and animal-based payments) to environment- and climate-friendly farming practices and standards known as 'Good Agricultural and Environmental Conditions' (GAECs) and Statutory Management Requirements (SMRs). There are a total of 10 GAECs in the future CAP, an extra 3 new GAECs compared to the current CAP (Directorate-General Agriculture and Rural Development, 2019):

Climate Change

a) GAEC 1 – Permanent pastures - relates to N2C's SL1 - Decrease CNP loss in soils;

b) GAEC 2 – Preservation of carbon rich soils such as peatlands and wetlands (new) – relates to N2C's SL1 - Decrease CNP loss in soils;

c) GAEC 3 – Maintenance of soil organic matter through ban on burning stubble - relates to N2C's SL1, SL5, SL11 - Decrease CNP loss in soils;

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Water

d) GAEC 4 – Establishment of buffer strips along watercourses - Decrease NP loss from water sheet flow into rivers;

e) GAEC 5 – Compulsory use of the new Farm Sustainability Tool for Nutrients (new) – relates to N2C's SL18, SL24 mainly. Also relates to N2C's SL1, SL2, SL3, SL4 - Better overall nutrient management and decreased NP losses from agriculture systems;

Soil Protection and Quality

f) GAEC 6 – Minimum land management under tillage to reduce risk of soil degradation including on slopes - relates to N2C's SL1 Decrease CNP loss from soils;

g) GAEC 7 – No bare soil in most sensitive period. relates to N2C's SL7 Decrease CNP loss from soils

h) GAEC 8 – crop rotation (replaces crop diversification). relates to N2C's SL1, SL2 Decrease CNP loss from soils, Crop rotation breaks pests' reproductive cycles. A lower pest pressure is likely to reduce the need for pesticides, which should consequently increase soil life and biodiversity, leading to higher levels of soil-C (organic matter), less nutrient losses and lower fertilization needs. This is likely to reduce contamination of groundwater and rivers with N and lower build/up of P. Rotation schemes including legumes may reduce the need for N-fertilisation.

Biodiversity and Landscape

i) GAEC 9 – Maintenance of non-productive features and areas including a minimum share of agricultural area devoted to non-productive features or areas, retention of landscape features, a ban on cutting hedges and trees during the bird breeding and nesting season, and as an option, measures for avoiding invasive plant species (replaces Ecological Focus Areas).

j) GAEC 10 – Ban on converting or ploughing permanent grassland in Natura 2000 sites (new). – relates to N2C's SL1 Decrease CNP loss from soils

The future CAP incorporates a new and innovative system, known as 'eco-schemes', to increase national environmental and climate-care action based on local needs and circumstances. It is mandatory for member states to design and offer one or more eco-schemes.

The Agri-environment-climate measures (AECMs) of the future CAP are designed to ensure best environmental and climate practices under the Rural Development framework. They aim to restore, preserve and enhance ecosystems; promote resource efficiency; and move towards a low-carbon and climate-resilient economy. AECM interventions could include: environmentally friendly production systems such as agroecology (relates to N2C's SL3, SL4) and agroforestry (relates to N2C's SL3); precision farming methods (relates to N2C's SL19,SL20, SL21); organic farming (relates to N2C's SL3, SL4); renewable energy and the bio-economy (relates to N2C's SL13, SL14, SL15, SL18).

The modernised CAP also links to the SDG 2030 goals, aiming to reduce food waste by 50%. Reduction of food waste is likely to generally slow down and reduce the fluxes through and losses of CNP in the agriculture sector; reduction of CNP losses from soils, a decrease of the availability of input streams for AD, composting and NRR and streams of nutrients from those NRR toward agriculture systems.

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A stronger emphasis on waste prevention calls for inclusion of other value chain actors, such as retail and food, in subsequent projects on nutrient (re)cycling.

Capping - the EU plans to put a 50.000€ ceiling per farm per year on direct payments, only to be exceeded if the farm supports a high number of quality jobs or has a high social and environmental performance. A higher number of small farmers may therefore be profiting from the CAP, incentivising them to comply with better nutrient management practices, improving nutrient management on their farms.

2.1.5. Conclusion

Introduced in 1962, the CAP has assisted the transition of the agriculture sector to become highly productive. Thanks to productivity gains and stable markets to assure food security, the CAP turned the European Economic Community into a food-exporting region in merely a decade. However, productivity gains were based on heavy use of chemical fertilizers and fossil energy. Therefore, the CAP has been a driver for increased fluxes of N and P through agricultural systems in Europe, for a net loss of C out of agro-ecological systems and for a respectively a flux and an accumulation of N and P into natural environments in Europe. As a reaction to societal demands, environmental measures have been put in place from 1992 and onwards, along with an initial small budget for environmental measures that has grown to become a considerable share of the CAP budget. Despite the most recent reforms from the 1992 MacSharry reforms and onward up to the 2013 CAP reforms, the CAP is still under heavy criticism (Monbiot, 2016) for its "weak environmental effectiveness" (Dupraz & Guyomard, 2019) and incentives to destroy wildlife habitats (Monbiot, 2016; Monbiot, 2018).

Nonetheless, the 30% of the budget of pillar 1 allocated to greening during CAP 2014-2020 confirms the willingness to provide environmental public goods through the CAP. However, the poor application rates of some of the most environmentally beneficial practices among the greening measures, largely linked to good nutrient management, confirm that environmental measures under Pillar 1 of the CAP are largely ineffective in conserving or restoring biodiversity and soil health, are inadequate to provide a sound nutrient management, and their implementation is too often poorly monitored. Current agri-environmental programmes are both under-funded and insufficiently targeted to address damage to the specific biodiversity of agricultural environments[2]. Despite "public money for public goods" being a flagship initiative of the current CAP 2014-2020, the promise of a transition towards more sustainable farming practices and systems is not living up to its initial expectations (Stolze, Sanders, Kasperczyk, & Madsen, 2016).

As response to the demands of civil society, the Commission has put forward its NDM that should allow Member States to better adapt the future CAP to their farming sector's priorities. Results-based monitoring also replaces compliance-based monitoring. Additional objectives aim to enhance and

[2] 2,500 scientists from several conservation organisations (Ornithologists Union; European Mammal Foundation; Societas Europaea Herpetologica; Societas Europaea Lepidopterologica; Butterfly Conservation Europe; European Bird Census Council) urged the EU to reform the environmentally 'damaging' CAP European in "*Open letter to MEPs. Reform the CAP: harmful agriculture is destroying nature"*. (2019, 11 05). Retrieved 01 06, 2020, from https://www.euractiv.com/section/agriculture-food/news/2500-scientists-urge-eu-to-reform-environmentally-damaging-cap/

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improve environmental and climate change actions and ambitions. Conditionality is still an integral part of the future CAP framework, through the GAECs and the SMRs. The eco-schemes, obligatory for member states, are introduced. As part of the Rural Development framework, AECMs are designed to ensure best environmental and climate practices.

Subsequent reforms of the CAP show a tendency that the CAP is evolving to undo some of the negative effects it has caused in the past. The question remains if the CAP can address the fundamental issues at hand and formulate answers that are strong enough and timely.

2.2. Water Framework Directive

The Water Framework Directive (European Parliament & Council of the EU, 2000) establishes a framework for Community action in the field of water policy. It establishes a comprehensive, cross-border approach to water protection organised around river basin districts, with the aim of achieving good status for European bodies of water by 2015, and defines environmental objectives for surface water, groundwater and protected areas. It has applied since 22 October 2000. EU countries had to incorporate it into national law by 22 December 2003. Member States' legal acts on water are typically based on the Water Framework Directive. They include regulations regarding the discharge of digester effluents, included purified liquid effluents, into water bodies (Hermann & Hermann, 2018) and are therefore relevant to the Nutri2Cycle project.

The Water Framework Directive sets out rules to halt deterioration in the status of EU water bodies and achieve 'good status' for Europe's rivers, lakes and groundwater by 2015. The Water Framework Directive is currently under review, among others due to the poor results regarding the improvements of the ecological status of water bodies in the EU. A priori, the challenges were mainly considered to be the frequent and non-transparent use of exemptions, lack of control and particularly agricultural practices (Hermann & Hermann, 2018). The results of the review are mixed (Directorate-General Environment of the European Commission, 2019). On the one hand, the Water Framework Directive has been successful in setting up a governance framework for integrated water management for the more than 110,000 water bodies in the EU, slowing down the deterioration of water status and reducing (mainly point source) chemical pollution. On the other hand, no substantial progress in water bodies' overall status has been made between the first and the second river basin management cycles. The Directive's implementation has been significantly delayed and less than half of the EU's water bodies are in good status, even though the deadline for achieving this was 2015, except for duly justified cases (Directorate-General Environment of the European Commission, 2019).

One of the factors that hindered the achievement of better results was the fact that it proved more difficult than envisaged to establish a governance framework that takes into account the specific conditions in each Member State. In addition, good status depends not only on mitigation measures to address current pressures, but also on restoration measures to address pressures from the past, such as hydromorphological changes and chemical pollution. Finally, good status of water bodies also critically depends on the full implementation of other pieces of EU legislation, such as the ND and the Urban Waste Water Treatment Directive, as well as better integration of water objectives in other policy areas such as agriculture, energy or transport. This has not happened yet at the scale necessary (Directorate-General Environment of the European Commission, 2019).

Lack of financial resources is another factor that stands in the way of achieving better results. The measures proposed by Member States are often determined by what can be delivered with the budgets and policies already in place, rather than being the result of an integrated approach. Member

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States tend to rely on easy technological fixes that address point source pollution, while leaving diffuse sources of pollution largely unaddressed. This leads to ineffective implementation, because the approach taken is not based on the pressures and impacts analysis and monitoring data, which would help Member States determine what action is needed to target the pressures on water bodies and determine the scale of the action needed. For the Water Framework Directive, studies on the value of ecosystem services and the restoration of rivers indicate that: (i) the benefits of measures to improve the status of water bodies outweigh the costs; and (ii) citizens' willingness to pay exceeds the current expenditure on water measures. Insufficient use is being made of the principle of cost recovery, while exemptions based on disproportionate costs are not always adequately justified (Directorate-General Environment of the European Commission, 2019).

2.2.1. Groundwater Directive

Article 17 of the Water Framework Directive states that the European Parliament and the Council shall adopt specific measures to prevent and control groundwater pollution (European Parliament & Council of the EU, 2000), paving the way for the Groundwater Directive (European Parliament & Council of the EU, 2006), therefore also known as the 'daughter directive' to the Water Framework Directive . Furthermore, in 2013, the Water Framework Directive repealed Directive 80/68/EEC on the protection of groundwater against pollution by certain dangerous substances. This directive is designed to protect groundwater and fill the legislative gap following the repeal of Directive 80/68/EEC. The Groundwater Directive has applied since 16 January 2007 and EU countries had to incorporate it into national law by 16 January 2009. It is designed to prevent and combat groundwater pollution in the EU and includes procedures for assessing the chemical status of groundwater and measures to reduce levels of pollutants. It includes criteria for assessing the chemical status of groundwater, for identifying significant and sustained upward trends in groundwater pollution levels, and for defining starting points for reversing these trends. It prevents and limits indirect discharges (after percolation through soil or subsoil) of pollutants into groundwater.

Groundwater protection is a priority in EU environmental policy for several reasons. Once contaminated, groundwater is harder to clean than surface water and the consequences can last for decades. Furthermore as groundwater is frequently used for the abstraction of drinking water, for industry and for agriculture, groundwater pollution can endanger human health and threaten those activities. Moreover groundwater provides the base flow for many rivers (it can provide up to 90% of the flow in some watercourses) and can thus affect the quality of surface water systems. It also acts as a buffer through dry periods, and is essential for maintaining wetlands (European Union, 2017).

According to the Groundwater Directive, the good chemical status of groundwater is based on EU standards of nitrates (not to exceed 50 mg/l) and pesticides and on threshold values for all pollutants and indicators of pollution, established by Member States.

One of the threshold values set by EU countries is cadmium (Cd). Cadmium is a heavy metal with specific hydro-chemical characteristics causing its potential mobility in groundwater. It remains in solution at near neutral pH (< 6.5) in contrast to the typical fixation of other heavy metals. Cd is therefore one of the most mobile heavy metals in the environment. The elevated mobilization potential is the reason for faster Cd release from soil into groundwater than other heavy metals.

Cd sources can be anthropogenic and natural. Important anthropogenic Cd sources include mining, atmospheric deposition of combustion emissions, and agricultural applications, e.g., sewage sludge and phosphate fertilizers. Cd leaching from waste material, landfills, and fertilization only can happen

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where Cd release is promoted by replacement, formation of soluble complexes, acidification, or oxidation. Excessive N fertilization also decreases soil pH, which is associated with increased ionic strength and enhanced Cd mobility. Summarized, the following scenarios can lead to Cd release (Kubier, Wilkin, & Pichler, 2019):

a) Natural origin and release of Cd. Elevated Cd concentrations in groundwater are linked to rock types with increased Cd contents, e.g., sulfides. Cadmium is released in the context of weathering or naturally caused acidification.

b) Anthropogenically induced release of naturally occurring Cd. In this case, Cd originates from natural sources, but its release is caused by anthropogenic influences, e.g., atmospheric deposition or acidification linked to denitrification of nitrogen fertilizers.

c) Anthropogenic Cd input. According to the most likely reason for elevated Cd in groundwater, Cd originated from P fertilizers and atmospheric deposition. Further entries are linked to industrial activities and traffic.

The Groundwater Directive, through its good chemical status of groundwater, limits the use of fertilisers that give high risk of nitrate-leaching. Moreover this may limit the use of fertilisers with a high Cd-content, such as certain P-fertilisers from phosphate rock, as well as fertilising products that increase the solubility of Cd through acidification.

2.2.2. Nitrates Directive

The 1991 ND is one of the earliest pieces of EU anti-pollution legislation of then European Economic Community. Although older than the Water Framework Directive , The ND forms an integral part of the Water Framework Directive and is one of the key instruments in the protection of waters against agricultural pressures. It is the most important piece of European (EU) regulation for reducing environmental impacts of N and P from fertilizer and manure and for increasing nitrogen use efficiency (van Grinsven, et al., 2012) and closely links to other EU policies which address air and water quality, climate change and agriculture.

To promote good agricultural practices and reduce water nitrate pollution from agricultural sources, the Directive sets out a number of steps to be fulfilled by Member States, notably: monitoring of all water body types; identification of waters that are polluted or at risk of pollution; designation of nitrate vulnerable zones; and establishment of codes of good agricultural practices and national action programmes. The ND also contributes to the achievement of the Sustainable Development Goals in the EU by helping reducing negative environmental impacts associated with food production (SDG 2), by supporting improved water quality (SDG 6) and by reducing pollution affecting freshwater and ecosystems (SDG 14 and SDG 15) (European Commission, 2018; European Commission, 2018).

At this moment the DG ENVI en JRC are performing a study under the name SAFEMANURE which could lead to a revision of the ND in the future (next to the new Fertilising Products Regulation, see below). The objective is to define harmonised criteria that could allow N fertilisers, partially or entirely derived from manure, to be used in areas with water pollution by N following the same provisions applied to N containing chemical fertilisers as defined in the ND, while ensuring adequate agronomic benefits. In other words, criteria need to be developed that define the point at which N-rich manure derived materials, referred to as RENURE (REcovered Nitrogen from manURE) materials, meet standards to act as 'chemical fertilisers' as defined in the ND. Guidelines then need to allow member states to grant farmers to use RENURE materials to replace chemical fertilizers, above the threshold of 170 kg/ha N

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established by the ND (Directorate-General of Environment of the EC; Joint Research Centre, 2019). This will most likely be realized through a system of derogations.

RENURE materials should have a mineral N:total N ratio ≥ 90% or a total organic carbon (TOC):total N ratio ≤ 3, where the ratios should be adjusted for any Haber-Bosch-derived N added during the manufacturing process. Limit values of Cu, Hg and Zn are proposed. Provisions should be taken to minimise nutrient leaching and run-off losses and to prevent and minimise NH_3 emissions from RENURE. Recovered ammonium nitrate and ammonium sulphate (also called scrubbing salts), and recovered mineral concentrates through reverse osmosis are top priority materials under study. Anaerobic digestate (liquid fraction) and struvite are medium priority. Untreated manure, liquid-solid separated manure without treatment, concentrate from vacuum evaporation or stripping, and dried fibrous organic material are low priority materials (Directorate-General of Environment of the EC; Joint Research Centre, 2019).

In September 2020, the JRC has published its report on the "Technical proposals for the safe use of processed manure above the threshold established for Nitrate Vulnerable Zones by the Nitrates Directive (91/676/EEC)" (SAFEMANURE, 2020). Earlier in 2019 the JRC published its study on P-salts, biochar and ashes and the study on by-products is still ongoing (see below).

Results indicate that most contaminants of emerging concern (CECs) levels are generally reduced in candidate RENURE N fertilisers relative to raw manure, although some candidate RENURE N fertilisers contain higher levels of some CECs than the Haber-Bosch N fertilisers they will be replacing (SAFEMANURE, 2020). Manure processing therefore has also the potential to reduce inputs of veterinary drugs (as CEC) into the environment and be effective in decreasing the overall residual antibiotic load relative to the current business-as-usual scenario of manure land spreading (Directorate-General of Environment of the EC; Joint Research Centre, 2019).

Some effects of the ND are: the enforcement of limited periods for fertilizer application, a balanced N fertilization, limitations to manure nitrogen application, a limitation to N fertilizers on sloping soils during wet conditions and near watercourses decreasing N leaching (Velthof, et al., 2010). The ND implementation within EU-27 has decreased N losses between 2000-2008 by: 16% for N leaching & runoff, 9% for NO_x, 3% for NH_3 emission and 6% for N_2O emission. But much larger effects were seen in countries with intensive agricultural: N leaching: 36-60%, NH_3: 12-16%, N_2O: 12-20% (Velthof, et al., 2013). Balanced N fertilization decreases the N fertilizer input to (because of lower N contents of grass) and the production of manure by cattle and, by that, reduces N emissions. The implementation of the ND decreased both N leaching losses to ground and surface waters, lowering nitrates concentrations in both surface and groundwater, and decreased gaseous emissions to the atmosphere. The lower emissions were mainly due to the lower and regulated N inputs by fertilizers and manures (Velthof, et al., 2013; van Grinsven, et al., 2012; European Commission, 2018). Thanks to the ND, eutrophication – the excess growth of weeds and algae that suffocates life in rivers and seas – has also decreased. The ND puts regions with a high concentration of animals under pressure, contributing to improving livestock management and fertilising practices and thereby reducing emissions of greenhouse gases (GHGs) such as nitrous oxide and methane. Some would even argue that the ND as a consequence also contributes to discussions on the reduction of livestock numbers in some countries.

Despite this positive overall trend, nitrates pollution and eutrophication continue to cause problems in many Member States (European Commission, 2018). Almost 30 years after the ND implementation, groundwater nitrate contamination is still a serious threat to ecosystems and human health

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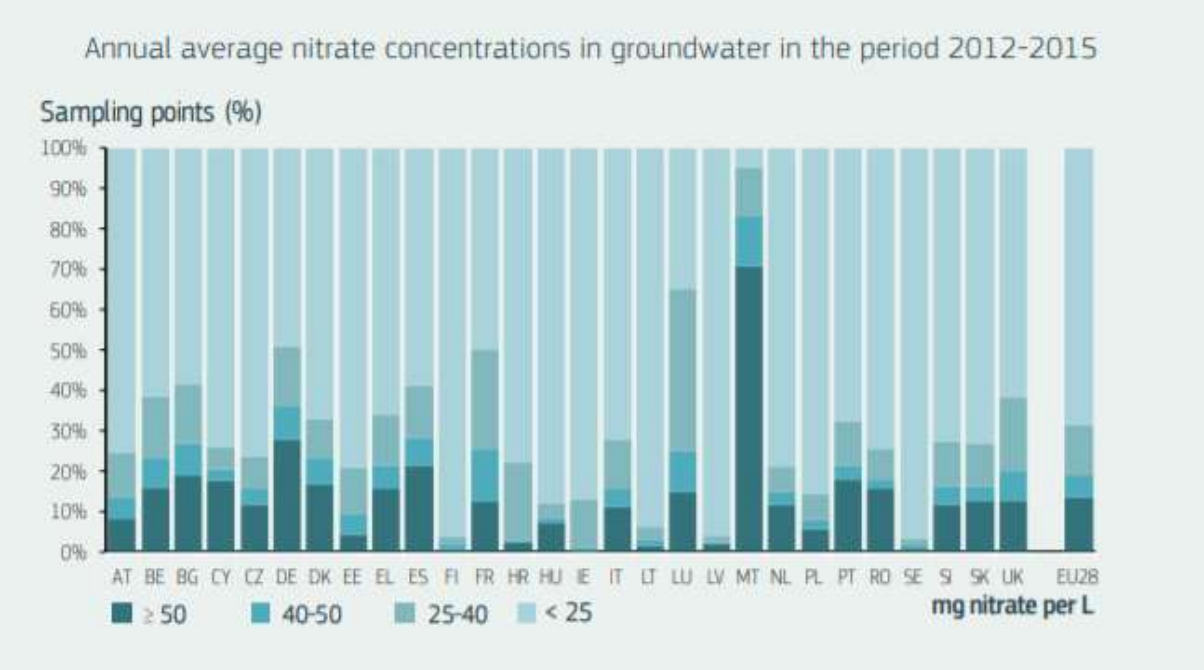
(Musacchio, Re, Mas-Pla, & Sacchi, 2019) and the nitrate target of 50 mg/l is still exceeded in groundwater in several regions in Europe.

Figure 1 Nitrate concentrations in groundwater in the EU 2012-2015 (European Commission, sd)



In some countries limitations on manure application also leads to higher proportions of chemical fertilizer applications leading to loss of C and a decrease in organic matter (Vlaamse Landmaatschappij, 2020).

The authorisation of RENURE materials would allow N fertilisers, partially or entirely derived from manure, to be used following the same provisions applicable to chemical fertilisers containing N as defined in the ND. This development could have the potential to increase the interest in and the value of outputs of manure processing products and can therefore increase the importance of the pathway of manure processing relative to the current business-as-usual scenario of manure land spreading If farmers can more easily dispose their manure through manure processing, this will decrease the untreated manure spreading and thus N and P losses to the environment, especially in regions with a high concentration of animals. The overall effect is likely to be a decreased influx of N (through the Haber-Bosch process) and also of P (imported phosphate rock and derived fertilisers) into European agro-ecosystems.

Moreover, the expected decreased application of N obtained through the high-energy intensive Haber-Bosch process, would also reduce the carbon-footprint of the agriculture sector and the reliance on natural gas used for this process. Also the potentially reduced inputs of CECs to agricultural soils and the environment may have positive effects on soil life and biodiversity, thereby potentially increasing the levels of C in the soil, which could lead to an increasing N retention and an increasing potential of soils to accumulate P in their organic material, decreasing losses to the environment over all.

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2.2.3. Conclusion

Under the Water Framework Directive , the Groundwater Directive and the ND contribute to reducing water pollution from agricultural sources, mainly by limiting the use of fertiliser.

The Groundwater Directive may limit the use of fertilisers with high risk of nitrate-leaching, fertilisers with a high Cd-content such as certain P-fertilisers from phosphate rock, as well as fertilising products that increase the solubility of Cd through acidification.

The implementation of the ND decreased both N leaching and ground runoff losses to surface waters, lowering nitrates concentrations in both surface and groundwater, and decreased gaseous emissions of NO_x, NH_3 and N_2O to the atmosphere. Thanks to the ND, eutrophication has also decreased, while sustainable agricultural practices in relation to nutrients management have become more widespread. The ND contributes to reduced emissions of greenhouse gases (GHGs) such as nitrous oxide and methane.

Despite this positive overall trend, nitrates pollution and eutrophication continue to cause problems in many Member States (European Commission, 2018). Almost 30 years after the implementation of the ND, the contamination of groundwater with nitrate is still a serious threat to ecosystems and human health (Musacchio, Re, Mas-Pla, & Sacchi, 2019) and the nitrate target of 50 mg/l is still exceeded in groundwater in several regions in Europe.

Limitations on manure application may have also lead to higher proportions of chemical fertilizer applications in some countries, leading to loss of C and a decrease in organic matter.

The authorization of RENURE materials (SAFEMANURE study) in the future could allow N fertilisers, partially or entirely derived from manure, to be used following the same provisions applied to N containing chemical fertilisers as now defined in the ND and will result in fertilising products that can be exported from high nutrient regions to low nutrient regions. Moreover, decreased application of N obtained through the high-energy intensive Haber-Bosch process could also reduce the carbon-footprint of the agriculture sector.

The potentially reduced inputs of CECs to agricultural soils and the environment may also have positive effects on soil life and biodiversity, thereby potentially increasing soil-C levels, potentially increasing N retention and decreasing N-losses, and increasing the potential of soils to accumulate P in their organic material which decreases losses to the environment.

2.3. Climate and Energy Package

2.3.1. Introduction

In its vision for a climate neutral economy by 2050, published on 28th of November 2018, the European Commission states that the agriculture and forestry sectors will need to provide sustainably produced food, feed and fibre to the economy. At the same time, they will have an important role to play in preserving biodiversity and moving to a net-zero GHG economy.

The EU climate and energy targets are set in the:

a) The 2020 Climate & Energy Package with three key targets (European Commission, sd):
    a. 20% cut in GHG emissions (from 1990 levels)
    b. 20% of EU energy from renewables

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c. 20% improvement in energy efficiency

b) The 2030 Climate & Energy Framework with three key targets (European Commission, sd):

a. At least 40% cuts in GHG emissions (from 1990 levels)

b. At least 32% share for renewable energy (revised upwards from 27%)

c. At least 32.5% improvement in energy efficiency (revised upwards from 27%)

According to the governance of the energy union and climate action rules, which entered into force on 24 December 2018, EU countries are required to adopt integrated National Climate and Energy Plans (DG Energy of the European Commission, 2019) for the period 2021-2030. Member States had to submit their draft plans by the end of 2018. The final plans must be submitted by the end of 2019.

The LULUCF Regulation (European Parliament & Council of the EU, 2018), adopted 30 May 2018, EU Member States have to ensure that GHG emissions from land use, land use change or forestry are offset by at least an equivalent removal of CO_2 from the atmosphere in the period 2021 to 2030. This is known as the "no debit" rule. Member States already partly undertook this commitment individually under the Kyoto Protocol up to 2020, but the LULUCF Regulation enshrines the commitment for the first time in EU law for the period 2021-2030 and extends the scope to all land uses (including wetlands by 2026). Emissions of biomass used in energy will be recorded and accounted towards each Member State's 2030 climate commitments.

Regulation (EU) 2018/842 on binding annual GHG emission reductions (European Parliament & Council of the EU, 2018) sets binding annual GHG emission reductions by Member States from 2021 to 2030.

2.3.2. Conclusion

With the targets under the 2020 Climate and Energy Package and 2030 Climate & energy framework, C-fluxes are likely to decrease in the European agricultural systems and form a stimulus for the sector of renewable energy production.

Upcoming more stringent cuts in GHG emissions pose a challenge for the biogas (AD) sector because of the possible methane losses caused during the production, storage or spreading of the digestate. It is known that methane is much stronger GHG then carbon dioxide (27 times stronger). All the AD installations are coping with small methane loses through membranes, through torches, through water siphons, through connections in the production line etc.

On the other hand, through AD the organic C can be reused and energy is produced: 1 ton of biowaste might produce 100 m^3 of biogas or 2000 kwh. Otherwise, if the organic C is composted (or dumped), energy will be required but might capture C better and create a loop: composting biowaste will cost 100 kwh to prepare the biowaste.

2.4. Clean Air Package

The clean air package aims to substantially reduce air pollution across the EU. The proposed strategy sets out objectives for reducing the health and environmental impacts of air pollution by 2030, and contains legislative proposals to implement stricter standards for emissions and air pollution.

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The package was published by the Commission on 18th December 2013, and consists of a communication on the 'clean air programme for Europe' and the three following legislative proposals on emissions and air pollution:

a) The clean air programme for Europe (European Commission, 2013) consisting of strategy outlining measures to ensure that existing targets are met and setting out new air quality objectives for the period up to 2030;

b) A revised national emission ceilings directive with strict emissions ceilings for the five main pollutants: nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO2), ammonia (NH3) and fine particulate matter (PM2.5);

c) The Medium Combution Plant Directive (EU) 2015/2193 on the limitation of emissions of certain pollutants into the air from medium combustion plants;

d) A proposal to approve amended international rules on long-range transboundary air pollution (the Gothenburg Protocol) at EU level;

Implementing the clean air package would result in improved air quality for all EU citizens. The proposals would also benefit industry, as measures to reduce air pollution should boost innovation and enhance EU competitiveness in the field of green technology (Council of the EU; European Council, 2020).

2.4.1. Revised National Emission Ceilings Directive

The revised National Emission Ceilings Directive (NECD) (European Parliament & Council of the EU, 2016) entered into force in December 2016 and had to become law in the EU countries by 1 July 2018. The revised NECD sets national emission reduction commitments for Member States and the EU for five important air pollutants: nitrogen oxides, non-methane volatile organic compounds, sulfur dioxide, ammonia, and fine particulate matter.

The directive required National Air Pollution Control Programmes to be established from 1 April 2019. EU countries must update their programmes at least every 4 years, and consider measures applicable to all relevant sectors to limit emissions, including the agriculture sector. The NECD also includes a set of measures to reduce emissions from agriculture in its Annex III part 2, focusing on measures to control ammonia emissions, emissions of fine particulate matter and black carbon.

Furthermore, the revised NECD states that the Commission considers that there is a strong air quality case for keeping the development of methane emissions in the Member States under review in order to reduce ozone concentrations in the EU and to promote methane reductions internationally. The Commission confirms that on the basis of the reported national emissions, it intends to further assess the impact of methane emissions and will consider measures for reducing these emissions, and where appropriate submit a legislative proposal to that purpose. In its assessment, the Commission will take into account a number of ongoing studies in this field, as well as further international developments. The focus on methane is further reaffirmed in the Economic Commission's First Clean Air Outlook (European Commission, 2019).

The revised NECD will lead to a decrease of emissions of NH_3 from agriculture systems, a.o. through more stringent efficiency requirements as well as monitoring of air scrubbers, manure application measures etc. A limitation in NO_x emissions, may also impact agricultural transport NO_x emissions.

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Increased attention to methane emissions may pose challenges to the AD and composting sectors with regards to the possible methane losses during the process or during the storage and spreading.

2.4.2. Medium Combustion Plant Directive

The Medium Combustion Plant Directive (European Parliament & Council of the EU, 2015) applies from 18th December 2015, member states have to implement the new directive into national law by law by 19th December 2017. It fills the regulatory gap between large combustion plants (over 50 megawatts) which are covered by the industrial emissions directive and smaller appliances (<1MW), such as heaters and boilers, which fall under the scope the Ecodesign directive.

The Medium Combustion Plants Directive regulates pollutant emissions of SO2, NO_x and dust to air and also requires monitoring of carbon monoxide (CO) emissions. Furthermore it sets emission limit values that apply from 20th December 2018 for new plants and from 2025 or 2030 for existing plants, depending on their size. The regulations will apply to combustion plants in a variety of sectors regardless of the fuel type used.

The Medium Combustion Plants Directive is likely to reduce NO_x emissions from the European Agriculture sector and can pose challenges to some sectors, especially where diesel generators are used. Medium combustion plants providing heat and/or power for the agriculture sector will be affected by more stringent regulation: greenhouse and livestock building heating, grain dryers, combined heat-power generators and back-up generators.

But most importantly, the Medium Combustion Plant Directive is also applicable to AD plants. The biogas sector will have to comply with the directive and for example comply with the permit requirements and the emission limit values as they are implemented in national laws.

2.4.3. Conclusion

Through the revised NECD and the Medium Combustion Plant Directive, the Clean Air Package will decrease agricultural emissions to the air.

The revised NECD will lead to a decrease of emissions of NH_3 from agriculture systems. A limitation in NO_x emissions will mainly affect the transport sector, including agricultural transports. Increased attention to methane emissions may pose challenges to the AD and composting sectors because of the possible methane losses during the process, storage or spreading.

The Medium Combustion Plant Directive is likely to reduce NO_x emissions from the European Agriculture sector and can pose challenges to sectors where diesel generators are used, but also applies to AD plants which will have to comply with the permit regulations, as well as the emission limit values.

2.5. Biofuels Directive

2.5.1. Introduction

The revised Renewable Energy Directive (EU) 2018/2001 (European Parliament & Council of the EU, 2018) was adopted on 24 December 2018 and has to become law in EU countries by 30 June 2021. It establishes an overall policy for the promotion and use of energy from renewable sources in the European Union across the different sectors.

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2.5.2. Discussion

The Biofuels Directive aims to set a binding EU target for the share of energy from renewable sources in the energy mix in 2030, regulate self-consumption for the first time, and establish a common set of rules for the use of renewables in electricity, heating and cooling, and transport in the EU.

The new directive establishes a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023.

The new directive reinforces the sustainability criteria of bioenergy through different provisions, including the negative direct impact that the production of biofuels may have due to indirect land use change (ILUC) (as trees absorb CO2 from the atmosphere, removing them for biofuel production may result in an increase of net GHGs instead of a decrease and additional pressure on agricultural land may lead to loss of forest/nature).

To address the issue of ILUC in the Clean Energy for All Europeans Package, the revised renewable energy directive introduces a new approach. It sets limits on high ILUC-risk biofuels, bioliquids and biomass fuels with a significant expansion in land with high carbon stock. These limits will affect the amount of these fuels that Member States can count towards their national targets when calculating the overall national share of renewables and the share of renewables in transport. Member states will still be able to use (and import) fuels covered by these limits, but they will not be able to include these volumes when calculating the extent to which they have fulfilled their renewable targets. These limits consist of a freeze at 2019 levels for the period 2021-2023, which will gradually decrease from the end of 2023 to zero by 2030 (Directorate-General Energy of the European Commission, 2014).

The directive also introduces an exemption from these limits for biofuels, bioliquids and biomass fuels certified as low ILUC-risk.

Delegated regulation (EU) 2019/807 (European Commission, 2019) supplementing Directive (EU) 2018/2001 sets out the criteria for determining high ILUC-risk feedstock for biofuels (biofuels for which a significant expansion of the production area into land with high-carbon stock is observed) and the criteria for certifying low ILUC–risk biofuels, bioliquids and biomass fuels.

2.5.3. Conclusion

Relevant to nutrient (re)cycling in agriculture and therefore to Nutri2Cycle, is that this directive and delegated regulation can potentially reduce emissions from agriculture through reduced ILUC. Objection recorded during the feedback period for this act mentioned that the criteria that define food crops that are unfit for EU biofuels (High ILUC risk) were perceived too weak, the bar would be set so low that soy for biofuel is not even handled. Moreover, the derogations that allow ‘certain’ productions of palm oil to be used for biofuels (the low risk criteria) are considered unacceptable. Scientists involved in research carried out in the Horizon2020 project “Moving Towards Adaptive Governance in Complexity: Informing Nexus Security (MAGIC)”, showed concerns about article 5 that defines low indirect land-use change-risk. Implementing these measures could potentially be a source of GHG emissions, e.g. when increased yields are obtained via increased fertilizer application. Moreover, there would be too much uncertainty in the data on the amount of abandoned or low-productive land and amount of available by-products (Ripa, 2019).

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2.6. Circular Economy Package

2.6.1. Introduction

With the publication of the European CE Package in December 2015 (Directorate-General for Environment of the European Commission, 2019), the EU Commission paved the way for a resource-efficient society and sustainable recycling industry across Europe. At its core, the defining element of the CE Package is the “restorative use” of resources in which raw materials would no longer be transformed to discarded waste, as found in the traditional linear economy (Geisendorf & Pietrulla, 2017).

In addition to setting out an action plan (European Commission, 2015), the CE Package includes revisions to key EU waste legislation with the aim of avoiding, reusing and recycling more waste in the future. The main aim of these revisions is to prevent waste arising in the first place, and then to promote "closing the loop" of product lifecycles through greater recycling and re-use, in order to save resources within Europe and bring benefits for both the environment and the economy. The plans aim at extracting the maximum value and use from all raw materials, products and waste, fostering energy savings and reducing GHG emissions. (European Compost Network, 2020; Hermann & Hermann, 2018).

2.6.2. Discussion

The main features of the waste proposals are:

a) A new target of 65% of municipal waste to be recycled by 2030;

b) A new target of 75% of packaging waste to be recycled by 2030;

c) A reduction on the landfilling of municipal waste to a maximum of 10% by 2030;

d) A ban on landfilling separately collected waste;

e) The promotion of economic instruments to reduce waste disposal;

f) The introduction of simplified and improved definitions and harmonized calculation procedures for recycling rates in the EU;

g) The introduction of measures to promote product re-use;

h) The promotion of economic incentives for producers to market more environmentally friendly products; and

i) Support for recycling and recycling systems (e.g. packaging, batteries, electrical and electronic equipment and vehicles).

Of particular relevance to the future development of bio-waste treatment in Europe are the proposed changes to the EU Landfill Directive, namely:

j) to reduce the landfilling of municipal waste to 10% by 2030, and

k) a general ban on the landfilling of separately collected waste.

As bio-waste is the largest fraction of Europe’s municipal waste stream, the 10% landfill target can only be met through sustainable bio-waste management, including composting and anaerobic digestion.

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The proposed ban on the landfilling of separately collected waste needs to be viewed in the context of proposed amendments to the Waste Framework Directive. What is essential is the amendment to Article 22 'Bio-waste', where proposed revisions will oblige Member States to introduce the separate collection of bio-waste as far as is technically, ecologically and economically feasible. Notably, the separate collection of bio-waste is a prerequisite to ensure compliance with quality standards for compost and digestate, as well as contributing towards attaining the 65% municipal waste recycling target. In addition, Member States will be required to introduce appropriate incentives to achieve waste prevention and recycling targets. The introduction and increase of landfill and incineration taxes are intended to contribute to the recycling of waste in accordance with the waste hierarchy (European Compost Network, 2020).

The 2019 report on the implementation of the CE Action Plan (European Commission, 2019) presents the main results and future challenges to shaping our economy and continuing to create a competitive advantage, paving the way towards a climate-neutral economy where pressure on natural and freshwater resources as well as ecosystems is minimised. The report reveals the accents that the European Commission emphasises in its CE Package:

a) turning waste into resources;

b) closing loops of recovered materials;

c) circular design and production processes;

d) consumer empowerment;

e) the EU strategy for plastics in a CE

Within the focus of Nutri2Cycle, the two first accents are discussed.

Under the CE package, waste legislation is identified to provide opportunities to turn waste into resources. A modernisation of the waste management systems in the European Union was needed and a revised waste legislative framework entered into force in July 2018. This includes:

a) new recycling rates

b) simplification and harmonisation of definitions and calculation methods and clarified legal status for recycled materials and by-products;

c) reinforced rules and new obligations on separate collection (bio-waste, textiles and hazardous waste produced by households, construction and demolition waste);

d) strengthened waste prevention and waste management measures, including for marine litter, food waste, and products containing critical raw materials;

e) minimum requirements for Extended Producer Responsibility;

The European Commission sets clear targets for reduction of waste and establishes a long-term path for waste management and recycling. Relevant to composting, AD and NRR are Directives (EU) 2018/850 (European Parliament & Council of the EU, 2018) amending Directive 1999/31/EC on the landfill of waste, and (EU) 2018/851 (European Parliament & Council of the EU, 2018) amending Directive 2008/98/EC on waste. These are discussed under the Waste Framework Directive, paragraph 2.6.3, and the Landfill Directive, paragraph 2.6.4.

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The new Fertilising Product Regulation (FPR) has been conceived as the latest deliverable of the CE Package (Hermann & Hermann, 2018). In that regard, the new FPR is discussed below under paragraph 2.6.5.

2.6.3. Waste Framework Directive

Introduction

The Waste Framework Directive 2008/98/EC (European Parliament & Council of the EU, 2008) sets out the basic concepts and definitions related to waste management, such as definitions of waste, recycling and recovery. The directive also determines when waste ceases to be waste and becomes a secondary raw material (the so called end-of-waste criteria), which waste related properties render waste hazardous and how to distinguish between waste and by-products.

Discussion

The Waste Framework Directive was ammended by Directive 2018/851 (the so called "revised Waste framework Directive") and sets out some clear objectives for the future.

The Waste Framework Directive lays down some basic waste management principles to protect human health and wellbeing, and the enviroment. One of the main principles is the waste management hierarchy, which sets out an order of priority applicable to waste legislation and waste policy of the EU Member States. In addition, the Directive lays down the targets for recycling of certain waste streams.

Figure 2 - Waste hierarchy

The amendments (European Parliament & Council of the EU, 2018) to the Waste Framework Directive set new common EU targets for recycling:

a) 55% of municipal waste by 2025;

b) 60% of municipal waste by 2030;

c) 65% of municipal waste by 2035;

Furthermore, some ammendments to the Waste Framework Directive are particularly relevant to Nutri2Cycle, specifically regarding the separate collection and recycling of bio-waste and food waste reduction.

The amendment of article 5 of the Waste Framework Directive allocates a responsibility to the member states to ensure the recognition of certain substances as by-products, rather than to be

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considered as waste if certain conditions are met. Such conditions are for example: the further use of the substance or object is certain, the substance or object can be used directly without any further processing other than normal industrial practice, the substance or object is produced as an integral part of a production process, further use is lawful i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

To comply with the SDG 2030 Goals, article 9 was amenend to significantly reinforce the prevention of waste objectives, in particular requiring Member States to take minimum measures to tackle food waste:

> *"(g) reduce the generation of food waste in primary production, in processing and manufacturing, in retail and other distribution of food, in restaurants and food services as well as in households as a contribution to the United Nations Sustainable Development Goal to reduce by 50 % the per capita global food waste at the retail and consumer levels and to reduce food losses along production and supply chains by 2030; (h) encourage food donation and other redistribution for human consumption, prioritising human use over animal feed and the reprocessing into non-food products"*

The same goes for the added article 29.2.a stating the following:

> *"Member States shall adopt specific food waste prevention programmes within their waste prevention programmes"*

For the purpose of calculation of the targets, article 11.a.4 was added, stating specifically that:

> *"the amount of municipal biodegradable waste that enters aerobic or anaerobic treatment may be counted as recycled where that treatment generates compost, digestate, or other output with a similar quantity of recycled content in relation to input, which is to be used as a recycled product, material or substance. Where the output is used on land, Member States may count it as recycled only if this use results in benefit to agriculture or ecological improvement."*

Moreover, article 11.a.4 also specifies that as from 1 January 2027 member states may count municipal bio-waste entering aerobic or anaerobic treatment as recycled only if it has been separately collected or separated at the source in accordance with the article 22.

In article 11.a.5. the following was added:

> *"(…) end-of-waste materials to be used as fuels or other means to generate energy, or to be incinerated, backfilled or landfilled, shall not be counted towards the attainment of the recycling target"*

Furthermore, article 3 was amended to consider more types of waste as bio-waste, such as food and kitchen waste from offices, wholesale and canteens.

Due to the ammended article 10, waste has to be collected separately if that is needed to ensure re-use, recycling or other recovery and article 22 sets out that bio-waste specifically will be "*either separated and recycled at source, or collected separately and not mixed with other types of was*te" by the 31 December 2023. The recycling of bio-waste, including composting and digestion, also has be

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encouraged and the use of materials produced from bio-waste have to be promoted as stated in the Directive.

Conclusion

The changed recycling targets of 55% by 2025, climbing up to 65% by 2035, are expected to cause a shift of waste streams currently ending up in landfills to become available for composting, AD and NRR, boosting input availability for these sectors and increasing the availability of compost and digestate as sources of C, N & P on agricultural land.

Ammended article 5 decreases the margin for the Member States and thereby provides a more clear, certain and equal playing field for waste operators across Europe. If the AD industry can comply with the new conditions under article 5, many streams that are currently considered Organic-biological waste streams, can be regarded as by-product, without the risk of not being recognised by a member state. Operators will be subject to a clearer legal framework

The stronger emphasis on waste prevention in the amended article 9, and the reduction of food waste along the whole value chain (together with reduction of food waste under the CAP) specifically, may reduce the availability and choice of input streams for the AD sector. Composting and AD operating on the penultimate place in the order of priority of the waste hierarchy, makes that decreases of organic-biological waste streams will be noticed first this sector, and less in sectors with a higher place in the order of priority (e.g. recycling into pet-food).

This stronger emphasis on waste prevention also calls for inclusion of other value chain actors, such as retail and food, in possible subsequent European projects on nutrient (re)cycling.

The added article 11.a.4 is however expected to increase the availability of bio-waste as an input stream for AD, and improves the position of the digestate as a valued product for member states to attain their EU targets for recycling. This is expected to cause the Member States to stronger incentivize the use of digestate as soil enhancer/fertilizer and - as a result - ease the marketing of digestate. This could alter the source and type of fertilizers and soil conditioners used in agriculture. Moreover, the fact that from 1 January 2027 on member states may count municipal bio-waste entering aerobic or anaerobic treatment as recycled on the condition that it has been separately collected or separated at the source, is expected to increase the availability of bio-waste from municipal waste with a lower fraction of undesired materials.

Over all, the Waste Framework Directive is expected to increase the availability of input streams for AD, composting and NRR, is expected to boost the composting and AD sector and increase the availability of digestate as a fertilizer source. Sources of N & P on agricultural land can therefore change and become more bio-based. Also an increase of C levels in the soil are expected as a consequence of the application of compost on agricultural land. Therefore, competition with non-processed manure and chemical fertilizers are to be expected.

2.6.4. Landfill Directive

The Landfill Directive 1999/31/EC (Council of the EU, 1999) aims to prevent or reduce the negative impacts from landfilling on surface water, groundwater, soil, air or human health. It does so through stringent technical requirements. The Landfill Directive divides landfill sites into three categories: landfills for hazardous waste, landfills for non-hazardous waste and landfills for inert waste (waste

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which will not decompose or burn such as gravel, sand and stone). Landfill facilities are not allowed to accept liquid waste nor untreated waste.

While the Landfill Directive already set targets for the prevention of landfilling of biodegradable waste, the ammendments in Directive (EC) 2018/850 sets the bar higher and restricts the landfilling further.

The Directive (EC) 2018/850 ammending the Landfill Directive adds to article 5.3 that "*waste that has been separately collected for re-use or recycling"* cannot be accepted on landfills anymore, except when resulting from subsequent treatment operations of the separately collected waste for which landfilling delivers the best environmental outcome.

Furthermore, the ammendments added to article 5 of the Directive that "*as of 2030, all waste suitable for recycling or other recovery, in particular in municipal waste, shall not be accepted in a landfill with the exception of waste for which landfilling delivers the best environmental outcome"* and that the member states have to take all the necessary measures "*to ensure that by 2035 the amount of municipal waste landfilled is reduced to 10 % or less of the total amount of municipal waste generated (…)*".

Regarding rules on the calculation of the attainment of the targets, the ammendments added an article 5a stating that "*the weight of waste resulting from treatment prior to recycling or recovery of municipal waste, (…), which is subsequently landfilled shall be included in the weight of municipal waste reported as landfilled"*.

Conclusion

The ammending directive (EC) 2018/850 is expected to increase the availability of inputs for waste management industries such as composting, AD and NRR, in particular from municipal waste. The Directive is also expected to incentivize member states to ensure that digestate does not need to be landfilled, which only occurs when it is contaminated and cannot be spread on agricultural land. Therefore, this Directive is expected to encourage member states to assure high-quality sorting and avoidance of contamination in sorted bio-waste streams that are destined to undergo further treatment. The new calculation rules are expected to discourage exports and encourage local processing of waste, thus increasing the availability of local bio-waste.

2.6.5. New Fertilising Products Regulation

Introduction

The sustainable use of fertilisers made from organic waste material in agriculture could reduce the need for mineral-based fertilisers, the production of which has negative environmental impacts and depends on import of limited resources (phosphate rock).

Under Regulation (EC) No 2003/2003, only conventional and non-organic fertilisers, typically extracted from mines or produced chemically, can freely be traded across the EU. Innovative fertilising products produced from organic materials fall outside the scope of the Fertilisers Regulation 2003/2003. Their access to the single market is therefore dependant on mutual recognition between Member States, which is often difficult due to diverging national rules. Such products therefore have a competitive disadvantage which hampers innovation and investment in the CE.

Under the 2015 CE Action Plan, the Commission called for a revision of the EU regulation on fertilisers to facilitate the EU-wide recognition of organic and waste-based fertilisers. The most important

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change in EU legislation for nutrient recovery since Systemic's report (Hermann & Hermann, 2018) is therefore undoubtedly the New FPR (EU) 2019/1009 (European Parliament & Council of the EU, 2019), repealing Regulation (EC) No 2003/2003. The final act of the new FPR was signed by the co-legislators on 5 June 2019 and will apply in full from 16 July 2022.

The new FPR introduces harmonised rules for fertilisers produced from phosphate minerals and from organic or secondary raw materials such as agricultural by-products and recovered bio-waste in the EU. It opens the single market for these fertilising products which are not currently covered by the harmonized rules. The new FPR lays down common rules on safety, quality and labelling requirements for fertilising products. Furthermore it introduces limits for toxic contaminants for the first time. Moreover it maintains optional harmonisation, as it does not prevent non-harmonised fertilising products from being made available on the internal market in accordance with national law and the general rules on free-movement.

Discussion

Annex I of the Regulation identifies 7 Product Function Categories (PFCs) with minimum requirements that must be met for the product to be allowed to display the "CE" label and to be placed on the market of all EU Member States without any national restrictions.

Table 1 Product Function Categories under the new FPR

PFC 1	Fertiliser
PFC 2	Liming material
PFC 3	Soil improver
PFC 4	Growing medium
PFC 5	Agronomic additive
PFC 6	Plant biostimulant
PFC 7	Fertilising product blend

The Regulation also establishes an exhaustive positive list of 11 Component Material Categories (CMCs) that can be used to produce an EU fertilizing product. Quality requirements for such CMCs and operational requirements for their production and recovery are determined in Annex II of the new FPR.

Table 2 Component Material Categories under the new FPR

CMC 1	Virgin material substances and mixtures
CMC 2	Non-processed or mechanically processed plants, plant parts or plant extracts
CMC 3	Compost
CMC 4	Energy crop digestate
CMC 5	Other digestate than energy crop digestate
CMC 6	Food industry by-products
CMC 7	Micro-organisms
CMC 8	Agronomic additives
CMC 9	Nutrient polymers
CMC 10	Other polymers than nutrient polymers
CMC 11	Certain animal by-products

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The CMC list obviously leaves space for organic recycled CNP and the more materials covered by the CMC list, the more opportunities for the reuse of nutrients from organic sources and/or secondary materials. Digestate and compost are clearly mentioned in CMC 3, 4 and 5. Struvite, biochar and ashes are set out to be adopted in the CMCs as well. The study on these materials has already been finished and published in the so called STRUBIAS report (JRC, 2019). For CMC 11, the study and research on animal by-products needs to be finished by 2022 as set out in article 42.7 of the FPR. For now, there is not yet a list of the by-products falling under the scope of the FPR, which leads to uncertainties on the implementation in the member states. The definition of materials as CMC 11 by-products is very important because the FPR states that for these materials the Commission can determine the end point in the manufacturing chain and therefore exclude them from the scope of the EU 1069/2009 directive.

Sewage sludge, industrial sludge or dredging sludge are explicitly excluded from the CMC list as input materials.

The new FPR sets up common conformity assessment procedures, e.g. a process carried out by a third party, independent and impartial, demonstrating whether the requirements relating to CMCs and PFCs of the fertilizing product are fulfilled. Annex IV determines four modules for the conformity assessment procedures, from the least stringent to the most stringent and in proportion to the level of risk involved and the level of safety required. The new legislative approach for the conformity assessment will be defined in 2020 with the potential mandatory input of "the notified body" (created at national level by governments).

Table 3 Modules for conformity assessment under the new FPR

Module A	Internal production control
Module A1	Internal production control plus supervised product testing
Module B + Module C	EU-type examination followed by conformity to type based on internal production control
Module D1	Quality assurance of the production process

Differences with the 2003/2003 (former regulation):

a) Criteria for the input materials used by the manufacturers of the fertiliser instead of characteristics of the final fertiliser;

b) Criteria for the final product placed on the market by the manufacturers instead of clearly defined product types;

c) Introduction of limits for contaminants, including a new 60 mg/kg limit for Cd which is often found in phosphate fertilisers;

d) P Solubility criteria;

e) Limits for pathogens - e.g. Salmonella and E.coli - in organic fertilizing products.

The Committee of Professional Agricultural Organisations (COPA) and General Committee for Agricultural Cooperation in the European Union (COGECA) raised some concerns (Copa-Cogeca, 2019)

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regarding possible hikes in production costs and reduced quality of the fertiliser products sold to farmers. In addition Copa-Copega mentions that the proposed regulation is devoid of measures which will incentivise the processing of livestock manure, which is available in over-abundant supply in some EU regions (Copa-Cogeca, 2019).

Conclusion

The new FPR is intended to create a level playing field for all fertilizing materials in Europe and will thereby facilitate the conversion of bio-waste into useful fertilising materials and the access of organic and waste-based fertilisers to the EU Single Market. Thereby, it will boost domestic sourcing of nutrients, including the critical raw material phosphorus. This provides considerable opportunities to make European farming less dependent on imported mined and fossil raw materials such as natural gas and phosphate rock (European Commission, 2019). According to estimates, if more bio-waste was recycled, it could replace up to 30 % of non-organic fertilisers. Currently, the EU imports around 6 million tonnes of phosphates a year but could replace up to 30% of this total by extraction from sewage sludge, biodegradable waste, meat and bone meal or manure (European Commission, 2018).

Regulation of contaminants in the new regulation is expected to give higher levels of soil protection, which may increase soil organic matter content and nutrient retention in agricultural soils.

The predicted increased prices for chemical fertilizers could give a competitive advantage to compost, digestate and by-products from the bio-waste treatment industries to be used as CMC. Accessibility of slow-release fertilizers could also increase the use of these soil improvers such as compost and therefore the organic C-content brought onto land.

Insufficient measures to incentivize the processing of livestock manure, combined with an increased competition for use of manure, digestate and compost may cause difficulties for manure disposal.

From the perspective of compost and digestate, the new FPR is welcomed as it will finally define EU standards for composts and digestate products, alleviating distorted competition for bio-based secondary raw materials.

2.6.6. Conclusion

The revised Landfill Directive, the revised Waste Framework Directive and the new FPR under the Circular Economy Package are expected to cause considerable shifts in CNP-flows of biological origin towards agricultural land. Where CNP-flows ended up on a landfill until recently, resulting in loss of nutrients, the CNP will now be brought back into circulation. Composting and AD are processes that have the ability to extract energy from those streams and can turn them into forms that can improve certain features of those streams, providing great opportunities for growth in these sectors. An increased amount of by-products from bio-waste processing is expected to become available (e.g. compost, digestate and by-products extracted during the bio-waste processing) and are expected to partially replace N and P fertilizers that are produced by the chemical industry. With part of the by-products of composting and AD processes still containing high levels of organic carbon (e.g. compost and digestate), this shift towards more bio-waste sourced fertilizers is expected to also increase the flux of carbon back towards European agricultural soils.

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2.7. Synthesis

The **CAP** has assisted the process of an agriculture transition focused on high yields and a strong reliance on fertilisers and pesticides. Over the course of its lifespan since 1962, the CAP has been a driver for increased fluxes of N and P in the agricultural systems in Europe, causing a loss of C out of agro-ecological systems and an accumulation of N and P into natural environments. Successive reforms show a trend to address the negative effects of the current agricultural model, including loss of biodiversity, destructive exploitation of soil, depletion of natural resources and nutrient losses to the environment. It remains to be seen whether, within the current framework of a highly intensified agriculture, the CAP can address the fundamental issues at hand and timely provide the needed changes in Europe´s agriculture sector.

Under the **Water Framework Directive**, the Groundwater Directive and the ND contributed to the reduction of water pollution from agricultural sources, mainly limiting the use of fertiliser. The **Groundwater Directive** limits the use of fertilisers that give high risk of nitrate-leaching. Moreover the Groundwater Directive may also limit the use of fertilisers with a high Cd-content, such as certain P-fertilisers from phosphate rock, as well as fertilising products that increase the solubility of Cd through acidification. The implementation of the **ND** decreased nitrates leaching to surfaces and groundwater, lowering their nitrates concentrations. The ND also decreased P accumulation in soils and P-losses into water bodies, leading to less eutrophication. The ND also decreased gaseous emissions of NO_x, NH_3 and N_2O to the atmosphere. Furthermore, the ND may contribute to the reduction of livestock numbers in regions with a high concentration of animals. On the other hand, in some member states the limitations on manure may have led to a higher use of chemical fertiliser leading to loss of C and a decrease in organic matter. Despite the positive overall trend almost 30 years after the ND implementation, nitrates pollution and eutrophication continue to cause problems in many Member States.

The new FPR and the SAFEMANURE study could potentially allow N fertilisers that are partially or entirely derived from manure, to be used following the same provisions applied to N containing chemical fertilisers as defined in the ND (CMC 11). The new FPR and the so called RENURE products could prevent losses to or accumulation of nutrients in the environment, increase soil-C levels and reduce the carbon-footprint of the European agriculture sector.

With the targets under the **2020 Climate and Energy Package** and the **2030 Climate & Energy framework**, C-fluxes are likely to decrease in agricultural systems in Europe and are a stimulus for the sector of renewable energy production. Upcoming more stringent cuts in GHG emissions pose a challenge to the AD sector because of the possible methane losses during the processing, storage or spreading.

Through the revised NECD and the Medium Combustion Plant Directive, the **Clean Air Package** will decrease agricultural emissions to the air. The **revised NECD** will lead to a decrease of emissions of NH_3 from agriculture systems. A limitation in NO_x emissions, mainly affecting the transport sector, may also impact agricultural transport NO_x emissions. Increased attention to methane emissions may pose challenges or threats to the AD and composting sectors with regards to the possible methane losses. The **Medium Combustion Plant Directive** is likely to reduce NO_x emissions from the European Agriculture sector.

The **revised Renewable Energy Directive** and Delegated regulation (EU) 2019/807 reinforce the sustainability criteria of bioenergy, including the negative direct impact that the production of biofuels

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may have due to ILUC. This could potentially reduce emissions from agriculture by reducing ILUC emissions, although some concerns have been raised about a possible increase in GHG emissions.

Under the **CE package**, the revised Landfill Directive, the revised Waste Framework Directive and the new FPR are expected to bring about a shift for bio-waste streams currently ending up in landfills, to be directed towards composting, AD and NRR. An increased amount of by-products from bio-waste processing is expected to become available (compost, digestate and by-products extracted during the bio-waste processing), possibly partially replacing N and P fertilisers that are produced by the chemical fertiliser industry. Because some of the by-products of composting and AD still contain high levels of organic carbon (e.g. compost and digestate), this shift towards more bio-waste sourced fertilisers is expected to also increase the flux of carbon back towards European agricultural soils. The **new Waste Framework Directive** and the **new Landfill Directive** are expected to boost the input availability of waste streams for AD, composting and NRR sectors and to increase the availability of local, bio-based sources of CNP on agricultural land. Higher quality sorting and avoidance of contamination in sorted bio-waste streams, incentivized by the new Landfill Directive, are likely to improve the quality of bio-based fertilisers and can promote healthier soils that are fertilised with bio-based sources of CNP. The **new FPR** creates a level playing field for all fertilising materials in Europe through harmonised rules for fertilisers produced from phosphate minerals and from organic or secondary raw materials such as agricultural by-products and recovered bio-waste. The new FPR will facilitate the conversion of bio-waste into useful fertilising materials, boost domestic sourcing of nutrients, and will make European farming less dependent on imported raw fossil materials such as natural gas and phosphate rock.

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3. National Legal Frameworks

3.1. Introduction

The main conclusions of the survey are divided hereunder into subchapters which present, for each country, a set of selected technologies from the questionnaire. For each country, we selected the most promising technologies and presented the most impactful pieces of national legislation pertaining to these technologies and to CNP flows.

The sources in this document refer mostly to pieces of national legislation in their respective language. This is why, for the sake of clarity and ease of use, a number reference system was adopted for this section

3.2. Belgium – selected technologies and conclusions

- **Tailormade digestate products (tool development)**

Overall, Flemish legislation has a very positive impact (+3) on this technology.

Law RO/2016/01 [2] sets the legal framework for manure treatment and anaerobic digestion (AD). A recent addendum clarified and increased the list of organic inputs allowed (+3).

The Energy Decree (30/03/2018) [1] recently diminished the value of certificates but increased their duration from 10 to 15 years. As a result, biogas plants turned their attention to the feedstocks for additional income, preferring inputs with higher gate fees and a lower energy potential, which is positive for the nutrient recycling of low value input streams.

With the MAP 6 action plan [3] ("Mest Actie Plan" implementing the Nitrates Directive [17]), Flemish authorities focused on correct analysis, nutrient balances and dosing of nutrients in the field. In recent years, phosphorous (P) has become a limiting nutrient, whereas it used to be nitrogen (N). As a result, this element has to be reduced in organic fertilisers, emphasising a good N/P balance while retaining the carbon (C) content for local application. As content is directly linked to the inputs, biogas plants should perform N/P analyses of all inputs.

Whereas in the past the focus of manure treatment was on N removal, more and more, P removal techniques are showing up (evaporation, scrubbing, reverse osmosis, membrane filtration).

- **Small-scale anaerobic digestion of agricultural residues to increase local nutrient cycling and improve nutrient use efficiency**

The implementation of the Nitrates Directive [17] via the Flemish Manure decree since 1991 is rated as having a neutral effect in the questionnaire. Digestate products resulting from co-fermented animal manure with plant-based input streams are considered as 'animal manure' and are therefore limited in Nitrate Vulnerable Zones (NVZ) to 170 kg N/ha/y. The latest proposals from Flanders to add the liquid fraction of digestate as a fertiliser will be considered for approval by the Joint Research Centre (JRC) in 2020.

However, the legislation depends on the input materials and this limit does not apply to digestate which was obtained from feedstocks other than manure. The digestion of on-farm biomass feedstocks would therefore not fall under the 170 kg N/ha/y limit. For these reasons, overall, the effect is considered as neutral as it will depend on the type of feedstock to be digested.

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- **Ammonium stripping/scrubbing and NH4NO3 as substitute for synthetic N fertilisers**
- **Ammonium stripping/scrubbing and NH4SO4 as substitute for synthetic N fertilisers**
- **Mineral concentrate from reverse osmosis**
- **Concentrate from vacuum evaporation/stripping as nutrient-rich organic fertiliser**
- **Liquid fraction of digestate as a substitute for mineral N & K fertiliser**

In one form or the other, these technologies aim to substitute external mineral nutrient inputs from synthetic fertilisers with recycled organic-based fertilisers in arable farming.

The implementation of the Nitrates Directive [17] into the Flemish legislation is rated as very negative (-3) for the same reasons as for the technology on application of ammonia water from treatment of anaerobically digested manure. As stated above, since recycled fertilisers derived from animal manure are considered manure, they are limited in their applications to 170 kg N per hectare, making it necessary to complement the fertilising with synthetic fertilisers or organic fertilisers without manure (which are not bound by these restrictions). De facto, this impedes the use of recycled fertilisers from digestate containing manure, which represents the largest part. In this regard, Flanders submitted a proposal to the JRC for the liquid fraction of digestate (see above, point 2.1.2).

The new technologies for digestate treatment produce concentrates and ammonia water but their transformation into marketable products is currently a challenge: the concentrates because of the high salt content (high EC) and ammonia water because of the high variability in composition. At the moment, ammonia water has been accepted as a DeNox system in waste incineration to replace urea. The Flemish waste authority delivered a derogation for this application.

The fact that there is no 'end-of-manure' status for manure-based organic fertilisers constitutes a substantial obstacle for manure processing and nutrient recycling in Flanders. As a side effect, a lot of the organic nutrients that are being exported are being done so alongside the carbon they contain (C is not being returned to local fields). Since all recycled products derived from animal manure are limited to 170 kg N/ha, this is seen as a major roadblock.

However, recycled nutrients which don't contain manure are allowed as chemical fertiliser substitutes. For instance, duckweed grown on liquid recycled nutrients from the agroindustry can be used in animal feed. Its use in food is only allowed via EU derogation. There is specific legislation on small-scale biogas plants who process agricultural residues. If the process contains manure, the digestate should be spread in accordance with the 170 kg N/ha limit for manure. Digesters with no manure as feedstock can apply the resulting digestate – as a substitute for synthetic mineral fertilisers - above the 170 kg N/ha limit.

The solid fraction of manure can only be used as bedding material if it was produced and separated on-farm (provided that a set of hygiene requirements were met). On the other hand, the use of the solid fraction of digestate as bedding material is not allowed, even if this digestate was previously pasteurised.

The use of NIR sensors during fertilisation is a promising technology as it measures the exact nutrient concentrations contained in the fertiliser being applied. This is a compulsory step to be able to comply with the legislation (Nitrates Directive [17]) when applying high volumes of manure on field (and also for transport, sampling, analysis).

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Below some key points regarding legislation in Belgium:

- From a legal perspective, all by-products from manure are considered as manure and therefore cannot be considered as 'non-manure' organic fertilisers. The NER system (Nitrogen Emission Rights) [4] gave manure treatment a boost. Vlarema 6 [5] opens up more possibilities for concentrates (higher norms).
- The post-treatment of digestate is recognized as heat recovery from cogeneration for certificates (vacuum evaporation with the heat generated from the CHP).
- New and more efficient technologies are being developed to meet legal requirements on reduced spreading of nutrients on Flemish arable land by separating the nutrients from the liquid part (including P). A better selection of input streams is required to obtain a better separation efficiency at the end.
- The mix of inputs will determine the viscosity of the digestate. This list has been increased.
- The legal frame for fertigation (effluents from water treatment with concentrated nutrients).
- P is a limiting nutrient and should be reduced in the organic fertilisers. A good N/P balance should be emphasized, with retention of C for local application. The N/P content is directly correlated to the inputs. The biogas plants should perform N/P analyses of all inputs.

3.3. Croatia - selected technologies and conclusions

- **Application of digestate in large scale orchards (substituting external mineral nutrient input by recycled organic-based fertilisers in orchards & agroforestry)**

National legislation is perceived as having a very positive impact on the technology. The application of the Nitrates Directive [17] (12/12/1991) concerning the protection of waters against pollution caused by nitrates from agricultural sources is perceived as having a very positive impact on leaching reduction (+3). Law NN 32/19 [37] on fertilisers and soil improvers sets clearly defined characteristics for fertilisers (+3).

a) *The limit of 170 N kg/ha/y from manure [17]*

Compliance with the 170 kg N/ha limit is ensured by Croatian authorities on the field, specifically in areas identified as NVZ (marked in orange on the map below). Although the other areas do not fall under this obligation, in most cases, the limit is not exceeded due to low livestock production. The Paying Agency for Agriculture, Fisheries and Rural development is responsible for monitoring the correct application of the Nitrates Directive and, in case of poor management, farmers are fined and their regular incentives diminished.

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b) *Another important element for nutrient recovery is how the recycled fertiliser products are defined* (based on 'Fertilisers and soil conditioners, Classification', ISO 7851:1983 [36])

- Mineral fertilisers are fertilisers in which the declared nutrients are in the form of inorganic salts obtained by extraction and/or by industrial physical and/or chemical processes. Mineral fertilisers are divided into: N-P-K fertilisers, straight N-P-K fertilisers and compound N-P-K fertilisers.

P-K concentrates from scrubbing can be considered as mineral fertilisers, which opens the market to recycled products from manure above 170 kg N/ha.

- Organic fertilisers are organic materials, generally of vegetable and/or animal origin, added to the soil specifically for the nutrition of plants, and generally containing nitrogen of vegetable and/or animal origin.

Most of the recycled fertilisers fall under this definition.

- Soil conditioners/improvers are divided into:
  - Inorganic soil conditioners which do not contain organic matter, and which do not have declarable nitrogen, phosphorus, potassium or trace element contents;
  - Synthetic organic soil conditioners;
  - Organic soil conditioners which are products of vegetable or animal and vegetable origin, applied mainly to improve physical and biological properties of soils. An organic soil conditioner cannot be classified as a fertiliser because

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of its low total primary nutrient content which is normally less than 2% of the mass of the product;

- Organic soil conditioners with added fertilisers.

The biggest obstacle to the use of digestate as an organic fertiliser or soil improver in Croatian legislation (Official Gazette 117/14) [38] comes from meeting the legal requirements. It states that digestate:

- contains heavy metals and certain organic substances in an amount less than the value prescribed;
- contains at least 15% by weight of organic matter in the dry matter of the anaerobic digestate;
- does not contain more than 2 germinating plant seeds in a sample volume of 1 litre of anaerobic digestate;
- does not contain Salmonella sp. in a sample of 25 g of dry matter;
- contains a maximum of 1000 live bacteria (CFU) of Escherichia coli in a sample of 25 g of dry matter;
- contains macroscopic admixtures of plastic, metal or glass larger than 2 mm in an amount of less than 2% by weight of s.t. sample;
- contains mineral particles larger than 5 mm in an amount less than 5% by weight of the dry matter of the sample.

Consequently, the use of digestate on agricultural land can be limited if the aforementioned requirements are not fulfilled.

3.4. Denmark – selected technologies and conclusions

- **Slurry acidification with industrial acids to reduce NH_3 volatilisation from animal husbandry**
- **Slurry bio-acidification using organic waste products to reduce NH_3 volatilisation and increase fertiliser value**

National legislation is perceived as having a very positive impact on both technologies.

The national Cabinet Order on livestock manure N° 865 (23/06/2017) [9] is very favourable to the set of technologies (+3). It requires the presence of a lid on manure storage tanks to block ammonia emissions into the atmosphere. However, the solid cover can be replaced by a technology from the "List of Environmental Technologies" of the Danish Environmental Protection Agency (EPA) [11]. This list mentions in-house acidification and in-tank acidification as acceptable substitutes for lids.

In Denmark, acidification is mainly used for pig slurry but recently also to an increasing extent for dairy slurry. The acid consumption varies (and hence associated costs) with generally higher acid requirements for dairy slurry. Acidification is practically not used for digestate, since it has very high buffer capacity and hence the acid requirements to bring it down to pH 6 are too high (and costly). Yet digestate - due to its high pH and high carbonates content - is probably the manure type with the highest potential risk of NH_3 volatilisation when stored or applied in fields.

There is a direct link between the very specific legislation which promotes acidification and the success of this technology. Other EU countries, where this legislation doesn't exist, do not resort as much to this technology because of the cost of acidification, especially for digestate. For example, France is

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requesting that Flanders uses acidification in order to reduce odour emissions from the organic fertilisers which are exported to France for spreading. Flanders is considering acidification as an extra cost in relation to the effects.

The above-mentioned Order N° 865 also sets the requirements for injection of field-applied slurries (including digestate). In the same way as above, injection can be bypassed using a technology listed on the EPA technology list. Slurry acidification meets the criterion stated on the list and is therefore rated as very positive (+3).

Implementation of the EU Nitrates Directive [17] through the national Law on Use of Fertilisers and Land Cover LBK N°433 [10] imposes restrictions on nitrogenous fertiliser application rates. The acidification technology is in good alignment with the regulatory frame on the use of fertilisers, thus enabling farmers to increase the manure N efficiency uptake by plants and consequently contributing to reducing N leaching.

For the acidification and bio-acidification technologies, in the Danish context, the main barrier is the cost of technology implementation (both fixed/investment cost and running costs) when set against the achieved economic benefit in terms of increased slurry fertiliser value and the regulatory regime. Indeed, if the latter is not strict enough, the financial gain derived from the fertilisers will be insufficient to cover the costs related to the technology. As a result, the incentive is not sufficient, and the technology is not implemented, unless environmental regulation and permits require it.

3.5. France – selected technologies and conclusions

- **Closing the loops at farm scale: using livestock manure to fertilise the feeding crop on agroforestry plots**
- **Substituting mineral inputs with organic inputs in organic viticulture**

Overall, French legislation is perceived as fairly positive (ranging from +2 to +3).

The national standard for fertilisers makes a very clear difference between a fertiliser (French norm NFU 42.001 [33]) and an organic soil improver (French norm NFU 44.051 [34]) which applies for national and international products. Organic fertilisers with lower N-P-K but higher organic matter will be considered as organic soil improvers; the products with higher N-P-K (sum>7) will be considered as fertilisers. In organic viticulture the grape pulp is considered and allowed as an organic soil improver.

The rules about the use, sale and diffusion of fertilising materials (mineral and organic fertilisers, mineral and organic soil improvers and growing media) start in the French rural code from article N° L255-1 to L-255-18 [31] in the legislative part and from article N°R255-1 to R255-33 [32] in the statutory part.

The first and main rule is that the sale, diffusion or use of a material as fertilising product requires a marketing authorization from the French administration. Exemptions with licence allow to experiment new products or to sell a fertilising product authorized in another country of the EU (and equivalent to a French product). Exemptions without licence cover the following:

- Products in compliance with EU regulation;
- Products in compliance with the French compulsory standards NF U: NF U42-001 [33] for fertilisers, NF U44-001 [35] for mineral soil improvers (or liming products) and NF U44-051 [34] for organic soil improvers;

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- Wastes with a spreading plan as authorized by the Environment code;
- Materials authorized by a requirement specification approved by the Ministry (rare occurrence, the only known case pertains to digestates).

For wastes with a spreading plan, it is necessary to study the part of the environmental code on the spreading of different types of effluents:

- Types of breeding farms: Art L214-11 [25];
- Sewage sludge from waste waters: Art R214-1 [29], Art R211-25 to 47 [27] plus order of 08/01/1998;
- Farm effluents: Art R211-48 to 59 [28];
- Other types of farms or industrial activities: Art R511-9 [30] plus associated orders such as the order of 02/02/1998;
- Extracted sediments: Art. L215-15 [26].

The current interpretation of the French Environmental Code by the Ministry of Agriculture maintains the waste status for materials from waste or residual effluents, even if they are standardized. As a result, the production of bio-fertilisers is limited in its possibilities because these products must comply with high safety standards and must go through a costly procedure to be authorized on the market.

The French regional and national programmes (transposing the Nitrates Directive) forbid the use of organic fertilisers with a C/N ratio lower than 8 during the period from 1st July to 1st February. Consequently, these materials can no longer be used on crops in large parts of the French countryside during the autumn time.

Worthy of note, in 2017, France approved a set of specifications ("cahiers de charges") for market authorisation of digestate and for the agricultural use of digestate [23]. It was followed by an update in September 2019 [24]. The objective is to establish a self-monitoring and tracing system for digestates. These documents specify the process parameters as well as quality standards for the end product and the conditions of application.

France has a detailed regulatory framework for the use of organic fertilisers from domestic origin but also from other Member States. Significant amounts of organic fertilisers - i.e. nutrients, but more importantly the organic fraction - are being applied by the French farmers. Some regions including Flanders and the Netherlands are increasingly exporting organic matter, leading to depleted carbon stocks in their soils.

3.6. Germany – selected technologies and conclusions

The impact of legislation on both technologies is rated as fairly positive (ranging from +2 to +3).

- **Precision farming coping with heterogeneous qualities of organic fertilisers in the whole chain**

The Fertiliser Ordinance [6] has recently (2017) expanded the 170 kg N/ha/y limit from manure to all organic materials. As a result, precision farming and NIRS (Near-Infrared Spectroscopy) sensors are in line with the legislation (+2 rating) as it enables a more efficient use of organic nitrogen streams.

Fines were also raised from 10.000 to 50.000€ in case of a false or incomplete record of fertilisation levels. This requirement (+3) is well aligned with the technology as it provides reliable information on

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nutrient contents of N and P in organic fertilisers to be applied and/or transported, therefore reducing the risk of misreporting and inherent fines.

Furthermore, future amendments of the Fertilisation Ordinance (DüV) [6] and Ordinance for Application of Organic Fertilisers (WDüngV) [7], expected in 2020, will move towards further restrictions of application periods for organic fertilisers as well as limitations to the amount to be applied in certain periods or in the so called "red areas" (areas where groundwater bodies are in poor condition). This supports the trend of organic fertilisers moving towards a higher level of processing as a higher processing (biorefining) of organic fertilisers will allow for a more targeted application. The regulatory changes will further influence the quantity, application conditions and timing of organic fertilisation. In this sense, NIRS manure sensor technology can provide a valuable contribution for a more efficient and traceable N and P use of organic fertilisers. These expected changes are rated as positive (+2).

Ordinance for Substance Flow Analysis – SFA (StoffBilV) [8] (+3 rating) imposes obligatory SFA for certain farm types since 01/01/2018 and after 01/01/2023 further farm types will be brought into the fold. SFA applies to organic fertilisers only in the case where they are imported or exported from the farms. In these cases, NIRS technology would be helpful to quantify the nutrients transported to or from the farms.

The main obstacle at present is that NIRS manure sensor technology has been recognized as a nutrient quantification tool by only a few federal states (4 to the best of our knowledge) of Germany. In the remaining regions, where this technique is not acknowledged, farmers who export manure should still go through the conventional lab analysis to determine the nutrient content, which results in additional costs for farmers.

In other words, the adoption of this technology in a nationwide legal framework is currently lacking and is therefore hindering NIRS manure sensing technologies in Germany. Consequently, by-passing the laboratory tests, which this technology can do, is not made possible at the moment in most parts of the country. Incumbent costs are also susceptible to rise since collecting samples, sending them to the laboratory, analysing the samples and receiving the results is a time-consuming process which will increase manure storage time.

- **Precision farming and optimised application: under-root application of liquid manure for maize and other row crops**

The Fertilisation Ordinance (DüV) [6] limits P surplus at farm level at 20 kg P_2O_5/ha/y (the average surplus is determined based on the 5 previous years). Mineral under-root injection of P fertilisers limits the use of organic fertilisers due to their high P content, but also because of the associated risk of exceeding the upper limit for allowed P surplus. Therefore, substituting mineral fertilisers with manure in under-root fertilisation allows for a higher amount of organic fertiliser to be applied in total. However, this depends on the type of manure which is used.

The expected switch in the Fertilisation Ordinance (DüV) [6] (in the course of a further amendment in 2020) of the 170 kg N/ha/y upper limit of organic fertiliser application from farm average to field-specific average in the "red areas" should curtail the practice of compensating low application rates of organic fertilisers on one field by discharging high loads of organic fertilisers on another field, within the same farm. Higher application loads on a specific field is expected to result in higher leaching and gas emissions.

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If the upper limit becomes field specific, the relevance of under-root application with organic fertilisers becomes significantly greater for maize or similar row crops (that require particularly high levels of P in the early stages of seed development), as under-root application would play a greater role in coping with both limits (organic fertiliser and the P surplus).

The Fertilisation Ordinance (DüV) [6] requires immediate incorporation of organic fertilisers at the latest four hours after application (+3). Further limitations will be enforced from 2025 onwards, i.e. incorporation of organic fertilisers within an hour after application is under discussion. The under-root application process ensures that these additional restrictions shall be met, since incorporation and application of manure are conducted simultaneously.

Further amendments are expected in the Fertilisation Ordinance (DüV) [6] and the Ordinance for Application of Organic Fertilisers (WDüngV) [7] limiting/regulating the process and overall use of organic fertilisers. In this sense, under-root application of organic fertilisers is a valuable tool for a more efficient N and P use (+2).

Hungary – selected technologies and conclusions

- **Bio-Phosphate: high temperature reductive thermal process recovery of concentrated phosphorus from food grade animal bones**

National legislation is reported as having a very positive effect on this technology (+3).

Bio-based fertilising products require a valid permit issued by Member State authorities to be authorized and lawfully marketed. While the Member State national regulations remain in force, the new and binding EU Fertilising Products Regulation (EU)1009/2019 [21] lays down new rules for making market-available EU fertilising products and provides new legal opportunities to meet the CE marked EC fertiliser requirements. If a Member State prefers to maintain national provisions after the adoption of the harmonised limit values under this Regulation, and until those harmonised limit values are equal to or lower than the national limit values already in place, it should notify them to the Commission.

On the list of Critical Raw Materials (COM2017/490) [18] which identifies strategically important raw materials, special attention is given to phosphate/phosphorus, as over 88% is imported and there are no alternative sources, while it is also characterized by a low end-of-life recycling rate. The mined mineral phosphates - a non-renewable resource - naturally contain varying levels of cadmium and uranium which can reach toxic levels. Moreover, the chemosynthetic processing is detrimental to the environment (pollution) and highly demanding in energy and water. On the other hand, while mineral phosphates are quick-acting fertilisers, P use efficiency (plant uptake) usually doesn't exceed 20%. Consequently, the remainder is lost to the environment and causes significant eutrophication.

For these reasons, the chemosynthetically processed imported mineral phosphate used in agriculture needs to be replaced with recovered bio-based fertilisers as much as possible. The aim of the European Bioeconomy Strategy is to deploy the bioeconomy across Europe to foster inclusive and sustainable growth at the local level.

The renewable ABC-BioPhosphate is a natural apatite-type bio-based organic product, made from food grade animal bones (usually cattle bones) processed at a material core temperature of 850°C. The input food grade animal bones come from a wide range of European industries. The processing

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technology is the 3R zero emission carbon refinery, that has been specifically developed and designed for the ABC-BioPhosphate high temperature processing. This material presents unique characteristics and composition: 92% calcium phosphate plus 8% carbon content, with a highly microporous structure and a high level of recovered P. It contains high amounts of P expressed in P_2O_5 (>30% to <35%) and Ca (>37%) that are processed and formulated in a way that is available to plants; thus allowing for an efficient, environmentally safe and naturally renewable bio-phosphorous source. Beside the highly available recovered P and Ca content, ABC-BioPhosphate also contains other important recovered trace elements and nutrients such as K and Mg.

The ABC-BioPhosphate product is a safe and innovative fertiliser with a primary outlet in horticultural organic/low input farming cultivation systems with combined beneficial and multiple effects. Several open field and greenhouse cultivation tests were carried out in IT, IL, HU, DE, NL, SI and DK under different temperate climatic and soil conditions. The typical application doses are between 0.2-1.5 t/ha, usually applied every second year.

The ABC-BioPhosphate organic product received an Authority permit (6300/13393-2/2019) for agricultural applications, that meets the new Regulations (EU)1009/2019 (which takes effect on 16/07/2022) and (EU)515/2019 mutual recognition between Member States as well (which takes effect on 19/04/2020). The ABC-BioPhosphate bone char processing specific technology/product/system has been developed, validated and demonstrated between 2002 and 2019 under EU programmes and interlinked in 10 EU countries. Full industrialization of the process is expected by 2020/2021.

In general, there are two major streams of interest for nutrient recovery for fertilisers:

- *Recovery of LOW NUTRIENT DENSITY fertilisers that require high dose applications/ha:* a wide range of sources is available; the largest part coming from animal manure. However, with its utilisation come several challenges: potential contaminations in the material streams, such as pharmaceutical residues, copper and zinc PTE overloads, human/animal pathogens and resistant microbes. The higher dose requirements include higher handling fees and cost. If the bio-fertiliser nutrient density is low, the application dose will be higher thus increasing the release of PTEs and other potential contaminations per surface area, with unpredictable and complex impacts.
- *Recovery of HIGH NUTRIENT DENSITY fertilisers that require low dose applications/ha:* the ABC-BioPhosphate is a concentrated product (>30% P_2O_5), thus requiring lower doses. It can be used to provide NPK-C formulated organic compounds with controlled-release of nutrients.

- **Sensor technology to assess crop N status**

Overall, the national legislation is perceived as positive (+2 to +3).

17/2007 Governmental order [39] and its modifications on soil protection against nitrate pollution, together with the execution order 59/2008 of the Ministry of Agriculture [41] have had a positive effect on N leaching and runoff. There is currently a lack of legislation to differentiate liquid manure from digestate, which is rated as very positive for the technology (+3).

Catch crops have also had a very positive effect (50/2008 order of the Ministry of Agriculture [40]) on soil health by successfully linking the C/N/P flows by harmonising the animal husbandry and the crop

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production sector. The allowed nutrient application rates improve soil organic matter and reduce soil compaction. For crop production, the measures include crop rotation, a water permit for irrigation, inclusion of permanent grasslands, land coverage, …

In the long run, it would be preferable to make a distinction between manure and digestate, as digestate has superior fertilising properties (slower release and better plant-available form).

3.7. Ireland – selected technologies and conclusions

- **Crop farmer using a variety of manure and dairy processing residues to recycle and build soil C/N/P fertility**
- **Integration of UAV/Drone and optical sensing technology into pasture systems**

National legislation is rated as having a fairly positive effect on the technologies (+1 to +3).

As a general measure, the Nitrates Directive [17] was updated in 2017 in the NAP (national Nitrates Action Programme) [43]. The Nitrates Directive is regularly updated in the national legislation and this is considered as a good legal framework.

The mandatory storage capacity (4-16 weeks) of livestock manure was considered as a less important measure in the N-P loses.

The prohibited application periods of fertilisers and the land conditions were not appreciated as the best (+/-) measures for nutrient losses by Teagasc. They have developed two online tools for precision farming and reducing nutrient losses:

- Greenbook [42]

Provides advisory services to farmers on nutrient recycling and availability from organic materials. The Major and Micro Nutrient Advice for productive Crops (Teagasc Green Book) is an advice manual for all crops and is reviewed and updated once every 4 years. In recent years, this document informs policymakers on the latest and most up-to-date nutrient advice based on the most recent research information. This information is then used to update nutrient legislation once every 4 years during its review.

- NMP (Nutrient Management Planning) [44]

NMP Online is a farm fertiliser planning tool that is used by all advisors and consultants in Ireland to prepare fertiliser plans for farmers. This is a fertiliser and lime planning tool and the advice it generates comes from the Teagasc Green Book and complies with current nutrient legislation.

The aim is to improve nutrient management at farm level and meet statutory requirements through efficient and quality farm fertiliser plans. The result should be an improvement of the environmental outcomes, particularly in relation to water quality and gaseous emissions.

3.8. Italy

National legislation is perceived as having a very positive impact on the proposed technologies. The use of digestate in agriculture as a fertiliser is specified in legislation since 2016. It has had a stimulating effect on the recycling of nutrients from digestate.

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The biggest drawback from the Italian point of view is that under the Nitrates Directive, processed manure falls under the animal by-products' category. As such, a product such as the liquid fraction of digestate with a high nutrient efficiency is weighed down by nutrient input ceilings (170-340 kg/ha). As a result, complementary chemical fertilisation is necessary the meet crop requirements in some cases.

- **Pig manure refinery into energy (biogas) and fertiliser using a combination of techniques applicable at industrial pig farms**

The implementation of the EU Nitrates Directive [17] through Minister Decree 19/04/1999, Law Decree 152/2006 [47], and Minister Decree 25/02/2016 [48] is perceived as generally positive (+2). These laws impose N application limits (in NVZ) which are in line with the biorefinery of pig manure into bio-fertilisers, and conducive to a more balanced and controlled release of nutrients.

The Decree of the Ministry of Agricultural, Food and Forestry Policies of 25/02/2016, through its Art. 4, establishes general technical criteria and standards for the regional regulation of the agronomic use of livestock manure and wastewater, as well as for the production and agronomic use of digestate. Certain types of companies are also required to prepare an Agronomic Use Plan (art. 5) ("Piano di Utilizzazione Agronomica") [45]. This Decree is rated as clearly positive (+2) as it sets the quality requirements and legal framework for agronomic valorisation of digestate.

On the registration of ammonium sulphate as a fertiliser (+2), the Italian Ministry of Agriculture ensures that the standards for fertilisers and conformity thereof are met through official testing, which is carried out in certified laboratories using standardized methods. However, the Fertiliser Regulation (EU 2019/1009) [21] is aiming to iron out the differences between regulations and methods of analysis which are applied at national level. This will ensure a greater efficiency and uniformity, both for products and testing.

- **Using digestate, precision agriculture and no-tillage: focus on organic matter stocking in an area characterized by the lack of organic matter in sandy soil**

The agricultural use of digestate regulated by the Decree of the Ministry of Agricultural, Food and Forestry Policies of 25/02/2016 (Art. 4 and 5) [48] is perceived as positive (+2).

National legislation on precision farming techniques is not yet available. The Decree of the Ministry of Agricultural, Food and Forestry Policies n° 33671 (22/12/2017) [46] contains guidelines for the future development of this sector, also in compliance with European Common Agricultural Policy 2014-2020.

- **Pilot-scale crystallizer for P recovery**

The use of struvite as a fertiliser is not yet widespread in Italy because it is not specifically regulated. Therefore, some administrations consider it 'waste' rather than a 'by-product'.

Recovered phosphate salts, ash-based materials and biochar have been accepted as component material categories (CMCs). These materials will be added to the EU Fertilising Products Regulation (EU 2019/1009) [21] annexes at a later date. From the moment these products comply with all the requirements in the Regulation, such products cease to be regarded as waste within the meaning of Directive 2008/98/EC [19]. It should then be possible for fertilising products containing or consisting of such recovered waste materials to gain access to the internal market.

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3.9. The Netherlands – selected technologies and conclusions

- **Pig manure evaporation plant**
- **Annual Nutrient Cycling Assessment (ANCA)**
- **Precision arable farming using bio-based fertilisers in potato growing**
- **Nitrate sensor for optimal grassland management**

National legislation is reported as having a fairly positive effect on the technologies (+2 to +3).

The Nitrates Directive [17] is implemented through the Manure and Fertilisers Act ("Meststoffenwet") [50], which is perceived as having very positive effects on the set of technologies.

Stricter application methods were made obligatory for animal manure products and mineral fertilisers with the aim to prevent ammonia emissions from manure-based fertilisers into the atmosphere. The use of manure is restricted in favour of other (recycled) fertilisers.

Regarding the treatment of pig slurry, local authorities only recognize reversed osmosis as 'best available technique' in order to clean water for discharge to surface water, which has a considerable effect on CNP technologies. As a drawback, other techniques (such as ultra-filtration, evaporation combined with scrubbing and biological treatment) must be evaluated separately for each permit application.

Application rates of fertilisers and manure are actually mentioned per soil category and crop type, but they are not linked to yield results. The idea of ANCA (Annual Nutrient Cycling Assessment) [49] is that a higher yield of protein should allow for higher application rates of N fertiliser. The ANCA system has not yet been accepted.

In recent developments, a new nitrogen act was handed down as a result of the Netherlands' not having met their goals for Natura 2000 areas. While the new policies are still being discussed, this state of play will likely have a stimulating effect on the use of recovered N-P fertilisers to prevent N losses. However mineral concentrates are known to have a high potential for ammonia emission. Ammonia reduction techniques will have to be used during fertiliser storage and application.

The climate act of 2019 suggests that the production and use of recovered N-P fertilisers (and replacement of chemical fertilisers) can have a positive effect on lowering CO_2 emissions in agriculture.

The main obstacles at the moment are the following:

- Bio-based fertilisers, derived from animal manure, must still comply with the application restrictions of untreated animal manure as per the Nitrates Directive (91/676/EEC) [17]. The interpretation of the distinction between N from animal manure and from industrial processes is currently being studied by the Joint Research Commission. Once the conclusions of the study are made official, it is expected that some bio-based fertilisers will be exempted from the current limits (170 kg N).
- There is no incentive for arable farmers and dairy farmers to make use of bio-based fertilisers as long as the combination of untreated manure and chemical fertilisers is cheaper. The market needs to be developed.
- EU and national government want to stimulate the development, production and use of bio-based fertilisers instead of using chemical fertilisers. However, local authorities are reluctant

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to issue permits to companies/installations that want to start processing animal manure into bio-based fertilisers.

3.10. Poland – selected technologies and conclusions

Most pieces of Polish national legislation are rated as very positive (+3).

Since 2007, the Act on fertilisers and fertilisation [51] accompanied by executive documents provide specific information and requirements. A lot of new regulations on biogas, renewable energy, organic waste etc. stimulated the investment in AD, leading to substantial recycling of nutrients and C from organic waste.

The Animal By-products Regulation EU 1069/2009 [51] derogation laying down health rules as regards animal by-products and derived products not intended for human consumption was an important steppingstone for the recycling of animal by-products by way of AD.

Regarding biochar in particular, the Polish national legislation is lacking legal quality requirements and a clear set of rules on end-of-waste criteria. As a result, biochar production, especially from waste of non-plant origin, is limited. The only suitable act is the "Act on fertilisers and fertilisation" where the executive documents provide specific information and requirements (from 2007 with further amendments). Therein, regulations about soil improvers and organic fertilisers can be found, although there is no separate category for "biochar".

With the current legislation, production of soil improvers and/or fertilisers from organic waste is restricted to the national market. With the introduction of the harmonized law, it is foreseen that the production of organic soil improvers and/or fertilisers will gradually increase, and fertilising products will be introduced to the EU markets.

Producers of organic fertilisers in Flanders and the Netherlands are currently exporting to Poland, indicating a positive legal framework for organic fertilisers.

- **Production of growing substrates for horticulture application from poultry manure, solid state digestate and biochar through composting**

National legislation is perceived as having a very positive impact on the technology. It specifies the rules for soil application of fertilisers as well as the procedures for placing fertilisers on the market in order to prevent risks to human health, animals and the environment.

The main framework is set by the Polish legal Act of 10 July 2007 on Fertilisers and Fertilisation, (Act of 10/07/2007 on Fertilisers and Fertilisation, Journal of Laws No. 147, item 1033, with amendments [51]). Rules for the implementation of this Act are provided in the Regulation (Ministry of Agriculture and Rural Development Regulation of 18/06/2008 on the Implementation of Certain Provisions of Fertilisers and Fertilisation, Journal of Laws No. 119, item 765, with amendments). For the organic and organic-mineral soil fertilisers and improvers, the biological tests confirming the sanitary condition of these products are required. The Regulation specifies the type of biological requirements for organic fertilisers:

- 0 counts/1g of live eggs of intestinal parasites (Ascaris spp., Trichuris spp., Toxocara spp.);
- 0 CFU/1g of Salmonella spp;
- No more than 1000 cfu/g Enterobacteriaceae.

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The Regulation of the Council of Ministries from 05/06/2018 (Journal of Laws No. 2018, item 1339) [53] regarding the implementation of the "Programme of actions to reduce the contamination of water by nitrates from agricultural sources and prevention of further contamination" through limited periods of spreading is rated as having a very positive impact (+3) on leaching reduction. This Regulation also implements increased monitoring of N application.

- **Recovery of energy from poultry manure and organic waste through anaerobic digestion**

National legislation is perceived as having a very positive impact on the technology. A series of national laws on renewable energy sources, on waste management related to biogas plants and requirements concerning AD feedstocks are rated as having a very positive effect on biogas production and the agricultural use of digestate. These laws open up new possibilities for the disposal of organic waste. For instance, this expanded range of authorized substrates allows for a better digestion of poultry manure (mono-digestion of poultry manure may cause process inhibition).

In turn, this can probably improve the economic viability of the biogas plant (e.g. wastewater treatment plant) by an increased process performance (usually enhanced VS removal, methane yield). This approach fits into the Polish Energy Policy [52].

3.11. Portugal – selected technologies and conclusions

In Portugal, nutrients (N-P-K) contained in fertilisers can be from mineral sources (mineral fertilisers) or animal and vegetable sources (organic fertilisers). If an organic material does not fulfil the requirements of an organic fertiliser, it is classified as organic amendment. This means that the mineral origin is not exclusive to fertilisers and amendments, and thus opens up possibilities in the circular economy. France has a similar classification in NFU 42.001 ('Fertilisant') and NFU44.052 ('Amendement organique'). Law Decree Nº103/2015 (15/06) [55], Ordinance nº259/2012 (28/08) [57] and Dispatch nº1230/2018 (Diário da República nº25, 05/02) [54] are perceived as very important legislations to promote organic fertilisers as they define organic fertiliser and manures (+2 rating).

There is a positive list of waste that can be used in any organic fertiliser. The same list (based on EURAL codes) exists in the Netherlands and in Belgium for biogas inputs. The creation of a biowaste platform is an important stimulator for nutrient recycling.

Sewage sludge can be used in agriculture, provided it has been stabilised. This potential waste stream for nutrient recycling can also be used in France but not in Belgium.

Since 2006, specific legislation is aimed towards C sequestration and greenhouse gas emissions reductions. Generally, the following measures were considered as good legal frames:

- Incorporation of fertilisers;
- Special measures for vulnerable zones with adequate fertiliser plans;
- Storage of manure during the winter (from 6 months to 10 months).

The commercialisation and certification of bio-based fertilisers under Law Decree Nº103/2015 [55] is very restrictive. In that regard, the range of materials that can be used to produce bio-based fertilisers is very limited.

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On the other hand, the process of certification is quite long due to the number of tests that are required. In some cases, over a year can pass before obtaining this certification. In practice, the reuse of organic materials as bio-based fertilisers is weighed down by this cumbersome bureaucracy which is perceived as the biggest obstacle and deterrent.

- **Blending of raw and treated organic materials to produce organic fertilisers**

The general definitions and specifications of organic fertilisers and manures are rated as having a positive effect (+2). The national product definitions of organic and mineral products (fertilisers or improvers) seem sufficiently adequate and specify the allowed quantities of nutrients per product. Nutrient content, nutrient ratio and organic matter content in organic fertilisers must fulfil minimal requirements.

Furthermore, national decrees 103/2015 [55] and 71/2006 [56] lay down definitions and requisites regarding the use of 'waste' which can be valorised in bio-based fertilisers. Biowaste-based fertilisers need to go through a stabilization process, namely composting or AD, followed by the composting of the digestate. These decrees have had a very positive impact on the technology (+3).

However, the commercialisation and certification of these bio-based fertilisers (Law Decree №103/2015) [55], impose limits on pathogens (Salmonella, E. Coli), weed seeds, inorganic materials, heavy metals and organic contaminants. These requirements are rated as negative (-1) because they are too strict, and quality control very expensive.

The degree of maturity has implications on labelling for commercialization, but also affects other parameters for legal limits. The certification implies not only the evaluation of the chemical composition, regarding nutrients and pollutants, but also the evaluation of the agronomical value of the product. There are rules concerning the information which needs to be provided on the label. The numerous and costly steps which must be taken before being able to place a product on the market are seen as an obstacle (-1).

The effect of the Nitrates Directive [17] and the restrictions on the application of manure, through Dispatch 1230/2018 [54] and Ordinance 631/2009 [58], are perceived as having a positive effect on the technology (+2).

Techniques to reduce ammonia emissions (decree 20/2004) can be used if they reduce the emissions by at least 30% compared with reference values. The use of such techniques is beneficial to this technology (+3). Decree-Law 71/2006 creates a national fund for carbon (+3). As such, the technology receives support for its capacity to sequester carbon and reduce emissions.

3.12. Spain – selected technologies and conclusions

- **Catch crops to reduce N losses in soil and increase biogas production by anaerobic co-digestion (Catalonia)**

In the case of Catalonia, the adaptation of the Nitrates Directive [5] into national legislation for both technologies is generally perceived as having a positive influence on the technologies.

A series of Decrees (261/1996 [14]; 136/2009 [12] ; 153/2019 [13]) regulate the management of manure and by-products (limited periods of spreading, slopes, storage, …) Since the use of catch crops to increase N uptake and reduce leaching is well-aligned with legal restrictions on manure application, the legislation is understandably rated as very positive (+3).

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While the legal framework might be satisfying, clearly defined parameters for the implementation of the legislation are sometimes lacking, as in the following examples:

- It is required to increase compliance with legislation but at the same time the driving force for improving manure management is still weak. Indeed, most of the actions related to environmental protection which the farmers undertake are driven by fulfilling legal requirements.
- The efficiency of the treatment technologies hasn't been defined yet. To this aim, an expert committee has been set up in 2017.
- The fertilising value of the by-products is not clearly defined and additional constraints for manure-based fertilisers are hampering their use.

- **Nitrogen and phosphorus recovery from pig manure via struvite crystallization and design of struvite based tailor-made fertilisers**
- **Use of an inoculate of microbiota and enzymatic pre-cursors to reduce ammonia emissions and optimize nutrient use efficiency in poultry manure**

In Spain it is possible to use by-products of animal origin not intended for human consumption from category 2 and category 3 of the Animal By-Products Regulations [20]. Waste classified in category 1 cannot be used for the production of fertilisers.

The biggest national legal barrier is that currently some bio-fertilisers (such as struvite or ashes with a high P content from thermal treatments) are being denied access to the market because these products are classified as waste. Hopes are that the European Fertilising Products Regulation will pave the way for the use of these products in Spain.

For that reason, the Spanish regulations on fertiliser products - Royal Decree 506/2013 (28/06) [15] and general provisions such as Royal Decree 999/2017 [16] - are perceived as having a very negative effect (-3) on the N and P recovery technology from pig manure via struvite crystallization and design of struvite based tailor-made fertilisers as they are currently blocking business opportunities.

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3.13. Synthesis

Whether in the context of country-specific regulations or the implementation into national legislation of a European Directive, it is apparent that the national legal stage plays a pivotal role in the advancement or stasis of these technologies and, as a consequence, is also an important driver for the betterment of CNP cycles in Europe.

In all Member States, the Nitrates Directive is perceived as a successful legislative tool to reduce the loss of nutrients and to allow for the application of recycled nutrients over unprocessed manure or chemical fertilisers. In Germany and Belgium, the implementation of the Directive into national legislation is moving towards stricter monitoring and higher fines.

In some Member States, fertilisers recovered from organic matter or manure after chemical processing are considered as mineral fertilisers. As such, these fertilisers are exempt from the restrictions associated with animal by-products in Nitrate Vulnerable Zones (NVZ). However, as a rule of thumb, within the Nitrates Directive [17], all products derived from livestock manure are capped at a maximum application rate of 170 kg N/ha (for NVZ).

So, while the questionnaire indicated that the Nitrates Directive was generally well accepted, several responses also highlighted that the current indiscriminate limitations associated with livestock manure products run the risk of weighing down on the development of a European market for nutrient products recovered from manure. As many of the technologies presented in this report are manure-driven, this acknowledgment rings especially true. In an attempt to bring the legislation up to speed with the latest technological and market developments, the European Commission has mandated the JRC to perform an assessment of Nitrogen fertilising products derived from animal manure (labelled “RENURE” products).

Each Member State can choose to apply for a derogation and thus bypass the capped application rate. Two Dutch pilot plants producing mineral concentrates have applied within the JRC’s SafeManure study. The Flanders Region is currently preparing a new submission to have several products exempted by 2020. Such products include the liquid fraction of digestate (from manure) and mineral concentrates. Obtaining the derogation is an expensive process in which the stability and the quality of the product are of utmost importance.

By all accounts, the Fertilising Products Regulation [21] will further boost the streamlining and recycling of organic waste streams (manure, sewage sludge, bio-waste) into organic bio-fertilisers, and encourage the upgrading of raw materials - such as manure and digestate - into refined bio-fertilisers. The incorporation of struvite, biochar and ash into the Regulation will expand the range of fertiliser products, market opportunities and synergies.

It appears that both a harmonized set of criteria for nitrogen-based fertilisers from livestock manure (SAFEMANURE) and the implementation of the Fertilising Products Regulation (inclusion of “STRUBIAS” products as CMCs) would be crucial in order to successfully carry and promote the current innovations in nutrient reuse, recovery and recycling.

The innovative technologies for processing manure or digestate result in a broad range of new fertilising products and soil improvers that, in order to be viable, need to find a home in fertilising applications. At the moment, some of these products still suffer from certain issues such as a lack of stability, homogeneity, possible contaminations, high EC, etc. As such, they cannot be applied directly on land/crops and require further processing by the chemical or organic fertiliser industries. The lack

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of predictability and standardization which mars some of these products is likely to discourage industry acceptance, thus also slowing down effective development of a market for nutrient recycling.

As an example, in certain countries (the Netherlands, Germany and Belgium), recovery of phosphate from organic materials is gaining a lot of traction. However, due to some of the quality issues mentioned above, the resulting concentrates (which can contain up to 25% of the nutrients) do not find a suitable outlet. This leads to the concentrates being reincorporated to either digestate or compost (after having been initially extracted). While it's a far cry from the goals of sustainability and the circular economy, in some cases this situation is paradoxically encouraged at the national level through the obtention of permits which reward the recycling of certain feedstocks (some gate fees are higher than others) but do not pay sufficient attention to how these nutrient streams are being dispatched.

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Annex 1. Questionnaires

1.1. Belgium

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
UE	56	Application of ammonia water from treatment of anaerobically digested manure	Manure Decree (1,2,18) NER system (5) VLAREMA 6	Y	--- +++ ++	All subproducts from manure are considered as manure and are not allowed to apply as non-manure organic fertilizer The NER system gave a boost to manure treatment Vlarema 6 gives more possibilities for concentrates (higher norms)
			Certificates for CHP (19)	Y	0	The post treatment of digestate is recognized as heat recovery from cogen for certificates. Vacuum evaporation with the heat of the CHP.
	58	Electro Coagulation for separation of manure or digestate	Manure decree (1,2, 18)	N	3+	New and efficient technology to fulfil the obligation to reduce spreading of nutrients on Flemish arable land by separating the nutrients from the liquid part, including the phosphor. Selecting input to obtain a better separation efficiency at the end.
	59	Impact of viscosity on digestate treatment	Manure Decree (1,2,18) RO/2016/01 (25)	N	3+	The mix of inputs will determine the viscosity of the digestate. The list of inputs has increased.
	60	Irrigation – Fertigation	Testgarden and draught (23)	Y	3+	Legal frame for fertigation (effluent form water treatment with concentration of nutrients)

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			Manure decree (1,2,18)			
	61	Tailor made digestate products (tool development)	Manure decree (1, 2,18) RO/2016/01	Y	3+	Phosphor became a limiting nutrient and should be reduced in the organic fertilisers. Emphasis on god balance N-P, with retention of the Carbon for the local market. The N/P content is directly correlated to the inputs. The biogas plants should take N/P analyses of all inputs
			Energy decree (10,19)	Y	3+	Less certificates over a longer period makes that the biogas plants are looking for income from the input side. This means that they will prefer input with a higher gate fee and a lower energy potential, which is positive for the nutrient recycling of low value input streams.
	75	Ammonification & De-ammonification as a pretreatment for N-recovery	OVAM: waste authority	Y	---	This technology is supposed to disappear to 2030. OVAM (waste authority) will no longer give permits for this technology after 2030 because the organic N is released as N2 gas I the air: destruction of nutrients!
INAGRO	40	Insect breeding as an alternative protein source on solid agro-residues (manure and plant wastes)	Food/Feed legislation (26); Animal by products (27) ; VLAREMA	Y	0	All products derived from insects are categorized as Novel Food. A 'Novel Food'-application can be handed in to be allowed to trade 10 different insect species. Also there should be good hygienic practices, traceability, reporting obligation, labelling and an auto control system based on HACCP. Companies rearing insects to trade these for human consumption should be registered at FAVV (Federaal Agentschap voor de VoedselVeiligheid). Companies processing or distributing insects or food products based on insects should be recognised by FAVV. If these companies (http://www.afsca.be/levensmiddelen/insecten/)

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			(20); VLAREM (21)			Living insects are forbidden in the ruminants' feed. Other animals can be fed with living insects. Dead insects and products of dead insects should be processed in a category 3-processer. The obtained melted fats can be used in feed for all animals. The protein flour and whole processed insects can be used as feed for pet animals and also for aquaculture since 1 July 2017. (http://www.afsca.be/dierlijkeproductie/dierenvoeding/insekten/default.asp)
	34	Utilization of crop residues in animal feed / Secondary harvest: additional valorisation of crop harvest and processing residues	?	?	?	This is dependent on what kind of biomass is being reused and for what purpose
	11	Recycling fibres of manure as organic bedding material for dairy cows	Animal by products (27) Circular bedding (28)	Y	-	The thick fraction can only be used as bedding material when coming from on-farm and when separated on-farm. Also it is necessary to work hygienically.
	10	Small scale anaerobic digestion of agroresidues to	Nitrate Directive Manure	Y	0	The digestate is treated as a recycling derived fertilizer (coming from manure) as soon as some animal manure is going in the digester (even if it is only a small amount), so it is limited until 170 kg N per hectare. This is not the case when there is no manure going in the digester.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
		increase local nutrient cycling & improve nutrient use efficiency	decree (1,2,18)			
			Input material RO/2006/01 (25)	Y	0	The legislation depends on the input material. To keep it as simple as possible it is suggested to digest only on-farm biomass
			Digestate VLAREMA (20)	Y	0	The end product needs to fulfil different legislations regarding use, transport, analysis, …
			Exploitation VLAREM (21)	Y	0	There are a lot of administrative obligations to fulfil. Emissions are regulated too.
	50 & 51	50: Utilization of NIR sensors on fertilization machine 51:Utilization of NIR sensors on storage	Nitrate Directive Manure Decree (1,2,18)	Y	3+	Using NIR sensors during fertilization is promising because it is possible to know the exact nutrient concentrations in fertilizers, which is necessary to fulfil the legislation about using manure on field.
			Sample manure (manure decree(1,2,18)	Y	3+	When transporting manure, sampling and analysis is necessary. By using NIR sensors this could be done in a more efficient, economic and reliable way.
INAGRO/ UGent	24	Adapted stable construction for separated collection of solid manure and urine in pig housing	No external thick fraction as bedding material	Y	-	The thick fraction can only be used as bedding material when coming from on-farm and when separated on-farm. Also it is necessary to work hygienically.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
		(followed by separate post-processing)				
	41	Floating wetland plants grown on liquid agro-residues as a new source of proteins	Food/Feed legislation (26)	Y	?	Duckweed may be used and traded in the feed industry as long as it copes with HACCP, is known in the Feed Materials Register and fulfils registration and tracing obligation. It may not (yet) be used in the food industry in the European Union. It is possible to hand in a request for application in the food industry to the European Commission. (https://www.grensregio.eu/assets/files/site/Rapport-Eendenkroos-Richting-Veevoer.pdf)
	1, 2, 3, 6 & 9	1 Ammonium stripping / scrubbing and NH4NO3 as substitute for synthetic N fertilizers 2 Ammonium stripping / scrubbing and NH4SO4 as substitute for synthetic N fertilizers 3 Mineral concentrate from reverse osmosis 6 Concentrate	Nitrate Directive Manure Decree (1,2,18)	Y	---	The use of recycling derived fertilizers (rdf) (coming from animal manure) is limited to 170 kg N per hectare, making it difficult to apply only rdf's without external mineral nutrient input from synthetic fertilizers

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
		from vacuum evaporation/ stripping as nutrient-rich organic fertilizer 9 Liquid fraction of digestate as a substitute for mineral N & K fertilizer				
UG	8	Acid leaching of P from organic agro-residues in order to produce OM-rich soil enhancers and P-fertilizers	MAP6 – P limits	Y	2+	Since MAP6 has strict P limits to apply fertilizers on land, it is a positive evolution for farmers to have each nutrient in a separate product. In this manner, a good mix can be made to fulfil the limit for each both N en P.
	7	Acidification as a tool to reduce ammonia emission from manure (storage)	Nitrate Directive Manure Decree (1,2,18)	?	?	Is the acid added to the manure or are we talking about an acid air washer?
	65	Struvite as a substitute of synthetic P fertilizer	Application on land	Y	-	No impact of the Nitrate Directive (only for N) or MAP6. For P there is no distinction between synthetic P or animal-derived P (as is the case for N) to fulfil the limits.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						If the struvite is recovered from human urine or faeces, there are restriction on application on land because heavy metals can be present.

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1.2. Croatia

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
IPS	66	Application of digestate in large scale orchards (Substituting external mineral nutrient input by recycled organic based fertilizers in orchards & agroforestry)	fertilizer transport	Y	2+	direct result on GHG emissions	Law about fertilizers and soil improvers (NN 32/19)
			clearly defined characteristics of fertilizers	Y	3+	technology standardization and direct effect on plants	
			during one calendar year, an agricultural holding can fertilize agricultural land with manure to a limit of 170 kg N/ha	Y	3+	direct result on leaching	Nitrate directive (91/676/EEC)
			storage of manure strictly defined/prescribed	Y	0	no extra value when limited period of spreading	Official Gazette 60/17
			manure should be equally distributed over the soil surface	Y	3+	direct result on runoff	
			slurry must be stirred up before application	Y	3+	direct result on N leaching and vaporization	
			The use of manure is forbidden: - in II. category of areas with sanitary protection of sources, unless otherwise specified by regulations governing water management, - on the ground with saturated	Y	3+	direct result on runoff	Nitrate directive (91/676/EEC); Official Gazette 60/17

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
			water, - on the snow covered ground, - on frozen soils and on floating lands, - in the production of vegetables, berry fruits and medicinal herbs, within 30 days before harvest, - mixed with waste sludge or compost from waste sludge, - from farms where diseases with pathogens resistant to conditions in the fertilizer pit have been identified, - not on agricultural land.				
			Prohibited the application of liquid manure and slurry: a) in II. category of areas with sanitary protection of sources, unless otherwise specified by regulations governing water management b) 25 m away from wells c) 20 m away from lakes d) 5 m away from other water courses e) on sloping terrains where there is surface leaking	Y	3+	direct result on runoff	NN 56/08 ; Official Gazette 60/17

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
			f) on sloping terrains along water courses with a slope greater than 10 % at a distance less than 10 m from the water courses				
			Limited period spreading: 1. fertilization with manure and slurry on all agricultural areas, regardless of coverage from December, 1st – March, 1st 2. fertilization with slurry and manure spread on the surface without entering the soil on all agricultural areas as of May, 1st – September, 1st 3. fertilization of solid manure on all agricultural areas as of May, 1st - 1 September, 1st	Y	3+	direct result on leaching	
			must have a durable cover or a well-defined bark on the surface / floating layer in digestate storage containers	Y	3+	direct result on potential leaching and vaporization	Official Gazette 60/17
			digestate storage tank placed in a shady place and protected from wind blast	Y	0	unpleasant odours in the surrounding area	

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1.3. Denmark

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
UCPH	18 & 19	18: Slurry acidification with industrial acids to reduce NH_3 volatilisation from animal husbandry 19: Slurry bioacidification using org. waste products to reduce NH_3 volatilisation and increase fertiliser value	Requirement for cover on manure storage tanks to avoid ammonia emissions ("The Cabinet Order on Livestock Manure", Order No. 865 of 23 June 2017)	Yes Latest ver. 23 June 2017	3+	§22 contains rules about cover on tanks for liquid manure, including digestate of manure/any biomass of vegetable origin: · Tanks must have cover. Either a solid cover (e.g. tent, roof, concrete deck or fabric membrane) or a tight cover (natural surface crust layer or equivalent). In 2013 it was estimated that 10-12% of the Danish slurry is stored in tanks with solid cover, and the share is probably somewhat higher today. · The solid cover on tanks can be replaced with a technology that appears on the Technology List of the Danish Environmental Protection Agency (EPA). · According to the Technology List, in-house acidification and in-tank acidification can replace a solid cover. · The Technology List can be found at : http://eng.mst.dk/trade/agriculture/environmental-technologies-for-livestock-holdings/list-of-environmental-technologies/
			Limitations of N fertilisation via maximally allowed application norms ("Law on use of fertilisers and plant cover", LBK nr 433 of 03/05/2017; this is the	Yes Latest ver. 3 May 2017	2+	The law outlines the general regulatory frame for the use of fertilisers and related demands for crop cover and other measures in relation to the overall aim of reducing leaching of N. The law is implemented through annual Cabinet Orders, published in an annual Guidance Document. The law states that: · Each farm must make fertilisation plans and report fertilisation accounts to authorities for each cropping year. · Each farm is allocated an annually calculated maximum quota for use of fertiliser N which cannot be exceeded (penalties are given for exceedance).

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			Danish implementation of, amongst others, the EU Nitrates Directives).			· The max. quota is calculated based on the crop area composition and rotation, including N standards for each crop (equal to or below the economically optimal N application rate) · The max. quota includes N in both mineral fertiliser and livestock manures, including sold and bought manures, digestate, etc., though with allowance for their N efficiency relative to mineral fertiliser. · Farmers utilising manure acidification will be able to increase their manure N efficiency and hence better meet crop N needs, or substitute more mineral fertiliser N application (both increasing their profit margin)
			Requirements for injection of field applied slurry (”The Cabinet Order on Livestock Manure”, Order No. 865 of 23 June 2017)	Yes Latest ver. 23 June 2017	3+	§30 contains rules about requirements for field application of liquid manures, including digestate of any biomass of vegetable origin: · Field spreading of liquid manures, including digestate, can only be undertaken by use of such spreading technologies as trailing hoses, trailing shoe or soil injection. · Injection must be used for liquid manure spreading on fields without crops (bare soil) or grasslands. · Injection may be omitted if the livestock manure has been treated before or in connection with the application by a technique listed on the Danish EPA Technology List (see above), with at least the same effect on ammonia volatilisation as injection – slurry acidification technology fulfils this criterion · In Denmark, slurry is spread by injection on approx. 20% of the area that receives field-spread with slurry. A substantial proportion of this is now being replaced by slurry acidification, due to the

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						higher field capacity, lesser grass sward damage and improved fertiliser value.

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1.4. France

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
CA17	15	Closing the loops at the scale of farm : using the livestock manure to fertilize the feeding crop on agroforestry plots	Modified national order of 19/12/2011 concerning the national action program to be implemented in the vulnerable areas to reduce water pollution by nitrates of agricultural origin.	Y	3+	-Nitrogen fertilizer applications are prohibited during certain periods which vary according to the type of crop and the type of nitrogen fertilizer: -Storage of livestock effluents: farmers must have storage capacity expressed in months of effluent production for each animal species. -The balance of the fertilization: the computation of the projected dose of nitrogen to be made is obligatory on each cultivation plot and according to a regional reference which defines the method of calculation for each culture -The manure plan and the nitrogen fertilization practice book are mandatory for each crop plot. -The limitation of the amount of nitrogen contained in livestock manure that can be applied annually per hectare of useful agricultural area must be less than or equal to 170 kg of nitrogen -Nitrogen fertilizer application must comply with specific conditions for distance spreading to watercourses. -Vegetated strips along watercourses

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						and waterbodies larger than 10 hectares must be bordered by a grass or wooded strip with a width of at least 5 meters. -Control of nitrogen leakage on outdoor palmipedes: courses must not exceed maximum production of animals per year and per hectare and must be located at minimum distances from watercourses. -Soil cover during rainy periods: the risk of nitrate leakage is high during rainy periods in autumn and winter. Late summer and fall soil cover helps limit nitrate leakage by temporarily immobilizing inorganic nitrogen in organic form.
			Rural Code, sections L255-1 to L255-5	Always	3+	To use fertilizing materials as commercial products : Only fertilizers with market authorization or conform to the kind described by standards - mainly the french standards NF U42-001 and NF U44-051
			Environment Code, sections L511-1 to L511-2, R511-9.	Always	2+	To use fertilizing materials with a spreading plan : this concerns the effluent production of the farm. The spreading interventions must be registered. These requirements are linked to the order about vulnerable areas
			Modified national order of 27/12/2013 on general requirements for classified environmental protection installations	Y (01/01/2014)	1+	

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			subject to declaration under headings 2101-1, 2101-2, 2101-3, 2102 and 2111			
	14	Substituting mineral inputs with organic inputs in organic viticulture	Modified national order of 19/12/2011 concerning the national action program to be implemented in the vulnerable areas to reduce water pollution by nitrates of agricultural origin	19/12/2011	3+	-Nitrogen fertilizer applications are prohibited during certain periods which vary according to the type of crop and the type of nitrogen fertilizer: -The balance of the fertilization: the computation of the projected dose of nitrogen to be made is obligatory on each cultivation plot and according to a regional reference which defines the method of calculation for each culture -The manure plan and the nitrogen fertilization practice book are mandatory for each crop plot. -The limitation of the amount of nitrogen contained in livestock manure that can be applied annually per hectare of useful agricultural area must be less than or equal to 170 kg of nitrogen -Nitrogen fertilizer application must comply with specific conditions for distance spreading to watercourses. -Vegetated strips along watercourses and waterbodies larger than 10 hectares must be bordered by a grass or wooded strip with a width of at least 5 meters. -Soil cover during rainy periods: the risk

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						of nitrate leakage is high during rainy periods in autumn and winter. Late summer and fall soil cover helps limit nitrate leakage by temporarily immobilizing inorganic nitrogen in organic form.
			Rural Code, sections L255-1 to L255-5	Always	3+	To use fertilizing materials as commercial products : Only fertilizers with market authorization or conform to the kind described by standards - mainly the french standards NF U42-001 and NF U44-051
			Rural Code, section D665-34	05/01/2018	1+	Explain the recycling of the grape pulp with spreading.
			Environment Code, sections L511-1 to L511-2, R511-9.	Always	2+	To use fertilizing materials with a spreading plan : this concerns the effluent production of the farm. The order proposes the framework of the spreading plan. The spreading interventions must be registered. These requirements are linked to the order about vulnerable areas.
			Order of 15 March 1999 on the general requirements applicable to classified environmental protection installations subject to declaration under heading 2251 (Preparation, packaging of wine, the production capacity being greater than 500 hl / year but less than or equal to at 20 000 hl / year).	15/03/1999	2+	
			Council Regulation (EC) n° 834/2007 of june 28 2007 and Commission Regulation	2008	3+	The farm can only use organic effluent from organic farms or the conform

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			(EC) n° 889/2008 of September 5 2008, about organic farming			products described in the annex 1 of the regulation number 889/2008

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1.5. Germany

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
THU	30	Precision farming coping with heterogeneous qualities of organic fertilizers in the whole chain	Fertilization Ordinance (DüV): Upper limit for organic fertilizer/soil conditioner application (170 kg N/ha/a)	(Y) 2.6.2017	2+	Since 2017, the 170 kg N/ha/a limit refers to all types of organics, before that only manure was regulated. This limits the amount of organic bound N being used as fertilizer per plot. The upper limit shall trigger more efficient use of restricted amount of organic fertilizers in the sense of precision farming; that –in turn– may promote use of NIRS manure sensors.
			Ordinance for Substance Flow Analysis – SFA (StoffBilV): Obligatory SFA for certain farm types since 1.1.2018; after 1.1.2023 further farm types obliged	(Y) 1.1.2018	3+	Necessity to document and report N and P quantities in used, transported, exported/ imported organic fertilizers. Amendment expected in 2019 to cover further farm types starting in 1.1.2021 instead of 1.1.2023.
			Increase of fines from 10,000€ up to 50,000€, in case of a false or incomplete record of fertilization levels	Expected in 2020	3+	Federal states in Germany can decide on the methodology for monitoring/ verification and quality criteria. If acknowledged as an accredited method, NIRS manure sensors (certified by i.e. DLG) can receive more attention by providing reliable information on nutrient contents of N and P in organic fertilizers applied

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						and/or transported, therefore it can reduce the risk of misreporting.
			Expected amendment in “Fertilizer Requirement Planning” in “Fertilization Ordinance” (DüV): 10 percentage-points increase in accounting N available in manure and liquid digestate if applied with low-emission methods (expected), and planned amendment as 5 percentage-points increase in accounting N available in cattle and pig manure, and digestate before application compared to excretion (to be in force 1.1.2020)	Expected/planned in 2020	0	It will force farmers to increase N efficiency with N application. So that, this can create an incentive to use low-emission techniques, such as NIRS manure sensors, if coupled with some financial or administrative benefits. Otherwise, farms using these techniques may be disadvantaged, if increased accounting and, thus, more limited use only applied to those farms, while others can keep applying comparatively more organic fertilizers.
			Nutrient Balance in Fertilization Ordinance (DüV) is expected to be abolished, due to the running infringement process on the EU Nitrates Directive	Expected in 2020	0	If abolished, no track changes possible at field level anymore. It was argued that with the ex-ante N fertilizer planning, the ex-post N budget becomes obsolete. Nevertheless, this is not the case if available/useful N in organic fertilizers is calculated less than 100% of N applied with organic fertilizers. The higher the proportion of N applied in organic fertilizers, the more relevant the N balance becomes to trace the fate of N that does not end up in crop production, but might be emitted to the surrounding

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						environment. Possible reasons for such N losses furthermore include misjudgement of the target yield, thus, the reference N rate, inefficient livestock feeding, and mismanagement of organic fertilizers.
			Further various amendments are expected in Fertilization Ordinance (DüV) and Ordinance for Application of Organic Fertilizers (WDüngV) limiting/regulating the process and overall use of organic fertilizers.	Expected in 2020	2+	There are many other changes expected in the regulations that are being planned and discussed to limit the overall use of organic fertilizers and improve the level of processing of organic fertilizers, so that its use in the whole chain follows a similar pattern as for mineral fertilizers. For instance, the higher the processing level of organic fertilizers is achieved, the more targeted they can be applied. The regulatory changes will further influence the quantity, application conditions and timings of organic fertilization. In this sense, NIRS manure sensor can make a valuable contribution to a more efficient and traceable N and P use with organic fertilizers.
	28	Precision farming and optimised application: unter-	Fertilization Ordinance (DüV): Limit for phosphorus surplus at farm level 20 kg P2O5/ha/a	(Y) 2.6.2017	2+	Use of mineral under-root (injection) application of phosphorus fertilizers limits the use of organic fertilizers due

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
		root application of liquid manure for maize and other row crops	considering 5 previous years to calculate an average surplus			to their high phosphorus content, and accordingly due to exceeding the upper limit for allowed P surplus. Therefore, substituting mineral fertilizer by manure in under-root fertilization can make more organic fertilizer applicable in total. Nonetheless, this depends on the manure fractions used for injection, as well as for the further organic fertilization.
			Fertilization Ordinance (DüV): Expected change for the upper limit of organic fertilizer application 170 kg N/ha/a from farm average to field-specific average (presumably it will apply to regions with intensive livestock production)	Expected in 2020	2+	This change will avoid applying high rates of organic fertilizers at one field compensated by lower application at another field within the same farm. Higher application at a specific field is expected to result in higher leaching and gas emissions. If upper limit holds field specific, the importance of under-root application with organic fertilizers gets greater for maize or similar row crops that require especially high level of phosphorus in early stages of seed development, while coping with the total application allowed for organic fertilizers besides the limit for phosphorus surplus.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			Immediate incorporation of organic fertilizers according to Fertilization Ordinance (DüV), at the latest four hours after application. Further limitation to be enforced from 2025 on, i.e. incorporation of organic fertilizers within an hour after application is under discussion.	(Y) 2.6.2017	3+	Organic fertilizers, with significant content of available N, should be applied immediately, not later than four hours after the start of the application. Under-root application process assures to be in line with this rule, since incorporation is conducted simultaneously with application of manure.
			Further various amendments are expected in Fertilization Ordinance (DüV) and Ordinance for Application of Organic Fertilizers (WDüngV) limiting/regulating the process and overall use of organic fertilizers.	Expected in 2020	2+	There are many other changes expected in the regulations that are being planned and discussed to limit the overall use of organic fertilizers and improve the level of processing of organic fertilizers, so that its use in the whole chain follows a similar pattern as for mineral fertilizers. For instance, the higher the processing level of organic fertilizers is achieved, the more targeted they can be applied. The regulatory changes will further influence the quantity, application conditions and timings of organic fertilization. In this sense, under-root application of organic fertilizers can make a valuable contribution to a more efficient N and P use.

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1.6. Hungary

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
TH	22	BIO-PHOSPHATE: high temperature reductive thermal process recovery of concentrated Phosphorus from food grade animal bones	36/2006. (V. 18.) FVM regulation on authorisation of fertilising products (HU)	Y	3+	Accredited Authorisation aiming to permit of qualified fertilisers.Blocked use of fertilising product without a valid Authority permit. ABC-BioPhosphate product horticultural application permit number: 02.4/102-2/2015. This permit sets the requirements for high quality and safety conditions including minimum nutrient content, maximum level of contaminants and product packaging & labeling conditions as of CLP Regulation. This permit can be extended to other EU MSs based on the EUMutual Recognition Regulation (Reg. EC764/2008).
			9/2015. (III. 13.) FM Decree on the rules for the use of direct subsidies linked to agri-production. (HU)	Y	3+	Obligation for keeping and regullary reporting of Farming Management Logs for all agricultural activities including using of fertilising products.
			59/2008. (IV. 29.) FVM Nitrate regulation and related mandatory requirements for Good Agricultural Practices (HU)	Y	3+	Supporting ecologically sustainable agro business, food safety and susbsurface water quality protection (prevention of runoff and leaching). Detailed requirements for Good Agricultural Practices. Blocked use of fertilising product if not met to mandatory Good Agricultural Practices (nutrient stop).
			(EC) No 1907/2006 REACH, CLP Regulation EC No	Y	3+	As the ABC-BioPhoshate is a chemically modified substance, REACH is to be applied. The ABC-BioPhosphate product

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			1272/2008 for Classification, Labelling and Packaging. 2000 XXV. law about chemical safety (HU)			permit sets the requirements for packaging&labelling as of CLP reg.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
SOLTUB	13	Sensor technology to assess crop N status	17/2007 Governmental order and its modifications on soil protection against nitrate pollution together with the execution order 59/2008 of the Ministry of Agriculture	2008	3+. positive effect on avoiding N leaching and N runoff, in general avoiding pollution with nutrients on fields and storage facilities. A lack of the legislation is making no difference between liquid manure and digestate.	limiting the spreading the manure 170 kg/ha N, limiting the stop periods of fertilisation between October 31 and February 15, limiting the liquid manure spreading on slopes over 6%, limiting the application of mineral fertilizers on slopes over 12%, maximising the storage capacity of manure up to 6th month, spreading liquid manure only with soil health permits
			43/2007 order of the Ministry of Agriculture on the nitrate vulnerable zones inclusion in the land parcel identification system	2008	2+. positive effect on avoiding N leaching and N runoff, in general avoiding pollution with nutrients on fields	traceability of parcels identified in the nutrient vulnerable zones
			50/2008 order of the Ministry of Agriculture on cross-compliance	2008	3+. establish the criteria for the good agricultural and environmental condition. Has positive effect on prevention of soil erosion, maintaining soil organic matter and soil structure, in ensuring a minimum level of soil maintenance,	linking the C-N-P flows by regulating the animal husbandry sector and the crop production sector, the application criteria improve soil organic matter, reduce soil compaction, include the crop rotation, the utilisation of water for irrigation only having the water permit, inclusion of permanent grasslands
			10/2015 order of the Ministry of Agriculture regarding greening	2015	2+. positive effect on improving soil organic matter (SOM) and soil N content	inclusion in rotation the legume crops, crop diversification (avoiding monoculture), establishing ecological areas, establishing permanent grasslands

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1.7. Ireland

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
TEAGASC	17 & 68	17: Crop farmer using a variety of manure and dairy processing residues to recycle and build soil C, N, P fertility 68: Integration of UAV/Drone and optical sensing technology into pasture systems	Ireland's Nitrates Action Programme (NAP, 2017)	Yes	3+	o Major implication for use of N and P fertilisers in farming system. o To comply with EU regulations (S.I. No. 605/2017) of "Good Agricultural Practice for Protection of Waters". o To exercise good practice of farmyard management and fertiliser application plan.
			Storage period for livestock manure	Yes	1+	o Compliance with NAP (2017) Regulations and the avoidance of water pollution. o Required storage capacity varies between 16 – 22 weeks as identified for regional requirement in Ireland.
			Prohibited application periods of fertilisers o Chemical fertiliser: 15 September – 12/15/31 January o Organic fertilisers: 15 October – 12/15/31 January o Farmyard manure: 1 November – 12/15/31 January o Livestock manures or any chemical fertilisers should not be applied to land when it is waterlogged, flooded or likely to	Yes	0	Prevent risk of nutrient loss.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			flood, frozen or if heavy rain is forecasted within 48 hours.			
			Teagasc nutrient advice for productive agricultural crops (known as “Greenbook”)	Yes	3+	To provide economic optimal yield of the crop or grazing livestock in compliance with reducing risk and consequences of losses to the environment. Advisory service to farmers on nutrient recycling and availability from organic materials.
			Teagasc Nutrient Management Planning (NMP Online)	Yes	3+	o To improve nutrient management at farm level, facilitating more efficient, competitive and profitable farming systems. o Meeting statutory requirements through efficient and quality farm fertiliser plans. o To improve environmental outcomes, particularly in relation to water quality and gaseous emissions.

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1.8. Italy

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
UMIL	23	Pig manure refinery into energy (biogas) and fertiliser using a combination of techniques applicable at industrial pig farms	Limit for N load (Nitrate vulnerable zones)	Yes	2+	A web application Nitrate Management Procedure which is accessed through the Portal of Agricultural Companies in Lombardy, a web application that integrates certified databases updated and transversal to the entire agricultural system. B ase on legislation for this is European Nitrate Directive 91/676/CEE. Italian national legislation is in compliance with this directive, in particular have been defined rules and limits for N load in agriculture though Minister Decree 19 April 1999, Law Decree 152/2006, and Minister Decree 25 February 2016. This national rule must by applied by local administrations, who must indicate which areas are “Nitrate Vulnerable” and set appropriate Action Program.
			Digestate site production	Yes	0	It is produced in plants - corporate and inter-company - of anaerobic digestion authorized and fed with livestock manure and a series of materials including vegetable waste and some waste from the agro-industry (**Art. 22) . Decree of the Ministry of Agricultural, Food and Forestry Policies 25 February 2016. It establishes general technical criteria and standards for the regional regulation of the agronomic use of livestock manure and waste water, as well as for the production and agronomic use of digestate

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			Agronomic use of digestate (Type)	Yes	2+	Submit to the Municipality's SUAP the communication to agronomic use (**Art. 4); certain types of companies are also required to prepare the Agronomic Use Plan - PUA (**Art. 5) . Decree of the Ministry of Agricultural, Food and Forestry Policies 25 February 2016. It establishes general technical criteria and standards for the regional regulation of the agronomic use of livestock manure and waste water, as well as for the production and agronomic use of digestate.
			Registration as fertiliser of ammonium sulphate	Yes	2+	Detailed traceability system through the registration of products and fertilizer manufacturers. mineral fertilizers for the supply of main nutrients. In the case of Mineral fertilizers, it applies specifically for; *Ammonium sulphate Chemically obtained product containing as essential component ammonium sulphate, optionally with not more than 15% calcium nitrate (nitrate of lime) 19.7% N, Nitrogen evaluated as total nitrogen. Maximum title of nitric nitrogen in the case of the addition of calcium nitrate (lime nitrate): 2.2% N When marketed as a combination of ammonium sulphate and calcium nitrate (lime nitrate), the designation must specify "containing up to 15% calcium nitrate (lime nitrate). New fertilizers placed on the market must be pursuant to standards, so are subjected to official controls to verify their conformity (type of fertilizer, declared titles of fertilizer elements, declared titles of the forms and solubilities of these elements) by recognized national laboratories fit for purpose, using sampling and analysis methods officially adopted by Italian Ministry of

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						Agriculture. Work is currently underway at EU level for the regulatory reorganization of the sector, through the revision of Regulation (EC) n. 2003/2003, in order to achieve greater uniformity both between the various national regulations and between the methods of analysis used, as well as to guarantee greater efficiency and uniformity in controls.
			Method of storage, control and monitoring	Yes	1+	Methods of storage and agronomic use as well as the controls and monitoring necessary for verifying the concentration of nitrates in water and assessing the trophic state.
	16	Using digestate, precision agriculture and no-tillage focusing on OM stocking in an area characterize by the lack of OM in sandy soil	Agronomic use of digestate (Type)	Yes	2+	Submit to the Municipality's SUAP the communication to agronomic use (**Art. 4); certain types of companies are also required to prepare the Agronomic Use Plan - PUA (**Art. 5). Mineral fertilizers, specialized fertilizers - such as water-soluble products, products with controlled release of nutrients, products with a bio-stimulant effect, and soil improvers, corrective substances and substrates.
			Digestate site production	yes	0	It is produced in plants - corporate and inter-company - of anaerobic digestion authorized and fed with livestock manure and a series of materials including vegetable waste and some waste from the agro-industry (**Art. 22). Decree of the Ministry of Agricultural, Food and Forestry Policies 25 February 2016. It establishes general technical criteria and standards for the regional regulation of the agronomic use of livestock manure

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						and waste water, as well as for the production and agronomic use of digestate.
			Precision agriculture	No, (See comments)	0	National legislation on precision farming techniques is not yet available. Decree of the Ministry of Agricultural, Food and Forestry Policies number 33671 22 December 2017 contains guidelines for the future development of this sector , also in compliance with European Common Agricultural Policy 2014-2020.
	52	Pilot-scale crystallizer for P recovery	Registration as fertiliser	Yes	2+	The use of struvite as a fertilizer is still not widespread in Italy because is not specifically regulated and therefore some administrations consider it a "waste" rather than a "by-product". However, on 24 October 2017, thanks to a series of amendments to the European fertilizer directive, struvite and biochar are among the fertilizers with the CE marking. Amendments adopted by the European Parliament on 24 October 2017 on the proposal for a regulation of the European Parliament and of the Council laying down rules on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 (COM(2016)0157 – C8-0123/2016 – 2016/0084(COD))

**The articles (statements) are based on the Decree of the Ministry of Agricultural Food and Forestry Policies of 25 of February 2016. *REGULATION (EC) No 2003/2003 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 October 2003

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1.9. The Netherlands

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
ZLTO	43	Pig manure processing and replacing mineral fertilizers	Dutch Fertiliser Act: 1. Meststoffenwet 2. Uitvoeringsbesluit meststoffenwet 3. Uitvoeringsregeling meststoffenwet	Yes 27-11-1986	3+	Different N application levels for N from animal source and from mineral source
			Adjustment to interpretation Nitrate Directive under study from JRC	No, 2022	3+	…
			Dutch Fertiliser Act: 1. Meststoffenwet 2. Uitvoeringsbesluit meststoffenwet 3. Uitvoeringsregeling meststoffenwet	Yes 27-11-1986	3+	Objective current law is to prevent emission from ammonia to air when using animal manure fertilizers
			Local authorities and 'water-boards' only recognise reversed osmosis as 'best available technique' to clean water for discharge to surface water (can you state the piece(s) of legislation)?	…	2+	This is not national legislation but local legislation used to issue permits for manure processing plants.
	32	Nutrient mass flow analysis to better map and understand NPC flows at farm level	Dutch Fertilizer Act: application rates are mentionned per soil category and crop, but not related to yield	Yes 27-11-1986	2+	Idea of ANCA is that more yield of protein should allow higher application rate of nitrogen fertilizer. The ANCA system is not yet accepted as objective and certified method for accountability of nutrient flows
	73	Field assessment of of precision arable farming using bio-based fertilizers in potato growing	Dutch Fertiler Act: Different N application levels for N from animal source and from mineral source	Yes 27-11-1986	3+	same as 43
			Adjustment to interpretation Nitrate Directive under study from JRC	No, 2022	3+	same as 43

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
	76	Nitrogen sensor technology to make real-time crop assessment	…	…	…	The sensor is not subjected to legislation, it will provide management information to the farmer only.

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1.10. Poland

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
PcZ	47	Production of growing substrates for horticulture application from poultry manure, solid state digestate and biochar through composting	Limited period of spreading	Act on fertilizers and fertilization with the executive documents provide specific information and requirements (from 2007 with further amendments)/Y +++ Regulation of the Council of Ministries from June 5th 2018 regarding the implementation of „The Program of actions to reduce the contamination of water by nitrates from agricultural sources and prevention of further contamination" /Y +++ The Act of 20 July 2017 - Water Law (Journal of Laws No. 1566 and 2180 and of 2018, items 650 and 710)Y +++ Regulation of the Ministry of Agriculture and Rural Areas Development from June 18th 2008 regarding the laws on fertilizers and fertilization. /Y +++ The act of 14th December 2012 on waste (Journal of Laws 2013, item 21)/Y	Fertilizers and soil improvers +++ Biochar +++ This technology has a very strong connection with CNP cycles	Limitations to biochar production due to lack of legal quality requirements and lack of clarity on end-of-waste criteria Direct results on leaching Food quality maintaining soil quality maintaining Soil organic carbon sequestration, CO2 soil emissions reduction
			Frozen land, slopes, water			
			Nutrient content			
			Pollutants content			
			Source of the fertilizer			

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
	25	Soybeans in Poland - innovative solutions in the cultivation, plant protection and feeding on farms	GMO regulations	The Act on Plant Protection Journal of Laws No..2017.0.2138, Act of 18 December 2003 on plant protection /Y 1+	N cycle improvement +++ N P fertilizers usage decrease +++	The act creates a register of GMO crops, adapts Polish regulations to the EU regulations
			Crops rotation	Act of 16 March 2001 about organic farming(Journal of Laws No. 38, item 452)Y +++		
			Fertilizers usage limitations	Regulation of the Council of Ministries from June 5th 2018 regarding the implementation of „The Program of actions to reduce the contamination of water by nitrates from agricultural sources and prevention of further contamination" +++ The Act of 25 August 2006 on food and nutrition safety (Journal of Laws of 2015, item 594Y		Prevention against GMO plantation is a key issue
			Reduction of crop diversity	The Act on Plant Protection Legal status valid for: 06/05/2019 Dz.U.2017.0.2138 t.j. - Act of 18 December 2003 on plant protection Y ++		Increase of food safety, plants cultivation control
	48	Recovery of energy from poultry manure and organic waste through anaerobic digestion	Renewable energy sources	Polish Energy Policy until 2030 +++ The act of 10 April 1997 - Energy Law) (Journal of Laws of 2012, item. 1059 as amended); Y +++	biogas production +++ agricultural use of anaerobic	Opens up new possibilities for disposal of organic waste – especially those wastes, which would be difficult

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
				The act of 20 February 2015 on renewable energy sources (Journal of Laws of 2015, item. 478 and 2365 and of 2016 item. 925); Y +++ Development directions of agricultural biogas plants in Poland in 2010÷2020 (M. P. No. 74 of 2010, item 945); Y +++ The act of 25 August 2006 on biocomponents and liquid biofuels (Journal of Laws of 17 February 2017, item. 285 as amended); Y +++	digested sludge +++	to digestion separately; enhances performance of anaerobic digestion of poultry manure; improves quality of anaerobic digested sludge
			Waste management from biogas plants	The act of 14th December 2012 on waste (Journal of Laws 2013, item 21); Y +++ The Act of 10 July 2007 on fertilizers and fertilization (Journal of Laws No 147, item 1033, as amended); Y +++		
			Waste management - change of waste codes	The Regulation of the Ministry of the Environment of December 9th 2014 on a catalogue of waste (Journal of Laws 2014, item 1923); Y +++ Regulation of the Minister of the Environment of 20 January 2015 on the recycling process R10 (Journal of laws of 2015 item 132); Y +++		

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
			Requirements for biogas plant feedstock	Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption; Y +++ Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation), Y +++		

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1.11. Portugal

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
ISA	62	Blending of raw and treated organic materials to produce organic fertilizers (NPC)	Definition and specification of organic fertilizer and manures	Law Decree Nº103/2015 of 15 of June Ordinance nº259/2012 of 28 of August Dispatch nº1230/2018 from Diário da República nº25 of 5 of February	y	2+	In Portuguese, the definition of fertilizer includes two different materials, which do not have an exact equivalent word in English. Materials which are added to soil with the main purpose of adding nutrients (directly), which, in most of the cases, have a mineral origin, but could also be mineral-organic or organic, are called 'adubos', and are distinguished from another group of fertilizers, which are the conditioners or amendments: materials (organic or inorganic), which are added to soil with the main purpose of altering their properties (e.g., increasing organic matter content, modifying soil pH) in a way that the nutrition its indirectly beneficiated. Of course, even organic amendments can release nutrients, but that is a slow process, and they are not usually considered in the fertilization plan Because of that, to respect the legislation, we should distinguish what is a "mineral fertilizer", an "organic fertilizer", and a "biowaste-based fertilizer". Definition concerning what is a mineral fertilizer and an organic fertilizer. There is a restriction on the percentages of

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
							nutrients contents and organic matter in the case of the organic fertilizer.
			The use of fertilizers with ammoniacal nitrogen to avoid ammonia volatilization	Dispatch nº1230/2018 from Diário da República nº25 of 5 of February	y	0	The use of ammoniacal nitrogen fertilizers should be incorporate into soil quickly, maximum 24h after soil application.
			Seasons and application techniques concerning nitrogen fertilizers	Dispatch nº1230/2018 from Diário da República nº25 of 5 of February	y	1+	If the new bio-based fertilizer is formulated to crops sown in autumn, the quantity applied should be lower since it is a rainy period and the crop's growth is slower.
			Nitrate Vulnerable zones in Portugal	Ordinance nº259/2012 of 28 of August	y	0	The fertilization in some areas, considered in Portugal as nitrate vulnerable zones, is restricted. For example, if the agricultural land is adjacent to a water reservoir, there is a limit distance to be considered to the water reservoir.
			List of wastes that can be used to produce biowaste-based fertilizers Definition of wastes and biomass	Law Decree Nº103/2015 of 15 of June Law Decree nº71/2006 Of 5 of September	y	3+	Special requisites are applied to the wastes which can be used in the preparation of the biowaste-based fertilizers.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
			Certification and commercialization of biowaste-based fertilizers	Law Decree Nº103/2015 of 15 of June	y	-	Bio-waste based fertilizers have legal limits for: indicator pathogenic microorganisms (Salmonella spp. and Escherichia coli), seeds and seeds of weeds, anthropogenic inorganic materials, heavy-metals, and organic contaminants. The legal limits established for heavy metals allows the classification of the biowaste-based fertilizers in Classes: I, II, IIA and III, which conditions the type of agricultural application and the annual quantities which can be applied. Biowaste-based fertilizers need to be submitted to a stabilization process, namely composting or anaerobic digestion, followed by the composting of the digestate. The degree of maturation has implications on its labelling for commercialization, but also affects other parameters which have legal limits. The certification implies not only the evaluation of their chemical composition, regarding nutrients and pollutants, but also the evaluation of its agronomical value. There are rules concerning the information which needs to be provided in the label.
			Application of manures	Dispatch nº1230/2018 from	y	2+	There is a limit concerning the microorganism content as well as heavy metal content. There

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
				Diário da República nº25 of 5 of February Ordinance nº631/2009 of 9 of June			is also restrictions on the application according to slope and water proximity, storage and time of application are also regulated. To enhance the manure use in agriculture, there is some measures according to the code of good agricultural practice that need to be considered. There is also a limitation on the period that manures can be applied to soil (November, December and January have a restricted application) and areas with water proximity are also regulated.
			Agronomic value of sewage sludges and soil application	Law Decree nº276/2009, of 21 of June	y	1+	The management of sewage sludges for agriculture can only be practiced by the producer of sludges or an accredited technician, and subjected to a Management Plan. Sludges can only be used in agricultural soil if previously treated/stabilized and if complying with legal limits for: indicator pathogenic microorganisms (Salmonella spp. and Escherichia coli), heavy-metals, and organic contaminants. Legal limits for heavy metals are less restrictive than those established for biowaste-based materials, namely compost. Sludge application is restricted to some periods of the year.

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments	
			Techniques to reduce emissions	Decree nº20/2004 of 20 of August	y	3+	According to the Protocol established in 1979, techniques to reduce the emissions manures can be use if they reduce 30% the emission according to the reference values.
	57	Recovered organic materials and composts for precision fertilization of apple orchards and vineyards	Creates the Portuguese fund for carbon	Decree-Law nº71/2006 - Diário da República nº60/2006, Series I-A of 24 of February	Y	3+	Support projects of sequestration of C and adoption of new technologies to avoid emissions
	63	Precision fertilization of Maize using organic materials	…	…	Y	…	Same legislation above mentioned for the use of manure, organic fertilizers, biomass and other residues

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1.12. Spain

Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
CARTIF	49	Nitrogen and phosphorus recovery from pig manure via struvite crystallization and design of struvite based tailor-made fertilizers	Requirements to be met by the fertilizer to be commercialized	Y Spanish regulations on fertiliser products (Royal Decree 506/2013 of 28 June and general provisions such as Royal Decree 999/2017)	-	Brief summary of Spanish legislation affecting technology: - The following types of fertilizers are defined: organic fertilizer (from animal or vegetal), organic-mineral fertilizer, biodegradable organic waste, manure and compost. - For the production of fertilisers, only the use of raw materials of organic, animal or vegetable origin, expressly included in the list of biodegradable organic waste in the Royal Decree, is permitted. Raw materials of animal origin used in the manufacture of fertiliser products shall comply with the requirements laid down in Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 and the relevant provisions implementing or amending that Regulation. - Fertilising products consisting entirely or partly of biodegradable organic waste must also meet requirements of: humidity, granulometry, maximum furfural limit, maximum polyphenols limit. - Maximum values for Salmonella and Escherichia coli are established for products containing raw materials of organic, animal or

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						plant origin may not exceed. - Products made with raw materials of organic, animal or vegetable origin may not exceed the heavy metal content described in the Royal Decree.
			Permit stop	Y Spanish regulations on fertiliser products (Royal Decree 506/2013 of 28 June and general provisions such as Royal Decree 999/2017)	---	Blocked agro business. The need to control possible risks to health and the environment arising from the use of such organic waste means that organic fertilisers and amendments, together with organic-mineral fertilisers, must have an administrative authorisation in order to be placed on the market, which is specified in the Register of Fertilising Products Currently, according to Spanish legislation struvite is classified as a waste and not as a fertilizer. All this prevents the marketing of struvite in Spain.
	27	Use of an inoculate of microbiota and enzymatic pre-cursors to reduce ammonia emissions and optimize nutrient use efficiency in poultry manure	Requirements to be met by the fertilizer to be commercialized	Y Spanish regulations on fertiliser products (Royal Decree 506/2013 of 28 June and general provisions such as Royal Decree 999/2017)	-	Brief summary of Spanish legislation affecting technology: - The following types of fertilizers are defined: organic fertilizer (from animal or vegetal), organic-mineral fertilizer, biodegradable organic waste, manure and compost. - For the production of fertilisers, only the use of

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						raw materials of organic, animal or vegetable origin, expressly included in the list of biodegradable organic waste in the Royal Decree, is permitted. Raw materials of animal origin used in the manufacture of fertiliser products shall comply with the requirements laid down in Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 and the relevant provisions implementing or amending that Regulation. - Fertilising products consisting entirely or partly of biodegradable organic waste must also meet requirements of: humidity, granulometry, maximum furfural limit, maximum polyphenols limit. - Maximum values for Salmonella and Escherichia coli are established for products containing raw materials of organic, animal or plant origin may not exceed. - Products made with raw materials of organic, animal or vegetable origin may not exceed the heavy metal content described in the Royal Decree.
			Permit Ok		1+	Product with commercial authorization. The need to control possible risks to health and the environment arising from the use of such organic waste means that organic fertilisers and

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Partner	Longlist n°	Technology	National legislation	Entry into force	Impact on technology	Comments
						amendments, together with organic-mineral fertilisers, must have an administrative authorisation in order to be placed on the market, which is specified in the Register of Fertilising Products. The product has administrative authorisation for marketing and is currently being marketed. There was no impediment to registering the product as "green product".

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