European Commission

GUIDANCE TO MEMBER STATES IN IMPROVING THE CONTRIBUTION OF LAND-USE, FORESTRY AND AGRICULTURE TO ENHANCE CLIMATE, ENERGY AND ENVIRONMENT AMBITION

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With guidance in assessing these sectors in the NECPRs, the draft updated NECPs and the amendment requests to CAP Strategic Plans

Report for: EUROPEAN COMMISSION DIRECTORATE-GENERAL CLIMATE ACTION

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Table of Contents

GLOSSARY

ABER – Agricultural Block Exemption Regulation

AECC – Agriculture Environment Climate Commitments

BAT – Best Available Techniques

BREF – BAT Reference Documents

CAP – Common Agricultural Policy

CAP SP – CAP Strategic Plans

CBD – Convention on Biological Diversity

CCS – Carbon Capture and Storage

CH4 - Methane

CINEA - Climate Infrastructure and Environment Executive Agency

CMEF – Common Monitoring Evaluation Framework

CO2 – Carbon Dioxide

CO2e – CO2 Equivalent

EAFRD – European Agricultural Fund for Rural Development

EEA – European Environment Agency

ENVCLIM – Environment, Climate-related, and other management commitments

ERDF – European Regional Development Fund

ES – Ecosystem Services

ESD – Effort Sharing Decision

ESR – Effort Sharing Regulation

ETC – European Topic Centre

ETS – Emissions Trading System

FRMP – Flood Risk Management Plans

GAEC – Good Agricultural and Environmental Conditions

GHG – Greenhouse Gases

IACS – Integrated Administration and Control System

IED – Industrial Emissions Directive

IPCC – Intergovernmental Panel on Climate Change

JRC – Joint Research Centre

LCA – Life Cycle Assessment

LIFE – Programme for the Environment and Climate Action

LPIS – Land Parcel Identification System

LULUCF – Land Use, Land Use Change, and Forestry

MNF – Mineral Nitrogen Fertiliser

N2O – Nitrous Oxide

NAPCP – National Air Pollution Control Programmes

NAS – National Adaptation Strategies

NBSAP – National Biodiversity Strategies and Action Plans

NECP – National Energy and Climate Plan

NECPR – National Energy and Climate Plan Reports

NGO – Non-Governmental Organisation

NH3 – Ammonia

NMVOC – Non-Methane Volatile Organic Compound

NOx – Nitrogen Oxides

NVZ – Nitrate Vulnerable Zones

PAF – Prioritised Action Framework

PaMs – Policy and Measures

PM10 – Particulate Matter 10µg/m^3

PM2.5 – Particulate Matter 2.5µg/m^3

PMEF – Performance Monitoring Evaluation Framework

RBMP – River Basin Management Plans

RED – Renewable Energy Directive

RES – Renewable Energy Supply

RRF – Recovery and Resilience Fund

RRP – Recovery and Resilience Fund

SAPs – Standard Action Projects

SIPs – Strategic Integrated Projects SME – Small and Medium Enterprise

SMN – Soil Mineral Nitrogen

SNAPs – Strategic Nature Projects

SNMP – Soil and Nutrient Management Plans

SO – Strategic Objectives

SO2 – Sulphur Dioxide

SOC – Soil Organic Carbon

SWOT – Strengths Weaknesses Opportunities Threats

TA – Technical Assistance

UAA – Utilised Agricultural Area

UNFCCC – United Nations Framework Convention on Climate Change

VOC – Volatile Organic Carbon

WAM – With Additional Measures

WEM – With Existing Measures

WFD – Water Framework Directive

WM – With Measures

WMP – Waste Management Plans

WPP – Waste Prevention Plans

OBJECTIVES OF THIS GUIDANCE

The objective of the guidance document is to provide support to Member States in updating information and enhancing the ambition of the policies and measures planned and implemented for climate, energy and environmental purposes, in the land-use, forestry and agriculture sectors, also referred to as the land sector.

This guidance note covers:

1. Guidance for National Energy and Climate Plan Report (NECPR) requirements (what needs to be reported to meet the expectations of the Commission).
2. Guidance for National Energy and Climate Plan (NECP) updates (how ambition can be increased through enhanced policies and measures). This particularly references the enhanced ambition agreed with the trialogue agreements on the legislative acts included in the Fit for 55 packages such as the updated Effort Sharing Regulation (ESR), the Land Use, Land Use Change and Forestry (LULUCF) regulation, REPowerEU, and more.
3. Guidance on optimising the processes and documents within and connected to the Common Agricultural Policy (CAP) regulation to inform ambition and action in the land sector. This includes how ambition can be increased through enhanced policies and measures in Member States' CAP Strategic Plans (CSPs).

1 IMPLEMENTATION AND AMBITION

This section introduces:

- *The needs and challenges faced by the EU and Member States related to climate, environment, and energy issues in the land sector,*
- *the main policies and directives affecting the land sector, all of which seek to abate said issues.*
- *Policy interactions and the importance of the European Green Deal are discussed.*
- *The Common Agricultural Policy is covered in detail in chapter 5 but remains an important legislative instrument in this area.*

1.1 NEEDS AND CHALLENGES

1.1.1 Climate Action – Policies and Drivers

Sustainable land management will be critical to achieving the EU's 2030 and 2050 climate and climate neutrality objectives as it will increase the amount of carbon captured and stored in plants and soils. It is also key to reach other interrelated environmental objectives of the European Green Deal: tackling biodiversity loss, pollution, and resource depletion in a systemic and coherent manner. However, while forests show annual net carbon removals at EU level, all other land uses such as croplands, grasslands, wetlands, and settlements show overall annual net emissions, with significant differences between Member States. In addition, national Greenhouse Gas (GHG) inventories submitted to the UNFCCC report that net removals from terrestrial ecosystems in the EU have been on a declining trend over the last decade, largely driven by the deteriorating carbon sinks in forest ecosystems. Carbon sinks and stocks and biodiversity are interrelated, as demonstrated by scientific literature[1] and it is concerning that forest ecosystems are in bad conservation status according to the Habitats Directive. Sustainable land management is also key for climate adaptation: healthy ecosystems provide services such as protection against floods and desertification, air pollution and urban heat reduction, etc.

[1] See for instance: Osuri, A. et al. (2020) "Greater stability of carbon capture in species-rich natural forests compared to species-poor plantations", in Environ. Res. Lett. 15 (2020) 034011; Lewis, S. et al. (2019) "Regenerate natural forests to store carbon", in Nature 4 April 568; Strassburg, B. et al. (2019) "Global priority areas for ecosystem restoration", in Nature, **586**, 724–729; Grantham, H.S. (2020) "Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity" in Nature Communications, 11:5978; Van der Plas, F. et al. (2016) "Jack-of-all-trades effects drive biodiversity-ecosystem multifunctionality relationships in European Forests", in Nature Communication, March 2016.

In 2018, the EU adopted a GHG emission reduction target of 40% for 2030 compared to 1990, which included only the marginal performance of land. The 2021 European Climate Law[2], however, substantially increased the ambition of the EU's 2030 target (as articulated by the EU "Fit for 55 Package"[3]) through a binding target of at least 55% net emission reduction by 2030 compared to 1990. New EU target created a need to upgrade the EU LULUCF Regulation[4]. The revised regulation thus establishes a new target of removing 310 million tonnes of CO2eq by 2030 at EU level and sets individual net removal targets for Member States from 2026 onwards. This represents, for the EU, an increase of removals of about 15% compared to pre-2023 levels

In the EU, GHG emissions from energy demand in agriculture could reduce between 30.5% to 39.2% by 2030 compared to 2015, depending on the scenario, with large social, environmental and climate benefits[5]. Agricultural non-CO_2 emissions include methane from livestock and manure, and nitrous oxide from soil as a consequence of nitrogen fertiliser application, and from manure. There is scope to decrease these emissions, but the scale of this decrease is highly uncertain, and will be determined by the success, or not, of multiple mitigation actions, including, for example, decreased nitrogen fertiliser usage. Some of the mitigation actions for agricultural non-CO_2 emissions can influence production, with potential for emissions leakage as production is displaced to other locations. Agricultural non-CO_2 emissions are covered by the EU Effort Sharing Regulation (ESR). Based on national projections, a decline of 2% of agricultural non-CO_2 emissions is expected by 2030 compared with 2005 levels, and additional measures could increase this decline to a 6% reduction. Yet, it is expected that based on current policies, by 2050, agricultural non-CO_2 emissions will be the largest emitting sector in the EU, representing around 50% of non-CO_2 emissions[6]. Updates to the EU Energy Efficiency Directive responding to the Fit for 55 package will help to better implement existing programmes and implement new measures.

It is crucial to remember that environmental protection, biodiversity, pollution, natural resources depletion, and climate change adaptation are strongly connected to agriculture and the land sector, and these synergies go both ways. Sustainable management of land will help to mitigate and adapt to climate change while reversing biodiversity loss in a cost-effective way. For example, sustainable management of degraded forests can increase biodiversity as well as carbon stocks, and restoration of degraded ecosystems such as wetlands and peatlands can protect freshwater sources and reduce flooding while supporting carbon sequestration. On the other hand, unsustainable land use changes can also contribute to biodiversity loss, and increasing forest area can challenge biodiversity and carbon sinks and stocks (for example, when biodiverse and carbon-rich ecosystems are replaced by monoculture plantations) and intensify competition for land and water, if not managed well. By combining ecosystem-based measures, Member States can achieve win-win-win solutions for climate adaptation, biodiversity and ecosystem restoration, and climate change mitigation.

Greater action will be incentivised by the increased binding national targets within the framework of the 2023 updated ESR[7] and increased focus and ambition in the 2023 updated LULUCF regulation. To achieve the potential of the land sector to support the achievement of these increased targets, Member States will need to identify and deliver coherent policies and programmes of action across policy areas relevant to the land sector and highlight them in the NECPs. For example, Member States will be responsible for caring for and expanding their carbon sinks to meet their national targets and will need to create synergies with other policy areas, where relevant for the LULUCF regulation. Likewise, Member States need to explain how the policies and measures contribute to their increased ambition in the ESR which includes agriculture non-CO_2 emissions. The role of the NECPs has therefore increased in importance, and the potential of the CAP, in particular the new CSPs in funding and delivering meaningful change is essential.

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[2] European Climate Law (europa.eu)

[3] EUR-Lex - 52021DC0550 - EN - EUR-Lex (europa.eu)

[4] EUR-Lex - 52021PC0554 - EN - EUR-Lex (europa.eu)

[5] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020SC0176&rid=9

[6] *Idem.*

[7] https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3543

1.2 OVERVIEW OF POLICY INTERACTIONS

The European Green Deal sets out a strategic roadmap for the EU with specific milestones that focus political action on a just green and energy transition. Its plan has the following objectives:

- To make the EU climate neutral by 2050.
- To protect human life, animals, and plants by reducing pollution.
- To contribute to guaranteeing a fair and integrated transition.
- Development of clean energies, reliable and affordable, and developing the transition funding.
- Supporting sustainable agriculture and rural development.

The figure below details the policy interactions that are relevant for the land sector, as the focus of this guidance document. The European Green Deal has supported the development of various strategies, laws, action plans, and packages, which in turn have aided changes in other policies and directives and will continue to do so into the future. Some of the major aims of the European Green deal are for Europe to:

- Be the first climate-neutral continent by 2050.
- Have at least 55% less net greenhouse gas emissions by 2030, compared to 1990 levels.
- Have 3 billion additional trees planted in the EU by 2030.

Meeting the EU's ambitious targets, while ensuring that synergies are optimised and trade-offs are minimised, can only be achieved through increased and dedicated action by all members of the Union. The key regulations and policies set out in the following figure are essential to both the European Union as a whole and Member States setting out their programmes for the achievement of the objectives of the European Climate Law in the context of the land sector.

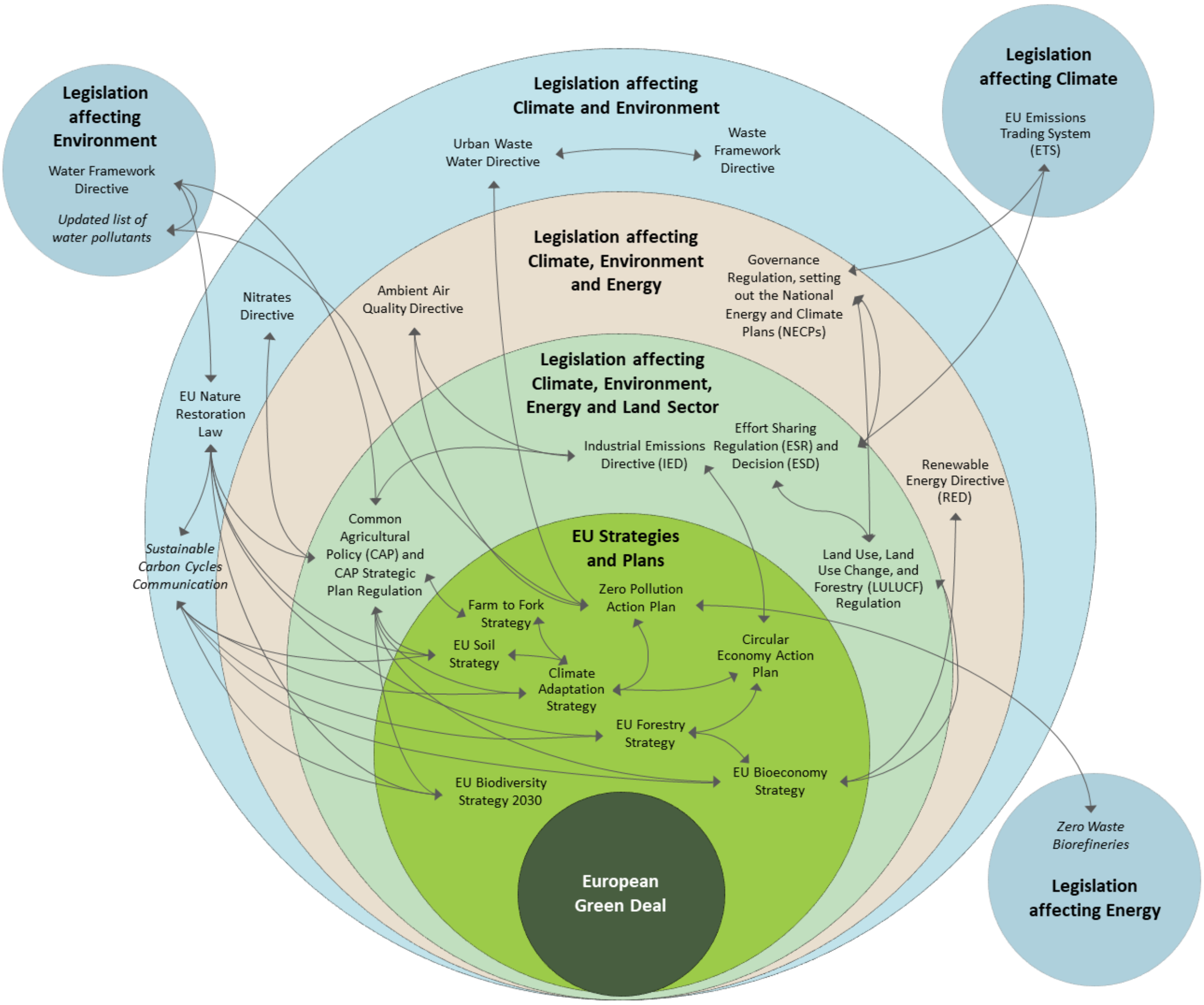

Figure 1:1 Overview of policies and policy interactions related to climate, energy, and environment.

Under the EU Green Deal, there are a wide range of initiatives been implemented. Relevant to the land sector, these include:

- ‘Fit for 55’ package: The package is a set of proposals to revise climate-, energy- and transport-related legislation and put in place new legislative initiatives to align EU laws with the EU’s climate goals.
- The European Climate Law: The European climate law regulation turns the political ambition of reaching climate neutrality by 2050 into a legal obligation for the EU.
- EU Strategy on adaptation to climate change: The strategy outlines a long-term vision for the EU to become a climate-resilient society that is fully adapted to the unavoidable impacts of climate change by 2050.
- EU Biodiversity Strategy for 2030: The EU Biodiversity Strategy for 2030 aims to help recover Europe’s biodiversity by 2030. This would bring benefits for people, the climate, and the planet, and integrate biodiversity objectives into other sectors such as agriculture, fisheries, and forestry and for a coherent implementation of EU measures in these fields
- 'Farm to fork' strategy: The Commission’s ‘farm to fork’ strategy aims to help the EU achieve climate neutrality by 2050, by shifting the current EU food system towards a sustainable model.
- Circular economy action plan: Decoupling economic growth from resource use and shifting to circular systems in production and consumption is key to achieving EU climate neutrality by 2050.

- Forest strategy: This builds on the EU's Biodiversity Strategy and forms a key part of efforts to reduce greenhouse gas emissions by at least 55% by 2030[8].

The 'Fit for 55' package outlines a set of revisions to climate and energy related legislation, as well as new legislation, to align the EU's laws with the climate goals. Relevant to the land sector, this includes (but not limited to):

- a revision of the effort sharing regulation on member states' GHG emission reduction targets in sectors currently outside the EU ETS
- a revision of the LULUCF regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry
- a revision of the renewable energy directive
- a recast of the energy efficiency directive
- ReFuelEU Aviation for sustainable aviation fuels

Further, through the EU Green Deal and beyond, a variety of EU policy developments seek to boost GHG mitigation in the agriculture sector, the Farm to Fork strategy, the new CAP, the Carbon Farming Initiative, Circular Economy Action Plan and Fit-for-55 package. This will be a stimulus for further actions across EU Member States.

The policies, strategies, laws, directives, and action plans covered in the figure have some relationship to the European Green Deal or will be amended in future to reflect the Green Deal's ambitions. Each arrow represents connections and relations between policies that are relevant to this guidance note, but these are not comprehensive. This presents the complexity of legislation affecting climate, environment, energy, and the land sector, and show the ways in which they interact.

The European Environment Agency (EEA) provides a detailed and useful overview of the European Green Deal in relation to natural resources and the land sector, which can be found here.

1.2.1 Climate change and biodiversity synergies

Climate change and biodiversity loss are global security issues: their negative impacts undermine many Sustainable Development Goals (SDGs), challenging the stability of states and societies. The climate and biodiversity crises are increasingly seen not only as mutually reinforcing but as one crisis with two acute emergencies. Delaying action is by far costlier to society than taking immediate action. Transformative changes are required to decarbonise the economy and reverse the destruction and degradation of ecosystems.

Climate, biodiversity, and society are interlinked, requiring synergies and coherence in policies and actions. Nature-based solutions (NbS) include biodiversity conservation and restoration measures that support climate change mitigation, adaptation, and sustainable development. However, climate change also affects ecosystems and reduces their potential to serve as NbS[9].

Despite growing recognition that climate change and biodiversity loss are highly interlinked, policy efforts addressing both crises in an integrated manner remain limited. There is a need to make better use of existing opportunities to translate synergies into policies and implementation.

Since issues related to biodiversity and climate change are inherently interlinked, the processes of formulating and implementing NAPs and NBSAPs present opportunities for alignment of the global agendas of CBD and UNFCCC, ensuring that actions under both plans are mutually supportive and not undertaken in isolation from one another. Countries are asked to develop their NBSAPs with cross-sectoral and intersectional considerations in mind, such as addressing the linkages between biodiversity loss and gender, sustainable development, poverty reduction, traditional practices, public health, and climate change.

[8] European Green Deal - Consilium (europa.eu)
[9] 02-thematic-paper-linkages-biodiv-climate-science-policy-practice-giz-iisd-ufz.pdf (adaptationcommunity.net)

1.2.2 Emissions and carbon removals from agriculture and LULUCF sectors

The main sources of GHG emissions from the agriculture sector are N2O from soil and CH4 from ruminant livestock and manure management. Agriculture is often the largest contributor of both these GHGs in any Member State. N2O emissions from soils are due to microbial activity, which increases with the addition of nitrogen-based fertilisers, the spreading of slurry and manure, and livestock grazing returns. Emissions of CH4 from ruminant livestock come from the enteric fermentation during the digestion process and from manure management. CH4 emissions are influenced by the breed, age and weight of the animal and is also influenced by the quality and quantity of feed consumed[10]. With the right management farms can sequester carbon in soil and vegetation as well, meaning agriculture can also act as a sink for emissions[11] and simultaneously be a haven for nature, while optimising food, fibre, and other production.

Carbon sequestration in agricultural lands is reported under the LULUCF sector of the IPCC reporting mechanism. In general, LULUCF acts as a sink by accumulating carbon in soils and vegetation. Forests represent a large carbon stock, although GHGs can be emitted through unsustainable management. Grassland and cropland act as a carbon stock through carbon stored in plant organic matter and soil[12]. Peatlands and peaty soils hold a similar but more significant role, as they can act as an immense carbon sink with a greater capacity to lock in carbon than grassland, croplands, and forestry when managed correctly. Poorly managed or exploited peatlands can be a large carbon source.

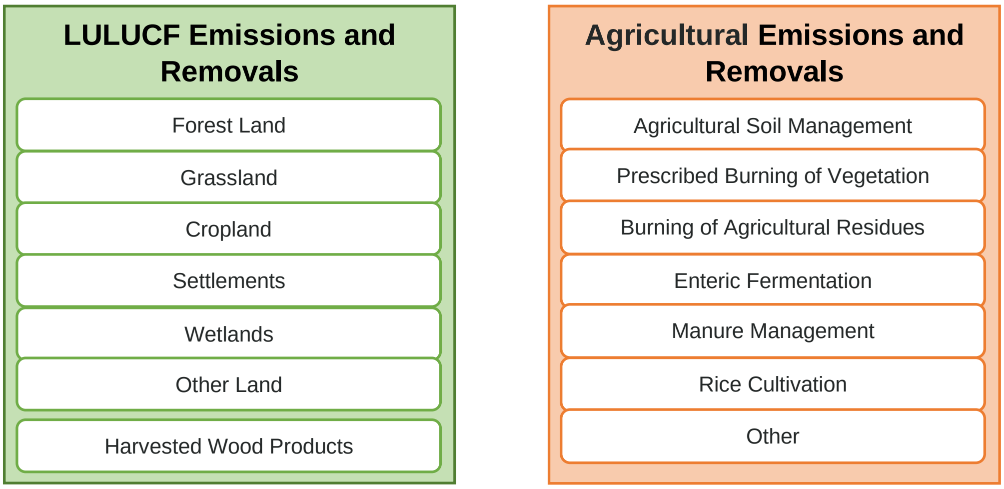

Figure 22: Different categorisations of emissions from Agriculture and LULUCF based on the IPCC categories. In Europe, emissions, and removals from most LULUCF land are relevant. Under agricultural emissions, not all categories are relevant; for example, rice cultivation is not found in many countries in the EU.

When considering possible programmes and measures, including their potential synergies and trade-offs, inspiration can be drawn from:

- the impact assessments of the LULUCF Regulation[13]
- the Commission communication on Sustainable Carbon Cycles[14]
- the proposal and impact assessments for a Nature Restoration Law[15]

[10] IBERS (2014) AC0015 Final Report http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17180&FromSearch=Y&Status=3&Publisher=1&SearchText=ghg%20platform&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[11] Antonia Weishaupt et al., 'Land Use, Livestock, Quantity Governance, and Economic Instruments. Sustainability Beyond Big Livestock Herds and Fossil Fuels' (2020) 12:2053 Sustainability 10; Verschuuren (n 5), section 3.2.

[12] UNFCCC (2022) Land Use, Land-Use Change and Forestry (LULUCF) https://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf

[13] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021SC0609

[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0800&qid=1673634064972

[15] Nature restoration law (europa.eu)

- the proposal and impact assessment for a Regulation on an EU certification for carbon removals[16]

1.3 EU POLICIES AFFECTING THE LAND SECTOR

1.3.1 LULUCF Regulation

The LULUCF Regulation, adopted in 2018, aims to increase removals and decrease GHG emissions from the LULUCF sector. When originally adopted, it did not set specific targets to do this, but instead provided an aim to achieve "no net debit", meaning emissions and removal had to be balanced[17]. The amendment adopted in 2023 establishes a new net target of removing 310 million tonnes of CO2eq by 2030 at EU level and sets individual net removal targets and values for Member states from 2026 onwards (Table 1). This represents, for the EU, an increase of removals of about 15% compared to today.

Table 1: The Union target (column D), the average greenhouse gas inventory data for the years 2016, 2017 and 2018 (column B) and the national targets of the Member States (column C) pursuant to Article 4(2) to be achieved in 2030[18]

A	B	C	D
Member State	**The average greenhouse gas inventory data for the years 2016, 2017 and 2018 (kt of CO2 equivalent), 2020 submission**	**Member State targets, 2030 (kt of CO2 equivalent)**	**Value of the greenhouse gas net removals in (kt of CO2 equivalent) in 2030, 2020 submission (Columns B+C)**
Austria	-4,771	-879	-5,650
Belgium	-1,032	-320	-1,352
Bulgaria	-8,554	-1,163	-9,718
Czechia	-401	-827	-1,228
Denmark	5,779	-441	5,338
Germany	-27,089	-3,751	-30,840
Estonia	-2,112	-434	-2,545
Ireland	4,354	-626	3,728
Greece	-3,219	-1,154	-4,373
Spain	-38,326	-5,309	-43,635
France	-27,353	-6,693	-34,046
Croatia	-4,933	-593	-5,527
Italy	-32,599	-3,158	-35,758
Cyprus	-289	-63	-352

[16] Carbon Removal Certification (europa.eu)

[17] Nabuurs, G., Arets, E. J. M. M. and Schelhaas, M. (2018) Understanding the implications of the EU-LULUCF regulation for the wood supply from EU forests to the EU. *Carbon Balance and Management 3(18)* https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-018-0107-3#:~:text=The%20LULUCF%20regulation%20aim%20to%20incentivise%20EU%20Member,debit%E2%80%99%20target%20for%20LULUCF%20%28Forests%20and%20Agricultural%20soils%29.

[18] pdf (europa.eu)

A	B	C	D
Latvia	-6	-639	-644
Lithuania	-3,972	-661	-4,633
Luxembourg	-376	-27	-403
Hungary	-4,791	-934	-5,724
Malta	4	-2	2
Netherlands	4,958	-435	4,523
Poland	-34,820	-3,278	-38,098
Portugal	-390	-968	-1,358
Romania	-23,285	-2,380	-25,665
Slovenia	67	-212	-146
Slovakia	-6,317	-504	-6,821
Finland	-14,865	-2,889	-17,754
Sweden	-43,366	-3,955	-47,321
EU-27/Union	*-267,704*	*-42,296*	*-310,000*

The current LULUCF Regulation set a binding commitment for each Member State to ensure that **accounted emissions** do not exceed **accounted removals** through action in the sector. In practical terms this commitment means that the result of the accounted emissions/removals is (not larger) than zero but can be negative (meaning the sector is a net sink). However, there are some exceptions (so-called flexibilities) which allow for deviations. This will be treated in the analysis part.

Member States should note that “accounted emissions/removals” under the LULUCF Regulation are different from “reported emissions/removals” from the national GHG inventory or projections.

Article 4 of the LULUCF regulation states that Member States “should set commitments for the periods from 2021 to 2025 and from 2026 to 2030, taking into account the flexibilities provided for in Articles 12 and 13, each Member State shall ensure that emissions do not exceed removals, calculated as the sum of total emissions and total removals on its territory in all of the land accounting categories referred to in Article 2 combined, as accounted in accordance with this Regulation.”

The new LULUCF legal framework needed to recognise three key issues:

1. Declining carbon removals from terrestrial ecosystems in the EU over the last decade, largely driven by the deteriorating trend in carbon removals in the forest ecosystems, continued emissions from organic soils, natural disturbances, and a lack of focus of policy and financial incentives.
2. Relatively complex and burdensome accounting, monitoring, and reporting rules in the current LULUCF Regulation which present implementation challenges: in particular, the process to establish Forest Reference Levels.
3. Insufficient integration of the climate and land sector policies due to the lack of a coherent framework that would integrate agriculture and other land categories.

It addresses these through:

1. Enhancement of carbon removals across all Member States by setting ambitious targets, and thereby placing the EU on track for the climate neutrality objectives of the medium and longer term.
2. A key upgrade to the new target framework is that it requires enhanced quality of monitoring, reporting and verification of emissions and removals. The new framework therefore places strong emphasis on simplifying the accounting rules and exploiting the opportunities created by existing land monitoring technologies (such as geographically explicit data – digital mapping – and remote sensing) and ancillary

datasets (such as the CAP) to better monitor the climate performance of the LULUCF sector. Better information in the hands of Member States will enable them to make better decisions and adopt more effective policies and measures in the land sector.

3. A fair, flexible, and integrated climate policy framework is needed to incentivise effective policymaking and implementation. This should enhance cost-efficient and synergistic mitigation action in the land sector. Strong synergies can be promoted between climate mitigation measures and environmental protection measures related to areas under agriculture and forestry as well as natural and semi-natural areas. The restoration of carbon rich ecosystems, therefore, will contribute alongside sustainable land management to addressing the climate and biodiversity crisis.
4. Despite the relatively cost-effect options for GHG mitigation on land, mobilising funding (such as CAP, LIFE projects, private revenues) remains key. The framework therefore also seeks to develop new business opportunities such as carbon farming and carbon storage products for farmers and forest managers. Such new business models could be based on carbon farming incentives or on the certification of carbon removals and will need to be increasingly employed in the period through 2030 and beyond.

1.3.1.1 Some elements adjusted in the legal framework

There are no substantial changes in the first compliance period from 2021 to 2025, when current rules continue to apply. From a compliance perspective, Member States need to continue to ensure that the accounted emissions do not exceed accounted removals within the sector ("no net debit"). However, given the longer lead times of impact of measures in the sector, this "business as usual" compliance frame should not discourage Member States from looking ahead to 2030.

A significant step-change takes place at the beginning of the second compliance period from 2026 to 2030. First, the Union 2030 target of GHG net removals of 310 Mt CO2eq has been distributed between Member States based on their managed land area and the net removals (for years 2016-18) reported in the GHG inventories. These national 2030 values are recorded in the legal text[19].

Second, a process to establish an annual national trajectory for the period from 2026 to 2029 has been defined, which sets out a pathway for each Member State to follow to successfully reach the 2030 values. The exact level for each year will be determined based upon the GHG inventory submissions in 2025. A new system of governance of the target compliance has been introduced, which will allow the Commission to interact with Member States in the fulfilment of these obligations. Moreover, a substantial land use "flexibility" mechanism has been created, addressing risk of non-compliance by Member States[20].

The agreement is a further tool to support those Member States that have difficulties in meeting their targets owing to natural disturbances (such as wildfires, pests and the effects of climate change and organic soils on emissions), provided that the Union meets its 2030 target. The agreement also lays down the criteria to assess whether the EU-wide target is being met and consequently if the flexibility mechanism can be used.

Member States will be allowed to use the above mechanisms up to a limit, provided, among other conditions, that they submit appropriate evidence to the Commission following a methodology which will be defined in secondary legislation.

The agreement introduces a governance mechanism for the targets in the regulation, including the measures to be taken if a Member State does not meet its national target in the second period (i.e., 2026-30).

As before, Member States remain responsible for managing and expanding their carbon sinks effectively to meet the new targets. Member States are therefore to be supported in their exposure to a wide range of measures to improve land management, such as improvements in sustainable forest management or the rewetting of peatlands.

As a result, the following steps will be needed:

1) to identify more effective policies and measures to reach the 2030 LULUCF removal targets;

[19] LULUCF Regulation (EU) 2023/839, Annex II a, column D.

[20] The agreement keeps the possibility to purchase and sell removal units between Member States and use surplus annual emission allocations under the ESR to reach the LULUCF targets, and to use surplus removal units to comply with the ESR national targets up to Member States' specific limits as defined in the ESR.

2) to shorten the feedback loops between monitoring, the identification of areas at most promise or need and the relevant policies decisions being enacted.

1.3.2 Sustainable Carbon Cycles and Carbon Farming

In December 2021, the Commission adopted the Communication on “Sustainable Carbon Cycles”[21] as follow up to the Carbon Farming Initiative announced by the Farm to Fork Strategy. The Communication sets out an action plan on how to develop sustainable solutions to increase carbon removals, identifying key challenges and proposing short- to medium-term actions to tackle them, which includes carbon farming.

There are several ways to remove and store carbon, all with strong relevance to the land sector:

- NbS, such as restoring forests, soils, and innovative farming practices.
- Technological solutions, such as bioenergy with carbon capture and storage, or direct air carbon capture and storage.
- Long-lasting products and materials, such as wood-based construction.

1.3.2.1 Carbon farming targets and incentives

The land sector is key for reaching a climate-neutral economy because it can capture CO2 from the atmosphere. However, to encourage the agriculture and forestry sectors to deliver on climate action and contribute to the European Green Deal, it is key to create direct incentives for the adoption of climate-friendly practices, as currently there is no targeted policy tool to significantly incentivise the increase and protection of carbon sinks for land managers[22].

By 2028, every land manager should have access to verified emission and removal data, and carbon farming should support the achievement of the proposed 2030 net removal target of 310 million tonnes of CO2 equivalent (Mt CO2eq) in the land sector.

Incentives for land managers include:

- promoting carbon farming practices under the CAP and other EU programmes such as LIFE and Horizon Europe, under the Mission “A Soil Deal for Europe”, and under public national financing[23];
- driving forward the standardisation of monitoring, reporting and verification methodologies to provide a clear and reliable framework for carbon farming; and
- providing improved knowledge, data management and tailored advisory services to land managers.

There are a range of measures that can support the sequestration of carbon within the land sector, such as:

- Afforestation and reforestation.
- Agroforestry.
- Use of catch crops, cover crops, conservation tillage and increasing landscape features.
- Conversion of cropland to fallow or of set-aside areas to permanent grassland.
- Restoration of peatlands and wetlands.

1.3.2.2 Example of carbon farming: protection and restoration of peatlands

Carbon farming increases carbon sequestration and storage while often providing important co-benefits for biodiversity and other ecosystem services. An illustrative example is the rewetting of peatlands: raising their water table has multiple benefits as it contributes to carbon sequestration, preserving biodiversity, providing ecosystem services linked to water purification and helping flood control and drought prevention, whereas trade-offs resulting from the loss of agricultural land could be addressed through support for paludiculture (farming under wet conditions). The enhanced conditionality under the CAP now includes GAEC 2 which specifically protects peatlands and wetlands that are on agricultural area, while eco-schemes and rural

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[21] com_2021_800_en_0.pdf (europa.eu)
[22] Carbon Farming (europa.eu)
[23] More information on financing can be found in Section 2.4, and Appendix 3

development interventions have further potential to support restoration of drained peatlands and storage of carbon removals in other soils.

GAEC 2 requires the effective protection of wetlands and appropriate maintenance of peatlands, and consequently the protection and restoration of carbon rich soils. Peatland and wetland areas are major stores of carbon and therefore the timely implementation of GAEC 2 in Member States is encouraged. The effective implementation of this condition by land managers will require accurate monitoring; high resolution terrain mapping will be highly beneficial when mapping the extent and condition of peatland, as well as for long-term monitoring of restoration activities[24]. This will be necessary to assess the level of changes because of the GAEC 2 (and other conditions under the CAP). Member States could provide in their CAP Strategic Plans that this GAEC will only be applicable as from claim year 2024 or 2025, where this is justified because of the planning of the mapping exercise and the establishment of the management system. Further, Member States, when establishing this GAEC, are required to ensure that there is a suitable agricultural activity to maintain it as agricultural area.

Additionally, under Article 9 of the proposal for the Nature Restoration Law (Section 1.3.6.6), Member States will be required (if approved) to put in place restoration measures that support the rewetting of peatland areas, especially those that have been drained, which in turn enables greater potential for peatland areas and organic soils to sequester carbon.

1.3.2.3 Certification of carbon removals

The Commission has proposed a regulatory EU framework for the certification of carbon removals[25]. The certification framework will help ensure the transparent identification of carbon farming and industrial solutions that unambiguously remove carbon from the atmosphere. The Commission, supported by an Expert Group, will develop tailored certification methodologies for the different types of carbon removal activities. This is described in more detail in section 2.3.8.

1.3.3 EU Governance Regulation

The regulation on the Governance of the Energy Union[26] and climate action provides an integrated approach to governance and monitoring of energy and climate-related actions at European, regional, national, and local level. It requires that Member States develop integrated national energy and climate plans[27] (NECPs) and report on progress of implementing their NECPs. The first NECPs were published in early 2020 setting out the visions for energy and climate for 10 years. The plans set out the transition to decarbonisation, energy efficiency, energy security, internal energy markets and research, innovation, and competitiveness. The European Commission subsequently published an EU-wide assessment of the plans[28] reviewing the overall approach in the first phase of the NECPs. Relevant to this study the review identified a need to increase investments in agriculture and to increase the attention on adaptation and increasing carbon sinks.

To ensure that the objectives and targets of the Energy Union are delivered successfully, it is vital that Member States' plans are developed and updated consistently to a high quality, and that NECPRs identify the progress of implementation. This guidance document aims to support Member States in meeting their reporting requirements. In addition, under the Climate Law, Member States must demonstrate continuous progress on climate adaptation by adopting and implementing national adaptation strategies and plans, and by reporting on the current state of adaptation under Article 19 of the Governance Regulation. The Commission is then required to assess the NECPs, NECPRs, and adaptation reporting, and may issue recommendations.

Every Member State in the EU must produce a long-term strategy to meet their Paris Agreement commitments and the objectives of the EU Energy Union, that cover at least 30 years of total and sectoral GHG reductions and removals, as well as progress to transition to a low carbon economy. These long-term strategies, that

[24] PROTECTING PEATLANDS & CARBON RICH SOILS (catchmentbasedapproach.org)

[2525] Proposal for a Regulation on an EU certification for carbon removals | Climate Action (europa.eu)

[26] https://energy.ec.europa.eu/topics/energy-strategy/energy-union_en#regulation-on-the-governance-of-the-energy-union-and-climate-action

[27] https://ec.europa.eu/info/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en

[28] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0564&from=EN

underpin sustainable investment aiming to increase effective carbon sequestration, sustainable resource management, and long-term stability and adaptability of carbon pools within the land sectors, are essential.

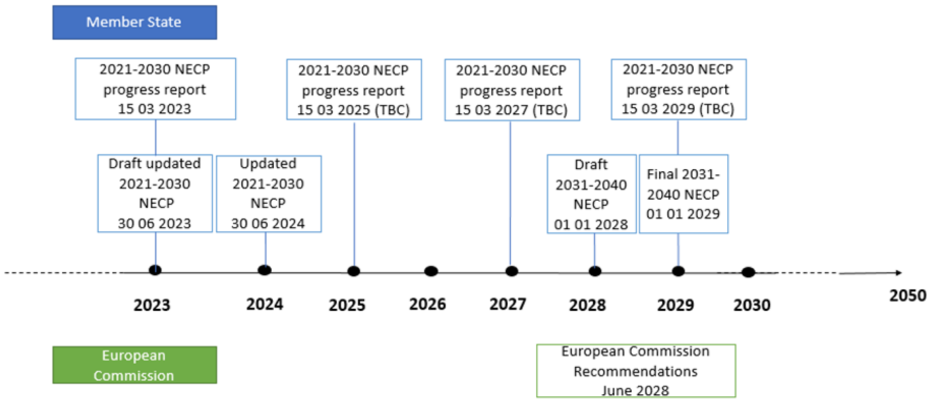

Figure 33: Timeline of NECP-related reporting

Amendments to the LULUCF Regulation introduce additional provisions to the Governance Regulation, specifically related to the consistency of relevant financing measures, e.g., CAP funding, with LULUCF commitments and the sustainability of LULUCF policies and measures.

1.3.3.1 The Commission's role in guiding and supporting Member States

Through the integrated NECPRs, Member States are required to note down their progress against NECPs, which includes data for the land sector. Further, Member States are requested to improve contributions from all sectors in the updated integrated NECPs and revisions of CSPs to "enhance the climate, energy and environmental ambition" of national objectives, which additionally includes objectives within the land sectors. These are the main opportunities through which Member States can seek to enhance these ambitions. The Commission is tasked to provide guidance and recommendations directly to Member States, covering the design and relevant reporting instructions for Member States policies and measures (PaMs), whilst also assessing the ambitions of Member States. The Commission is expected to assess the progress submitted in the NECPRs, draft and final NECPs, and the consistency and combined contribution of the CSPs.

1.3.4 Effort Sharing Regulation (ESR)

The second piece of legislation regulating GHGs in the land sector is the ESR which covers GHG emissions from sectors currently not covered by the EU Emissions Trading Scheme (ETS), in particular emissions from transport, buildings, agriculture, waste, and small industry[29]. Of most relevance for the land sector are the emissions from manure management and fertiliser use in the agriculture sector.

The 2018 ESR sets an EU wide target to reduce GHG emissions in the effort sharing sectors by 30% by 2030 compared to 2005 levels (for the EU-28), which is translated into binding national GHG emission reduction targets for 2030. The national GHG emission reduction targets are determined based on the principles of fairness as reflected in the Gross Domestic Product (GDP) of the Member States and cost-effectiveness reflecting Member States' cost-effective GHG emission reduction potential. Member States with a higher GDP per capita have higher GHG emission reduction targets[30]. Based on a trajectory defined in the ESR , for each Member State an annual GHG emission limits (allocations) is determined for the years 2021-2030 for the

[29] European Parliament (2022) Revising the Effort-sharing Regulation for 2021-2030: 'Fit for 55' Package. https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2021)698812

[30] https://ec.europa.eu/clima/eu-action/effort-sharing-member-states-emission-targets/effort-sharing-2021-2030-targets-and-flexibilities_en

sectors covered by the ESR, which includes GHG emissions from agriculture[31]. The annual emission allocations as determined on the basis of the 2018 ESR are established in the Commission Implementing Decision (EU) 2020/2126.[32]

The ESR is amended as part of the 'Fit for 55' package. As per the Commission proposal, the EU wide target to reduce GHG emissions in the effort sharing sectors is increased to 40% by 2030 compared to 2005 levels (for the EU-27), which also translated into more ambitious binding national GHG emission reductions targets for 2030. Based on the new trajectory defined in the ESR, annual emission limits (allocations) will be determined for the years 2023-2030. The increased national targets are based on the same principles of fairness and cost effectiveness as the 2018 ESR. Member States binding national GHG emission reduction targets for 2030 are presented in Table 2, both their targets under the 2018 ESR as well as the revised ESR.

Table 2: Member State greenhouse gas emission reductions in 2030 in relation to their 2005 GHG emission levels as per 2018 ESR and the amended ESR.

Member State GHG emission reductions in 2030 in relation to 2005 GHG emission levels		
Member State	**ESR 2018/842/EU**	**ESR amendment (proposal**
Austria	- 36 %	- 48 %
Belgium	- 35 %	- 47 %
Bulgaria	- 0 %	- 10 %
Czechia	- 14 %	- 26 %
Denmark	- 39 %	- 50 %
Germany	- 38 %	- 50 %
Estonia	- 13 %	- 24 %
Ireland	- 30 %	- 42 %
Greece	- 16 %	- 22,7 %
Spain	- 26 %	- 37,7 %
France	- 37 %	- 47,5 %
Croatia	- 7 %	- 16,7 %
Italy	- 33 %	- 43,7 %
Cyprus	- 24 %	- 32 %
Latvia	- 6 %	- 17 %
Lithuania	- 9 %	- 21 %
Luxembourg	- 40 %	- 50 %
Hungary	- 7 %	- 18,7 %
Malta	- 19 %	- 19 %
Netherlands	- 36 %	- 48 %
Poland	- 7 %	- 17,7 %
Portugal	- 17 %	- 28,7 %

[31] Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013.

[32] Link to Commission Implementing Decision: EUR-Lex - 32020D2126 - EN - EUR-Lex (europa.eu)

Member State GHG emission reductions in 2030 in relation to 2005 GHG emission levels		
Romania	- 2 %	- 12,7 %
Slovenia	- 15 %	- 27 %
Slovakia	- 12 %	- 22,7 %
Finland	- 39 %	- 50 %
Sweden	- 40 %	- 50 %

As presented in Table 2, the ESR sets for each Member State a single GHG emission reduction targets for all sectors covered by the ESR. EU policies in the sectors covered by the ESR support Member States in achieving their ESR targets which are complemented by national policies and measures which allow Member States to take into account their specific national circumstances.

Every year the Commission assesses and reports on Member States' progress towards their ESR targets in the Climate Action Progress report. If the Commission finds that a Member State is deemed to make insufficient progress, it will be required to prepare an appropriate action plan. Also, as for LULUCF, the progress towards the ESR targets is covered by the national energy and climate progress reports (NECPRs).

The ESR has two 5-year compliance cycles, for the years 2021-2025 respectively 2026-2030, including to allow for the potential contribution from the land use sector (which has a 5-year compliance period) to ESR compliance. During the compliance cycle the Commission will assess whether a Member State meets its annual obligations under the ESR. In meeting its annual obligations Member States have some flexibility, up to the limits defined in the ESR, to use some of its annual emission allocations in future or earlier years, to use some of its surplus achieved under LULUCF or to offset part of its GHG emission in the effort sharing sectors in ETS. The latter possibility is only available for some Member States. Where a Member State does not meet its annual obligation in any year, taking into account the use of flexibilities, the excess GHG emissions multiplied by a factor of 1.08 is added to the following year's obligation.

1.3.4.1 Some elements adjusted in the legal framework beyond the targets

As explained above, in order to comply with their annual obligations under the ESR, Member States that achieve a surplus of GHG emission reductions under the LULUCF Regulation can use the surplus for compliance in the ESR, up to certain Member State specific limits as defined in the ESR[33]. The amendments to the ESR maintained the maximum overall amount of surplus in LULUCF that can be used for ESR compliance but divided it equally over the two compliance periods. The total maximum amount of surplus in LULUCF that can be taken into account for both compliance periods is presented in Table 3.

Also there will no longer be an automatic transfer of Member States' deficits under LULUCF to ESR for the second compliance period, as the LULUCF Regulation will include its own compliance regime for the years 2026-2030 based on the national targets under LULUCF.

Table 3: TOTAL NET REMOVALS FROM THE CATEGORIES OF LAND COVERED BY REGULATION (EU) 2018/841 THAT MEMBER STATES MAY TAKE INTO ACCOUNT FOR COMPLIANCE FOR THE PERIOD 2021 TO 2030 PURSUANT TO POINTS (A) AND (AA) OF ARTICLE 7(1) OF THE REGULATION AMENDING THE ESR'

Maximum amount expressed in million tonnes of CO2 equivalent (50% for the first compliance period 2021-2025, and 50% for the second compliance period 2026-2030)	
Austria	2,5
Belgium	3,8
Bulgaria	4,1

[33] *Ibid.*

Maximum amount expressed in million tonnes of CO2 equivalent (50% for the first compliance period 2021-2025, and 50% for the second compliance period 2026-2030)	
Czech Republic	2,6
Denmark	14,6
Germany	22,3
Estonia	0,9
Ireland	26,8
Greece	6,7
Spain	29,1
France	58,2
Croatia	0,9
Italy	11,5
Cyprus	0,6
Latvia	3,1
Lithuania	6,5
Luxembourg	0,25
Hungary	2,1
Malta	0,03
Netherlands	13,4
Poland	21,7
Portugal	5,2
Romania	13,2
Slovenia	1,3
Slovakia	1,2
Finland	4,5
Sweden	4,9
Maximum total:	**262,2**

1.3.5 REPowerEU and Renewable energy in the EU

The REPowerEU communication was adopted in May 2022 in response to the disruption in the energy market caused by the war in Ukraine. Its main goals are to diversify energy supply, reduce energy consumption and accelerate the transition from fossil fuels to renewable energy in a range of sectors.

To increase the deployment and uptake of renewable energy, the Commission proposed increasing the target for the share of renewable sources in energy consumption across the EU, including biofuels, bioliquids and other biomass fuels, to 45% by 2030, compared to 40% in the proposal for the revised Renewable Energy Directive (RED). There is also a strong focus on solar energy, including the proposal to combine the use of agriculture land with solar photovoltaic technology (agri-voltaics or agri-PV), and the support for the use of agricultural and forest residues for biomethane.

1.3.5.1 Renewable Energy Directive (RED)

RED aims to increase the share of renewable sources in energy consumption by setting an EU-wide target (in addition to specific targets for the transport sector and for heating and cooling). To meet this overall EU target, Member States need to set national contributions as part of their national energy and climate plans. In the case of bioenergy, RED defines the biomass feedstocks that are eligible to be counted towards the targets. This is achieved through a set of rules and criteria that aim to ensure the sustainability of the biomass used to produce biofuels, bioliquids and biomass fuels.

In the case of forest biomass, RED II sets specific criteria (Article 29(7)) for its use to produce biofuels, bioliquids and biomass fuels. These criteria are intended to:

i. Protect biodiversity
i. Ensure forest biomass is produced from sustainably managed forests
ii. Ensure that the carbon impact of forestry biomass is properly accounted for under the LULUCF
iii. Promote the conversion of biomass to energy by the most efficient pathway

RED does not extend the same level of protection as for the use of agricultural biomass. Whilst it sets specific no-go areas for agricultural biomass, the same does not apply to forest biomass (except for protected areas). Whilst RED II provides incentives to economic operators to use forest biomass for energy (by zero-rating emissions from biomass combustion), the LULUCF Regulation disincentives countries to harvest beyond certain limits. The REDII bioenergy sustainability criteria and the LULUCF Regulation are therefore generally mutually supportive, reinforcing protection of carbon and biodiversity rich areas, while ensuring sustainable harvesting levels and contributing to enhancing the LULUCF carbon sink.

The revision of RED will help enhance the protection of high biodiversity lands and high carbon stock lands. In addition to the proposed increase in the targets for renewable energy consumption in the EU, the Commission's proposal for the revised RED also includes the strengthening of the current sustainability criteria. The revised text proposes extending the application of existing no-go areas for agricultural biomass to forest biomass (including primary, highly diverse forests and peatlands), and it introduces a provision that prohibits support for the use of saw logs, veneer logs, stumps, and roots[34] to produce energy and minimises the use of quality roundwood for energy in line with the cascading principle[35]. It also introduces provisions to increase protection of soil quality and biodiversity from harvesting practices.[36]

1.3.5.2 EU Solar Energy Strategy

The EU Solar Energy Strategy was adopted in May 2022 as part of the REPowerEU plan to address key barriers and accelerate the deployment of solar energy technologies in the EU. This strategy encourages Member States to consider including incentives for agri-voltaics in their CSPs and support frameworks for solar energy.

1.3.5.3 Financing

The REPowerEU communication also indicates that Member States will be able to transfer up to 12.5% of their allocation under the European Agricultural Fund for Rural Development of the CAP to the Recovery and Resilience Facility to help accelerate the implementation of relevant projects, namely, to allow farmers to reduce the use of synthetic fertilisers and increase the production of sustainable biomethane or renewable energy. More details on financing are covered in section 2.4.

[34] JRC Publications Repository - The use of woody biomass for energy production in the EU (europa.eu)
[35] More information on the cascading principle for biomass is provided in section **Error! Reference source not found.**.
[36] Art. 29 Renewable Energy Directive - Sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels (lexparency.org)

1.3.6 The EU Forest, Soil, and Biodiversity Strategies

1.3.6.1 EU Forest Strategy

The new EU Forest Strategy for 2030, published by the European Commission in July 2021[37] proposes an overall target to protect at least 30% of the EU land area under effective management regime, out of which 10% of the EU land should be put under strict legal protection. Forest ecosystems will need to contribute to this target. All primary and old growth forests will have to be strictly protected.

The EU Forest Strategy has also recognised that to deliver the measures there is a need for developing skills and empowering people for sustainable forest-based bioeconomy. Therefore, the Commission will encourage forestry stakeholders to join the Pact for Skills. This Pact will encourage forest and forestry stakeholders to work together to adapt education and training for foresters to the challenges and needs of today's realities.

The Forest Strategy states that given the increasing, and sometimes competing demands on forests, the EU and Member States must also ensure that the amount of wood that is used remains within sustainability limits and is optimally utilised in line with the cascading principle and the circular economy approach. The use of forest products must cater as much as possible for substituting fossil fuel-based products by long-lived circular materials and products that are of highest value for carbon storage and circular economy. Further, it is crucial that the EU optimises the use of wood in line with the cascading principle, in particular through market incentives, when building a sustainable and climate-neutral economy[38].

The cascading principle aims to achieve resource efficiency of biomass use through prioritising biomass material use to energy use wherever possible, increasing the amount of biomass available within the system. In line with the cascading principle, woody biomass should be used according to its highest economic and environmental added value in the following order of priorities: 1) wood-based products, 2) extending their service life, 3) re-use, 4) recycling, 5) bioenergy and 6) disposal.

1.3.6.2 EU Biodiversity Strategy

The EU's Biodiversity Strategy for 2030 is a comprehensive, ambitious, and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030 and contains specific actions and commitments.

The main actions to be delivered by 2030 include:

- the creation of protected areas covering at least 30% of the EU's land and sea area, extending the coverage of existing Natura 2000 areas
- the restoration of degraded ecosystems across the EU by 2030 through a series of specific commitments and measures, including the reduction in the use and risk of pesticides by 50% by 2030 and the planting of 3 billion trees across the EU
- the allocation of €20 billion per year to protect and promote biodiversity through EU funds and national and private funding
- the creation of an ambitious global biodiversity framework.

The EU Biodiversity Strategy for 2030 sets the target of protecting 30% of EU land and sea by 2030. One third of this, areas of very high biodiversity and climate value, should be under strict protection. The EU's Biodiversity Strategy for 2030 is a comprehensive, ambitious, and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030 and contains specific actions and commitments[39]. The EC has produced a set of criteria and guidance on the identification and protection of areas under legal protection. This includes:

- Ecological criteria
- Management effectiveness
- Stakeholder involvement
- Monitoring and reporting

[37] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM%3A2021%3A572%3AFIN
[38] Idem.
[39] Protecting biodiversity: Commission advises how to designate additional protected areas (europa.eu)

- EU coordination
- Formal designation criteria
- Coherence of the network[40]

The EU Biodiversity Strategy also pledges for at least 3 billion additional trees planted by 2030 in full respect of ecological principles i.e., the right tree species in forests, agricultural areas, urban and peri-urban areas and along infrastructure corridors. As part of this, the Commission have developed a tracker[41] that counts the number of trees planted and included a map which shows the areas of afforestation. At the time of writing, the count was just under 9.5 million trees. According to the EU Forest Strategy, enhanced afforestation is among the most effective climate change and disaster risk mitigation strategies in the forest sector and can create substantial job opportunities.

1.3.6.3 EU Soil Strategy

As the EU's largest terrestrial ecosystem, healthy soils sustain many sectors of the economy while soil degradation is costing the EU several tens of billion euros per year. Management practices that sustain and enhance soil health and biodiversity improve cost efficiency and limit the inputs (e.g., pesticides, fertilisers) needed to maintain yields. Halting and reversing current trends of soil degradation could generate up to EUR 1.2 trillion per year in economic benefits globally. The cost of inaction on soil degradation, which outweighs the cost of action by a factor of 6 in Europe, goes beyond the economic calculation; it would not only lead to fertility loss comprising global food security, but also impact on the quality of products and their nutritional value.[42]

1.3.6.4 Close-to-nature forestry

Criteria for the closer-to-nature forestry are being developed by the Commission and will feed into the work on indicators and new thresholds for sustainable forest management[43]. This work will be undertaken in close partnership and cooperation with Member States through the updated EU forest governance framework. Although the definition for closer-to-nature forestry is not universally defined yet, they are generally known to be multifunctional forests that combine biodiversity (even in planted forests), carbon stock preservation and timber-related revenues.

1.3.6.5 Biodiversity-friendly afforestation and reforestation

As part of the EU Biodiversity Strategy for 2030[44] the Commission developed guidelines for biodiversity-friendly afforestation, reforestation and tree planting. The guidelines will ensure that afforestation (including agroforestry) and reforestation measures in the Member States support biodiversity as it is widely recognised in the literature that a combination of restoration, conservation and reforestation are recommended for efficient carbon sequestration. The guidelines have been published on 20 March 2023[45].

1.3.6.6 Proposed Nature Restoration Law

The European Commission's proposal for a Nature Restoration Law is the first continent-wide, comprehensive law of its kind[46]. It is a key element of the EU Biodiversity Strategy, which calls for binding targets to restore degraded ecosystems, especially those with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters. Europe's nature is in alarming decline, with more than 80% of habitats in poor condition. Restoring wetlands, rivers, forests, grasslands, marine ecosystems, and the species they host will help to:

- increase biodiversity

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[40] SWD_guidance_protected_areas.pdf (europa.eu)
[41] 3 Billion Trees (europa.eu)
[42] EUR-Lex - 52021DC0699 - EN - EUR-Lex (europa.eu)
[43] EUR-Lex - 52021DC0572 - EN - EUR-Lex (europa.eu)
[44] EU Biodiversity Strategy for 2030
[45] https://environment.ec.europa.eu/publications/guidelines-biodiversity-friendly-afforestation-reforestation-and-tree-planting_en
[46] Nature Restoration Law (europa.eu)

- secure the things nature does for free, like cleaning our water and air, pollinating crops, and protecting us from floods
- limit global warming to 1.5°C
- build up Europe's resilience and strategic autonomy, preventing natural disasters and reducing risks to food security

Measures in the proposal should cover at least 20% of the EU's land and sea areas by 2030, and ultimately all ecosystems in need of restoration by 2050. Specific targets include:

- improving and re-establishing biodiverse habitats on a large scale, and bringing back species populations by improving and enlarging their habitats
- reversing the decline of pollinator populations by 2030, and achieving an increasing trend for pollinator populations, with a methodology for regular monitoring of pollinators
- identifying and removing barriers that prevent the connectivity of surface waters, so that at least 25 000 km of rivers are restored to a free-flowing state by 2030.

In this regard, the European Parliament has stated that the new EU 2030 LULUCF net target can be achieved by implementing, for example, measures related to the restoration of degraded land in line with the EU Biodiversity Strategy and the upcoming Nature Restoration Law[47].

EU countries are expected to submit National Restoration Plans to the Commission within two years of the Regulation coming into force, showing how they will deliver on the targets[48].

1.3.6.7 Proposed Soil Health Law

The EU Soil Strategy set the vision to have all soils in healthy condition by 2050, to make protection, sustainable use and restoration of soils the norm. The strategy proposes a combination of voluntary and legislative actions. As part of this, a new Soil Health Law is to be presented by the Commission Q2 2023, to ensure a level playing field and a high level of environmental and health protection, including addressing climate mitigation and adaptation. The new law will aim to help achieve the objective of healthy soils by 2050, with concrete actions by 2030. It will do so by identifying the key soil threats in the EU, such as erosion, floods and landslides, loss of soil organic matter, salinisation, contamination, compaction, sealing, as well as loss of soil biodiversity.[49]

2 POLICIES AND MEASURES FOR CLIMATE, ENERGY AND ENVIRONMENTAL BENEFITS

This section:

- *Provides a detail of existing policies and measures (PaMs) that are planned, adopted or implemented by Member States and an overview of specific measures and their potential.*
- *Highlights how Member States can identify additional PaMs.*
- *Discusses monitoring, reporting and verification (MRV) and quantification of PaMs, looking to existing sources, institutions, and schemes for ways to quantify impact. This subsection also provides specific requirements for the MRV and quantification of specific measures.*
- *Finally, this section covers the financing available to support the development and implementation of PaMs.*

[47] REPORT on the proposal for a regulation of the European Parliament and of the Council Amending Regulations (EU) 2018/841 as regards the scope, simplifying the compliance rules, setting out the targets of the Member States for 2030 and committing to the collective achievement of climate neutrality by 2035 in the land use, forestry and agriculture sector, and (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review | A9-0161/2022 | European Parliament (europa.eu)

[48] Nature restoration law (europa.eu)

[49] Soil health (europa.eu)

Every two years, all Member States report on their national GHG policies and measures or PaMs to the EEA to comply with Article 18 of the Governance of the Energy Union and Climate Action Regulation. Any substantial changes to the PaMs are to be reported in between the two year reporting cycle. Reporting on PaMs was initially required from 2015 under the predecessor of the Governance Regulation, the Monitoring Mechanism Regulation. Member States reported in 2015, 2017, 2019, 2021 with voluntary reporting in intermediate years by some Member States. Two Member States reported in 2022. Non-EU countries also report information on their national policies. For example, in 2021 Iceland, Norway and Switzerland reported.

Member State submissions undergo quality checks to ensure timeliness, completeness, consistency, comparability, coherence, transparency, and accuracy of the reported information. The results of which are communicated to Member States before, the data is published on the EEA website[50]:

The European Topic Centre (ETC) on climate change mitigation (ETC CM) and the ETC on climate change adaptation and LULUCF (ETC CA)[51] provide a range of research and recommendations to support climate mitigation and adaptation within the land sectors, covering agriculture, LULUCF, and energy. There is also an ETC dedicated to circular economy and resource use (ETC CE).

ETC Climate change mitigation:

The European Topic Centre on Climate change mitigation (ETC CM) is a consortium of 15 European organisations working in partnership with the European Environment Agency under a framework partnership agreement for the period 2022-2026.

The lead institution of the ETC CM is Vlaamse Instelling voor Technologisch Onderzoek (VITO).

The ETC CM informs decision-makers and the public by presenting reliable and comparable data and information on climate change mitigation, energy, and transport in Europe.

Climate change represents one of the EEA and Eionet's five areas of work outlined in their strategy for the period 2021-2030. In this area of work, the ETC CM will support EEA with monitoring Europe's progress towards climate neutrality and climate resilience.[52]

ETC Climate change adaptation and LULUCF:

The European Topic Centre on Climate change adaptation and LULUCF (ETC CA) is a Consortium of 16 European organisations with expertise in the topic area of climate change adaptation and Land Use, Land-Use Change and Forestry (LULUCF) working in partnership with the European Environment Agency under a framework partnership agreement for the period 2022-2026.

The lead institution of the ETC CA is Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici.

The ETC CA assists the European Environment Agency (EEA) in supporting the implementation and developments of EU legislation and policy by monitoring and assessing climate change impacts, hazards and adaptation and LULUCF, contributing to the harmonisation, quality assessment and sharing of data and/or information, the main supported policy process being the EU Strategy on Adaptation to Climate Change, in the framework of the EU Green Deal.[53]

ETC Circular economy and resource use:

The European Topic Centre on Circular Economy and Resource Use (ETC CE) is a consortium of European organisations working in partnership with the European Environment Agency under a framework partnership agreement for the period 2022-2026.

[50] To support countries in their reporting the EEA has a range of resources available including 'Guidelines Reporting on greenhouse gas policies and measures under Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action'

[51] We recommend the following ETC reports as a starting point for considering the enhancement of existing measures for climate adaptation and LULUCF:

- ETC CA Report 3/22 Climate change impacts on biomass production (national case studies) — Eionet Portal (europa.eu)
- ETC CA Report 2/22 Understanding the scaling potential of Nature-based Solutions — Eionet Portal (europa.eu)
- ETC CA Report 1/22 Management options for increasing the mitigation potential in LULUCF sector — Eionet Portal (europa.eu)

[52] ETC Climate change mitigation (ETC CM) — Eionet Portal (europa.eu)

[53] ETC Climate change adaptation and LULUCF (ETC CA) — Eionet Portal (europa.eu)

The lead institution of the ETC CE is Vlaamse Instelling voor Technologisch Onderzoek (VITO).

The ETC CE informs decision-makers and the public by presenting reliable and comparable data and information on circular economy and industrial transformation, the implementation of EU waste legislation and material flows and sustainable resource use in Europe.[54]

Best Available Techniques (BAT) are techniques recommended for preventing or minimising emissions and impacts on the environment. The majority of BREFs cover specific agro-industrial activities; such BREFs are referred to as 'sectoral BREFs'. There are also several 'horizontal BREFs' dealing with cross-cutting issues such as energy efficiency. A specific BREF was developed for the monitoring of emissions to air and water from installations under the Industrial Emissions Directive (IED). While BREFs are required for large installations, they are still applicable to smaller installations in providing recommendations for best practices.

BREFs can be found here.

2.1 OVERVIEW OF EXISTING POLICIES AND MEASURES

2.1.1 Collating current relevant PaMs

The EEA holds an updated list of GHG-related policies and measures that have been implemented by all Member States in all sectors. There is a reasonable consistency between the measures identified by the EEA in “ETC/CME Report 6/2021: Agricultural climate mitigation policies and measures. Good practice, challenges, and future perspectives”[55] and the overview presented in section 2.1.2, albeit with some differences in the level of detail and the titles used. The policies driving the measures are not fully covered in section 2.1.2, as the focus there is on measures applied by land managers. The details of these PaMs may exist at national, regional, or even at local levels. These details may be included within other reporting requirements, such as National Air Pollution Control Programmes (NAPCPs). The list covers PaMs included in the NECPs, the CAP Strategic Plans, and many other policies. This list can be found here. Table 4 and 5 below provides an overview for the number of measures which have been implemented because of a union policy, such as the CAP, ESR, or RED, that are related to the agriculture and LULUCF sectors and for energy supply. PaMs relevant to individual Member States are highlighted in the national fiches.

Table 4: Number of agriculture-, LULUCF-related PaMs that have links with EU policy in 2023[56]

EU Policy	Agriculture Sector PaMs	LULUCF Sector PaMs	PaMs that cover both Agriculture and LULUCF Sectors
Common Agricultural Policy	107	42	16
Effort Sharing Regulation (2018/842)	36	23	7
Nitrates Directive	33	23	2
Energy Union (Governance Regulation)	11	19	2
LULUCF Regulation (2018/841)	4	38	3
Renewable Energy Directive	13	4	2
Industrial Emissions Directive	2	0	0

[54] ETC Circular economy and resource use (ETC CE) — Eionet Portal (europa.eu)

[55] ETC/CME Report 6/2021: Agricultural climate mitigation policies and measures. Good practice, challenges, and future perspectives

[56] EEA database on greenhouse gas policies and measures in Europe — European Environment Agency (europa.eu)

EU Policy	Agriculture Sector PaMs	LULUCF Sector PaMs	PaMs that cover both Agriculture and LULUCF Sectors
Waste Management Framework Directive	7	3	2
Water Framework Directive	9	2	2
Landfill Directive	2	1	0
Energy Efficiency Directive	2	1	1
Biofuels Directive	1	2	1
No information	90	93	19

Table 5: Number of energy supply and consumption-related PaMs that have links with EU policy in 2023[57], with numbers for agriculture and LULUCF sector PaMs

EU Policy	Energy Supply			Energy Consumption		
	All Sectors	Agriculture Sector	LULUCF Sector	All Sectors	Agriculture Sector	LULUCF Sector
Common Agricultural Policy	12	10	3	5	2	0
Effort Sharing Regulation (2018/842)	14	6	0	83	1	0
Nitrates Directive	3	1	0	0	0	0
Energy Union (Governance Regulation)	36	3	2	34	3	2
LULUCF Regulation (2018/841)	2	1	2	0	0	0
Renewable Energy Directive	208	10	3	82	1	1
Industrial Emissions Directive	10	0	0	0	0	0
Waste Management Framework Directive	7	1	2	2	0	0
Water Framework Directive	0	0	0	0	0	0
Landfill Directive	4	0	1	1	0	0
Energy Efficiency Directive	74	0	0	78	0	0
Biofuels Directive	6	1	2	1	0	0
No information	114	12	11	205	14	10

Member States have often indicated that they pursue climate goals through State aid or other measures outside the CAP Strategic Plans. The preparation of the NECP is an ideal opportunity to provide updates and indicate how the Member State intends to cover the measures that they design.

[57] EEA database on greenhouse gas policies and measures in Europe — European Environment Agency (europa.eu)

2.1.2 Overview of measures

A compendium of land-use, forestry, and agriculture measures is provided in Appendix 1. The list of measures was developed initially in a previous study for DG CLIMA reported in 2016[58], and then refined further in more recent work[59]. For this guidance note the details of each measure have been further updated. The presentation of these measures includes estimates of the scale of the potential climate benefits per hectare of land or head of livestock so that Member states can use this information by scaling it to their own circumstances.

There are interactions between PaMs, including synergies and trade-offs for climate, energy, and environmental benefits, in particular biodiversity. To highlight these interactions measures have been grouped and detail is provided about implementation and the potential or not for additionality of climate and other benefits. For climate benefits this information will help Member States estimate the overall potential climate benefit when multiple measures are applied together.

The measures are grouped under the following headings, with further sub-groups as needed:

- Non-CO2 abatement measures, 24 measures

  Reduction of agriculture emissions covered by the ESR, namely the reduction of non-CO_2 emissions from agricultural activities such as livestock management, manure management, and use of fertilisers, the reduction of energy/heating/fuel consumption in the farm holdings; and measures to prevent food waste and losses and to enhance the circular economy.

- Carbon stock change, 16 measures

  Enhancement of the LULUCF net sink, including the reduction of greenhouse gas emissions associated with land-use changes such as deforestation and grassland to arable, the enhancement of carbon removals including through carbon-farming, long-lasting carbon storage products (such as wood-based construction products), with a focus on integrated approaches such as NbS in order to also contribute to the objectives of ecosystems protection and restoration, and other environmental objectives.

- Substitution of fossil fuels and fossil materials, 6 measures

  Contribution to the reduction of emissions covered by the ETS, including through substitution effects associated with the replacement of fossil-based energy by sustainable bioenergy and the replacement of fossil-based materials by bio-based materials.

  Production and use of renewable energy, including wind, solar energy, biogas, biofuels and other forms of bioenergy.

- Climate resilience measures, 2 measures

  Climate resilience, including measures to adapt land management, farming, and forestry systems to the impacts of climate change, including extreme weather events and conditions, pest outbreaks, and slow onset change in climate conditions.

Measures are placed in the group to which they are most relevant, but many measures will have relevance to more than one group. It should also be noted that NbS are included, particularly in the carbon stock change category, and have specific importance for biodiversity. NbS can include new agroforestry, afforestation, hedges and woody margins, and peatland conservation and restoration.

These aspects are addressed within the details for each measure, and for each group, relevant measures in other groups are indicated. The relative importance of measures varies by Member State, and information on relevant policies and measures will be included in ‘country fiches’ that will be prepared as part of this European Commission study.

[58] Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) Mainstreaming. Ricardo 2016.

[59] Assessment of climate action in the programmes prepared by the Member States for cofunding from the European Regional Development Fund (ERDF), the Cohesion Fund (CF), The Common Agriculture Policy (CAP) and European Social Fund (ESF+) in the next multiannual financial framework (MFF) 2012-2027. Lot 2: Support to the assessment of the climate ambition of CAP Strategic Plans. CLIMA.A3/C3/C1/SER/2019/0014

Appendix 1 provides a detailed description of each measure, including the:

- Measure description
- Effect of mitigation action
- Abatement potential
- Overall emissions impact
- Displacement effect
- Permanence
- Measurement requirements
- Adaptation effect
- Barriers and constraints
- Co-benefits
- Risks and trade offs
- References

The mitigation potential values for each measure are summarised in Table 6. A report on policy options for including the land sector in the EU reduction commitment and policy instruments for increasing GHG mitigation efforts in the land and agriculture sectors is helpful in a high-level description of PaMs for agriculture and for forestry. Details and tables from this report are outlined below in Table 6 and 7.

Table 6: Mitigation potential values for each measure as per Appendix 1.

Mitigation action	Mitigation potential		Units and notes
	Low	High	
Avoid excess N	0.073	0.26	t CO_2e ha^{-1} yr^{-1}
Urease inhibitors	0.11	0.7	t CO_2e ha^{-1} yr^{-1}
Nitrification inhibitors	0.21	3.2	t CO_2e ha^{-1} yr^{-1}
Organic no synthetic N	Not assessed		
Slow release N	0.0048	0.19	t CO_2e ha^{-1} yr^{-1}
Variable rate N fertiliser	0.073	0.26	t CO_2e ha^{-1} yr^{-1}
Optimal soil pH	Not assessed		
Trailing shoe	0.0014	0.015	t CO_2e ha^{-1} yr^{-1}
Trailing hose	0.0014	0.019	t CO_2e ha^{-1} yr^{-1}
Slurry injection	0.0034	0.022	t CO_2e ha^{-1} yr^{-1}
Rapid incorporation	0.0054	0.3	t CO_2e ha^{-1} yr^{-1}
Cooling slurry	Not assessed		
Slurry acidification	0.06	1.1	t CO_2e $head^{-1}$ yr^{-1}
Cover slurry stores	0.13	1.7	t CO_2e $head^{-1}$ yr^{-1}
Livestock density Limits	Not assessed		
Herd fertility	0.024	0.05	t CO_2e $head^{-1}$ yr^{-1}
Reduction in endemic disease	0.024	0.73	t CO_2e $head^{-1}$ yr^{-1}
Feed additives	0.071	0.32	t CO_2e $head^{-1}$ yr^{-1}
Optimised feed strategies	0.036	0.22	t CO_2e $head^{-1}$ yr^{-1}
Optimised forage utilisation	Not assessed		
Breeding lower emissions animals	0.0003	0.035	t CO_2e $head^{-1}$ yr^{-1}
Crop breeding for N efficiency	0.021	0.46	t CO_2e ha^{-1} yr^{-1}
Legumes	0.021	0.46	t CO_2e ha^{-1} yr^{-1}
Improved rice cultivation	0.028	1.4	t CO_2e ha^{-1} yr^{-1}
Arable to grassland	1.2	5.3	t CO_2e ha^{-1} yr^{-1}
Grassland management	0.39	3.7	t CO_2e ha^{-1} yr^{-1}
New agroforestry	0.33	27	t CO_2e ha^{-1} yr^{-1}

Mitigation action	Mitigation potential		Units and notes
	Low	High	
Afforestation	8.8	21	t CO_2e ha^{-1} yr^{-1}
Forest management	8.4	17	t CO_2e ha^{-1} yr^{-1}
Hedges and woody margins	2.4	12	t CO_2e ha^{-1} yr^{-1}
Peatland conservation	2.6	10	t CO_2e ha^{-1} yr^{-1}
Peatland restoration	11	33	t CO_2e ha^{-1} yr^{-1}
Lowland peat management	0.33	1.3	t CO_2e ha^{-1} yr^{-1}
Arable fallow	Not assessed		
Catch/cover crops	-0.04	15	t CO_2e ha^{-1} yr^{-1}
Zero tillage	0.012	0.036	t CO_2e ha^{-1} yr^{-1}
Minimum tillage	0.0059	0.018	t CO_2e ha^{-1} yr^{-1}
Retain crop residues	0.11	2.2	t CO_2e ha^{-1} yr^{-1}
Mulching	Not assessed		
Avoid soil compaction	Not assessed		
Biogas from agriculture and forests	0.6	1.3	t C MWh^{-1}
Solar and wind energy	0.066	0.11	t C MWh^{-1}
Energy from biomass	0.17	0.35	t C MWh^{-1}
Biofuels	0.5	0.71	Proportion of C in fossil fuels displaced by
Materials from biomass	0.7	1.9	t CO_2e ha^{-1} yr^{-1}
Energy efficiency	0.02	0.26	Proportion of agriculture energy use
Rotations with perennial forage	0.7	1.9	t CO_2e ha^{-1} yr^{-1}
Intercropping	Not assessed		
GHG audits and eco design	0.033	0.1	Proportion of agriculture emissions

2.1.3 Potential for implementation of agricultural and forestry measures

In the synthesis report on 'Policy options for including LULUCF in the EU reduction commitment and policy instruments for increasing GHG mitigation efforts in the LULUCF and agriculture sectors'[60], analysis was carried out against a set of criteria to evaluate the effectiveness of agricultural and forestry mitigation measures. These criteria cover:

- Reliable outcome
- Potential per hectare
- Potential (across EU27)
- Cross-sectoral impacts
- Co-benefits
- Timing
- Measurability
- Permanence
- Leakage
- Cost

For the agricultural measures (Table 7), this analysis suggested that it is possible to develop an effective package of agriculture measures based on the conservation of carbon and sequestration of additional carbon. At the same time, risks of impermanence and competing claims on land must be addressed. There is no specific measure that scores well against all criteria. The ability to measure change in carbon stocks and the risks of impermanence of sequestered carbon are identified as the most important challenges for all measures.

[60] Policy options for including LULUCF in the Community reduction commitment and policy instruments for increasing GHG mitigation efforts in the LULUCF and agriculture sectors (europa.eu)

Most of the measures can have significant co-benefits in terms of soil quality improvement, reduction of soil erosion and increase in biodiversity. Box 1 below provides the key to the colour-codes in the following tables.

Box 1: Key to colour codes in Tables 7 and 8.

Colour	Interpretation
	High potential for effective implementation of the measure, when evaluated against the criterion
	Moderate potential for effective implementation of the measure, when evaluated against the criterion
	Low potential for effective implementation of the measure, when evaluated against the criterion

Table 7: Summary of the criteria analysis of agriculture measures. The colour-coding is defined in Box 1.

	Agronomy/advice on sustainable practices	Tillage/residue management	Agro forestry	Set-aside/land-use change	Grazing land management	Restoration of organic soils	Restoration of degraded lands
Reliable outcome							
Potential per hectare							
Potential (across EU27)							
Cross-sectoral impacts							
Co-benefits							
Timing							
Measurability							
Permanence							
Leakage							
Cost							

For the forestry measures (Table 8), it is possible to identify several specific measures that can reduce net emissions or increase net removals of GHG emissions through net sequestration of carbon in forest vegetation and soils. These measures include prevention of deforestation and afforestation. For forest management measures aimed at achieving mitigation in the LULUCF sector, options include longer rotations, avoidance of clear felling, restricted production/conversion to wilderness. If aiming to achieve mitigation in other sectors through changes to forest management, options include bringing rotation durations closer to productive maximum, intensified production, increased harvest of offcuts and branch wood and changes in species to enhance productive potential.

Table 8: Summary of the criteria analysis of forestry measures. The colour-coding is defined in Box 1.

	Prevent deforestation	Afforestation	Longer rotations	Avoid clear-felling	Restricted production/conversion to	Rotations closer to productive maximum	More production	Increase harvest of off-cuts and branch wood	Changing species
Reliable outcome									
Potential per hectare									
Potential (across EU27)									
Cross-sectoral impacts									
Co-benefits									
Timing									
Measurability									
Permanence									
Leakage									
Cost									

2.1.4 Renewables

When considering renewable energy PaMs, the following needs to be taken into consideration:

- The proposal for the revised RED (RED III) strengthens the need to minimise undue distortive effects on the biomass raw material market and negative impacts on biodiversity in line with waste hierarchy set out in Directive 2008/98/EC and the cascading principle[61]
- It proposes not supporting the use of saw logs, veneer logs, stumps, and roots to produce energy as well as practices which are not aligned with the cascading principle for biomass[62]
- Support for bioenergy should be for feedstocks with both limited market competition with the material sectors and positive effects on the climate and biodiversity, as outlined in the JRC report 'The use of woody biomass for energy production in the EU'
- It proposes to introduce the obligation to phase out support for electricity production from forest biomass from 31 December 2026 in electricity-only-installations (with some exceptions)
- It also proposes to extend the existing exclusions and limitations for sourcing agricultural biomass to include forest biomass (primary forests, highly biodiverse forests, grasslands, and peatlands) and reinforces the need to minimise the negative impact of harvesting on soil quality and biodiversity

[61] From RED III proposal: *The cascading principle aims to achieve resource efficiency of biomass use through prioritising biomass material use to energy use wherever possible, increasing thus the amount of biomass available within the system. In line with the cascading principle, woody biomass should be used according to its highest economic and environmental added value in the following order of priorities: 1) wood-based products, 2) extending their service life, 3) re-use, 4) recycling, 5) bioenergy and 6) disposal.*

[62] In particular to minimise the use of quality roundwood for energy production

2.2 IDENTIFYING ADDITIONAL POLICIES AND MEASURES

As noted previously, the EEA holds an updated list of GHG-related PaMs that have been implemented, adopted, or planned by all Member States (and other European countries such as Iceland, Norway, and Switzerland) in all sectors. A report by ETC CME notes that in 2021, Member States reported a similar share of planned PaMs compared to the total number of PaMs. In 2019, 20 EU Member States reported planned PaMs, which increased to 25 Member States in 2021. The increase in the number of reported PaMs may reflect the preparation and finalisation of the NECPs[63].

The search engine gives access to detailed information for each of the PaMs (or groups of PaMs). Countries report main characteristics of the PaMs, such as their description, objective, type, status, sectors affected, related Union Policy, entities responsible for their implementation, implementation period, etc. Where available, quantitative information on the GHG emissions savings achieved by PaMs (or groups of PaMs), both ex post (retrospectively) and ex ante (anticipated savings), as well as the projected and realised costs and benefits of the reported PaMs are reported.

For Member States, this database provides an essential bank of information to identify additional PaMs that are planned or implemented in other Member States, that would be appropriate and effective in their own country.

When considering PaMs, it may be useful to look at the Member State needs and their evaluation that have been identified across different policy areas. There are several national documents that do this following EU level advice. The following sections cover some examples.

2.2.1 Identifying needs in the CAP Strategic Plans

As part of the creation of CSPs [64], each Member State performed a SWOT analysis of their agricultural and rural situations in relation to the 10 specific objectives of the CAP, forming the evidence basis for an assessment of needs[65]. The assessment of needs then served as the basis for setting up the intervention strategy and for designing the interventions of the CAP SP. Member States had the obligation to involve stakeholders in the process to improve the outcomes by considering all sectoral, regional and other specificities. An ex-ante evaluation also had to be carried out to estimate the expected impacts of the draft CAP Strategic Plan.

The interventions in the CSPs which allow for these needs to be met (or partially met) are linked to common result indicators (in Chapter 2 of the CSPs). Those relevant to climate and energy in the land sector are listed in Table . Result indicators reflect the purpose of the actions within the CSPs. They are used for target setting in CSPs and for monitoring progress towards those targets, through annual performance reviews. These result indicators could be cross-referenced within the NECPs to monitor the success of CAP interventions. Indicators will often reflect the joint action of several interventions, rather than individual interventions. Further, they will need to be reassessed and possibly updated to reflect possible changes in CSP interventions following amendments to legislation such as ESR or LULUCF.

Table 9: Climate and energy specific result indicators from the CSPs. The full list of result indicators is available in Annex 1 of Regulation 2021/2115[66] .

Element	Result Indicator
Climate Change Mitigation	R.13 Reducing emissions in the livestock sector: Share of livestock units (LU) under supported commitments to reduce emissions of greenhouse gases and/or NH_3, including manure management. R.14 Carbon storage in soils and biomass: Share of utilised agricultural area (UAA) under supported commitments to reduce emissions or to maintain or enhance carbon storage

[63] ETC-CME_EIONET_report_5-2021.pdf

[64] The scope and tasks of the ex-ante evaluation are specified in the legal proposal for the CAP Strategic Plan, regulation (COM/2018/392 final), Article 125.

[65] See section 1.2.3.1 for more on structure of the CSPs.

[66] EUR-Lex - 02021R2115-20220422 - EN - EUR-Lex (europa.eu)

Element	Result Indicator
	(including permanent grassland, permanent crops with permanent green cover, agricultural land in wetland and peatland). R.19 Improving and protecting soils: Share of utilised agricultural area (UAA) under supported commitments beneficial for soil management to improve soil quality and biota (such as reducing tillage, soil cover with crops, crop rotation included with leguminous crops)
Climate Change Adaptation	R.12 Adaptation to climate change: Share of UAA under supported commitments to improve climate adaptation.
Promote Sustainable Energy	R.15 Renewable energy from agriculture, forestry and from other renewable sources: Supported investments in renewable energy production capacity, including bio-based (in MW).
Bioeconomy	R.16 Investments related to climate: Share of farms benefitting from CAP investment support contributing to climate change mitigation and adaptation, and to the production of renewable energy or biomaterials
Sustainable Forestry	R.17 Afforested land: Area supported for afforestation, agroforestry, and restoration, including breakdowns. R.18 Investment support for the forest sector: Total investment to improve the performance of the forestry sector. R.34 Preserving landscape features: Share of utilised agricultural area (UAA) under supported commitments for managing landscape features, including hedgerows and trees

The CAP SP regulation also decreed the creation of a Performance Monitoring and Evaluation Framework (PMEFs)[67] to replace the previous Common Monitoring Evaluation Framework (CMEF)[68].

The objectives of the PMEF are as follows:

- to monitor the progress made towards achieving the milestones and targets of the CAP Strategic Plans.
- to allow for the evaluation of the impact, effectiveness, efficiency, relevance, coherence, and Union added value of the CAP.
- to support a common learning process related to monitoring and evaluation.

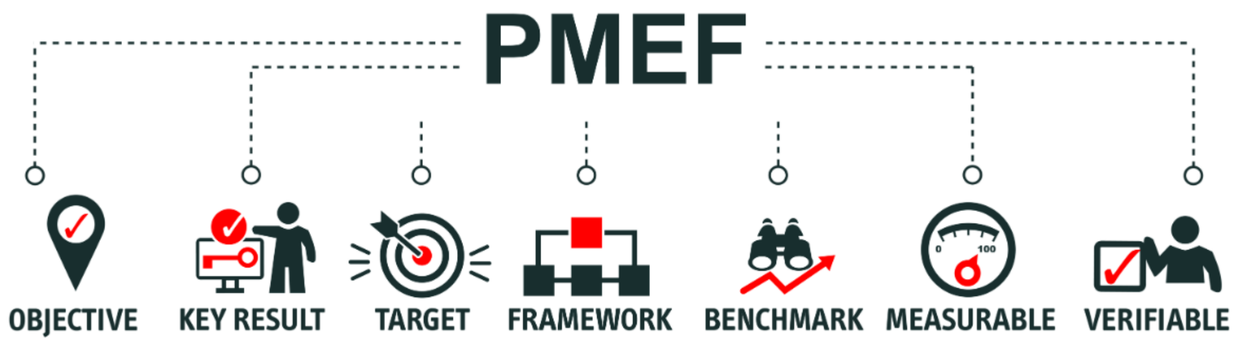

Figure 4. An overview of what the PMEF seeks to achieve for the CSPs

Under the CAP SP Regulation, the PMEF is composed of a set of elements, including common objectives and indicators, quantified targets and milestones, data management and reporting activities, and incentive

[67] More information on PMEF can be found here: Implementation (europa.eu)

[68] More information on the CMEF can be found here: Performance Monitoring and Evaluation Framework | The European Network for Rural Development (ENRD) (europa.eu)

mechanisms to reward good performance and address deviations from planned targets and milestones. The PMEF is set up at EU level with common elements, but it will need to be further adapted and developed in Member States.

As all these things are interlinked, it is possible to use them wider than just for CAP PaMs and thus could help with the evaluation and monitoring of other PaMs related to the land sector.

2.2.2 Identifying needs in the Prioritized Action Framework (PAF)

Article 8 of the Habitats Directive includes the need to develop a framework to support needs identification and measure update for the Natura 2000 network, called the Prioritized Action Framework (PAF). The PAF covers:

- Strategic multi-annual planning tools providing comprehensive overview of measures needed to implement Natura 2000 and related green infrastructure
- Specifying financial needs and priorities and linking to relevant EU funds.

PAFs require Member States to identify objectives and priorities for the current period, measure to achieve these priority objectives, quantification of priority measures, the estimated costs of state or EU (co-)financing sources. By following a similar framework for energy, climate, and environmental measures in the land sector to PAFs, Member States can identify these need and support uptake.

2.2.3 Identifying needs in climate adaptation strategies and measures

The European Commission adopted its new EU strategy on adaptation to climate change on 24 February 2021. The new strategy sets out how the European Union can adapt to the unavoidable impacts of climate change and become climate resilient by 2050. The Strategy has four principal objectives: to make adaptation smarter, swifter and more systemic, and to step up international action on adaptation to climate change. Additionally, the European Climate Law introduces a requirement for the implementation of national adaptation strategies. Many EU Member States have adopted National Adaptation Strategies (NASs). The design and adoption of the NASs requires coordination and collaboration among a wide range of actors and across different levels, supporting the identification of needs at the Member State level.

The Commission guidelines on developing adaptation strategies recognise that there is no 'one-size-fits-all' framework for adaptation, but there are certain common aspects for good adaptation policy:

- adaptation requires a sectoral focus and mainstreaming with existing programmes and policies.
- a wide range of stakeholders needs to be involved in policymaking for adaptation.
- effective communication and awareness-raising is needed.
- and adaptation strategies need to be continuously updated based on new insights in climate change research.

Additionally, the EU Mission for Adaptation to Climate Change recently launched by the Commission will be providing further information on climate adaptation at the Member State and other levels, as well as funding opportunities. More details on the Mission for Adaptation can be found here.

In partnership with the EEA, the Commission has also produced a platform called Climate-ADAPT, which provides a space for knowledge sharing of PaMs and case studies at the transnational, national, and local levels, EU policies, and networks to support climate adaptation and resilience. The Climate-ADAPT platform can be found here.

2.2.4 Identifying needs in the National Air Pollution Control Programmes (NAPCPs)

The National Emission Ceilings Directive (NECD; 2016/2284/EU) aims to achieve the 2030 objectives of the Clean Air Programme and reduce air pollution and its associated risks to the environment and human health in line with the objective of the Zero Pollution Ambition as part of the European Green Deal. The NECD requires Member States to meet national emission reduction commitments (ERC) for selected pollutants identified as being responsible for acidification, eutrophication, and ground-level ozone formation with potential for transboundary impacts. The Directive transposed the 2020 - 2029 reduction commitments set for the EU and EU Member States under the UNECE Gothenburg Protocol as well as setting more stringent ERC for 2030 and onward. Article 4 of the NECD sets national emission reduction commitments for 2020 to 2029, and 2030 and onwards, for SO2, NOX, NMVOCs, PM2.5 and NH3.

Article 6 required Member States to establish by 1 April 2019, at the latest, an initial National Air Pollution Control Programme (NAPCP)[69] to demonstrate how these reduction commitments will be met through the adoption of Policies and Measures (PaMs). NAPCPs must be updated at least every four years after the adoption date of their previous NAPCP (in accordance with Article 6(3)), unless the latest national emission inventory or national emission projections demonstrate that commitments as set out in Article 4 are not complied with or if there is a risk of non-compliance. In such cases, the PaMs included in NAPCP need to be updated within 18 months from submission of the data (in accordance with Article 6(4)). A core element of the NAPCPs is to ensure coherence with other policy areas, most notably the Ambient Air Quality Directive (AAQD) but also climate and energy policies and plans, such as the NECPs.

Minimum content of NAPCPs outlined in Annex III to the Directive require Member States to include in their NAPCP information on their projected emissions assuming no change to the PaMs already adopted (“With Measures” (WM) projections scenario). This allows Member States to understand whether they can expect to meet the emission reduction commitments with existing policies and if not, on what the additional PaMs should focus (whether it is on specific pollutants and/or sectors). The PaMs selected for adoption in the NAPCPs should then feed into the “With Additional Measures” (WAM) scenario for the projections.

Member States must present additional PaMs in their NACPCs if their emissions projections do not meet their emissions reduction commitments (ERCs). NAPCPs act as a platform for Member States to announce what PaMs they are adopting and implementing, or measures that they are considering for adoption (on the reserve list). While there is no standardised way for Member States to develop and identify additional PaMs, Member States can use other Member States’ NAPCPs to identify additional PaMs that they are proposing for further inspiration. Member States must update their NAPCPs at least every 4 years, unless they are found to be non-compliant with, or at high risk of non-compliance with, any of their emission reduction commitments according to their latest emissions inventory or projections. Member States use their NAPCPs to show the PaMs that they are using to achieve the 2030 ERCs. Appendix 2 in this document provides a list of example PaMs relevant to the land sector from some Member States’ NAPCPs for further inspiration.

2.2.5 Identifying needs in the Recovery and Resilience Plans (RRPs)

The national Recovery and Resilience Plans (RRPs) outline the objectives, reforms and investments Member States intends to carry out funds to mitigate the COVID-19 socio-economic impact and make each Member State a fairer, greener, and more inclusive, with a more competitive, dynamic, and innovative economy. The Recovery and Resilience Facility (RRF) at the heart of NextGenerationEU is an opportunity for deep structural transformation in each Member State.[70] The RRF deploys up to EUR 723.8 billion (in current prices) in loans and grants in order to support the reform and investment packages put forward by the Member States in their national RRP)[70].

The Technical Support Instrument (TSI) is available to help Member States with the preparation and implementation of their RRPs. So far, more than 300 projects approved under the TSI are linked to the preparation or implementation of Member States’ RRPs. TSI assistance has taken the form of general support, horizontally applicable for a smooth implementation of the plans, and thematic support, targeting specific reforms and investments in the RRPs[70]. The Recovery and Resilience Scoreboard (europa.eu) gives an overview of how the implementation of the RRF and the national recovery and resilience plans is progressing.

The RRF Regulation sets out six policy areas of European relevance structured in six pillars. The Recovery and Resilience Scoreboard displays the impact of the RRF on these six policy pillars:

- Green transition
- Digital transformation
- Smart, sustainable, and inclusive growth, including economic cohesion, jobs, productivity, competitiveness, research, development and innovation, and a well-functioning internal market with strong SMEs
- Social and territorial cohesion

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[69] National Air Pollution Control Programmes and Projections (europa.eu)
[70] Recovery and Resilience Plans (europa.eu)

- Health and economic, social, and institutional resilience with the aim of, inter alia, increasing crisis preparedness and crisis response capacity
- Policies for the next generation, children and the youth, such as education and skills

The EC website contains a list of national RRPs, which cover measures focused on the green transition (as well as the digital transition, and other information on assessment of the RRPs, payments, and further details).

The RRF is also at the heart of the implementation of the REPowerEU Plan, the Commission's response to the socio-economic hardships and global energy market disruption caused by Russia's invasion of Ukraine. In this respect, on 18 May 2022, the Commission proposed to make targeted amendments to the RRF Regulation to integrate dedicated REPowerEU chapters in Member States' existing RRPs. This comes in addition to the large number of relevant reforms and investments which are already in the RRPs. It also published a revised Guidance document on Recovery and Resilience Plans in the context of REPowerEU.[71]

On 1st February 2023 the European Commission published an updated guidance on RRPs in the context of REPowerEU, which is available here.

2.2.5.1 RRPs and NECPs

With regard to other policies instruments, some Member States have already started aligning measures in NECPs with RRP measures, especially those PaMs that focus on climate investment measures. Member States should aim to improve policy consistency between instruments – such as between the NECPs and RRPs. These plans currently have some conflicting data and measures. For example, for some Member States, only a few measures planned under the NECP will also be funded under the RRP; and several new measures are being planned under new Operational Programs (cohesion policy). Further, in the light of the current energy crisis, investments outlined in NECPs – as well as in the other spending plans, such as the 'REPowerEU' chapters of the RRPs – should embed distributional appraisals to address the needs of vulnerable households[72].

In the annex to the Commission's communication on the Guidance to Member States for the update of the 2021-2030 national energy and climate plans[73], several recommendations related to the RRPs are made to all Member States. The following table details these.

Table 10: Recommendations related to RRPs

Recommendation	Detail
It is important that Member States fully reflect the energy and climate investments and reforms of the national RRPs in the updated NECPs and build on them to achieve their updated 2030 targets, objectives, and commitments.	*In quantitative terms, the RRF provides the largest new funding source for energy and climate policy. Up to August 2026, the RRPs will continue to drive Member States' energy and climate reform and investment agendas to different degrees. The RRPs were prepared to contribute to the NECPs' objectives, targets, and contributions, in view of the increased ambition for 2030 and 2050. Under the REPowerEU plan, Member States should reflect additional policies and measures in their RRPs by including a specific REPowerEU chapter.*
To ensure transparency and consistency, the Commission invites Member States to clearly describe the role of the RRPs, including the REPowerEU chapters, in implementing the updated NECPs.	*To this end, the updated national plans should provide quantitative information with respect to the contribution of the RRP measures to the updated climate and energy objectives and targets, also in terms of financing.*

[71] The Recovery and Resilience Facility
[72] NECP-report-Taking-Stock-Planning-Ahead.pdf (caneurope.org)
[73] C_2022_8263_Guidance to MS NECP_2.pdf (europa.eu)

Recommendation	Detail
Member States are invited to cross-reference the RRP and REPowerEU chapter for each relevant policy and measure in their updated NECPs.	*Member States should indicate whether the policy or measure is fully or partially part of the RRP and REPowerEU chapter and the role of the NECP in complementing the RRPs and REPowerEU Chapters.*
The Commission encourages Member States to use their experience of the RRP process. This can further improve the level of detail of investments and reforms in the updated NECPs	*This is specifically in terms of cost estimates, financing, scope description, and including specific milestones and targets. The consistency between the two instruments will need to be maintained.*

2.2.6 Identifying needs in the National Biodiversity Strategies and Action Plans (NBSAPs)

The National Biodiversity Strategy and Action Plan (NBSAP) is a national policy that aims to provide strategic direction at the national level on the management and protection of biodiversity. It also streamlines various sectoral aspects to ensure sustainable use of natural resources; this ensures a better quality of life and the reduction in biodiversity loss.

The NBSAP is the principal instrument for implementing the United Nations Convention on Biological Diversity (CBD) at national level[74]. As required by the Convention, each signatory country (party) must develop an NBSAP or equivalent instrument in accordance with its conditions and capabilities. This creates an obligation for Parties to carry out national biodiversity planning and defining a course of action with specific targets and plans to fulfil the objectives of the Convention. In this context. NBSAPs are considered as one of the strongest implementation mechanisms in the CBD. Furthermore, the Convention requires each Party to ensure that its respective NBSAP is mainstreamed into the planning and activities of all those sectors that can have a positive or negative impact on biodiversity.[75] At the EU level, the EU Biodiversity Strategy sets out the need for implementing NBSAPs. The Strategy is an ambitious, constructive, and coherent strategy that delivers on the commitment from the EU and its Member States, as parties to the UN CBD, to protect the living world and implement national strategies and action plans to achieve it.

The main purpose of the NBSAP is to serve as a national policy driver to integrate biodiversity concerns into relevant sectoral or cross-sectoral plans, programmes and policies, especially those that can have a bearing on biological and natural resources.[75] The NBSAP reflects a country's vision for biodiversity and the broad policy and institutional measures that the country will take to fulfil the objectives of the Convention, while the action plan comprises the concrete actions to be taken to achieve the strategy.

As with other policies and instruments discussed in this section, Member States can look to NBSAPs for inspiration and to identify additional PaMs. The NBSAPs latest submissions for countries (not just EU countries) can be found here.

Examples of measures and actions in NBSAPs from European countries include:

- Protecting the best remaining examples of raised bogs
- Developing a range of collaborative species conservation programmes (for Corncrake, Grey partridge, Natterjack toad, Red Grouse, Roseate Tern)
- Continue and enhance measures for eradication, where feasible, control and containment of invasive species
- Increase connectivity of the protected areas network using appropriate buffer zones, corridors, steppingstones and/or flyways
- Maintaining the most valuable parts and sites of protected areas, and adapting protected areas to environmental education and training and the dissemination of information on protected areas

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[74] In the EU, the Bird and Habitat Directive ("Nature Directives") are the EU's oldest environmental laws. They form the backbone of EU biodiversity policy and are the legal basis for Natura 2000 network, and work in parallel with the NBSAPs.
[75] National Biodiversity Strategy & Action plan - ERA

2.2.6.1 Co-benefits

It is impossible to tackle climate change without addressing biodiversity loss. Protecting and restoring ecosystems can help us reduce the extent of climate change and cope with its impact. The Commission White Paper on Adapting to Climate Change – Towards a European Framework for Action (April 2009) and the EU Strategy on Adaptation to Climate Change both recognised the importance of ecosystems in tackling climate change. The White Paper encouraged the development of "measures which address biodiversity loss and climate change in an integrated manner to fully exploit co-benefits and avoid ecosystem feedbacks that accelerate global warming".

Protecting biodiversity can help climate change adaptation. Healthy ecosystems will be more resilient to climate change and so more able to maintain the supply of ecosystem services on which our prosperity and wellbeing depend. Healthy ecosystems must lie at the centre of any adaptation policy and can help mitigate climate change impacts, by absorbing excess flood water or buffering us against coastal erosion or extreme weather events. Forests, peatlands, and other habitats are major stores of carbon. Protecting them can also help us limit atmospheric greenhouse gas concentrations.

The Commission has produced a guidance document that presents the latest scientific information on the risks posed by climate change to species and habitat types of EU conservation concern. It also provides advice, supported by good practice examples, on how to deal with the impact of climate change when managing Natura 2000 sites. It is primarily addressed to site managers and policy makers. [76]

Measures related to the protection of biodiversity under Natura 2000, as well as the NBSAPs, can be categorised by the following. Most of the measures listed in Table 11 have co-benefits for climate and environment, as well as other benefits for society.

Table 11: The main categories of measures and the various measures falling into difference categories [77]

Category	Types of measures
Reduction of existing pressures	Restoration Buffer zone development Increase in reserve size
Increase ecosystem heterogeneity	Enhance structural gradients Allow natural processes
Ensure abiotic conditions	Water quality Water quantity Nutrient balance
Manage impact of extreme events	Fire management Flood management Storm management
Increase connectivity	Develop corridors/ steppingstones Wider landscape management Create new nature areas Spatial planning
Other	Review existing boundaries/ establish new sites Relocation Assess geographical distribution of protected area network

[76] Biodiversity and Climate Change

[77] Guidelines on climate change and Natura 2000 - Publications Office of the EU (europa.eu)

Category	Types of measures
	Invasive species control Spatial planning

2.3 MONITORING, REPORTING, AND VERIFICATION (MRV) AND QUANTIFICATION

Monitoring, reporting and verification (MRV) and quantification are essential for the continued implementation and success of policies and measures. MRV and quantification of PaMs can help Member States and other governing bodies ensure accountability in the use of resources for policy development and implementation, provide a clear basis for decision-making, and offer practical lessons from experience to guide future development interventions.

- MRV of GHG emissions, conducted at national, regional, or farm level to understand emissions profiles and report it.
- MRV of mitigation actions through PaMs to assess their GHG effects and other (non-GHG) effects as well as to monitor their implementation. This type of MRV focuses on estimating the change in GHG emissions or other non-GHG variables.
- MRV of support (e.g., finance, technology transfer, and capacity building) to track provision and receipt of climate and environment support, monitor results achieved, and assess impact.

2.3.1 MRV of agricultural climate mitigation PaMs

The ETC CM report on agricultural climate mitigation PaMs[78] looks at the experience of national and international agricultural experts to understand key barriers to uptake of PaMs and good practice, as well as plans and insights on future priorities for GHG mitigation. The report notes that the quantified mitigation potential of measures depends on the uptake rate of measures as well as their technical potential, and also on sufficiently accurate GHG inventories and projections to reflect their impact. Agricultural emissions are affected by trends in production, and mitigation policies implemented on farms may have impacts in other sectors.

The report also identifies some barriers to MRV:

- A lack of country-specific data on technology uptake or mitigation impacts.
- A lack of resources within inventory compilation teams.
- A lack of enforcement of the obligation to monitor the impact of measures on GHG emissions, contributing to a lack of real-world evidence of effectiveness.
- Inconsistent reporting practices across Member States.

The ongoing MELS (Mitigating Emissions from Livestock Systems) project[79] is currently gathering knowledge and data on the impact of mitigation measures for livestock. The project aims to develop a farm-scale decision support system aimed at farmers and advisors, as well as database of detailed emission factors and mitigation efficiencies, taking into account country-specific factors, to help improve national inventories.

2.3.2 MRV and Quantification of emissions at the farm, plantation, or parcel level

There are a range of calculator tools that can help to deal with the MRV of mitigation measures[80]. A modular GHG calculator tool would provide highest flexibility for farm level GHG Monitoring. A modular system building

[78] https://www.eionet.europa.eu/etcs/etc-cme/products/etc-cme-reports/etc-cme-report-6-2021-agricultural-climate-mitigation-policies-and-measures-good-practice-challenges-and-future-perspectives

[79] https://www.mels-project.eu/the-project/

[80] https://op.europa.eu/en/publication-detail/-/publication/efcb2fe1-7663-11e7-b2f2-01aa75ed71a1/language-en

a GHG tool with independent – and individually selectable – modules focusing on nutrient management, enteric fermentation, carbon sequestration and land use changes, and energy use will 'measure' proxies for GHG emissions rather than the implementation of a specific measure. These types of calculators therefore give a direct idea of the cost-effectiveness of climate-payments while considering possible positive or negative side effects. Collecting required data might be interesting also for farmers as they will get the information on the GHG emission intensity of their products, which might give a market advantage and thus enhancing the motivation for GHG emission reductions.

At the farm level, fuel consumption, energy requirement for housing or buildings, and livestock and soil management are all affected if the productivity is changed (e.g., animal efficiency, nitrogen use efficiency) as the same productivity can be achieved with less resources. Upstream of the farm, the energy requirements for production of fertilisers and other inputs and/or machinery and capital goods are impacted as well. The magnitude of these effects is difficult to quantify. However, they are directly reflected in the annual energy balances used for the GHG inventories, so this is something important to quantify

Most measures targeting the reduction of CH4 emissions from enteric fermentation and manure management on farms are captured if the feed composition is known. The IPCC Tier 2 methodology estimating feed intake via the quantification of the gross energy requirements is not sufficient as the measures act mainly through a change of feed digestibility and its effect on the CH4 production potential. Thus, data on actual feed intake, in contrast to data on feed supply by the farmers, need to be collected. Exceptions targeting the CH4 production for a given feed intake are measures such as genetic improvement or some feed additives which require the development of national data either with measurement programs (genetic improvement) and/or Tier 3 modelling (feed additives). Applying feed calculators is an effective measure to collect such data for national GHG inventories in countries in which data are not yet available, and to monitor CH4 emissions from enteric fermentation at the farm level if the quantification of feed digestibility and CH4 production based on available methodologies is implemented.

A land calculator aims at capturing carbon sequestration measures and measures linked to land use changes. Information required include tillage practices; periods a field is covered or un-covered during a year; input of carbon with crop residues; manure (including bedding material) or from other sources to the field. For nitrogen, mitigation effects through changes in activity data are fully captured in IPCC GHG inventories.

2.3.2.1 MRV in the LULUCF sector

The LULUCF sector differs from other sectors (such as energy or waste) in several ways that make it quite peculiar and complex. Besides including both emissions and removals, the sector is ruled by natural processes and interactions, with anthropogenic influences that can be difficult to monitor and distinguish. Natural and often unpredictable events such as droughts, fires, or floods can have an important impact on the carbon cycle, which may present cyclical trends complex to model and monitor, and every human action can have important legacy long-term effects on the environment of difficult accountability. In addition, emissions come from a distributed source over the earth surface, rather than from precise points as in other sectors. All these characteristics make LULUCF a complex sector, characterized by high uncertainties.

2.3.3 MRV and Quantification of emissions at the national and EU levels

Measuring and monitoring the effect of GHG mitigation actions requires understanding how the targeted emission type is calculated, which parameters are changing when applying the mitigation action, as well as which side effects it may have. Mitigation activities can be designed to target 'observations' or 'parameters'. In the first case, changes in data are usually easily quantified gathering new statistics or available information. Their effect is generally easily accountable using the IPCC guidelines. Changes in 'parameters' have a more localised effect, and often need experimental work to establish the new values needed.

Land calculations require spatial (land use and land management) data and is thus complex to implement and requires more efforts from the farmer to be used. Nevertheless, systems collecting many of the data that a land calculator tool would need are already in place (e.g., the Land Parcel Identification System – LPIS (discussed below) within the Integrated Administration and Control System (IACS) and are used by some Member State. However, for other Member States data collected within these systems are often not easily available for the purpose of GHG accounting (at farm level or at national level) due to data property issues among the different national and regional authorities. An extension of these data collection systems to include missing data could be a cost-efficient way of assessing farm level and national mitigation measures targeting carbon sinks and sources.

The EEA provides further information in workshops on policies and measures, including the evaluation and monitoring of PaMs as part of the ETC CM. Details can be found here. For example, the ETC CM provides a webinar on the evaluation of agricultural GHG PaMs across the EU , available here. Reducing GHGs in the agricultural sector has proven to be particularly difficult. PaMs have been able to reduce the emission intensity of the sector, but these gains have been offset by increased production. In this webinar, two case studies illustrated the challenges in monitoring and evaluating agricultural PaMs.

2.3.4 Agricultural Monitoring by the Joint Research Centre (JRC)

The Joint Research Centre (JRC) is responsible for the LULUCF and the agriculture sections of the EU's GHG inventory. Being a party to the UNFCCC as a whole, just as its single Member States, the EU has the same obligations of any other Annex I party in terms of reporting of its GHG emissions, and every year an EU inventory is prepared collecting and checking the inventory data prepared by the single MS and finally summing them up to obtain 8 total EU values.

Agricultural monitoring research at the JRC involves estimating crop production and supporting the implementation of the CAP. Agricultural monitoring is carried out at the JRC mainly to distinguish, identify, and measure the main crop production areas in Europe, estimate production early in the year and check the validity of farmers' applications for EU subsidies. The EC uses satellite earth-observation data as a cost-efficient way of gathering the necessary monitoring information. The JRC supports the implementation of the CAP and its instruments, such as the GAEC standards and the Farm Advisory System (FAS)[81].

The JRC promotes the use of Remote Sensing and GIS in the implementation, management, and monitoring or control of the GAECs. It also works toward the optimisation of the definition and control of GAECs through the exchange of best practices and supports the development and promotion of methods using traceability, quality, certification and record-keeping at farm or parcel level.

2.3.4.1 Digital Land Parcel Identification System (LPIS)

The Land Parcel Identification System (LPIS) was designed as the main instrument for the implementation of the first pillar in the previous iteration of the CAP, whereby direct payments are made to the farmer once the land and area eligible for payments have been identified and quantified. The CAP has now changed in the current programming period, but LPIS is still a valuable system[82].

The JRC participates in the standardisation processes in order to increase the interoperability of the spatial data through an LPIS core model and supports the development of user-friendly applications for data documentation. Furthermore, it supports EU Member States by providing guidelines on the production of ortho-imagery.

The JRC contributes to the standardisation processes by developing and harmonising LPIS control methods for checking CAP claims. It also provides the EU Member States with working documents, training courses and consultation services, and helps them verify the performance of their systems by implementing a Quality Assurance framework. The results of quality assessment are monitored by DG Agriculture and Rural Development. The JRC is developing an LPIS Quality Assurance web portal and will integrate consolidated guidelines on its MARS WikiCAP website.

2.3.4.2 Image acquisition and storage

The JRC oversees image acquisition in the context of CAP Controls with Remote Sensing. Two types of images are acquired: satellite imagery and aerial photography. These are used for the management of feasibility studies. The JRC also produces image acquisition specifications and performs benchmarking studies of newly launched satellite sensors.

The main advantage of aerial photography with respect to very high resolution (VHR) satellite imagery is that it can cover much larger areas (e.g., large administrative units such as full provinces) in a limited period of

[81] Agricultural monitoring (europa.eu)
[82] Monitoring Agricultural ResourceS (MARS) (europa.eu)

time. However, acquiring aerial photography has also some constraints such as restrictions over military zones and air traffic lanes.

2.3.5 Earth observation and monitoring

Geographically explicit monitoring is essential for the MRV of CAP requirements and for reporting on the LULUCF sector[83]. Since 2018, Sentinel-1 and Sentinel-2 (Copernicus) satellites, as well as other EU-level and Member State level earth observation missions, have been used to offer detailed and up to date information on crops, farmland, and land cover and land use change across Europe[84]. This reduces the administrative burden on Member States by reducing the need for physical, on the ground controls and checks on the 22 million farmers that operate in the EU, as well as foresters and other land managers.

Data generated from Copernicus Land Monitoring Service (CLMS) can be found here. The CLMS provides a range of products that can support monitoring PaMs including CORINE Land Cover, CLC+, High Resolution Layers and Biophysical Parameters[85].

Non-CO2 abatement measures

- The high-resolution vegetation phenology and productivity product captures crop type and crop rotation which, when combined with other data, could provide information the success of PaMs related to emissions from fertiliser application.

Carbon stock exchange

- High resolution vegetation phenology and productivity product captures crop type and crop rotation, which allows monitoring of PaMs related to the use of cover crops.
- The Pan-European High Resolution Layers product can map land cover type and can monitor the efficacy of PaMs related to conversion of forested area to grassland or cropland, and vice versa.

Climate resilience measures

- The high-resolution vegetation phenology and productivity product captures seasonal and inter-annual variation in vegetation cover, and changes in growing seasons. This means climate adaption measures can be planned strategically based on up-to-date data on how climate change is affecting Europe.
- The high-resolution vegetation phenology and productivity product monitors how ecosystems respond to changing climatic factors, which can help assess the efficacy of climate adaption PaMs.
- The Higher Resolution Layers product can also be used to monitor climate resilience PaMs relating to sealed soil, tree cover density, grasslands, and wetness and water.

High resolution data on vegetation phenology and productivity will contribute to the LULUCF reporting mechanism implemented by EU Member States for climate change mitigation purposes. The high resolution of the data (10 m^2) means it can also be used to monitor urban green areas.[86] It will also enable monitoring of crop type and crop rotation and will specifically be used in the CAP to monitor GAECs as outlined below in Table 12.

[83] Using Copernicus Land Monitoring Services (CLMS) to support the land use, land use change and forestry (LULUCF) regulation — Copernicus Land Monitoring Service

[84] ESA - Sentinels modernise Europe's agricultural policy

[85] Pan-European — Copernicus Land Monitoring Service

[86] High Resolution Vegetation Phenology and Productivity — Copernicus Land Monitoring Service

Table 122: GAECs relevant to this report and the use of CLMS for monitoring[87]

GAEC	Requirements and standards	Copernicus Land Monitoring Service use
GAEC 1	Maintenance of permanent grassland based on a ratio of permanent grassland in relation to agricultural area at national, regional, subregional, group-of-holdings or holding level in comparison to the reference year 2018	The Higher Resolution Layers product can be used to monitor land cover type including grasslands.
GAEC 2	Protection of wetland and peatland	The Higher Resolution Layers product can be used to monitor land cover type and wetness and water.
GAEC 3	Ban on burning arable stubble, except for plant health reasons	The Higher Resolution Layers product can be used to monitor land cover type.
GAEC 5	Tillage management, reducing the risk of soil degradation and erosion, including consideration of the slope gradient	The Higher Resolution Layers product can be used to monitor soil imperviousness and compaction, which may be of use when monitoring soil degradation.
GAEC 8	Minimum share of agricultural area devoted to non-productive areas or features	The Higher Resolution Layers product can be used to monitor land cover type.
GAEC 9	Ban on converting or ploughing permanent grassland designated as environmentally sensitive permanent grasslands in Natura 2000 sites	The Pan-European High Resolution Layers product can map land cover type including types of grassland.

While remote sensing has an important place in MRV and quantification of land use changes and emissions, this method is not always suitable for all types of monitoring. Remote sensing cannot replace granular details and measurements that can only be carried out “in the field”, and surveys of farmers or other land managers and operators, which may prove to be more precise and reliable.

2.3.6 Forest monitoring

Currently, Member States do not legally have to undertake extensive forest monitoring. The proposed Nature Restoration Law, the EU Forestry Strategy, as well as amendments to the LULUCF Regulation, will seek to improve monitoring by creating better reporting mechanisms, improving continuity, quality, timeliness, accessibility and availability of data, enabling better spatial and temporal resolution, and implementing common definitions.

In this respect, the new EU Forest Strategy for 2030 announced a legislative proposal for a forest observation, reporting and data collection framework, requiring Member States to develop long-term integrated plans for forests. The aim of the upcoming Forest Monitoring Law is to develop an EU-wide forest observation framework

[87] EUR-Lex - 32021R2115 - EN - EUR-Lex (europa.eu)

to provide open access to detailed, accurate, regular, and timely information on the condition and management of EU forests, and on the many products and ecosystem services that forests provide[88].

The European National Forest Inventory Network (ENFIN) is a network of large-scale monitoring systems providing coverage of forest data in Europe. It harmonises forest information with over half a million field plots which produce information using field surveys and remote sensing technology[89].

The Food and Agriculture Organisation's (FAO) Global Forest Resources Assessment (FRA) gives an overview of the status and trends of forests and related variables around the world. To ensure consistent MRV across the 236 counties and territories covered, the data were collected using commonly agreed terms and definitions. There was a transparent, traceable reporting process, with data from all countries stored on the same database for easy retrieval. National correspondents were nominated to oversee reporting and increase traceability.[90]

National Forest Inventories are collections of data on the location, composition, and distribution of forest resources at a local, regional, national or global level. The methodology for data collection is defined by the FAO in the Voluntary Guidelines on National Forest Monitoring (VGNFM), which means data compilation and analysis is unified across inventories. Data sources include field inventories and remote sensing.[91]

The Forest Information System for Europe (FISE) operates using a similar model, where data collected by individual counties is reported to and used by organisations like Eurostat, Forest Europe, the United Nations Economic Commission for Europe (UNECE) and the FAO, and information compiled at the European Environmental Agency (EEA).[92]

2.3.7 Certification schemes

Certification schemes are voluntary third-party guidelines and assessments of products, practices, and supply chains measured on a series of criteria and requirements. Meeting and complying with the appropriate criteria gain the practice, product or entity approval and certification, a clear indication for consumers of the product's environmental and social standards. Generally aimed at producers, manufacturers, traders and retailers, certification schemes can help entities identify weaknesses in their environmental practices and enable them to demonstrate commitments toward good environmental and food safety practices, as well as good ethical and social practices. Certification schemes enable action where national and international legislation does not go far enough and target mainstream adoption of better production practices.

Certification schemes provide a set of rules and procedures to certify operators. Typically, the following actions need to be performed:

- Establish certification criteria and develop the related certification methodologies. Often, certification schemes apply certification methodologies that are developed in a bottom-up fashion by external parties (often, the programme developers); in such cases, the schemes would establish a methodology approval process to check that the methodologies are aligned with the scheme's criteria.
- Validate projects ex-ante and verify climate benefits ex-post; this is often delegated to third-party auditors called certification bodies (see more below).
- Issue removal certificates corresponding to the verified carbon removals (or relevant environmental or climate benefit of the scheme) (this could also be done by certification bodies on behalf of certification schemes) and record them in a registry system[93].

2.3.7.1 Existing schemes: biofuels

Voluntary schemes and national certification schemes of EU countries help to ensure that biofuels, bioliquids and biomass fuels are sustainably produced by verifying that they comply with the EU sustainability criteria[94]. As such, the schemes check that:

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[88] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13396-EU-forests-new-EU-Framework-for-Forest-Monitoring-and-Strategic-Plans_en
[89] enfin.info
[90] Global Forest Resources Assessments | Food and Agriculture Organization of the United Nations (fao.org)
[91] National Forest Inventory | National Forest Monitoring | Food and Agriculture Organization of the United Nations (fao.org)
[92] Forest Information System for Europe (FISE) (europa.eu)
[93] 090166e5f489ccee.pdf
[94] Voluntary schemes (europa.eu)

- production of feedstock for these fuels does not take place on land with high biodiversity;
- land with a high amount of carbon has not been converted for such feedstock production;
- biofuel, bioliquid and biomass fuel production leads to sufficient greenhouse gas emissions savings.

2.3.7.2 Certification of carbon removals

Now and in the future, we need to scale up carbon removals, particularly in the land sector. Improving the MRV of carbon removals is the first fundamental step to enable robust markets and regulatory uses of carbon certificates[95]. Carbon farming and industrial projects that invest in carbon removals today should have a prospect of a future robust accounting and certification framework that ensures comparability and recognition of the action started already on the ground.

To this end, the Commission has proposed a regulatory EU framework for the certification of carbon removals. The aim of the proposal is creating a trustworthy framework to monitor, report and verify high-quality carbon removals. The proposal raises the quality bar for carbon removals and provides a framework to only certify high-quality carbon removals produced in the EU based on detailed methodologies for the following:

- permanent storage, such as bioenergy with carbon capture and storage, or direct air carbon capture and storage;
- carbon farming, such as better managing soils and restoring wetlands and forests;
- and, carbon storage in long-lasting products and materials such as wood-based construction.

The detailed methodologies will be developed together with an expert group, which met for its kick-off meeting on the 7th of March 2023.

The proposal will also harmonise the certification process and make it more transparent and reliable. By recognising the certification schemes that comply with the requirements in the Regulation, the Commission will provide a public guarantee that these schemes can be trusted to correctly certify high-quality carbon removals.

The proposed voluntary certification framework establishes a tool to enable public and private support to high-quality carbon removals. The certificates will transparently provide a large amount of information about the net climate benefit of a given carbon removal activity, the expected duration of the storage, and the co-benefits generated for the environment. This comprehensive information – offered by the certificate – will ensure that public authorities or private companies will be able to invest into high quality carbon removals that best fit the intended use.

Once the certification methodologies are in place, Member States can use this framework to channel public support to carbon removals through the Common Agricultural Policy, State Aid schemes, national certification schemes, green public procurement, or other forms of public financing.

2.3.8 Increased monitoring requirement under the revised LULUCF Regulation

In a nutshell, the Regulation requires progressively more precise monitoring (i.e., from “tier 1” to “tier 2” and “tier 3” for some specific areas.) In the second period from 2026 onwards “tier 2” is required for all land areas and from 2028 onwards “tier 3” for specific areas (such as those classified as high carbon stock). The 2028 data will then be reported in the 2030 inventories[96].

A specific LULUCF handbook for Member States is under development by DG CLIMA in order to support Member States in the development and improvement of GHG monitoring on the ground. This should be available towards the end of 2023/beginning of 2024[97].

[95] Carbon Removal Certification (europa.eu)

[96] https://data.consilium.europa.eu/doc/document/ST-15075-2022-INIT/en/pdf

[97] The definitions of the different tiers are the same as defined by the IPCC see Chp 1 of Volume 4: Agriculture, Forestry and Other Land Use, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Extract from the Regulation below:

From the greenhouse gas inventory submission in 2028 onwards, Member States shall use at least Tier 2 methodologies in accordance with the 2006 IPCC guidelines for national GHG inventories, ***whereas Member States shall as early as possible and from the greenhouse gas inventory submission in 2030 onwards*** *at the latest for all carbon pool emission and removal estimates falling in areas of high carbon stock land use units referred to in point (a) above, areas of land use units under protection or under restoration referred to in points (b) and (c) above, and areas of land use units under high future climate risks referred to in point (d) above,* ***apply Tier 3 methodology****, in accordance with the 2006 IPCC guidelines for national GHG inventories.*

Notwithstanding the previous subparagraph, where the area under any individual category listed in points (a) to (d) above represents less than 1% of the area of managed land reported by the Member State, Member States shall use at least Tier 2 methodologies in accordance with the 2006 IPCC guidelines for national GHG inventories.'

Timeline:

- the submission in 2030 "shall… apply" Tier 3
- For the scope in the paragraph above (a) to (d)
  - (a) a system for the monitoring of land use units with high-carbon stock land, as defined in Article 29(4) of Directive 2018/2001[98];
  - (b) a system for the monitoring of land use units subject to protection, defined as land covered in Annex III(b) of the proposal[99];
  - (c) a system for the monitoring of land use units subject to restoration, defined as land covered Annex III(c)[100];
  - (d) a system for the monitoring of land use units with high climate risk, which includes areas identified in Annex III(d)[101]

2.3.9 MRV and quantification requirements by measure

In Table 13, the MRV and quantification requirements are presented for each measure in this report's annex. This information can help authorities in Member States to plan data collection required to monitor, verify, and report the effects of measure implementation.

Table 3: MRV and quantification requirements for each measure.

Measure	MRV and quantification requirements
Non-CO_2 abatement measures: Measures for nutrient management	
Optimal pH for nutrient uptake in arable and improved grass	Measurement of the activity depends on farmer co-operation in sharing records of farm operations, and the results of soil pH tests.
Urease inhibitors coupled to mineral N fertilisers	Measurement of the activity depends on farmer co-operation in sharing records of farm fertiliser purchases and operations and can be verified by inspection during farm visits.
Nitrification inhibitors with mineral N fertilisers and manure	Measurement of the activity depends on farmer co-operation in sharing records of farm fertiliser purchases and operations and can be verified by inspection during farm visits.

[98] L_2018328EN.01008201.xml (europa.eu)

[99] https://data.consilium.europa.eu/doc/document/ST-15075-2022-INIT/en/pdf

[100] *Idem.*

[101] *Idem.*

Measure	MRV and quantification requirements
Organic production approaches - no synthetic N	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Slow and controlled release nitrogen fertiliser and organic-mineral fertilisers	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data. Furthermore, many national GHG inventories will need to be updated to with a non-linear emission factor to relate N_2O emissions to the application of many of the currently used N fertilisers in order to record emission reductions arising from the use of slow and controlled release N fertilisers.
Testing, planning and advice to avoid excess application of N fertiliser	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data
Precision farming coupled to fertiliser placement (variable rate distribution)	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data.

Measure	MRV and quantification requirements
Non-CO2 abatement measures: Manure applications	
Slurry application by trailing shoe	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of NH_3 and N_2O emissions are not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions for use with activity data.
Slurry application by injection	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of NH_3 emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Incorporation of slurry and solid manures within four hours of application	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of NH_3 and N_2O emissions are not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions for use with activity data
Non-CO2 abatement measures: Manure storage	
Cooling slurry	Measurement of the activity depends on farmer co-operation in sharing records of farm infrastructure and operations and can be verified by inspection during farm visits.
Slurry acidification	Measurement of the activity depends on farmer co-operation in sharing records of farm infrastructure and operations and can be verified by inspection during farm visits.
Covering manure and slurry stores	Measurement of the activity depends on farmer co-operation in sharing manure storage records and can be verified by inspection during farm visits.
Livestock Density Limits	This would be relatively easy to monitor through existing data collection structures and would have an impact on domestic GHG inventories.
Non-CO2 abatement measures; Livestock health	
Herd fertility	Measurement of the activity depends on farmer co-operation in sharing records of animal reproductive rates and allowing farm visits for verification. Measurement of emissions are not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emission factors for use with activity data.
Reduction in endemic disease	Measurement of the activity depends on farmer co-operation in sharing veterinary and production records and allowing farm visits for verification.

Measure	MRV and quantification requirements
Non-CO2 abatement measures; Livestock feeding	
Feed additives for ruminant diets	Measurement of the activity depends on farmer co-operation in sharing feed records and allowing farm visits for verification. Measurement of ruminant CH_4 emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Optimised feed strategies	Measurement of the activity depends on farmer co-operation in sharing feed records and allowing farm visits for verification. Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emission factors and stock change factors for use with activity data.
Optimised forage/grazed crop utilisation	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data.
Breeding lower emissions animals	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data. Measurement of the impact is likely to relate to the ability to measure and monitor the emissions from animals and recalculating emissions factors for lower methane animals. This requires scientific studies and publications to develop an evidence base to support changes in emissions factors.
Non-CO_2 abatement measures: Other	
Improved rice cultivation (alternate wet and dry techniques)	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data. However, the application of AWD varies greatly from farm to farm; the exact schedule often finalised for the convenience of the farmer (Thakur et al., 2018). Hence in the absence of a standard operating procedure monitoring the effectiveness of AWD will be difficult.
Crop breeding for varieties that use N more efficiently	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and can be verified by inspection during farm visits.
Legumes in a crop rotation and increased legume share in grass mixes	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016), and this can be used to estimate the areas of crops by species.
Carbon stock change	

Measure	MRV and quantification requirements
Conversion of arable land to grassland to sequester carbon in the soil	This measure should be relatively easy to collect data on and monitor using LPIS and/or remote sensing technology.
Grassland management to enhance C sequestration	Measuring the impact of management activity is difficult and would require field scale measurement and monitoring over many years. However, models could be used to predict the effects with supporting ground truthing activities.
New agroforestry	Sequestration rates are well understood for woody biomass products and calculated measurements of the effect can be achieved through modelling and can be detected in the inventory, provided accurate activity data is available. Activity data should be straightforward to collect as there is a physical feature available for measurement. Remote sensing could be deployed for measurement of activity data. Remote sensing may also enhance the accuracy of measurement of biomass accumulation as technologies advance to identify species and densities of woody biomass.
Afforestation / avoiding deforestation	Sequestration rates are well understood for woody biomass products and calculated measurements of the effect can be achieved through modelling and detected in the inventory provided accurate activity data is available. Activity data should be straight forward to collect as there is a physical feature available for measurement. Remote sensing could be deployed for measurement of activity data. Remote sensing may also enhance the accuracy of measurement of biomass accumulation as technologies advance to identify species and densities of woody biomass.
Woodland and forestry management	Activity data for different management approaches is required along with a detailed understanding of the effect of the management on sequestration rates and indirect impacts of the use of the harvested wood products. This can be a complicated area as evidenced by the lack of quantitative data available.
Hedgerows and woody field margins	Activity data for different management approaches is required along with a detailed understanding of the effect of the management on sequestration rates and indirect impacts of the use of the harvested wood products. This can be a complicated area as evidenced by the lack of quantitative data in this summary. There is the potential for remote sensing to assess overall hedge size and possibly the biomass density.
Peatland/wetland maintenance and conservation	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Peatland/wetland restoration	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. This applies to drained peatland including farmed lowland peatland and grazed upland peat. Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Lowland peatland/wetland appropriate use	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Carbon stock change: More diverse and longer crop rotations	

Measure	MRV and quantification requirements
Land fallowing of arable cropland	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016).
Catch/cover crops	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016).
Carbon stock change: Cultivation practices on arable land (zero tillage & minimum tillage)	
Zero tillage	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Minimum tillage	Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification. Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.
Carbon stock change: Soil organic carbon and soil fertility improvement	
Retention of crop residues on fields	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and can be verified by inspection during farm visits
Mulching, ridge and furrow	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of the application of this practice.
Appropriate timing of field operations to avoid soil compaction	Measurement of the activity depends on farmer co-operation in sharing records of farm activities.
Substitution of fossil fuels and fossil materials: Renewable energy	
Production of biogas using biomass originating from agriculture and forestry, such as manure, crop residues, ligno-cellulosic materials, etc. (substitution effect with fossil-based energy)	Measurement of the activity in relation to feedstock depends on farmer co-operation in sharing records and allowing farm visits for verification. Measurement of emissions is not currently practical. However, measurements and modelling made in scientific studies can be used to estimate abatement when combined with activity data.
Solar and wind energy production on farmland (substitution effect with fossil-based energy)	Measurement of the activity can depend on farmer co-operation in sharing records of installations and allowing farm visits for verification.
Production of energy (electricity, heat) using woody biomass originating from agriculture and forestry, such as perennial woody and herbaceous biomass crops (SRC, miscanthus, switchgrass, common reeds, cardoon, etc.), crop residues, etc.	Measurement of the feedstock production depends on farmer co-operation in sharing records and allowing farm visits for verification.

Measure	MRV and quantification requirements
Production of biofuels/advanced biofuels using biomass originating from agriculture and forestry (substitution effect with fossil fuels, especially in the transport sector)	Measurement of the activity depends activity data for production and use of biofuels, including data from farms on areas of crops grown for this use.
Production of materials using biomass from agriculture and forestry, such as woody biomass or crop derived products (e.g., straw) (substitution effect with fossil-based materials)	Measurement of the activity requires activity data and supplier records from users of the materials.
Energy Efficiency	The response can be measures through the reduction in reported fuel and electricity usage. Allocating the effect to specific technologies implemented will be difficult unless additional data collection activities are undertaken.
Climate resilience measures: More diverse and longer crop rotations	
Rotations with perennial forage crops	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016), and this can be used to estimate the areas of crops by species.
Intercropping/ crop consociation	Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits.
Cross-cutting measures	
GHG emissions assessment and eco design	The use of an emissions assessment is a measurement tool and can be used to assess the effectiveness of farm scale activity and also aggregate effects if data is structure and collected appropriately

2.4 FINANCING

There are a range of financing opportunities at the EU level to support the implementation and following action of programmes and measures that will support the achievement of the NECP targets and therefore reduce climate impacts and environmental harm and increase climate resilience. These financing options are listed in the table below, with further detail in Appendix 3. The table below further suggests which topic the funding covers across the following elements: non-CO2 abatement measures, carbon stock exchange, substitution of fossil fuels and fossil materials and climate resilience.

Table 4 Funding options at the EU level

Funding options	Non-CO2 abatement measures	Carbon stock change	Substitution of fossil fuels and fossil materials	Climate resilience measures
CAP	X	X	X	X
Cohesion Fund	X	X	X	X
Just Transition Fund	X	X	X	X
ERDF: Interreg	X			X
ERDF: Investment for jobs and growth goal	X			X
Horizon	X	X	X	X
Innovation fund	X	X	X	
InvestEU	X		X	X
Programme for the environment and climate action (LIFE)	X	X	X	X
Technical support instrument[102]	X	X	X	
NextGenerationEU, including the Recovery and Resilience Facility (RRF)			X	X

Table 5: Other funding options beyond EU funding

Funding options	Non-CO2 abatement measures	Carbon stock change	Substitution of fossil fuels and fossil materials	Climate resilience measures
State aid	X	X	X	X
Carbon removal certification		X	X	X

[102] Technical Support Instrument (TSI) (europa.eu)

In the new programming period of 2023-2027, the **CAP** has higher environmental ambitions, and will contribute to the EU Green Deal, Farm to Fork strategy, and Biodiversity strategy. There is an emphasis on results and performance in this new modernised policy, with a strong focus on climate and environmental objectives. It is worth noting that in previous programming periods, CAP funding has been available but not necessarily used to its full potential. For example: in the previous EAFRD programming period, of the €2.3bn available to be spent on Investments in renewable energy production 45% was approved and only 26% (€602m) was spent. Likewise, of the €2.8bn allocated to Investments in energy efficiency: 48% was approved and 27% (€771m) spent. This shows a large potential for funding but also a need to work out what the blockages are in these projects being applied for and even once approved, that the projects are completed.

The **Cohesion Fund** encourages investments that support climate change adaption, risk prevention and disaster resilience, as well as access to water and sustainable water management. The **Just Transition Fund** is a new instrument under the cohesion policy 2021-2027, for alleviating the negative impacts of the transition towards climate neutrality focusing on the most affected regions (energy and fossil-fuel intensive regions). Support through the **ERDF** (both **ERDF: Interreg** and **ERDF: Investment for jobs and growth goal**) is related to all five policy objectives of the cohesion policy, including PO 2 – a greener, low-carbon transition towards a net-zero carbon economy and resilient Europe by promoting a clean and fair energy transition, green and blue investment, the circular economy, climate change mitigation and adaption, risk prevention and management and sustainable urban mobility.

A new element of the EU’s key research and innovation funding programme, **Horizon Europe**, are the 5 main missions, including the NECP relevant, ‘Adaption to climate change mission’, ‘Soil deal for Europe’, and ‘Climate neutral and smart cities mission’. Pillar II of Horizon revolves around 6 clusters, including Climate, Energy, and Mobility, and Food, Bioeconomy, Natural Resources, Agriculture, and Environment, both of which can fund agriculture and land use activity that can improve ambition in NECPs.

The **Innovation Fund** invests in energy-intensive industries, including products substituting carbon-intensive ones, renewable energy generation, energy storage, carbon capture and utilisation, and construction and operation of carbon capture and storage.

The **InvestEU** programme aims to boost green growth, innovation, and job creation in Europe by leveraging substantial private and public funds and mobilising private investment.

fund to support environmental and climate objectives, the **programme for the environment and climate action (LIFE)**, is the EU’s financial instrument supporting environmental, nature conservation, climate action and sustainable energy projects. There are four subprogrammes under the LIFE programme with the two key for NECP ambition being climate change mitigation and adaption, and clean energy transition.

Technical support instrument provides tailor-made technical expertise to EU Member States to design and implement reforms in a range of policy areas, notably the green transition (including the environment, the circular economy, climate action and the energy transition).

NextGenerationEU is the EU’s temporary recovery instrument to support economic recovery from the coronavirus pandemic, and to build a greener, more digital, and more resilient future. While NGEU provides funding to several programmes including React-EU, JTF, Rural Development, InvestEU, Horizon Europe, and RescEU, the key instrument at the heart of NGEU is the **Recovery and Resilience Facility** (RRF). The RRF legislation stipulates an expenditure target of 37% on the climate transition, evidencing its relevance to achieving the targets of NECPs.

The RRF is also at the heart of the **REPowerEU** plan, which has two urgent objectives: (1) ending the EU’s dependence on Russian fossil fuels, which are used as an economic and political weapon and cost European taxpayers nearly EUR 100 billion per year, and (2) tackling the climate crisis. The RRF is supporting coordinated planning and financing of cross-border and national infrastructure, as well as energy projects and reforms, which are to be implemented by Member States, by integrating dedicated REPowerEU chapters into Member States’ existing Recovery and Resilience Plans (RRPs).

An assessment of CSPs has shown that many Member States want to use **State aid** in addition to CAP funding. In this regard, it should be noted that the European Commission has adopted revised State aid rules for the agricultural and forestry sectors. The revised rules align State aid with the EU’s strategic priorities, in particular the CAP and the European Green Deal, as well as the Farm to Fork Strategy and the Biodiversity Strategy. The new State aid rules are:

1. The revised Agricultural Block Exemption Regulation (ABER[103]). This declares specific categories of aid compatible with EU State aid rules and exempts them from the requirement of prior notification to and approval by the Commission if they fulfil certain conditions. This enables Member States to quickly provide aid, where conditions limiting the distortion of competition in the Single Market are met. Based on the experience gained by the Commission, the new rules block-exempt up to 50% of cases which before were subject to notification.

   The main changes to the ABER include a significant extension of scope of block-exempted measures. In particular:

   - New categories of block-exempted measures, such as aid in favour of climate and environmental management commitments, including result-based carbon farming schemes, aid for cooperation in the agricultural and forestry sectors and purely nationally funded aid for forestry measures up to given thresholds.
   - Tailor-made block-exempted measures for Community-led Local Development projects aimed at promoting the development of rural areas on a local scale.
   - A new ceiling for European Innovation Partnership Operational Group projects aimed at innovations in the farming sector and in rural areas. Projects below EUR 500,000 or up to EUR 2 million per company can be now block-exempted.
2. The new Guidelines for State aid to the agricultural and forestry sectors and in rural areas (Agricultural Guidelines[104]). These set the conditions under which the Commission assesses whether State aid measures that are not block-exempted are compatible with the Single Market.

   The revised Agricultural Guidelines introduce the following main changes:

   - A new, simplified procedure for the authorisation of State aid for measures co-financed under the CAP.
   - New incentives for farmers to commit to schemes under which they respect stricter environmental standards than what is required by law.
   - A higher incentive for forest ecosystem services, collective schemes and result-based payments schemes, such as carbon farming schemes.

The new rules apply as of 1 January 2023.

The first **EU certification framework of carbon removals** (see section 2.3.7.2), proposed by the Commission on 30 November 2022, will be an important instrument moving towards the EU's goal of becoming the world's first climate neutral continent by 2050. This framework will encourage more business, land managers, and other stakeholders to contribute to carbon sequestration, and allow them to generate further income by being part of a harmonised and reliable certification framework.

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[103] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2022.327.01.0001.01.ENG&toc=OJ%3AL%3A2022%3A327%3ATOC

[104] EUR-Lex - 52014XC0701(01) - EN - EUR-Lex (europa.eu)

3 NATIONAL ENERGY & CLIMATE PLAN REPORTS (NECPR)

This section provides:

- *an overview of the NECPRs and the structure and details the specific reporting requirements within each section of the NECPRs. The focus is on the expectations of the Commission, setting out the points of assessment and providing explanation of what should be reported, with justification based on Governance Regulation.*
- *The annexes and tables highlighted here are all relevant to the land sector specifically, covering agriculture, LULUCF, energy supply and consumption (with a focus on biofuels and biomass), and waste (where relevant to biomass and sector-relevant waste).*

3.1 OVERVIEW

Article 17 of the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action (Governance Regulation)[105] requires that all Member States shall report to the Commission on the status of implementation of its integrated NECP by means of an integrated NECPR covering all five dimensions of the Energy Union:

1. decarbonisation,
2. energy efficiency,
3. security of supply.
4. the internal energy market, and
5. research, innovation, and competitiveness.

The NECPRs represent a key source of information for the Commission in their assessment of progress by Member States under Article 29 of the Governance Regulation. NECPRs shall be completed by 15 March 2023, and every two years thereafter.

The Commission, assisted by the Energy Union Committee referred to in point (b) of Article 44(1) of the Governance Regulation, shall adopt implementing acts to set out the structure, format, technical details, and process for the integrated NECPRs). The Commission Implementing Regulation (EU) 2018/1999 (Implementing Regulation) sets the structure, format, technical details, and process for the NECPRs[106]. In accordance with Article 21 of the Implementing Regulation, Member States shall use the e-platform referred to in Article 28 of the Governance Regulation and the linked tools and templates for the submission of their NECPRs.

3.2 NECPR STRUCTURE

The NECPR structure is set out under the Commission Implementing Regulation (EU) 2022/2299 laying down rules for the application of Regulation (EU) 2018/1999 of the European Parliament and of the Council as regards the structure, format, technical details and process for the integrated NECPRs.

National energy and climate plan reporting is undertaken in a single template that builds on the structure of the NECPs: first covering progress achieved towards reaching objectives, targets and contributions in all five dimensions of the Energy Union, then reporting on PaMs and progress achieved, and lastly, other reporting obligations are provided, including additional reporting based on Annex IX of the Governance Regulation for renewable energy and energy efficiency elements, additional reporting on energy poverty, reporting of information on implementation of regional cooperation, recommendations referred to in Articles 32(1) or (2) of the Governance Regulation, multilevel climate and energy dialogue referred to in Article 11 of the Governance Regulation and reporting on just transition aspects.

[105] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0001.01.ENG&toc=OJ:L:2018:328:TOC
[106] L_2022306EN.01000101.xml (europa.eu)

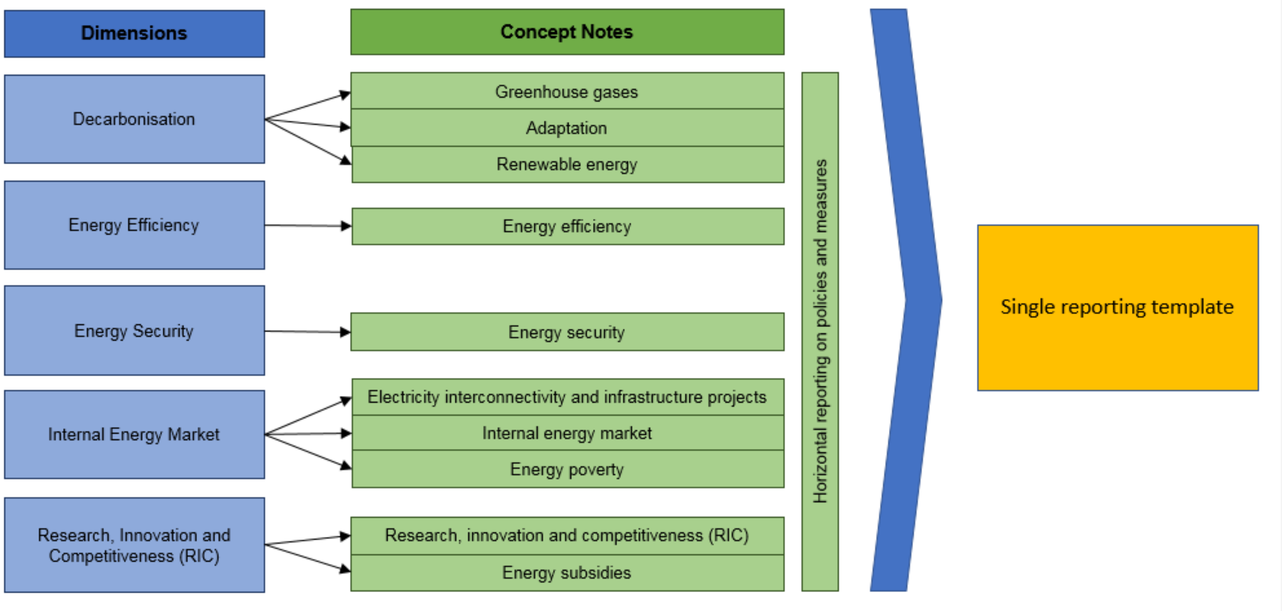

Figure 5. NECPR Structure

3.3 NECPR REQUIREMENTS

Within the NECPR, there are a range of reporting templates that enable Member States to report on progress in the Energy Union dimensions. There are several reporting tables that are specifically related to agriculture, LULUCF, and bioenergy, as well as tables where progress in these sectors can be reported on if applicable or available.

The following table outlines the relevant annexes and tables for reporting on Member State progress across the agriculture, LULUCF, and bioeconomy and bioenergy sectors, covering targets and objectives, PaMs, and other requirements.

Table 16:6 Relevant NECPR annexes and tables to the land sectors

Annex	Table	Area covered	Relevant scope
Annex I – Decarbonisation: GHG Emissions & Removals	Table 1	National progress towards national GHG emissions reduction targets	Data on current and projected progress towards GHG emissions targets
	Table 3	Current and projected progress towards commitments pursuant to the LULUCF Regulation (Regulation (EU) 2018/841)	All table data
	Table 4	Current and projected progress towards other national GHG related targets and objectives set out in integrated NECPs	Data on relevant sector targets
Annex II – Decarbonisation: Renewable Energy	Table 1	Sectoral shares of energy from renewable sources	Data on relevant reporting on biogas production
	Table 2	Total installed capacity from each renewable energy technology	Data on installed capacity from biomass and biofuels
	Table 3	Total actual contribution from each renewable energy technology in electricity	Data on biofuels
	Table 4	Total actual contribution from each renewable energy technology in heating and cooling	Data on biofuels

Annex	Table	Area covered	Relevant scope
	Table 5	Total actual contribution from each renewable energy technology in the transport sector	Data on biofuels
	Table 6	Biomass supply for energy use	All table data
Annex IX – Policies and Measures	Table 1	Progress towards implementing policies and measures	Data on sector reporting from LULUCF and agriculture, as well as renewable energy including biomass/biofuels
Annex XIV – Air Quality	Table 1	Impacts on air quality and emissions to air	All table data
Annex XV – Energy Subsidies	Table 1	Policies and measures to phase out energy subsidies	Data on sector reporting for LULUCF and agriculture, as well as renewable energy including biomass/biofuels
Annex XVI – Renewable Energy (additional reporting)	Table 2	Changes in commodity prices and land use associated with the use of biomass	All table data
	Table 4	Estimated excess production of energy from renewable sources compared to the national trajectory towards 2030 target	Data on development and deployment of biofuels made from feedstocks
	Table 5	Estimated impact of the production or use of biofuels on biodiversity and natural resource quality	All table data
	Table 7	Share of biodegradable waste in waste-to-energy plants used for producing energy	All table data
	Table 8	Electricity and heat generation from renewable energy in buildings	Data on biomass
	Table 9	Amount of solid biomass used for energy production	All table data, with a focus on 'other', which includes data from agriculture and forestry sectors
Annex XVII – Energy Efficiency	Table 1	Progress in each sector and reasons why energy consumption remained stable or was growing in final energy consumption sector	Data on sector reporting for agriculture, and LULUCF where applicable under 'other'

The reporting template for the NECPR are colour coded, which is used to identify where data needs to be reported directly by the Member State and where data may be reused from other sources. All mandatory data fields need to be completed, but from some fields the data can be derived from other sources. In some cases, the data can be automatically pre-filled, or automatically calculated. The reporting fields in the template have also been colour coded to help Member States to understand which fields need to be completed by Member States, and which are pre-filled/populated or automatically calculated (see table below). These differences are highlighted in the table explanations below.

Table 17:7 Colour coding of the NECPR reporting template

Colour coding	Description
	Data provided by Member State
	Pre-filled data (data provided into the reporting from another database (such as Eurostat)). As a principle, data should not be altered in the progress reporting, but rather through the process established for the source data. GHG data will be pre-filled from final data of submissions made in the same year to Article 26(3) and Article 18. Member States will be informed at submission to these Articles that the data is also considered valid for Article 17 reporting. There will be no need to confirm this data as Article 17(3) prescribes the data to be used in progress reports.

	Pre-populated data (data manually pre-populated into the reporting from another source). Data will be checked, validated and confirmed by the Member States. GHG data will be pre-populated from legislation. No validation and confirmation is required.
	Automatically calculated
	Not applicable to this reporting element

3.3.1 Annex I – Decarbonisation: GHG Emissions & Removals[107]

3.3.1.1 Table 1 - Current and projected national progress towards the national GHG emissions reduction targets in view of climate-neutrality by 2050

The purpose of this table is to report on national progress towards national GHG emissions reduction targets. Regarding the land sector, the role of removals, total GHG emissions excluding LULUCF, excluding international aviation, and total GHG emissions including LULUCF, excluding international aviation, should be reported on to provide an estimate on the total GHG emissions from the LULUCF sector. It is important to report on LULUCF targets, as previously submitted NECPs lacked data on progress towards LULUCF commitments.

Relevant reporting element(s):

Climate neutrality

- Mandatory, if applicable[108].
- Member States to provide the target year for climate neutrality.
- If national climate-neutrality objective is in place, targeted year for climate-neutrality.

Role of removals

- Mandatory, if applicable.
- Member States to provide GHG emissions targets and removals for 2030, 2040, and/or 2050.
- If national total GHG emissions target for 2030, 2040 or 2050 is in place, total estimated removals for the target year respectively. If national climate-neutrality objective is in place, total estimated removals for the target year of climate-neutrality in ktCO2e.

National GHG targets for 2030 and beyond, if available, and indicative milestones for 2040 and 2050

- Mandatory, if applicable.
- Provided by Member States according to information in current integrated NECP (*Objectives and targets consistent with the Paris Agreement and the existing long-term strategies*) and conforming to its long-term strategy reported under Article 15 of Regulation (EU) 2018/1999.
- Member States to provide the targets for 2030, 2040, and 2050.
- Indirect CO2-emissions should also be reported on.

The following elements are included in this table and are relevant, but data are pre-filled from other databases, such as Eurostat, or automatically calculated: *Historic emissions; Article 18 WEM and WAM scenarios; Current progress on the difference between historical data and values in line with national GHG target path; and Projected progress on the difference between WEM and WAM scenarios and values in line with national GHG target path.*

[107] Annexes to the Commission Implementing Regulation laying down rules for the application of Regulation (EU) 2018/1999 of the European Parliament and of the Council as regards the structure, format, technical details and process for the integrated national energy and climate progress reports.

[108] Member states must provide progress towards quantitative or qualitative objectives, if these objectives have been set

3.3.1.2 *Table 3 - Current and projected progress towards commitments pursuant to the LULUCF Regulation (Regulation (EU) 2018/841)*

The purpose of this table is to report on current and projected progress towards commitments in the LULUCF Regulation. This is important to report on LULUCF targets, as previously submitted NECPs lacked data on progress towards LULUCF commitments.

Relevant reporting element(s):

LULUCF commitment stated in current NECP

- Mandatory, if applicable.
- The individual national LULUCF commitment as stated in current integrated NECPs. Member States should note that this commitment will be updated to reflect the new LULUCF amendments once ratified later this year.
- Member States to provide textual description in column “Description”.
- Member States to provide numerical data in columns under “Year” and indicate the Unit and GWP used in the respectively titled columns.

The following elements are included in this table and are relevant, but data are pre-filled from other databases, such as Eurostat*: Land Use, Land-Use Change and Forestry; and Land Use, Land-Use Change and Forestry in the WEM and WAM scenarios.* For these elements, a description should be provided by the Member State, if available.

3.3.1.3 *Table 4 - Current and projected progress towards other national GHG related targets and objectives set out in integrated NECPs*

The purpose of this table is to report on the current and projected progress towards other national GHG related targets and objectives set out in integrated NECPs in other sectors, such as agriculture, if applicable.

Relevant reporting element(s):

Target/ Objective

- Mandatory[109].
- Member States to provide textual description in the column “Name of the national target or objective”, “Sector(s) addressed”, and “Description”.
- Textual description to be provided for clarification and in case targets / objectives and progress towards these cannot be expressed using the quantitative columns.
- Member States to indicate the Unit and GWP used, and quantitative data in the respectively titled columns.

Current progress

- Member States to provide quantitative data on current progress 3 and 2 years prior to the reporting year.

Project progress under WEM and WAM scenarios

- Member States to provide quantitative data on projected progress in the first future year ending with 0 or 5 immediately following the reporting year, and then 5 and 10 years subsequently.

Member States should add additional rows below where required to fill out information for all other national GHG related targets set out in the NECPs.

[109] Member states must provide progress towards quantitative or qualitative objectives, if these objectives have been set.

3.3.2 Annex II – Decarbonisation: Renewable Energy Sources

3.3.2.1 *Table 1 - Sectoral and overall shares of energy from renewable energy sources*

The purpose of this table is to report on the different sectoral and total shares of energy that come from renewable energy sources (RES). Member States here should focus on RES from biomass and biofuels.

Relevant reporting element(s):

Indigenous renewable hydrogen production

- Voluntary[110].
- Member States to provide quantitative data on sectoral energy shares 3 and 2 years prior to the reporting year.

Indigenous biogas

- Voluntary.
- Member States to provide quantitative data on sectoral energy shares 3 and 2 years prior to the reporting year.

There are several other reporting elements in this table, but they are all pre-filled from other data sources.

3.3.2.2 *Table 2 - Total installed capacity from each renewable energy technology*

The purpose of this table is to report on the total installed capacity from each renewable energy technology. Member States here should focus on RES from biomass and biofuels. All the relevant reporting elements in this table are pre-filled.

To note, as defined in Directive (EU) 2018/2001, 'biomass' means the biodegradable fraction of products, waste, and residues from biological origin from agriculture, including vegetal and animal substances, from forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin.

In case of blended solid or gaseous biomass fuels or bioliquids, only the capacity corresponding to the bio part should be considered. If no capacity data is available then Member States should provide an estimate based on inputs, efficiencies, generation, and full load hours of both fossil and RE fuels.

As defined in Directive (EU) 2018/2001 Article 2 Definitions (27) 'biomass fuels' means gaseous and solid fuels produced from biomass.

3.3.2.3 *Table 3 - Total actual contribution (gross electricity generation) from each renewable energy technology in electricity*

The purpose of this table is to report on the total actual contribution (installed capacity) from each renewable energy technology to meet the 2030 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity. Member States here should focus on RES from biomass and biofuels. All the relevant reporting elements in this table are pre-filled.

3.3.2.4 *Table 4 - Total actual contribution (gross final energy consumption) from each renewable energy technology in heating and cooling*

The purpose of this table is to report on the total actual contribution (installed capacity) from each renewable energy technology to meet the 2030 targets and the indicative interim trajectory for the shares of energy from renewable resources in heating and cooling. Member States here should focus on RES from biomass and biofuels. All the relevant reporting elements in this table are pre-filled.

3.3.2.5 *Table 5 - Total actual contribution (gross final energy consumption) from each renewable energy technology in the transport sector*

The purpose of this table is to report on the total actual contribution (installed capacity) from each renewable energy technology to meet the 2030 targets and the indicative interim trajectory for the shares of energy from

[110] Members states can provide optional information.

renewable resources in the transport sector. Member States here should focus on RES from biomass and biofuels.

Relevant reporting element(s):

Compliant biofuels in transport

- This includes only compliant biofuels and biomass fuels (Articles 29 & 30 of Directive (EU) 2018/2001), pure and corresponding renewable part of blended fuels used in transport.
- This section includes reporting on biofuels for different transport modes, feedstocks, and sectors.

There are a number of other relevant reporting requirements in this table relating to biofuels, feed and food crops, and feedstocks, which are all pre-filled.

3.3.2.6 Table 6 - Biomass supply for energy use

The purpose of this table is to report on the biomass supply for energy use from different sources, covering indigenous production, imports, exports, stock changes, and average net calorific value. All reporting elements are relevant and are all pre-filled.

There are two separate reporting elements that should be filled out by Member States under this table:

For forest biomass: Description how these meet the land-use, landuse change and forestry (LULUCF) criteria of Article 29(7) of Directive (EU) 2018/2001

- Member States to provide textual description in column "Description".
- With per country or regional economic integration organisation of origin of the forest biomass, detailing whether the country or organisation is a Party to the Paris Agreement and:
    - it has submitted a nationally determined contribution (NDC) that includes the LULUCF sector;
    - it reports to the UNFCCC a national GHG emission inventory that includes the LULUCF sector or will start doing so by 2025 at the latest; or
    - it has national or sub-national laws in place, in accordance with Article 5 of the Paris Agreement, applicable in the area of harvest, to conserve and enhance carbon stocks and sinks, and provides evidence that reported LULUCF-sector emissions do not exceed removals.

Relevant information in case the evolution on bioenergy supply has an impact on the overall and sectoral trajectories for renewable energy from 2021 to 2030.

- Member States to provide textual description in column "Description".

3.3.3 Annex IX – Policies and Measures

3.3.3.1 Table 1 – Key characteristics and progress towards implementing policies and measures

The purpose of this table is to report on policies and measures (PaMs) that can support all dimensions of the Energy Union, based on the PaMs set out in the NECP. As such, there are a number of required reporting elements for each PaM, some with specific objectives and targets depending on the dimension or sector that are relevant for PaMs related to the land sector. Member States should note that reporting on the PaMs sections of the NECPRs should be done in conjunction with PaMs stated in the NECPs and CAP strategic plans.

Relevant reporting element(s):

Relevant objective(s), target(s) the PaM contributes to

- Mandatory.
- Member States should select from the following (more than one can be selected):
    - In dimension **Decarbonisation: GHG emissions and removals** – Member State's binding national target for greenhouse gas emissions and the annual binding national limits pursuant

to Regulation (EU) 2018/842; Member State's commitments pursuant to Regulation (EU) 2018/841; Other objectives and targets, including sector targets and adaptation goals.

  - In dimension **Decarbonisation: Renewable energy** – Estimated trajectories per renewable energy technology (biomass focus); Estimated trajectories on bioenergy demand, disaggregated between heat, electricity and transport, and on biomass supply, by feedstock and origin; Other national trajectories and objectives, including those that are long-term or sectoral (e.g. share of renewable energy in district heating, renewable energy use in buildings, renewable energy produced by cities, renewable energy communities and renewables self-consumers, energy recovered from the sludge acquired through the treatment of wastewater)

Geographical coverage

- Mandatory.
- Member States shall select from the following categories: covering two or more countries, national, regional, local.

Sectors affected

- Mandatory.
- Member States shall select from the following sectors (more than one sector can be selected for cross-sectoral policies and measures):
  - Energy supply (comprising extraction, transmission, distribution, and storage of fuels as well as the transformation of energy for heating and cooling and electricity production), where related to biomass and biofuels.
  - Energy consumption (comprising consumption of fuels and electricity by end users such as relevant industry and agriculture). Energy consumption for all sectors should be selected where related to biomass and biofuels.
  - Agriculture.
  - LULUCF.
  - Waste management/waste, specifically where related to the land sector and waste that comes from the agriculture, forestry, and biomass renewables.
  - Other applicable sectors.

Objective

- Objective means 'initial statement of the outcomes (including results and impacts) intended to be achieved by the intervention'.
- Member States shall select from the following objectives (more than one objective may be selected, additional objectives may be added and specified under 'other'):
  - For **energy supply** — increase in renewable energy sources in the electricity sector (biofuels and biomass); increase in renewable energy in the heating and cooling sector (biofuels and biomass); switch to less carbon-intensive fuels; carbon capture and storage or carbon capture and utilisation; increase the number of sources used in primary energy generation; increase the ability of the power network to absorb increased share of renewable generation; other energy supply.
  - For **energy consumption** — efficiency improvement in industrial end-use sectors (e.g., agriculture); other energy consumption.
  - For **agriculture** — reduction of fertilizer/manure use on cropland; other activities improving cropland management; improved livestock management; improved animal waste management systems; activities improving grazing land or grassland management; improved management of organic soils; other agriculture.
  - For **LULUCF** — afforestation and reforestation; conservation of carbon in existing forests; enhancing production in existing forests; increasing the harvested wood products pool; enhanced forest management; prevention of deforestation; strengthening protection against natural disturbances; substitution of GHG intensive feedstocks and materials with harvested

wood products; prevention of drainage or rewetting of wetlands; restoration of degraded lands; other LULUCF.

- For **waste management/waste (where specifically related to the land sector)** – demand management/reduction; enhanced recycling; enhanced CH4 collection and use; improved treatment technologies; improved landfill management; waste incineration with energy use; improved wastewater management systems; reduced landfilling; other waste.

The following elements are included in this table and relevant and must be filled out by the Member State, but guidance on these is general and provided in the NECPR template: *PaM number in NECP, if different; Name of policy or measure; Single or grouped PaM; In case of grouped PaM, which single PaMs does it cover; Geographical coverage; Quantified objective; Short description… (see NECPR templates for others).*

3.3.4 Annex XIV – Impacts on air quality and emissions to air

3.3.4.1 Table 1 – Impacts on air quality and emissions to air

The purpose of this table is to report on PaMs supporting the reduction emissions to air and impacts on air quality. This table covers non-CO2 pollutants, such as SO2, NOx, NMVOC, NH3, PM2.5, and others, many of which come of agriculture sources.

Relevant reporting element(s):

Affected pollutant(s)

- Mandatory.
- Member States to select from the following pollutants (additional pollutants may be added and specified under ‘other’): SO2, NOx, NMVOC, NH3, PM2,5, other.

Quantified expected emission impacts (kt/yr)

- Mandatory, if available[111].
- Member States shall report expected increases in emissions as positive numbers or ranges, whereas expected reductions in emissions are shown as negative numbers or ranges.

The following elements are included in this table, are relevant and must be filled out by the Member State, but guidance on these is general and provided in the NECPR template and other guidance: *Reference year, General comments; Documentation/ Source of methodologies; Qualitative assessment of expected emission impacts; Details of the methodologies used for analysis; Qualitative description of uncertainties (where available).*

3.3.5 Annex XV – Energy Subsidies

3.3.5.1 Table 1 - Policies and measures to phase out energy subsidies

The purpose of this table is to report on the phasing out of energy subsidies, in particular for fossil fuels, through a range of PaMs. The entire table is pre-populated data (data manually pre-populated into the reporting from another source). However, data will need to be checked, validated and confirmed by the Member States.

Relevant reporting element(s):

Sector

- Member States should select from the following sub-sectors within each sector:
    - **Energy sector** (ENER-Fossil fuel extraction; ENER-Energy crops; ENER-Conversion-Liquid biofuels; ENER-Conversion-Biogas production; ENER-Conversion-Hydrogen production; ENER-Waste management).
    - **Agriculture** (AGRI-Crop, animal production, hunting; AGRI-Forestry and logging; AGRI-Fishing and aquaculture).

Carrier

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[111] Member states must consider these fields mandatory and leave them empty only if the information is not available.

- Member States should select from one or more from the following sub-carriers within each option:
    - **Fossil fuels** (FF-Peat)
    - **Bioenergy** (RES-Biogas; RES-Biomass & biogas; RES-Biomass (solid); RES-Biomass MSW; RES-Liquid biofuels; RES-Liquid biofuels-Biodiesel; RES-Liquid biofuels-Bioethanol);
    - **Hydrogen** (RES-Biogas).

3.3.6 Annex XVI – Renewable Energy (additional reporting)

3.3.6.1 Table 2 - Changes in commodity prices and land use associated with the use of biomass

The purpose of this table is to report on changes in commodity prices and land associated with the use of biomass. Reporting in this table is essential for understanding price fluctuations particularly related to biomass.

Relevant reporting element(s): *Report changes in commodity prices and land use within the Member State associated with its increased use of biomass and other forms of energy from renewable sources*

- Mandatory, if applicable.
- Changes in commodity prices to be reported at national level (or subnational if applicable). These include any shifts in prices related to food and feed crops. (Increased price for food/feed product due to increased energy use of the same feedstock). These also include shifts in prices related to increased demand for forest biomass for energy use – i.e., shifts in prices for material products made from waste and residue due to increased energy use and competition for feedstock.
- For land-use change, Member States should only report the actual change in land used for biomass consumed for energy, not all agricultural land.

3.3.6.2 Table 4 - Estimated excess production of energy from renewable sources compared to the national trajectory towards 2030 target

The purpose of this table is to report on the excess production of energy from renewable sources compared to the national trajectory towards the 2030 target, with specified reference to energy produced from biomass and biofuels.

Relevant reporting element(s):

Reporting on technological development and deployment of biofuels in your country made from feedstocks listed in Annex IX to Directive 2018/2001

- Mandatory.
- Deployment can be reported in installed capacities and actual production of different advanced biofuels based on different technologies. As well as the number of installations and feedstock type. Development could list the different technology pathways and give a brief description of their status in a qualitative manner (development phase, how close to market uptake, recent developments, investments).

3.3.6.3 Table 5 - Estimate impact of the production or use of biofuels on biodiversity and natural resource quality

The purpose of this table is to report on the estimated impacts of the production or use of biofuels on the following areas: *Biodiversity, Water stock (groundwater, surface water) and water availability, Soils, Air quality*.

For each area, there are several reporting elements that need to be provided by Member States.

Relevant reporting element(s):

Estimated impact of production of biofuels, bioliquids, and biomass

- Mandatory if available.

- Estimated impacts and the methods used can be described in quantitative and qualitative manner. If quantitative impacts are described, Member States should specify the Unit and the Time period they relate to.

Estimated impact of use of biofuels, bioliquids, and biomass

- Mandatory if available.
- Can be described in quantitative and qualitative manner. If quantitative impacts are described, Member States should specify the Unit and the Time period they relate to.

Description of methods to estimate the impacts (of production and of use)

- Mandatory if available.
- Can be described in quantitative and qualitative manner. If quantitative impacts are described, Member States should specify the Unit and the Time period they relate to.

3.3.6.4 Table 7 - Share of biodegradable waste in waste-to-energy plants used for producing energy

The purpose of this table is to report on the share of biodegradable waste used in waste-to-energy plants for energy production. As this table covers reporting on the share of biodegradable waste used for energy production, this is important for Member States to report on to understand how various shares of waste from the land sector (and other sources of biodegradable waste) are used.

Relevant reporting element(s):

Are waste-to-energy plants operated?

- Member States should state 'Yes' or 'No'. If yes, Member States should report on the following elements:
  - *Share of biodegradable waste used (%)*
  - *Methodology for estimating the share*
  - *Steps taken to improve and verify the estimates*

3.3.6.5 Table 8 - Electricity and heat generation from renewable energy in buildings

The purpose of this table is to report on electricity and heat generated and consumed from renewable energy in buildings. Member States here should focus on reporting on electricity and heat generated from biomass specifically. All the following reporting elements are mandatory, if the data is available, and should be report in ktoe. It should be noted that here, biomass is defined as biomass produced in accordance with the sustainability criteria for biofuels, bioliquids and biomass fuels, laid down in Article 29 of Directive (EU) 2018/2001. Member States to provide quantitative data on sectoral energy shares 3 and 2 years prior to the reporting year.

Relevant reporting element(s):

Total final energy consumption from renewables in buildings for heating purposes (biomass)

Total renewable heat consumed in buildings (biomass)

Total renewable heat produced and fed into the grid (district heating) (biomass)

Total renewable electricity production in buildings (biomass)

Total renewable electricity consumption in buildings (biomass)

Total renewable electricity fed into grid (biomass)

3.3.6.6 Table 9 - Amount of solid biomass used for energy production

The purpose of this table is to report on the amount of biomass used for energy production, depending on the sector. The data in this table is pre-filled data (data provided into the reporting from another database, such as Eurostat). As a principle, data should not be altered in the progress reporting, but rather through the process established for the source data. All reporting elements are mandatory. The data provided will be quantitative data on current progress 3 and 2 years prior to the reporting year.

Relevant reporting element(s):

Energy sector (total)

- Sub-sections on Electricity, Combined heat and power, and Heat
- Amounts of biomass used in the related sector, also covering transformation losses.

Transformation sector (except for energy)

- Amounts of biomass used in the related sector, also covering transformation losses.

Industry sector internal (consumed and auto-produced electricity, CHP and heat)

- Amounts of biomass used in the related sector, also covering transformation losses.

Direct final consumption residential

- Amounts of biomass used in the related sector, also covering transformation losses.

Other

- Amounts of biomass used in the related sector, also covering transformation losses.
- This includes, among others, agriculture, forestry and commerce, trade, and services.

3.3.7 Annex XVII – Energy Efficiency (additional reporting)

3.3.7.1 Table 1 - Progress in each sector and reasons why energy consumption remained stable or was growing in final energy consumption

The purpose of this table is to report on progress in the agriculture and other relevant sectors in energy consumption stability or growth. Member States should focus on the agriculture and other relevant sectors.

Relevant reporting element(s):

Agriculture

- Mandatory.
- Member States to choose from the following reasons (more than one reason can be selected, additional reasons can be specified under ‘other’): Economic growth; Decline of fuel prices; Increase of value added; Increase of employment; Increase of transport of goods; Increase of transport of passengers; Increase of population and/or households; Increase of disposable income of households; Worsening of winter climatic conditions; Worsening of summer climatic conditions; Exceptional event; Change in the methodology of measurement or calculation of energy consumptions; other.

Other sectors

- Mandatory, if applicable.
- Additional sectors may be added and specified under ‘other’.
- Member States to choose from the following reasons (more than one reason can be selected, additional reasons can be specified under ‘other’): Economic growth; Decline of fuel prices; Increase of value added; Increase of employment; Increase of transport of goods; Increase of transport of passengers; Increase of population and/or households; Increase of disposable income of households; Worsening of winter climatic conditions; Worsening of summer climatic conditions; Exceptional event; Change in the methodology of measurement or calculation of energy consumptions; other.

4 NATIONAL ENERGY & CLIMATE PLAN (NECP) UPDATES

This section discusses:

- *The guidance for NECP updates, focusing on how Member States can increase their ambition by introducing enhanced policies and measures.*
- *The structure of the NECPs and highlights requirements and important sections where Member States can improve their contributions towards the climate and energy related ambition in the land sector, through the introduction of new policies and measure and the enhancement of existing measures.*

4.1 OVERVIEW

The national energy and climate plans (NECPs) are the strategic planning tool under the Governance Regulations. They should be used as a tool to help Member States to plan and deliver together on energy and climate objectives under the European Green Deal, the European Climate Law and the Fit for 55 package, while also taking into consideration more recent developments and plans such as the REPowerEU.

To ensure that the plans are in line with the EU targets and that Member States set the right level of ambitions, they shall be updated regularly. Since the first submissions in 2018-2019 Member States are now asked to update their national plans for 2021-2030 by June 2023 (draft plans) and June 2024 (final plans). The updated plans are expected to be bring more ambitious targets and actions and to deliver a faster energy transition.

This guidance will focus on the role of the agriculture and LULUCF sectors and how Member States should consider increasing their ambitions while introducing new and enhanced policies and measures.

This document should be read together with the "Guidance to Member States for the update of the 2021-2030 national energy and climate plans" published by the European Commission in December 2022[112]. In this guidance, the Commission set the following principles (partial selection):

- Member States shall set higher ambition to speed up the green transition to climate neutrality and reinforce resilience of the energy system in line with the Climate Law, Fit for 55 package and REPowerEU.
- Set out objectives and targets to reduce methane emissions and integrate increased targets as well as mitigation and adaptation measures in the land-use, forestry, and agriculture sectors, regarding CO_2 and non-CO_2 emissions and carbon removals.
- Explore synergies between the objectives, targets and contributions, and policies and measures of the five dimensions of the Energy Union.

4.2 NECP STRUCTURE

The NECP binding structure is defined in Annex I of the Regulation on the governance of the energy union and climate action (EU)2018/1999 and covers the five dimensions of the Energy Union, as referred to in Article 1(2) of Governance Regulation. These are: energy security, internal energy market, energy efficiency, decarbonisation and research, innovation, and competitiveness.

While planning actions for the land-use, forestry and agriculture sector, the following sections of the NECP should be particularly considered:

[112] https://energy.ec.europa.eu/system/files/2022-12/C_2022_9264_1_EN_ACT_part1_v2%20%281%29_0.pdf

4.2.1 Part 2: National Objectives & Targets: Dimension decarbonisation:

4.2.1.1 *Section 2.1.1 GHG emissions and removals (i): the elements set out in point (a)(1) of Article 4*

Article 4(a)(1.ii) refers to Member States' commitments pursuant to Regulation (EU) 2018/841[113] which is the regulation regarding the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, referred as the LULUCF regulation.

Therefore, considering the above regulations and enhanced targets, in section 2.1.1(i) of the NECPs Member States should state how they intend to increase their ambitions in this sector. In particular:

- Member States should fully clarify how they plan to comply with the commitment under the revised LULUCF regulation and explain how LULUCF emissions will not exceed removals, including how they are planning to make use of LULUCF flexibilities.

Guidance based on previous year NECPs submissions

Key for credible LULUCF accounting is establishing an accurate benchmark, the so-called Forest Reference Level (FRL), proposed by Member States in their National Forestry Accounting Plans (NFAPs). During the 2018-2019 submissions, Member States had an additional difficulty in setting targets under this sector, as the forest reference level was not yet agreed with the Commission.

Since then, Member States have submitted their NFAPs to the Commission, including these reference levels. Therefore, in the updated NECP, Member States should clearly state the overall forest reference level and comparing this with the LULUCF emissions projection, they should provide a clear explanation on how and if the flexibilities between the ESR and LULUCF Regulation will be used to achieve the “no-debit” rule, i.e., emissions will not exceed removals in relation to the reference period 2005-2009. Member States can in fact either decide to use ESR allocations to fulfil the LULUCF no debit requirement or use additional net removals from LULUCF to comply with ESR.

The plan should also explain the foreseen role of forestry in the country, for example, one Member State stated that their forestry sector is likely to change in terms of CO2 sinks due to extraordinary logging related to the elimination of bark beetle calamity. For these reasons, it is likely that the category of the managed forest land will temporarily show CO_2 emissions.

If the Member States estimates that over the period 2021-2030, will generate LULUCF credits, which will then be used to comply with its commitments in the ESR, it is expected the NECP explains in detail how these credits will be generated, and should also confirm if the ESR flexibility will be used.

When stating the targets in the LULUCF and agriculture sector, Member States are also invited to include a reference to the major policies and measures which will be used. In particular, synergies between agriculture with LULUCF and renewables should be emphasised. These could include biogas plants, land management for better nitrogen retention and organic farming.

4.2.1.2 *Section 2.1.1 GHG emissions and removals (ii): Where applicable, other national objectives and targets consistent with the Paris Agreement and the existing long-term strategies. Where applicable for the contribution to the overall Union commitment of reducing the GHG emissions, other objectives and targets, including sector targets and adaptation goals, if available*

Member States shall explain how they plan to contribute to the EU forestry strategy and the EU biodiversity strategy, as well as the objectives and targets relevant to the agriculture and LULUCF sectors under the relevant EU policies, and in any Member State level laws or strategies. Each Member State should state:

- Objectives, milestones and timeline in relation to the EU target to protect at least 30% of the EU land area.

[113] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.156.01.0001.01.ENG

- Objectives, milestones and timeline in relation to the EU target to put under strict legal protection 10% of the above-mentioned protected land.
- Objectives, milestones and timeline in relation to the EU expected legally binding instrument for ecosystem restoration, this will include targets for restoring forest ecosystems.

Objectives, milestones and timeline in relation to the EU pledge to plant at least 3 billion additional trees by 2030 in full respect of ecological principles with long-term planning and monitoring. There will also be other relevant objectives and targets under EU policies and in national laws and strategies that should be included. This will be elaborated on in the final guidance. Additionally, Member States can refer to the Draft Commission Notice on the 'Guidance to Member States for the update of the 2021-2030 national energy and climate plans', which was released in December 2022.

Guidance based on previous years NECPs submissions

Examples of other objectives:

Agriculture

- To reduce direct and indirect emissions of N2O and CH4 by x% by applying the principles of agroecology and high-precision agriculture by 2025, 2030 and 2050.
- To reduce CO_2 emissions by x% linked to the consumption of fossil fuels and increasing the use of renewable energies in the agriculture and land sector by 2025, 2030 and 2050.
- Achieve a specific target for carbon stored in agricultural soils to be removed, in keeping with the initiative '4p1000, soils for food security and the climate';

4.2.1.3 *Section 2.1.2 Renewable energy (iv): estimated trajectories for forest biomass, an assessment of its source and impact on the LULUCF sink*

When estimating trajectory for forest biomass, Member States should consider bioenergy as a whole, and ideally provide demand and supply information.

For the **demand** side, the following should be considered: in the **electricity** sector, data on solid biomass, biogas, landfill gas, biodegradable municipal waste, and sewage sludge gas; in the **heating & cooling** sector, data on solid biomass and biogas; in the **transport** sector, data on bioethanol and biodiesel.

For **supply** side, data on domestic production or imports should be provided for bioenergy from forestry, agricultural crops, agricultural residues and from waste.

Ideally, Member States should set milestones, objectives, and targets in relation to bioenergy demand, disaggregated by sectors, imports etc.

The country should then explain how the use of biomass could impact on the LULUCF sink targets and projections and if there are national agreements and legislations which ensure that biomass used in the country fulfils internationally recognized sustainability demands and thus, the biomass must come from forests that are operated in a sustainable way, and the use of biomass must lead to real CO_2 reductions.

Member States should also explain whether the sustainability of the used biomass is documented in annual reports and which parties/sectors are obliged to report.

Moreover, it is important that the Member States explains how the use of biomass will impact on the forestry levels, and if there are specific regulations which aim to maintain the existing forests and increase the forest area, and how these will interact with the production and use of biomass.

Finally, Member States should also state whether the sustainability criteria of the revised renewable energy directive have been implemented.

4.2.2 Part 3: Policies and measures: Dimension decarbonisation

4.2.2.1 *Section 3.1.1 GHG emissions and removals (i): […] Policies and measures to comply with Regulation (EU) 2018/841 [LULUCF], covering all key emitting sectors and sectors for the enhancement of removals, with an outlook to the long-term vision and goal to become a low emission economy and achieving a balance between emissions and removals in accordance with the Paris Agreement*

In Part 3 of the NECP, Member States shall describe the implemented, adopted, and planned policies and measures which will be necessary to achieve the objectives and targets mentioned under Part 2 of the same document.

Member States can structure this information using different approaches, such as a simple list of measure, tabular formats, graphs, etc. Nevertheless, it is necessary that quantifiable information on specific measures or strategies that can enhance LULUCF sink, and promote bioeconomy is clearly provided and explained.

Examples on how to structure this section, based on best practiced from the first final NECPs submissions are provided below.

Guidance based on previous year NECPs submissions

The section could be divided by sector, and for each sector relevant policies are described, for example:

Policies and measures in relation to agriculture

- Planned policies and measure shall be described, including a description of national plans which set out a holistic vision of the transformation of agricultural practices
- Quantitative targets and objectives shall be stated, e.g., target percentage of utilised agricultural land to be used for organic crops by 2025, 2030, 2050.
- Quantitative information on national funds allocated to the above stated targets and strategies, including sources of funds, timeline, scope, budget allocated, etc. E.g., increase in the amount of funding available for conversion aid, funding available under the EU's EAFRD scheme topped up with other state funding; implementation of specific funds which aims to support organic agriculture processes, etc.
- Description on how the NECPs reflect the CAP framework. – This will be provided in the final iteration of this guidance document.

Other cross-sectoral policies can be described, including the expected impacts and timeline, such as:

- Carbon pricing implemented in the agricultural sector
- Tax mechanisms on specific emissions such as HFCs
- Introduction of a low-carbon label for the certification of emissions-reducing projects

Economic policies should also be described, including the allocated budget and funds. These could cover:

- Policies which send the right signals to investors, particularly in respect of carbon prices, and give a clear, long-term view of climate policies. Information on whether the revenue is expected to be re-invested into the sector should be given.
- Policies which promote investment into projects that foster the low-carbon transition, through funding tools that limit the risks incurred by investors and by adopting stringent criteria for identifying appropriate projects.
- Develop more stringent criteria and analyses to assess the climate impacts of measures implemented with public funding or under public policies, to ensure that measures that would not have a positive impact towards short- and long-term climate targets do not benefit from public funding.

Policies and measures to comply with Regulation (EU) 2018/841 (LULUCF)

- Planned policies and measure shall be described, including specific targets, milestones, allocated budget, expected impacts and achieved impacts. The policies could include:
    - **specific measures on the promotion of the use of energy from biomass**, especially for new biomass mobilisation considering:
        - biomass availability, including sustainable biomass: both domestic potential and imports from third countries
        - other biomass uses by other sectors (agriculture and forest-based sectors); as well as measures for the sustainability of biomass production and use
    - **specific measures and strategies implemented in the forestry and wood sector,** including

        - Implemented or planned upstream measures to guarantee the timely preservation and strengthening of carbon sinks and stores in the forestry and wood sector, and their resilience to climate stresses.
        - Policies and measures aimed at maximising the effects of carbon substitution and storage in wood products by leveraging supply and demand.
        - Implemented or planned policies placing limits on anthropogenic soil development and reducing carbon emissions caused by urbanisation.
    - Other policies which support the other objectives and targets as described in section **2.1.1(ii)** of the NECP

Related economic policies should also be described, including the allocated budget and funds. The plan should also describe and address subsidies for afforestation of agricultural land, support for preventing damage of forests, increase wood and wood product consumption.

4.2.2.2 *Section 3.1.2 Renewable energy (vii): Where applicable, specific measures on the promotion of the use of energy from biomass, especially for new biomass mobilisation considering:*

- *biomass availability, including sustainable biomass: both domestic potential and imports from third countries*
- *other biomass uses by other sectors (agriculture and forest-based sectors); as well as measures for the sustainability of biomass production and use*

Similarly, to section 3.1.1.(i) Member States should clearly describe the implemented, adopted, and planned policies and measures which will be necessary to achieve the objectives and targets mentioned under Part 2 of the same document.

Member States can structure this information using different approaches, such as a simple list of measure, tabular formats, graphs, etc. Nevertheless, it is necessary that quantifiable information on specific measures or strategies are clearly presented.

Member States should also estimate the expected impact of the mentioned policies in relation to biomass availability and biomass used, including quantitative values and projections up to 2050.

4.2.3 Part B: Analytical basis- current situation and projections within existing policies and measures: Dimension Decarbonisation

4.2.3.1 *Section 4.2.1. GHG emissions and removals (i) Trends in current GHG emissions and removals in […] the LULUCF sectors and different energy sectors*

The LULUCF Regulation sets a binding commitment for each Member State to ensure that **accounted emissions** do not exceed **accounted removals** through action in the sector. In practical reasons this commitment means that the result of the accounted emissions/removals is (not larger) than zero but can be negative (meaning the sector is a net sink). However, there are some exceptions (so-called flexibilities) which allow for deviations. This will be treated in the analysis part.

Please note that "accounted emissions/removals" under the LULUCF Regulation are different from "reported emissions/removals" from the national GHG inventory or projections[114].

Member States should report the actual and projected LULUCF emissions **accounted** (according to EU legislation requirements) for annually from 2020 to 2050. These values should be reported in the Annex I Part 2 both for the "with existing measure" (WEM) scenario and the "with additional measure" (WAM) scenario.

Additionally, it should be noted that draft updated NECPs should reflect the Fit for 55 package, including considerations of the revised LULUCF regulation with a focus on the 2030 national targets, and provisions about the use of EU funding.

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[114] https://ec.europa.eu/clima/lulucf_en

4.2.4 Part B: Analytical basis- Impact assessment of planned policies and measures

4.2.4.1 Section 5.3. Overview of investment needs:

i. existing investment flows and forward investment assumptions about the planned policies and measures

ii. sector or market risk factors or barriers in the national or regional context

iii. analysis of additional public finance support or resources to fill identified gaps identified under point ii

Member State shall describe both existing and future investments in relation to the policies mentioned within the other sections. Member States should provide a general overview of the investment needed to achieve the objectives, targets and contributions set out in the NECP, including the LULUCF commitments and other planned objectives and targets.

It is essential to identify and quantify the expected investment needs. This quantification of investment needs should be a result of or should be supported by model-based analysis. The section should include clear what figures such as: total vs additional investments, per year or per period, divided by sector, technology, etc.

Additionally, it should be noted that draft updated NECPs should reflect the Fit for 55 package, including considerations of the revised LULUCF regulation with a focus on the 2030 national targets, and provisions about the use of EU funding.

5 THE COMMON AGRICULTURAL POLICY (CAP)

This section covers the CAP, including:

- *Guidance on the structure of the CAP and CAP Strategic Plans, highlighting requirements and important sections where Member States can improve their contributions towards the environment, climate and energy related ambition in the land sector, through the introduction of new policies and measure and the enhancement of existing measures.*
- *The section also details how to increase ambition in the CAP and beyond, considering the relations with other policies and instruments that support PaM development and implementation in the land sector.*

5.1 THE NEW CAP

The CAP is now considered the main support instrument for climate, energy, and environmental action in the land sector. On the 2 December 2021, the horizontal regulation for the current CAP was agreed (EU 2021/2116[115]), and implementation began on the 1 January 2023. This includes a new governance structure with the EU legislation setting basic policy parameters (objectives of the CAP, broad types of intervention and minimum requirements) and Member States setting out in national CAP Strategic Plans (CSP) on how to meet the 10 common CAP objectives and to achieve targets required to meet the challenges identified in the MS concerned, contributing to of the Green Deal, Farm to Fork and Biodiversity strategies.

According to the CSP Regulation (EU 2021/2115[116]), Member States design their interventions within this overall structure to address their specific needs. The CSPs furthermore identify national measures outside the CAP that would contribute to deliver increased climate impacts and commitments to follow up on the implementation of green measures under and outside the CAP. To support the drafting of the CSPs the Commission issued tailor-made recommendations to identify the key areas on which the MS should focus. Furthermore, in the context of the assessment of the draft CSPs the Commission provided several observations, some of which were included in the final versions of the CSPs. Outstanding recommendations and observations have the potential to inform higher ambition, identify where existing policies could be improved and identify new programmes and measures including the review of the CSPs and/or the integration in other related policies[117].

[115] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2021.435.01.0187.01.ENG
[116] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2021.435.01.0001.01.ENG
[117] The recommendations and observations to the CSPs will be included within the national fiches as part of this project.

The CSPs are a programming tool that define the key parameters for the implementation of all CAP instruments (direct payments, rural development, and sectoral programmes) for each Member State, to align with the Green Deal ambitions. At least three of the ten key objectives, as shown in Figure 6, concern climate and the environment directly, with all other objectives having the potential to indirectly influence climate. A common set of indicators is proposed at the EU level to ensure a level-playing field in assessing the effectiveness of the interventions used and to measure performance. The CSPs are important mechanisms in the implementation of measures to respond to the targets set out in the ESR and LULUCF regulations. Reporting on their implementation and the coherence of the CSPs in relation to the LULUCF and ESR targets is therefore important to ensure Member States can report on emissions reductions, policies, and projections within the wider governance mechanisms.

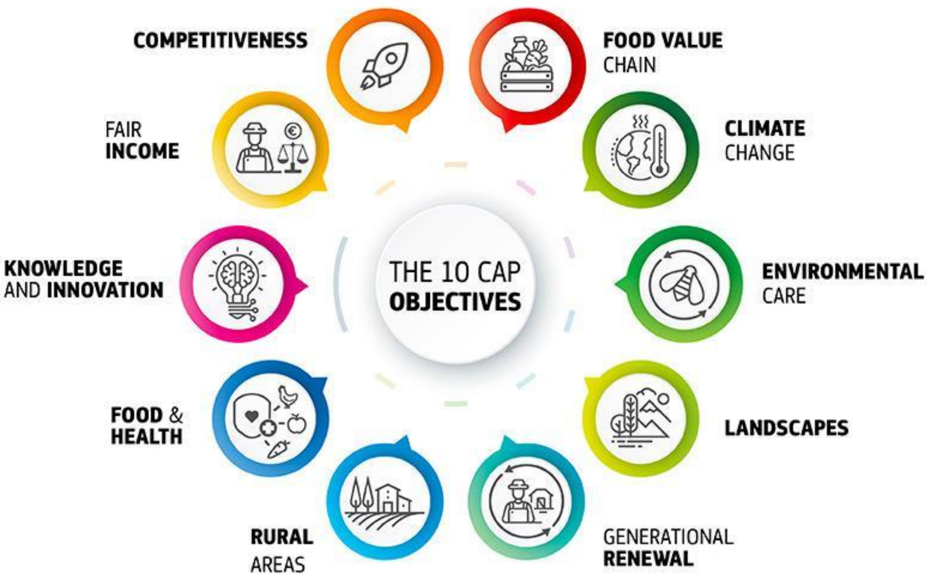

Figure 6: Key policy objectives of the new CAP (europa.eu)

5.2 CAP'S GREEN ARCHITECTURE

A common framework has been created to meet this greater ambition and is referred to as Green Architecture. The financial contributions from different interventions that are part of this architecture can be seen in Figure 7. A selection of interventions in this architecture includes:

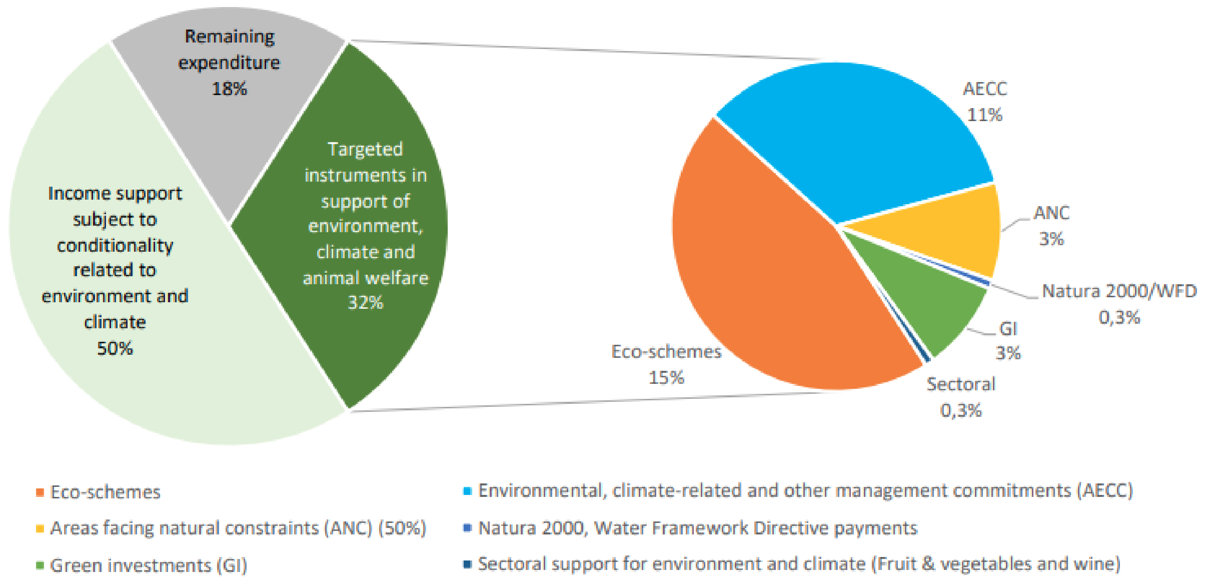

Figure 7: CAP public financing contributing to protection of environment, climate and animal welfare (EAGF/EAFRD and national funds, % 2023-2027)[118]

5.2.1 Conditionality

All farmers receiving CAP income support must comply with a set of statutory management requirements (SMRs) and basic standards for environment and climate GAECs, called 'conditionality'. Conditionality is applicable on 89 % of EU agricultural land. These conditions have been strengthened compared to the previous CAP, including

- upgraded 'greening' requirements, such as applying crop rotation instead of crop diversification
- requirements to protect EU agricultural wetlands and peatlands to reduce carbon release and increase carbon removals.
- further requirements to increase carbon mitigation with restricted tillage and a ban on conversion, draining, burning or extraction of peat.
- an enhanced requirement to maintain non-productive areas and features, on at least 4% of arable farmland will also increase the carbon removal from the atmosphere at farm level.

5.2.2 Coupled Income Support (CIS)

Whereas the main objective of CIS is to provide targeted aid to a specific agricultural sector or sub-sector facing difficulties, some of the CIS interventions could also meet climate needs. For example, CIS is used to support legume cultivation to reduce the EU's dependency on imports of plant protein for feed and can help cushion the shortage of nitrogen fertilisers, both which can reduce GHG emissions and increase carbon removals. It is expected that support for protein crops and legumes will increase by 25% compared to 2022, with the area reaching 7 million ha in 2027.

5.2.3 Eco-schemes

Beyond conditionality, farmers across 35% of the EU's agricultural area will be incentivised to further change production methods to store carbon in soil and biomass and reduce emissions through appropriate management practices, such as extensive grassland management, growing of leguminous and catch crops, reducing inorganic fertiliser use and/or agroforestry. In total 23.6% or EUR 44.7 billion of direct payments (EAGF funds) are dedicated to eco-schemes.

[118] https://agriculture.ec.europa.eu/system/files/2022-12/csp-at-a-glance-eu-countries_en.pdf

Interventions to support afforestation and agroforestry differ across the Member States but Eco-schemes and AECC are examples to support action. Across the CAP interventions, 623 000ha of forestry and agroforestry are currently planned.

5.2.4 Agri-Environment Climate Commitments (AECC)

AECC are a voluntary layer of commitment to actions on top of both conditionality and eco-schemes where land managers need to comply with further restrictions. For example, there are actions in some Member State CSPs to reduce methane and ammonia emissions from livestock, predominantly through optimised feeding. Interventions to support afforestation and agroforestry differ across the Member States but AECC is one way to support some action. Across the CAP interventions, 623 000ha of forestry and agroforestry are currently planned across the CSPs.

AECC accounts for 11% of the total CAP budget[119].

5.2.5 Green investments

Almost 180 000 farms are expected to receive support for investments contributing to climate change mitigation and adaptation and to the production of renewable energy or biomaterials from the CAP between 2023-2027. Planned investments will add 1556 MW in renewable energy production on farms such as biogas production as well as support nutrient recycling, technologies for optimal and reduced use of fertilisers, biomass processing, energy efficiency, precision farming and genetic improvement: all supporting a reduction in GHG emissions. This adds up to 3% of the CAP public financing contribution.

5.2.6 Advice, demonstration, & training – Agricultural Knowledge & Innovation System (AKIS)

Great advice and knowledge sharing is key to ensuring the designed interventions have the required impact. The CSPs boost support for advice, demonstration, and training to help farmers transition to a more resource efficient (including precision farming), resilient and sustainable agricultural system. More than 6 million people are expected to benefit from AKIS, including 200,000 independent advisors, or will participate in innovation projects under the European Innovation Partnership with a specific focus for some on environmental and climate performance or social and rural aspects.

5.3 CSP STRUCTURE

All the CSPs follow the same structure, and an outline of the chapters can be seen in Table 18. Detailed versions of the key policy objectives shown above are also known as Specific Objectives (SO); most of which are interlinked. In chapter 2, each Member State has linked the identified needs to a relevant SO. Specific objective 4 (SO4) relates to 'Contributions to climate change mitigation and adaptation, including by reducing GHG emissions and enhancing carbon sequestration, as well as promoting sustainable energy.' As such, SO4 is most relevant to the NECPs. However, some interventions may have been programmed to other equally relevant SOs, for example water adaptation elements to SO5 (environment), bioeconomy related action to SO8 (promoting employment), or to more horizontal themes such as knowledge transfer.

The intervention logic goes into further detail of:

- Relevant national plans
- Legislative instruments
- Intervention types and output indicators
- Overview – depending on the Member State this overview may provide a lot of detail on the needs and solutions around SO4. If not in great detail, further information will be available in other sections of the CAP SP.

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[119] csp-at-a-glance-eu-countries_en.pdf (europa.eu)

Table 188: CAP SP structure outline

Chapter	Content	NECP Relevant sections
1	Strategic Statement	
2	Needs assessment. (This is broken into needs per SO in the CSPs.)	SO4 section: • Strengths Weaknesses Opportunities and Threats (SWOT) analysis • Identification of needs • Relevant national plans • Relevant legislative instruments • Intervention logic • Use of InvestEU • Result Indicators
3	Consistency of strategy	Good Agricultural & Environment Condition (GAEC) 1: Maintenance of permanent grassland GAEC 2: Protection of wetland and peatland GAEC 3: Ban on burning arable stubble (Other GAECs may also be relevant depending on the Member State interpretation)
4	Common elements	Definitions of: • agricultural activity, • agricultural area, • arable land, • permanent crops • permanent grassland • eligible hectare
5	Interventions	This provides detail on the different interventions if not sufficient detail is provided in chapter 2 under the intervention logic.
6	Financial Plan	This gives an indication of ambition of take-up of individual interventions if not provided in chapter 2
7	Governance	n/a
8	Modernisation	n/a
9	Annexes	Annex XI, XIII has the relevant legislative instruments

The interventions have different aims depending on their funding origin. Each Member State has license to design their own interventions. Examples of some versions of the interventions that may be relevant to SO4 are captured in Table 19.

Table 199: Examples of interventions under different CAP instruments

CAP Instruments	Interventions
Direct Payment Interventions	Eco-schemes
	Coupled income support (CIS)

CAP Instruments	Interventions
Sectoral Interventions	Fruit and vegetables
	Livestock
Rural Development Interventions	Environmental, climate-related, and other management commitments (ENVCLIM)
	Agri-Environment Climate Commitments (AECC)
	Organic Farming Scheme
	European Innovation Partnerships
	Green investment

5.3.1 The Bioeconomy

The bioeconomy, consisting of all sectors and systems that rely on biological resources, stretches across all the CAP objectives and is seen as a 'catalyst for systemic change'[120].[121]. There is huge potential to substitute the use of fossil fuels for energy and applications in products. This can be achieved while increasing rural area's resilience through better optimisation of the bioeconomy and its integration from farm to fork and non-food uses. A sustainable bioeconomy can contribute to renewable energy through production of bioenergy, produces materials for bio-based products, as well as improving efficiency and waste prevention through reducing and/or recovering waste and residues[122].

The 2018, updated Bioeconomy Strategy paves the way for the renewal of European industries and primary sectors through bio-based innovation, the provision of food and nutrition security and the valorisation and protection of ecosystems and biological resources. It focuses on circular bioeconomy practices. It addresses the twin challenges of achieving a climate neutral economy by 2050 and preserving Europe's natural environment. FOOD 2030 is the EU R&I policy framework to drive sustainable, healthy, and inclusive food systems and thus achieve co-benefits for nutrition, climate, circularity, and communities through its 10 Pathways for Action to be deployed in Horizon Europe (food systems intervention area, missions, and partnership on "Safe and Sustainable Food Systems for People Planet and Climate").

5.3.2 Quantification of mitigation potential

In the context of the assessment of the CSPs, the Commission provided recommendations and observations addressed to some Member States on the need for better quantification of emissions and expected emissions in the Commission's evaluation of the CAP Strategic Plans. The detail of these is included in the individual Member State fiches. If these recommendations have not been addressed in the final CSPs, they can be followed up in the NECPs depending on the MS decisions selected P&M.

Member States have often indicated that they find it difficult to assess the mitigation potential of CSP interventions before knowing the uptake of the relevant measures due their often-voluntary nature, the high level of granularity and the diversification of impacts related to the different factors affecting mitigation potentials. The availability of activity data remains the first step toward the improvement of quantitative assessments of GHG emissions.

5.4 REFLECTING INCREASED AMBITION IN THE CAP AND BEYOND

For the CSPs, all Member States were urged to increase their ambition on the previous CAP, and in some cases the Commission provided guidance in the form of observation and recommendations on the draft CSPs as to:

1. the implementation and enhancement of existing measures and
2. the introduction of new policies and measures.

[120] European Commission, Directorate-General for Research and Innovation, How the bioeconomy contributes to the European Green Deal, Publications Office, 2020, https://data.europa.eu/doi/10.2777/67636

[121] https://research-and-innovation.ec.europa.eu/system/files/2019-12/ec_rtd_factsheet-food-bio-resources-agri-envi_2019.pdf

[122] https://op.europa.eu/en/publication-detail/-/publication/edace3e3-e189-11e8-b690-01aa75ed71a1/

In December 2020, the Commission prepared a general communication COM (2020) 846[123] and Member State specific annexes with recommendations for each Member State on designing their CSPs. The recommendations aimed to ensure achievement of the ten CAP objectives, including those relevant to the NECPs, as well as the alignment to the relevant Green Deal ambitions referencing the Farm to Fork and Biodiversity Strategy targets.

Member States then submitted draft CSPs, to which the Commission responded with observation letters[124], including an overview document. These letters examined how Member States had identified their needs, the use of underlying evidence, the interventions they had designed and their targets.

Some of these recommendations and observations were included within the final approved CSPs[125], while others still can further heighten ambition and create action by including further measures in relation to the new higher climate ambitions. There is capacity within the CAP regulation for Member States to make changes to their CSPs.

The NECP needs to include these new CAP contributions as a matter of priority. Likewise, in case of amendments to relevant legislation listed in the CAP Regulation, Member States are obliged to assess their CSP, in the light of these changes. As stated in Article 120 of the CAP Regulation (EU) 2021/2115:

"When an amendment is made to any of the legislative acts listed in Annex XIII, each Member State shall assess whether its CAP Strategic Plan should be amended accordingly, in particular the explanation referred to in Article 109(2), point (a)(v), and the further elements of the CAP Strategic Plan referred to in that explanation. Each Member State shall, within six months after the deadline of transposition of the amendment in the case of a Directive listed in Annex XIII or within six months after the date of application of the amendment in the case of a Regulation listed in Annex XIII, notify the Commission of the outcome of its assessment with an accompanying explanation and, if necessary, submit a request to amend its CAP Strategic Plan in accordance with Article 119(2)."

The legislative acts listed in Annex XIII are:

- Directive 2009/147/EC on the conservation of wild birds.
- Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.
- The Water Framework Directive 2000/60/EC
- Nitrates Directive 91/676/EEC
- Air Quality Directive 2008/50/EC
- Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants,
- LULUCF Regulation (EU) 2018/841
- Effort Sharing Regulation (EU) 2018/842
- Renewable Energy Directive (EU) 2018/2001
- Energy Efficiency Directive 2012/27/EU
- Governance of the Energy Union and Climate Action Regulation (EU) 2018/1999
- Sustainable Use of Pesticides Directive 2009/128/EC of the European Parliament

Some of these acts are in the process of being reviewed in response to increased climate ambition in the Fit for 55 package, triggering the abovementioned review process. Of relevance are the updated LULUCF regulation, as discussed in section 1.3.1, and the ESR with their new ambitious targets. In this respect, it is worth bearing these new targets in mind when preparing the NECPs.

Other related pieces of legislation, like the Energy Efficiency Directive, the ESR and Renewable Energy Directive updates are also expected to be finalised soon and the same expectations for the CSPs to reflect relevant changes will apply (in this case within 6 months from the deadline for transposition).

[123] https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans_en#cap-strategic-plans-recommendations
[124] Observation letters (europa.eu)
[125] Relevant excerpts are available in the Member State Fiche.

APPENDIX 1 POLICIES AND MEASURES FOR ENERGY AND ENVIRONMENTAL BENEFITS

A.1 Non-CO2 abatement measures

A.1.1 Measures for nutrient management

A.1.1.1 Testing, planning and advice to avoid excess application of N fertiliser

Measure description

Testing soil for available soil mineral nitrogen (SMN), combined with taking full account of the plant available N in recently applied organic manures, and estimating the amount of N potentially available for crop uptake from mineralisation of the residues of previous crops and livestock manure applications can reduce the need for applications of mineral N fertiliser (MNF). Soil and nutrient management plans (SNMP) provide guidance to farmers on how to take account of plant available N in soils, manures and crop residues (Martineau et al., 2016).

Effect of Mitigation measure

Soil and nutrient management plans by reducing the need for MNF can reduce emissions of the GHG nitrous oxide (N_2O) in three principal ways.

Reducing the need for MNF will reduce GHG emissions arising from the manufacture of MNF.

Direct emissions of N_2O following the application of N fertiliser to land will be reduced.

Emissions of ammonia (NH_3) following N fertiliser application will be reduced and hence indirect emissions of N_2O following the deposition to land of NH_3 will be less.

Abatement potential

Emissions of N_2O following application of MNF to land will be reduced in direct proportion to the reduction in MNF applied (IPCC, 2006). Hence if the use of a SNMP reduces N fertiliser application by 10% then emissions of N_2O will be reduced by 10%. Eagle et al. (2017) confirmed the efficacy of good management of N fertiliser application in a meta-analysis of several field experiments.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.072 to 0.26 t CO_2e/ha/y[126].

Overall emissions impact

Measures such as SNMPs have long been used in Nitrate Vulnerable Zones (NVZ) in order to reduce the risk of nitrate leaching.

Displacement effect

Displacement effects can occur when yield is decreased, through increases in production and emissions in other locations, driven by market demand. There should not be any displacement from the use of SNMPs providing they are designed to ensure enough N is applied to obtain optimum economic yield (N*opt*).

Permanence

Providing the guidance in SNMP is followed every year the reduction in emissions should be permanent.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

N/A

[126] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Barriers and constraints

The major barrier to avoiding the application of excess N fertiliser lies in the accurate identification of N*opt*. Typically, the standard error of N*opt* is c. 10% (Van Grinsven et al., 2012) and because the value of crop yield lost by applying <N*opt* tends to be greater than the cost of applying slightly more than N*opt*, farmers can apply more N fertiliser than recommended to avoid the risk of under-fertilising. However, for many years, farmers in NVZ have been advised not to go above N*opt*, and in some cases required to apply less than N*opt*, so the practice of insurance fertilising appears to be in decline.

Co-benefits

In addition, the measure will reduce other losses of N, in particular leaching of nitrate (e.g., Eagle et al., 2017).

Risks and trade-offs

Avoiding the application of excess N fertiliser should maintain crop yields and farm profitability and may be considered a low-risk option to reduce N_2O emissions.

References

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A.1.1.2 Urease inhibitors coupled to mineral N fertilisers

Measure description

Urease inhibitors can be applied with fertilisers that contain urea, to inhibit the hydrolysis of urea, which is catalysed by urease enzymes in the soil. Hydrolysis of urea leads to emission of ammonia to air, and it is mitigation of this emission that is the main purpose of urease inhibitor applications. However, there can also be effects on both direct and indirect emissions of nitrous oxide.

The most widely used urease inhibitor is N-(n-butyl) thiophosphoric triamide, known as nBTPT.

Effect of mitigation measure

Effects of urease inhibitors on nitrous oxide emissions reported in the literature are not consistent (e.g., Smith et al., 2012). Urease inhibitors decrease the availability of ammonium for nitrification and denitrification reactions, that can lead to direct emission of nitrous oxide. Emission of ammonia is abated with concomitant mitigation of indirect nitrous oxide emission, that occurs following deposition of ammonia.

Urease inhibitors also save in greenhouse gas (GHG) emissions from the manufacture and supply of inorganic nitrogen fertilisers.

Abatement potential

The nitrous oxide abatement effect of urease inhibitors ranges from 0 to 53% (e.g., Smith et al., 2012; Cowan et al., 2019).

For GHG abatement from avoided fertiliser use, the decrease in GHG emissions per kg of nitrogen that is conserved in the soil, i.e., is not lost to the atmosphere as ammonia, is 1.9 kg CO_2e per kg N (Hoxha and Christensen, 2018). This saving in GHG emissions represents emissions from the supply of manufactured urea fertiliser, normally needed to compensate for the loss of ammonia to air that occurs.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.11 to 0.70 t CO_2e/ha/y.[127]

Overall emissions impact

Decreased emission of nitrous oxide will decrease total GHG emissions at a territorial level.

Displacement effect

There is no evidence of leakage, or displaced emissions from this mitigation measure. Indirect effects can include savings in ammonia emissions and therefore greater supply of nitrogen to crops that have urea fertilisers applied, with consequent savings in GHG emissions from manufacture and supply of inorganic nitrogen fertilisers.

Permanence

There is no evidence for measurable effects on stored carbon, or influence on permanence of carbon already stored in soil.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm fertiliser purchases and operations and can be verified by inspection during farm visits.

Adaptation effect

N/A

Barriers and constraints

There are no major barriers or constraints. Urease inhibitors are available commercially, and the additional cost of using a urease inhibitor are compensated by improved nitrogen use efficiency through decreased loss of nitrogen to the environment.

Co-benefits

Use of urease inhibitors is primarily aimed at abatement of ammonia emission, but in the context of this assessment of effects on climate, ammonia abatement is a co-benefit. Ammonia emission abatement typically ranges from around 50% to 90%: for example, Singh et al. (2013) reported ammonia abatement of 47% when used on grassland in New Zealand; and Cowan et al. (2019) reported ammonia abatement of 90% when used on grassland for silage production in Scotland, UK.

Risks and trade-offs

Temporary impacts on internal N metabolism have been found in plants due to absorption of nBTPT through plant roots (Cantarella et al, 2018; Mathialagan et al, 2017).

Temporary yellowing of leaf tips caused by urea toxicity has been reported soon after application of nBTPT due to changes in metabolic pathways, but there were no impacts on growth (Cantarella et al, 2018).

References

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[127] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

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A.1.1.3 **Nitrification inhibitors with mineral N fertilisers and manure**

Measure description

Nitrification inhibitors can be applied with nitrogen fertiliser to slow nitrification and (indirectly) denitrification reactions in the soil, thereby decreasing the emission of nitrous oxide to air.

Widely tested nitrification inhibitors include dicyandiamide (DCD) and 3,4-dimethylpyrazole phosphate (DMPP).

Effect of mitigation measure

Nitrification inhibitors deactivate the ammonia monooxygenase enzyme responsible for the oxidation of ammonium (NH_4^+) to nitrite (NO_2^-) (Kim et al., 2012), and work by slowing the activity of *Nitrosomonas*, the genus of nitrifying bacteria responsible for the oxidation (nitrification) reaction (Kim at el., 2010). The inhibition of nitrification results in less denitrification with less nitrous oxide emission.

Abatement potential

Abatement potential for nitrous oxide has a wide range because of differences in the form of nitrogen fertiliser used, and differences between alternative nitrification inhibitors, formulations, application methods, soil types, climate, and crop uptake of nitrogen. Published values range from 8% to 67% abatement (Lam et al., 2016; MacLeod et al., 2015). Many published values are around 40% (e.g., Gilsanz et al., 2016).

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.21 to 3.2 t CO_2e/ha/y.[128]

Overall emissions impact

Decreased emission of nitrous oxide will decrease total GHG emissions at a territorial level.

Displacement effect

There is no evidence of leakage, or displaced emissions from this mitigation measure.

Permanence

There is no evidence for measurable effects on stored carbon, or influence on permanence of carbon already stored in soil.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm fertiliser purchases and operations and can be verified by inspection during farm visits.

Adaptation effect

N/A

Barriers and constraints

The main constraint is the additional cost to the farmer. There is some evidence that the benefit of improved nitrogen use efficiency (NUE) through decreased nitrate leaching (Ruser and Schulz, 2015) can overcome the barrier of increased cost, but the evidence is not consistent.

Co-benefits

The main co-benefit is decreased nitrate leaching (Ruser and Schulz, 2015), with benefits for the environment (water quality) and improved NUE, which can lead to decreased use of manufactured inorganic fertilisers (with concomitant savings in greenhouse gas emissions at the manufacture stage), and also can improve crop yields, with commercial benefits.

Risks and trade-offs

Depending on soil properties, nitrification inhibitors risk increased ammonia emissions due to extended availability of NH_4^+ (Wang, et al., 2020; Misselbrook, et al., 2014). When ammonia is emitted to air, indirect N2O emission can follow (Lam, et al., 2017).

DCD application has been shown to increase soil emission of methane (Dong, et al., 2018).

[128] Based on Ricardo calculations and literature review, assuming a mitigation potential range of 8 to 57% of N20 mitigated.

There is a risk of DCD leaching into surface and ground waters (Bell, et al., 2015a; Bell, et al., 2015b). Potential leaching of DCD can have adverse effects on aquatic systems by blocking nitrification processes (Bell, et al., 2015a).

There is uncertainty for impacts on non-target and nitrifying organisms in soils (Ruser & Schulz, 2015).

References

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A.1.1.1 Organic production approaches - no synthetic N

Measure description

Under organic farming rules, the application of nitrogen (N) fertiliser manufactured from atmospheric N is not allowed (*EU regulation* 834/2007).

Effect of mitigation measure

Eliminating the use of manufactured N fertiliser (MNF) reduces GHG emissions in three ways.

Direct emissions of nitrous oxide (N_2O) following the application of N fertiliser to land will be eliminated on the organic farm.

Emissions of ammonia (NH_3) following N fertiliser application will not take place on the organic farm and hence indirect emissions of N_2O following the deposition to land of NH_3 will not take place.

No greenhouse gas (GHG) emissions from the manufacture of N fertiliser will be associated with the organic farm.

Abatement potential

By foregoing the use of MNF all emissions associated with the manufacture and used of MNF will be reduced to zero, at the farm level. However, due primarily to reduced output, and also to the use of organic sources of

N to replace MNF, GHG emissions per ton of product can be considerable and, in many farm systems greater, than from conventional production.

In view of the high uncertainty because of displacement effect, with potential for increased emissions per unit of production[129], we assume no mitigation for this measure.

Overall emissions impact

The meta-analysis of Toumisto et al. (2012) showed that organic farming practices generally reduce the adverse impacts of farming on the environment per unit of area, but not necessarily per unit of product. While organic farms tend to have reduced nutrient losses (N leaching, nitrous oxide (N_2O) emissions and NH_3 emissions) per unit of field area than conventional farming, NH_3 emissions, N leaching and N_2O emissions per product unit were greater from organic systems. Organic systems had smaller energy requirements, but greater land use per product unit. The variation within the results across different studies was wide due to differences in the systems compared and research methods used.

Displacement effect

Displacement effects can occur when yield is decreased, through increases in production and emissions in other locations, driven by market demand. The scale of yield reductions from the adoption of organic farming is contentious due to difficulties in finding matched organic and conventional farming systems (van de Ven et al., 2018). Those authors demonstrate a yield deficit of c 20% from organic farming compared with conventional. But that finding was based on the yield data for leeks, potatoes, silage maize and spring barley but the dataset did not allow comparison of some of the most important arable crops: winter wheat, winter barley and oilseed rape. Boone et al. (2019) used a life cycle assessment (LCA) approach to compare the environmental impacts of conventional and organic farming. Those workers considered that the environmental impacts of farming should not be allocated only to the end product but based on the capacity of agricultural systems to deliver ecosystem services (ES) over all agricultural outputs (i.e., provisioning, and other ES). Using their LCA approach, Boone found that some crops (e.g., potatoes, maize silage, maize grain, carrots) had a smaller environmental impact when grown in organic systems, but others, including the major crops (winter wheat, oilseed rape and barley) still had a smaller impact when grown under conventional systems.

Permanence

Any reductions in GHG emissions that do occur are likely to be permanent if the farming system remains organic.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

N/A

Barriers and constraints

A major barrier to the adoption of organic farming is the demand for organic produce. Since organic food is generally more expensive than conventional food the demand is limited. Furthermore, most organic farming systems rely on livestock to provide essential crop nutrients, especially potassium (K), and increasingly, those concerned about the environmental and health issues arising from conventional agriculture are choosing plant-based diets.

Co-benefits

Organic farms have been shown to provide greater biodiversity and require less energy than conventional farms (Toumisto et al., 2012). However, it is still unclear whether conventional farming with specific practices

[129] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

for biodiversity conservation (i.e., agri-environmental schemes) can also provide the benefits associated with organic farming (Hole et al., 2005; cited in Toumisto et al., 2012).

Risks and trade offs

Adopting the organic farming practice of not using MNF is likely to cause considerable displacement of production to other regions and thereby increasing the potential for deleterious land use change. There are two reasons for this. First, for some key crops, yields are smaller under organic farming than under conventional farming, therefore more land will be needed to grow the same amount of crops. Second, organic farming is more than just avoiding MNF and other synthetic inputs. Organic farming attempts to take a more holistic approach to food production and the conservation and recycling of nutrients within the farm. Simply applying one aspect of organic farming more widely (i.e., no use of chemical fertilisers) without also adopting some of the nutrient recycling compensating techniques used by organic farmers risks greater yield reductions than might be expected to occur arising from a switch from conventional to organic farming.

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A.1.1.4 Slow and controlled release nitrogen fertiliser and organic-mineral fertilisers

Measure description

Polymer coated urea granules provide a slow-release fertiliser that may reduce NH_3 emissions (e.g., Rochette and others, 2009; cited in Bittman et al, 2014), the extent of which will depend on the nature of the polymer coating and whether used with surface fertiliser application or combined with urea injection. By reducing NH3 emission the need for N fertilisers can be reduced and in consequence greenhouse gas (GHG) emissions will be less.

Effect of mitigation measure

Slow and controlled release N fertilisers reduce emissions of NH_3 following application N fertiliser to land. Reducing emissions of NH_3 from fertiliser use has the potential to reduce the need for N fertiliser and hence reduce emissions of GHGs. Slow-release N fertilisers have also been claimed to reduce the need for N fertiliser by better synchronising the availability of N from the fertiliser to crop demand, albeit the results have been inconsistent. Reducing N fertiliser use can reduce emissions of the GHG nitrous oxide (N_2O) in three principal ways.

Reduced GHG emissions during the manufacture of N fertiliser.

Direct emissions of N_2O following the application of N fertiliser to land will be reduced.

Emissions of NH_3 following N fertiliser application will be reduced and hence indirect emissions of N_2O following the deposition to land of NH_3 will also decrease.

In addition, emissions of N_2O following the application of many types of N fertiliser have been shown to be non-linear; the proportion of N emitted as N_2O increasing with the size of the N application (Shcherbak et al., 2014).. However, the relationship between the amount of N fertiliser applied and N_2O emissions was closest to linear when controlled release N fertilisers were used.

Abatement potential

Bittman et al. (2014) cite a reduction of 30% of NH_3 emissions from the use of slow-release urea-based N fertilisers. If this reduction in NH_3 emissions is accompanied by a reduction in N fertiliser use, then emissions of N_2O will be reduced *pro rata* to the reduction in N fertiliser applied.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.0048 to 0.19 t CO_2e/ha/y.[130]

Overall emissions impact

Quantifying the impact of using slow and controlled release N fertilisers on N_2O emissions is difficult. Per ha emission reductions are likely to be small but since N fertilisers are applied to a large area of farmed land cumulative emission reductions may be substantial. However, since the current IPCC methodology assumes a linear increase of N_2O emissions with increased N fertiliser use, any national-level reductions in N_2O emissions may not be recorded in national GHG emission inventories.

Displacement effect

Displacement effects can occur when crop yield is decreased, through increases in production and emissions in other locations, driven by market demand. As long as the use of slow and controlled release N fertiliser does not reduce yield, displacement is not likely to occur.

Permanence

Emission reductions achieved using slow and controlled release N fertilisers are likely to be permanent.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data. Furthermore, many national GHG inventories will need to be updated to with a non-linear emission factor to relate N_2O emissions to the application of many of the currently used N fertilisers to record emission reductions arising from the use of slow and controlled release N fertilisers.

Adaptation effect

N/A

Barriers and constraints

The likely barrier to the uptake of slow and controlled release N fertilisers is likely to be the additional cost (Trenkel, 2010).

Co-benefits

In addition to the potential to reduce emissions of N_2O, nitrate leaching losses may also be reduced (Trenkel, 2010).

Risks and trade-offs

Han et al. (2017) considered that while the use of polymer-coated urea has been shown to reduce N_2O emissions, because of the influence of weather on N_2O emissions reductions from the use of such fertilisers may not be achieved in every year.

References

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[130] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

A.1.1.5 Precision farming coupled to fertiliser placement (variable rate distribution)

Measure description

Precision farming, in the context of nutrients application, aims to adjust the application of fertilisers and other agrochemical inputs to take account of the spatial variability in nutrient availability (or pest or disease incidence) in order to match inputs more precisely to crop needs. Placement of N fertiliser under the soil surface and close to the crop seed or roots is considered to potentially increase the proportion of N fertiliser available for crop uptake and minimise N losses.

Effect of Mitigation measure

Through targeted use of inputs, precision farming matches inputs more closely to crop requirements thereby reducing N lost into the wider environment and thereby both farm and environmental costs (Finger et al., 2019).

Abatement potential

At farm level the abatement potential is extremely variable as it will depend on the spatial heterogeneity of factors such as soil nutrient reserves, available water holding capacity and other factors that contribute to crop yield and the need for agrochemical inputs.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.072 to 0.26 t CO_2e/ha/y.[131]

Overall emissions impact

As indicated above the impact on overall emissions from precision farming will be very hard to quantify due to the variability in the abatement potential at farm and field level.

Displacement effect

Displacement effects can occur when yield is decreased, through increases in production and emissions in other locations, driven by market demand. There should not be any displacement from the use of Precision farming since which would be expected to maintain yields but reduce emissions intensity.

Permanence

Any reductions in GHG emissions arising from the use of precision farming will be permanent providing the new techniques are continued.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data.

Adaptation effect

N/A

Barriers and constraints

The amount of capital investment needed for new equipment will be a barrier to many farmers, especially those with smaller farms (Finger et al., 2019).

Co-benefits

As well as reducing GHG emissions by reducing the need for fertiliser other agrochemical input can be reduced with consequent benefits to the environment (Finger et al., 2019).

Risks and trade offs

Large capital investment in equipment for precision farming may be needed. The resultant reductions in inputs and improvements in yield may not be large enough to provide a satisfactory return on the investment.

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[131] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

References

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A.1.1.6 Optimal pH for nutrient uptake in arable and improved grass

Measure description

The optimum soil pH is between 6.0 and 6.5 depending on the crop (AHDB, 2020). Where the soil pH is below the optimum value, it may be increased by the addition of lime, an alkaline agent.

This mitigation measure is relevant to land that receives nutrient applications, including land that is cultivated for crop production and improved grassland.

Effect of mitigation measure

Emissions of nitrous oxide (N_2O) from soil have been reported to increase as soil pH decreases below c. 6.0, mainly due to an increase in the ratio of N_2O to N_2 emissions (Martineau et al., 2016). Maintaining agricultural soils between pH 6.0 and 6.5 also increases N use efficiency by crops and hence may further reduce N_2O emissions (Martineau et al., 2016). Maintaining crops at optimum pH has benefits for crop yields (AHDB, 2020), with further benefits for greenhouse gas emissions.

However, the use of lime leads to emission of carbon dioxide as calcium carbonate ($CaCO_3$) dissolves following applications to land (Barton et al., 2014). The balance between additional greenhouse gas (GHG) emissions when lime is applied and saved GHG emissions (N_2O) is not well understood and is dependent on multiple variables including crop requirement and N supply. Benefits will be closely linked to matching crop requirement.

Abatement potential

Hénault et al. (2019) showed that N_2O emissions decrease progressively as pH is adjusted from pH 5.0 to pH 7.0. These authors then quantified the abatement potential for fertilised soils in France, as 15.7% abatement for N_2O at a national level. The level of abatement on an individual site, following application of lime varied from 0 to 49%, depending on the soil pH.

We estimate that the emission of carbon dioxide from lime dissolution is of a similar order of magnitude to the emission abatement of nitrous oxide because of applying lime to raise soil pH. We have assumed application of limestone at 5 t/ha at a frequency of 4 years. We used IPCC default emission factor (0.12 t C emitted per t limestone applied, IPCC, 2006). We assumed abatement of 49% of nitrous oxide emissions following annual application of 180 kg/ha nitrogen as fertiliser, with an emission factor of 0.01 kg N emitted as N_2O, per kg N applied (IPCC, 2006). We calculated abated N_2O emissions as 0.41 t/ha CO_2e, and CO_2 emissions from liming as 0.55 t/ha CO_2e. This comparison will vary by field, with soil type, and according to the N applications made. The emissions factors used are default values and have high uncertainty. We can conclude that emissions from dissolution of lime and abated emissions of nitrous oxide may have a similar order of magnitude with respect to global warming potential. A more detailed study is needed to confirm this.

In view of the high uncertainty and poor evidence for an overall mitigation effect, we assume no mitigation for this measure.[132]

Overall emissions impact

Optimal pH for nutrient uptake will influence overall greenhouse gas emissions at a territorial level. There may also be indirect effects on greenhouse gas emissions through increased yield and market-driven effects on production in other locations. However, these indirect effects are expected to be small.

Displacement effect

There is no evidence of leakage, or displaced emissions from this mitigation measure.

[132] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Permanence

There is no evidence for measurable effects on stored carbon, or influence on permanence of carbon already stored in soil.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm operations, and the results of soil pH tests.

Adaptation effect

N/A

Barriers and constraints

There are no major barriers or constraints, since maintenance of optimal pH will enhance productivity, and is regarded as good practice.

Co-benefits

Improved productivity.

Risks and trade-offs

There are no major risks or trade-offs.

References

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A.1.2 Manure applications

A.1.2.1 Slurry application by trailing shoe

Measure description

Slurry is discharged in narrow bands at ground level to grass land through a series of flexible trailing hoses. The bands of slurry are c. 3-5 cm wide and c. 20 cm apart. Application via a trailing shoe (TS) places the slurry beneath crop grass canopies so that little of the slurry adheres to and contaminates the grass. By placing the slurry on the soil surface and under the grass canopy, emissions of ammonia (NH_3) are reduced due to more rapid infiltration of the slurry by the soil and reduced exposure of the slurry to wind (Bittman et al., 2014).

Effect of mitigation measure

The TS reduces NH_3 emissions by placing slurry on the soil's surface by applying the slurry through a pipe which slides (or floats) on the surface of the ground with little or no penetration. The hose or shoe is intended to part the herbage, or any crop residue present to allow slurry placement directly on the soil surface. The greater efficiency (plant utilisation) generally reported with the sliding shoe compared with the simple application via trailing hoses (Webb et al., 2010) is attributed to manure being in narrower bands, having more contact with the soil and having less contact with live or dead vegetative material because vegetation is better pushed aside by the shoe than the hose, even if the hose is very close to the ground. The benefit of the shoe compared with the hose is greatest for taller grass canopies because of the reduced degree of canopy contamination.

Abatement potential

Bittman et al. (2014) cite reductions in NH_3 emissions from TS application of 30-60% compared with broadcast spreading of slurry. The greater reduction is associated with greater crop canopy and with placement precision. The JRC report a mean abatement efficiency of 40%, close to the middle of the range cited by Bittman et al. (2014). However, given that JRC report that the mean emissions factor was derived from 44 studies of NH_3 abatement by trailing hose, a much larger number than available to Bittman et al. (2014), the findings of the JRC may have included studies where a method akin to the trailing hose was used.

We estimate the mitigation potential per ha from avoided fertiliser use, in CO_2 equivalent units, to be in the range 0.0014 to 0.015 t CO_2e/ha/y.[133]

Overall emissions impact

The overall emissions impact is a substantial (30-60%) reduction in emissions of NH_3 when slurry is applied to grassland by means of TS. While techniques that reduce NH_3 emissions but leave slurry on the soil surface have been shown to lead to some increases in N_2O emissions (e.g., Webb et al., 2010 and references cited therein) the increase is small. The JRC report indicates a non-significant increase in N_2O emissions from slurry application via TS. When indirect emissions are considered, i.e., reduced N_2O emissions arising following the deposition of the NH_3 emitted to land, the net effect of application of slurry by TS on N_2O emissions is negligible (Smith et al. 2008; Webb et al., 2010)

Displacement effect

None.

Permanence

Emission reductions following application of slurry by TS will be permanent as losses of NH_3 are negligible once the slurry has infiltrated the soil.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of NH_3 and N_2O emissions are not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions for use with activity data.

Adaptation effect

N/A

Barriers and constraints

The main barrier to spreading slurry to grassland by TS is the slower work rate of these machines compared with broadcast spreaders.

Co-benefits

The TS deposits slurry below the crop canopy with much reduced contamination of the herbage and less sward damage (Bittman et al. 2014).

Risks and trade offs

The slower work rate of TS machines can increase the time needed to apply slurry in the spring. However, the reduced risk of herbage contamination from application by TS allows spreading to be continued until nearer to the time livestock are put outside to graze.

References

Bittman S, Dedina M, Howard CM, Oenema O, Sutton M.A, (eds). 2014. Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen, Centre for Ecology and Hydrology, Edinburgh, UK.

Smith E, Gordon R, Bourque C, Campbell A, 2008. Management strategies to simultaneously reduce ammonia, nitrous oxide and odour emissions from surface-applied swine manure. Canadian Journal of Soil Science 88, 571-584.

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[133] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Webb J, Pain B, Bittman S, Morgan J. (2010). The impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response - A review. Agriculture Ecosystems and Environment 137, 39-46.

A.1.2.2 Slurry application by dribble bar (trailing hose)

Measure description

Slurry is discharged in narrow bands at ground level to grass or arable land through a series of flexible trailing hoses, which either hang a short distance (<150 mm) above the soil or are dragged along the soil surface. The bands of slurry are c. 30-50 mm wide and c. 250-350 mm apart. Slurry may be applied between the rows of a growing crop.

Effect of mitigation measure

Slurry application by trailing hose (TH) reduces emissions of ammonia (NH_3), compared with conventional slurry broadcasting, by reducing the surface area to volume ratio of the applied slurry and by placing slurry at the soil surface. The greater and taller the crop canopy the greater the emission reduction, depending on placement precision and the extent of herbage contamination.

Abatement potential

The average reduction is reported to be 30 - 35% (Bittman et al., 2014) with up to a 75% reduction when the slurry band is placed beneath a tall crop canopy (Sommer and Oleson, 2001).[The JRC report cites a reduction of 39.7% which is appears too large for an overall abatement]

We estimate the mitigation potential per ha from avoided fertiliser use, in CO_2 equivalent units, to be in the range 0.0014 to 0.019 t CO_2e/ha/y.[134]

Overall emissions impact

Applying slurry by means of TH has the capacity to reduce NH_3 emissions by an average of 30-35% following slurry application when application by more effective reduced emission spreaders is not an option. This could be either because of the slower work rate of injection or trailing shoe machines or because slurry needs to be applied to a crop with a substantial canopy. Thus, while the TH is, on average, far less effective in reducing emissions of NH_3 than injection or trailing shoe application the faster work rate and the capacity for use on growing row crops means that more farmers may be willing to use it.

Displacement effect

There is unlikely to be any displacement as production is not compromised by use of the TH.

Permanence

When slurry is applied by TH the reduction in NH_3 emissions will be permanent.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of NH_3 and GHG emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data.

Adaptation effect

N/A

Barriers and constraints

Cost increases associated with purchasing and maintaining or hiring contractors with new application machinery can be a disincentive to the adoption of abatement techniques. Trailing hose spreaders are not always suitable for use on steeply sloping land due to run-off potential. Small, irregularly shaped fields also present difficulties for large machines.

[134] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Co-benefits

As contamination of grass with slurry is reduced, the required period between slurry application and grazing or silage harvest is reduced, extending the window of opportunity for slurry application. For arable crops, trailing hose application extends the window for slurry application later into the spring when crop height would normally exclude conventional surface broadcast slurry application because of crop damage and contamination risks (Bittman et al., 2014).

Risks and trade offs

The slower work rate of TS machines, compared with surface spreading, can increase the time needed to apply slurry in the spring.

References

Bittman S, Dedina M, Howard CM, Oenema O, Sutton M.A, (eds). 2014. Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen, Centre for Ecology and Hydrology, Edinburgh, UK.

Sommer SG, Olesen JE, 2000. Modelling ammonia volatilization from animal slurry applied with trail hoses to cereals. Atmospheric Environment 34, 2361-2372.

A.1.2.3 Slurry application by injection

Measure description

There are two types of machines for the injection of slurry into soil: open and closed slot. Open (or shallow) injectors cut open 'V' shaped slots in the soil that are filled with slurry or liquid manure. The slot injector tines apply slurry in bands c. 30-50 mm wide typically 40-60 mm deep and 250-300 mm apart. They are most used on grassland. Closed slot injectors place slurry to depths of 50 to 200 mm and have discs to lift soil and cover the slurry. Closed injectors have a working width of up to 4m and are used mainly on arable soils.

Injection systems are normally fitted to the rear of slurry tankers, which are either towed by a tractor or form parts of self-propelled machines. An alternative is for the application system to be attached directly to the rear of a tractor and slurry transported to it by an "umbilical" hose from a stationary tanker or store. Such umbilical systems can reduce soil compaction damage caused by heavy slurry tankers.

Effect of mitigation measure

Injecting slurry into soil can reduce emissions in two principal ways.

By injecting slurry into the soil, the free NH_3 in the slurry is either no longer exposed to the atmosphere (closed injection) or the slurry surface exposed to the atmosphere is greatly reduced (slot injection). Diffusion of NH_3 from the slurry to the air can no longer take place following closed injection, while slot injection greatly reduces diffusion of NH_3 by reducing the area of exposed slurry.

Injecting slurry into soil also means that the ammonium (NH_4^+) ions, the precursors to molecular NH_3, are adsorbed onto negatively charged clay and organic matter particles thereby immobilizing them. Subsequently the NH_4^+ ions will be oxidised to nitrate (NO_3^-) and hence no longer be a source of NH_3. In addition, since soils tend to be slightly acid, and NH_3 molecules in the manure will be ionised to NH_4^+.

Abatement potential

Open slot injection of slurry reduces NH_3 emissions following slurry application by 70% (Bittman et al., 2014). Closed slot injection reduces NH_3 emissions following slurry application by 80% if the depth of injection is <150mm and by 90% if the slurry is injected to >150 mm. (Bittman et al., 2014).

We estimate the mitigation potential per ha from avoided fertiliser use, in CO_2 equivalent units, to be in the range 0.0034 to 0.022 t CO_2e/ha/y.[135]

Overall emissions impact

The overall impact of injection will vary across different regions. Land that is relatively flat or with regular and gentle slopes, large fields and or farms and regions where soils are neither shallow nor stony, will all make the

[135] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

adoption of slurry injection more likely. In regions where soil type, landform or farm size make slurry injection difficult slurry may have to be spread using techniques with less abatement potential.

Displacement effect

Displacement may occur if the additional costs of slurry injection led to farmers give up livestock production leading to increases in production and emissions in other locations.

Permanence

Where slurry is applied by injection, emissions from that slurry application will be permanently reduced. However, NH_3 abatement in future seasons depends on continued application of slurry by injection.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of NH_3 emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

N/A

Barriers and constraints

Slurry injection is not applicable on very stony soils, or on very shallow or compacted soils, where it is impossible to achieve uniform penetration to the required working depth. Open slot injectors are not always suitable for use on steeply sloping land due to the potential for run-off along the injection lines. Small, irregularly shaped fields present difficulties for large machines. Open slot injectors are more applicable to a wider range of soil types and conditions than closed slot machines.

Injection systems will have a greater tractor power requirement than broadcast or band-spreading equipment. Umbilical systems have the advantage of faster work rates (but long set up times) and of lessening the risk of soil damage by compaction and can preferably be used on farms with small distances between slurry store and fields.

Grass yield can be reduced by injection. Damage can arise from the injector cutting contact between roots and soil. However, when injection is used effectively the increased N supply and placement of slurry N closer to the roots can compensate for this damage.

Due to the greater power required to pull injection machinery through the soil, the costs of slurry injection are greater than those of other spreading methods and the work rate of injection machinery is also less. There are also greater repair costs associated with injection machinery due to greater soil/machine contact than splash plate machines and more moving parts.

Co-benefits

By reducing NH_3 emissions a greater proportion of the crop-available N in the slurry is conserved and made available for the crop. This will reduce the requirement for N fertiliser thereby reducing GHG emissions from the manufacture of N fertiliser and NH_3 emissions following N fertiliser application. Slurry injection can also reduce the unpleasant odour associated with slurry spreading.

Risks and trade-offs

Injection of slurry may either increase or have no impact on direct emissions of N_2O. The impacts of application techniques will vary according to the aeration of the soil, soil N concentrations in soil and the length of the diffusion path of N_2O to the atmosphere. A longer diffusion path increases the likelihood of N_2O being reduced to N_2. However, while there are circumstances under which slurry injection may increase direct emissions of N_2O, such increases are not inevitable and when they occur, they are frequently small. In addition, by greatly reducing emissions of NH_3 by slurry injection, indirect emissions of N_2O, when the NH_3 is deposited to land, will be reduced. Therefore, concern over such emission trade-offs should not inhibit the use of injection in order to reduce emissions of NH_3 (Smith et al. 2008; Webb et al., 2010).

References

Bittman S, Dedina M, Howard CM, Oenema O, Sutton M.A, (eds). 2014. Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen, Centre for Ecology and Hydrology, Edinburgh, UK.

Smith E, Gordon R, Bourque C, Campbell A, 2008. Management strategies to simultaneously reduce ammonia, nitrous oxide and odour emissions from surface-applied swine manure. Canadian Journal of Soil Science 88, 571-584.

Webb J, Pain B, Bittman S, Morgan J. (2010). The impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response - A review. Agriculture Ecosystems and Environment 137, 39-46.

A.1.2.4 Incorporation of slurry and solid manures within four hours of application

Measure description

Emissions of ammonia (NH_3) effectively cease when livestock slurries and manures are covered by soil. Thus, incorporation of slurry and solid manures soon after application to land decreases the time during which emission takes place. The more slurries and manures are covered by soil, the greater the emission reduction. Since emissions of NH_3 begin immediately after application, the sooner the incorporation is carried, out the greater will be the emission reductions. Even short (4–6 h) delays in incorporating manures after application will greatly reduce the efficacy of rapid incorporation as a means of NH_3 abatement (Webb et al., 2010). Therefore, the greatest emission reductions are achieved by inversion of soil within 4 hours of application.

Effect of Mitigation measure

Incorporation of slurry and solid manures within four hours of application can reduce net emissions in two principal ways.

By burying slurry or solid manure under soil (inversion techniques) or mixing the slurry or manure with soil (non-inversion techniques) the free NH_3 in the manure is no longer exposed to the atmosphere and hence diffusion of NH_3 from the manure to the air can no longer take place.

Incorporating manure into soil also means that the ammonium (NH_4^+) ions, the precursors to molecular NH_3 are adsorbed onto negatively charged clay and organic matter particles thereby immobilising them. Subsequently the NH_4^+ ions will be oxidised to nitrate (NO_3-) and hence no longer be a source of NH_3. In addition, since soils tend to be slightly acidic, and NH_3 molecules in the manure will be ionised to NH_4^+.

Abatement potential

The abatement potential of incorporating slurries and manures within 4hrs depends greatly upon the machinery used to carry out the incorporation. Machines that invert the soil (ploughs and discs), thereby covering the manure, are more effective than machines that mix the manure and soil (tines and harrows). There is also an interaction between machine and manure type. Machines that mix the manure with soil are more effective with slurries and poultry manures than with straw-based farmyard manure (FYM). Bittman et al. (2014) give the following abatement efficiencies (% reduction from surface applied) for incorporation of manures within 4 hours: by plough, 80; by disc; 65; by tine, 45.

We estimate the mitigation potential per ha from avoided fertiliser use, in CO_2 equivalent units, to be in the range 0.0054 to 0.030 t CO_2e/ha/y.[136]

Overall emissions impact

The overall emissions impact is a large (45-80%) reduction in emissions of NH_3 when slurry or solid manures are incorporated within 4 h of application to land. Incorporation of FYM appears to reduce or have no impact on direct N_2O emissions (Bittman et al., 2014). When indirect emissions are considered, i.e., reduced N_2O emissions arising following the deposition of the NH_3 to land, the net effect of incorporation within 4hrs application of slurry and solid manure on total N_2O emissions is likely to be a small reduction (Smith et al. 2008; Webb et al., 2010).

[136] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Displacement effect

The greater machinery and labour requirement of incorporating slurry or manure within 4hrs of application may reduce the amount of manure that can be spread before planting crops thereby increasing the length of time manure needs to be stored. This has the potential to increase NH_3 emissions during storage.

Permanence

Emission reductions following application of slurry by trailing shoe will be permanent as losses of NH_3 are negligible once the slurry has infiltrated the soil.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of NH_3 and N_2O emissions are not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions for use with activity data.

Adaptation effect

N/A

Barriers and constraints

This technique is mainly applicable to arable land. Incorporation cannot be used on permanent grassland, although it may be possible to use in grassland systems either when changing to arable land (e.g., in a rotation) or when reseeding pasture, although nutrient requirements may be low at both times. It is also less applicable to arable crops grown using minimum cultivation techniques compared with crops grown using deeper cultivation methods. Incorporation is only possible before crops are sown. The technique is the main technique applicable to achieve emission reductions from application of solid manures on arable soils, although new applicators for injecting poultry litter into sod are being tested in North America. It is also effective for slurries where closed-slot injection techniques are not possible or available or present a risk of leaching. It is also difficult to use on small farms with a limited labour supply as two tractors and drivers will be needed, one for the manure spreader, the other for soil cultivation.

Co-benefits

Reducing NH_3 emissions by incorporating manures into soil within 4hrs of application will conserve N and increase the proportion of manure N available for crop growth. This will enable a small reduction in the need for N fertiliser which will also reduce GHG emissions arising from the manufacture and use of N fertiliser.

Risks and trade offs

Incorporation of FYM appears to reduce or have no impact on N_2O emissions (Bittman et al., 2014).

References

Bittman S, Dedina M, Howard CM, Oenema O, Sutton M.A, (eds). 2014. Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen, Centre for Ecology and Hydrology, Edinburgh, UK.

Webb J, Pain B, Bittman S, Morgan J. (2010). The impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response - A review. Agriculture Ecosystems and Environment 137, 39-46.

A.1.3 Manure storage

A.1.3.1 Cooling slurry

Measure description

Stored livestock manures emit methane (CH_4). Liquid manures (slurry) in storage, under livestock housing, in tanks or lagoons, can be cooled, decreasing methane emissions (Smith et al., 2007). Some systems use a cooling system in or on the floor of a slurry store, using a heat pump for heat recovery. Other systems use cool ground water circulated through floating fins on the slurry surface and can be combined with a heat pump system for heat recovery. Cooling pipes or fins are connected to a heat exchange system to provide heat for livestock buildings (e.g., for pig houses used for weaners) or other purposes such as domestic heating or glasshouses (Santonja et al., 2017).

Effect of mitigation measure

Cooling slurry decreases emissions of methane (Smith et al., 2007). Methane production is low at temperatures below 15°C but increases exponentially as the temperature rises above 15°C (Santonja et al., 2017). Methane emission is a result of the anaerobic degradation of organic matter by the activity of methanogenic bacteria (Santonja et al., 2017), and in general, these biological activities decrease as temperature decreases.

Abatement potential

Performance for methane abatement has not been verified (Santonja et al., 2017).

For greenhouse gas abatement from avoided fertiliser use, we provide values for the decrease in greenhouse gas emissions (kg CO_2e) per kg of nitrogen that is conserved in the slurry, i.e., is not lost to the atmosphere as ammonia. Values below are from Hoxha and Christensen (2018). These savings in GHG emissions represent emissions from the supply of manufactured nitrogen fertilisers.

greenhouse gas saving if urea is replaced by saved N	1.9 kg CO_2e per kg N
greenhouse gas saving if ammonium nitrate is replaced by saved N	3.3 kg CO_2e per kg N

Calculation of abatement per tonne of stored slurry is complex and depends on the total ammoniacal nitrogen content of the slurry, the methods of slurry cooling and storage, and the losses at spreading. This requires a bespoke calculation for each situation.

When slurry is cooled to conserve nitrogen and abate ammonia emissions, reduced emission spreading techniques should be used to ensure that loss of the nitrogen conserved in storage is minimised when the slurry is spread to land.

Taking into account the available evidence, savings in fertiliser through decreased N loss are highly uncertain and depend on an integrated approach to avoid losses of conserved N at later stages. Evidence is lacking. Therefore, there is poor evidence for an overall mitigation effect, we assume no mitigation for this measure.[137]

Overall emissions impact

Decreased emissions of CH_4 will decrease total greenhouse gas emissions at a territorial level.

Displacement effect

There is no evidence of leakage, or displaced emissions from this mitigation measure. Indirect effects can include savings in ammonia emissions and therefore greater supply of nitrogen to crops that have manures applied, with consequent savings in greenhouse gas emissions from manufacture and supply of inorganic nitrogen fertilisers.

Permanence

There is no evidence for measurable effects on stored carbon, or influence on permanence of carbon already stored in soil.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm infrastructure and operations and can be verified by inspection during farm visits.

Adaptation effect

N/A

Barriers and constraints

Manure cooling systems on the base of a store is not effective for large volumes of slurry, so is best used where slurry is frequently removed. Retrofitting is possible in manure pits where the cooling pipes can be placed above the concrete (Santonja et al., 2017).

[137] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

It was also reported by Santonja et al. (2017) that surface cooling systems using fins on the slurry surface can be retrofitted in existing houses as the design and the size of the pen are not critical for the applicability of the system. However, the technique is not applicable:

when straw bedding is used because a floating layer may form, interfering with heat transfer,

when heat reuse is not possible,

if pumping of groundwater is not possible.

There are reports that systems with surface fins are not easy to apply or operate, and maintenance has been reported to be difficult and expensive (Santonja et al., 2017).

Co-benefits

Cooling of slurry is primarily aimed at abatement of ammonia emission, but in the context of this assessment of effects on climate, ammonia abatement is a co-benefit. Cooling slurry decreases ammonia emissions (Mottershead et al., 2019), but care is needed to account for ventilation rate, which could increase alongside heat recovery systems, especially in naturally ventilated livestock houses (EIP-Agri Focus Group, 2017). Ammonia emissions are reduced by 45–75% depending on the animal category and the extent of cooling (Santonja et al., 2017).

Use of heat pumps reduces fuel consumption to heat buildings (Santonja et al., 2017).

Decreasing the temperature by 3°C has been shown to reduce odour emissions by 20–25% (Santonja et al., 2017).

Risks and trade offs

Increased infrastructure cost is a trade-off.

References

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Mottershead D, Maréchal A, Allen B, Keenleyside C, Lóránt A, Bowyer C, Martin I, Daydé C, Bresson C, Panarin M, Martineau H, Wiltshire J, Menadue H, Vedrenne M, Coulon A. 2019. Evaluation study of the impact of the CAP on climate change and greenhouse gas emissions. Final Report to the European Commission, Directorate-General for Agriculture and Rural Development, Directorate C — Strategy, Simplification and Policy Analysis, Unit C4 — Monitoring and Evaluation.

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, 2007: Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

A.1.3.2 Slurry acidification

Measure description

Slurry acidification is the lowering of slurry pH by addition of a strong acid, usually sulphuric acid (Fangueiro et al., 2015). The target pH is typically pH 5.5, at which ammonia emission is decreased and there are also changes in greenhouse gas emissions.

Slurry may be acidified in a livestock house, by flushing into a treatment tank where the acid is added with stirring; the slurry may then be returned to slurry channels under the house or sent to storage. Another option is for the acid to be added to a storage tank or lagoon with mixing, and a further option is addition of acid in the field immediately preceding application to land (Fangueiro et al., 2015).

Effect of mitigation measure

Acidification may influence emissions of methane through inhibition of methanogenic bacteria at low pH (Santonja et al., 2017). Nitrous oxide emission may be abated through prevention of crust formation (Santonja et al., 2017), and through increased nitrogen content (Santonja et al., 2017) of slurry applied to land.

A further effect of slurry acidification is the greenhouse gas saving from avoided fertiliser use, as a consequence of conserving nitrogen in the manure/slurry.

Abatement potential

The abatement potential for greenhouse gases is not well quantified. It is reported that methane is abated from slurry in housing, and from slurry in storage (Santonja et al., 2017). Nitrous oxide may be abated in storage, and following field application, but there is large uncertainty, and in some circumstances nitrous oxide emission may increase following field application (Fangueiro et al., 2015).

Santonja et al. (2017) reports abatement values for methane and nitrous oxide emissions from slurry in housing and storage[138] as follows:

- Methane from slurry in housing: 33%
- Methane from slurry in storage: 60%
- Nitrous oxide from slurry in housing: 83%
- Nitrous oxide from slurry in storage: 36%

However, abatement at and following land spreading is not given, and for nitrous oxide this is important as nitrous oxide emissions can be large after land spreading and effects of acidification may be positive or negative (Fangueiro et al., 2015). Therefore, the overall abatement potential is highly uncertain.

For greenhouse gas abatement from avoided fertiliser use, we provide values for the decrease in greenhouse gas emissions (kg CO_2e) per kg of nitrogen that is conserved in the slurry, i.e. is not lost to the atmosphere as ammonia. Values below are from Hoxha and Christensen (2018). These savings in greenhouse gas emissions represent emissions from the supply of manufactured nitrogen fertilisers.

Greenhouse gas saving if urea is replaced by saved N	1.9 kg CO_2e per kg N
Greenhouse gas saving if ammonium nitrate is replaced by saved N	3.3 kg CO_2e per kg N

Calculation of abatement per tonne of stored slurry is complex and depends on the total ammoniacal nitrogen content of the slurry, the pH of the slurry before and after acidification, housing design, methods of storage and spreading. This requires a bespoke calculation for each situation.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.060 to 1.1 t CO_2e/head/y.[139]

Overall emissions impact

Decreased emission of methane and nitrous oxide will decrease overall greenhouse gas emissions at a territorial level.

Displacement effect

There is no evidence of leakage, or displaced emissions from this mitigation measure. Indirect effects can include savings in ammonia emissions and therefore greater supply of nitrogen to crops that have manures applied, with consequent savings in GHG emissions from manufacture and supply of inorganic nitrogen fertilisers.

Permanence

There is no evidence for measurable effects on stored carbon, or influence on permanence of carbon already stored in soil.

[138] Calculated from values in units of kg/tonne of slurry.

[139] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm infrastructure and operations and can be verified by inspection during farm visits.

Adaptation effect

N/A

Barriers

For acidification in livestock houses, the type of housing influences applicability: buildings using slatted floors are the most suitable for retrofitting (Wiltshire, 2019). Santonja et al. (2017) state that no technical restrictions are reported for the implementation of the technique, and that about 80% of Danish livestock houses can be retrofitted without major renovations.

Health and safety risks are a perceived barrier (Wiltshire, 2019), but we have not found evidence of farm accidents or health impacts.

With soil injection techniques, acidification during spreading to land is expected to have a limited abatement affect (Santonja et al., 2017).

Santonja et al. (2017) provide estimates of investment and maintenance costs and state that suppliers' estimates of total annual costs range from EUR 1 to EUR 2 per tonne of treated slurry.

Co-benefits

Acidification of slurry is primarily aimed at abatement of ammonia emission, but in the context of this assessment of effects on climate, ammonia abatement is a co-benefit. Fangueiro et al. (2015) reviewed the effect of acidification on ammonia emissions and reported ranges as follows, for acidification using sulphuric acid:

In house acidification: 50 – 70% abatement

Storage acidification: 50 – 88% abatement

Field acidification: 15 – 80% abatement (varies with type of manure)

Following acidification, the benefits of decreased emissions are realised at each following stage, so acidification in housing abates emissions in storage and at field spreading.

Risks and trade-offs

Cost is a trade-off – see barriers and constraints above.

There are health and safety risks associated with the use of strong acids, but we have not found evidence of farm accidents or health impacts.

Acidification of slurry increases the need for lime application to manage soil pH. Practical experience suggests an increase in lime application rates of less than 10%, with no change to the frequency of application (Santonja et al., 2017).

Hydrogen sulphide emission can occur, or be increased following acidification, and may be accompanied by increased odour (Fangueiro et al., 2015; Santonja et al., 2017).

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A.1.3.3 Covering manure and slurry stores

Measure description

Covering manure and slurry stores places a barrier between the manure or slurry and the air, and may include:

- Covering solid manure heaps with plastic sheeting, or loose material such as sawdust, wood chips or peat.
- Rigid cover on a steel or concrete slurry tank.
- Flexible cover on a slurry tank.
- Floating covers on slurry, including natural crust, chopped straw, polystyrene balls, light expanded clay aggregates (LECA), floating flexible covers on lagoon, floating plastic tiles, air inflated cover.
- Flexible plastic sheeting used to cover a slurry lagoon, secured on the lagoon banks and supported by floats.
- Use of a slurry bag for enclosed slurry storage.

More details are given by Santonja et al. (2017), Section 5.4.

Effect of mitigation measure

Covering manure and slurry stores is done as a mitigation measure for ammonia and odour emissions. Effects on greenhouse gas emissions are less well documented. Covering imposes a physical barrier between manure/slurry and the atmosphere, can increase temperature of the stored material, and change the oxygen status (Santonja et al., 2017). These changes influence emissions of methane and nitrous oxide.

Methane emissions from slurry stored in lagoons or tanks can be reduced by use of solid covers (Smith et al., 2007). As an example, use of a rigid cover on an underground store gave a methane emission reduction in the range of 32% to 70% (Santonja et al., 2017).

Use of plastic sheeting decreases oxygen in the manure/slurry, reduces nitrification (and therefore, denitrification), decreasing nitrous oxide emissions. With some types of covers, e.g., LECA, oxygen can still enter the slurry, enabling nitrification and denitrification with emissions of nitrous oxide. Under these circumstances, the effect of covering on nitrous oxide emission is unclear (Santonja et al., 2017). Use of a rigid cover on an underground store gave a nitrous oxide emission reduction in the range of -30% to +50% (Santonja et al., 2017).

A further effect of covering manure and slurry is the greenhouse gas saving from avoided fertiliser use, as a consequence of conserving nitrogen in the manure/slurry.

Abatement potential

A Danish study on storage of slurry fibre fractions (i.e., the solid fraction following slurry separation) has shown decreases in emissions of nitrous oxide and methane of 99% and 88% respectively, by using an airtight cover (Hansen et al., 2006, cited in Santonja et al., 2017). Reduction effects on nitrous oxide from broiler litter heaps ranged from 0.17% to 0.81% of the total N for sheeted heaps, and from 0.55% to 0.70% of the total N for un-sheeted heaps.

For greenhouse gas abatement from avoided fertiliser use, we provide values for the decrease in greenhouse gas emissions (kg CO_2e) per kg of nitrogen that is conserved in the slurry, i.e., is not lost to the atmosphere as ammonia. Values below are from Hoxha and Christensen (2018). These savings in greenhouse gas emissions represent emissions from the supply of manufactured nitrogen fertilisers.

Greenhouse gas saving if urea is replaced by saved N	1.9 kg CO_2e per kg N
Greenhouse gas saving if ammonium nitrate is replaced by saved N	3.3 kg CO_2e per kg N

Calculation of abatement per tonne of stored slurry is complex and depends on the total ammoniacal nitrogen content of the slurry, the methods of storage and covering, and the losses at spreading. This requires a bespoke calculation for each situation.

When stores are covered to conserve nitrogen and abate ammonia emissions, reduced emission spreading techniques should be used to ensure that loss of the nitrogen conserved in storage is minimised when the slurry is spread to land.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.13 to 1.7 t CO_2e/head/y.[140]

Overall emissions impact

Decreased emission of methane and nitrous oxide will decrease overall greenhouse gas emissions at a territorial level.

Displacement effect

There is no evidence of leakage, or displaced emissions from this mitigation measure. Indirect effects can include savings in ammonia emissions and therefore greater supply of nitrogen to crops that have manures applied, with consequent savings in GHG emissions from manufacture and supply of inorganic nitrogen fertilisers.

Permanence

There is no evidence for measurable effects on stored carbon, or influence on permanence of carbon already stored in soil.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing manure storage records and can be verified by inspection during farm visits.

Adaptation effect

N/A

Barriers and constraints

Costs are a barrier and are specific to the farm circumstances and type of covering selected.

Greenhouse gas emissions from covering manure and slurry stores can arise from decreased loss of nitrogen to atmosphere in the form of ammonia, with consequent savings in use of nitrogen fertiliser and the associated greenhouse gas emission. However, losses of ammonia from storage of manures are small relative to losses from livestock housing and from spreading to land. Data from the UK inventory of ammonia emissions show that, for 2017, losses from livestock housing and spreading were 27% and 15% respectively, of ammonia emissions from agriculture (Misselbrook and Gilhespy, 2019). By comparison, emissions of ammonia from storage of manures were 8% of ammonia emissions from agriculture (Misselbrook and Gilhespy, 2019). Furthermore, when nitrogen is conserved by covering a store, it is important to also conserve nitrogen at spreading, otherwise the emissions savings made in storage can be lost later. This may be a barrier to adoption of store covering, with attention given to ammonia mitigation measures that have greater potential.

Covering of solid manure heaps that have frequent additions can be impractical, and also can be ineffective, with no significant reduction of ammonia emission compared with an uncovered manure heap (Santonja et al., 2017).

Safety and practical concerns are barriers to covering solid manure heaps, with concerns about difficulties in covering a heap when working alone, about lone workers falling into a wet part of a heap, and about sheets blowing away and causing collisions on roads (Wiltshire, 2019).

Co-benefits

Covering manure or slurry stores is primarily aimed at abatement of ammonia emission, but in the context of this assessment of effects on climate, ammonia abatement is a co-benefit. Typically, covering stores has high abatement efficiency for ammonia, with values of up to 50% for solid manure heaps and rigid covers are reported to give ammonia and odour reductions of at least 80–90% (Santonja et al., 2017).

Risks and trade-offs

Secondary negative impacts include safety (possible dangers from trapped hydrogen sulphide, and from sheeting a solid manure heap), and increases in nitrous oxide emissions.

[140] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

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A.1.3.4 Livestock Density Limits

Measure Description

By placing limits on the stocking density of livestock, direct methane emissions by livestock are reduced and manure management emissions are also reduced. With better manure management, the utilisation of nutrients in manures can be improved.

Effect of Mitigation measure

The direct effect of limiting the numbers of livestock that can be carried on land parcels and farms is the reduction in methane emissions from enteric fermentation and the reduction in methane and nitrous oxide from manure management. Also, where nutrient utilisation in manures can be optimised, this reduces the need for manufactured fertiliser and reduces the risk of excess nutrients being applied. Obviously, this assumes that limits set for livestock numbers are below the current stocking densities.

Theoretically this activity has benefits, however there is significant complexity. Grossi et al, 2019 reports the "extreme hereogenity" of the agricultural sector and that mitigation strategies will be different across livestock systems, species and climates. No single mitigation measure in isolation will encompass the full emissions reduction potential and a range of options will be required to reach the best result (Lonch et al. 2017)

Although limiting the numbers of livestock by imposing stocking density restrictions would have a direct effect on the emissions, the indirect effects are clear as production will to be displaced if consumption levels remain the same.

Abatement potential

Limited direct references were found relating to reducing stocking densities as a mitigation approach.

Stocking densities range significantly depending on the terrain, land quality, climate, rainfall, farming system and many other factors. Generally, stocking densities are set to suit the environment. To illustrate, the impact of reducing stocking densities from a relatively high level of 2.2 cows/ha to a standard or average density of 1.8 cows/ha for a lowland beef producer could reduce emissions from the livestock by 18%.

These reductions should be treated with some caution due to the displacement effect and the potential negative consequences on productivity. Farms with higher stocking densities will tend to be more productive and make better use of forage which results in better (lower) emissions intensities.

The nitrates directive and areas designated as Nitrate Vulnerable Zones already place some limits on land carrying capacities. This is due to whole farm limits for nitrogen applications. Such restrictions tend to only affect large intensive livestock units and there is the option to 'export' manures off the farm to other farms.

In view of the high uncertainty because of displacement effect, with potential for increased emissions per unit of production, we assume no mitigation for this measure.[141]

Overall emissions impact

The overall impact of reducing livestock densities is likely to be neutral or negative due to the displacement effect. It would be a 'blunt instrument' in policy terms and would not address the complexity of the livestock farming sector. Impacts on productivity could have a detrimental impact on emissions intensity.

Displacement effect

Displacement effect is likely to be significant and directly linked to consumption. There is a risk that as a result of reduced production in the EU, demand would be met by supply from other countries.

Permanence

Livestock numbers will fluctuate depending on a range of market, policy, and environmental drivers.

Measurement requirements

This would be relatively easy to monitor through existing data collection structures and would have an impact on domestic GHG inventories.

Adaptation effect

Livestock can lead to soil compaction, destruction of soil structure and loss of vegetation. This may reduce infiltration and increase the risk of runoff. Reducing livestock density contributes to reduce soil compaction. Improvements in soil structure in turn reduce erosion risks, reduce overland run off, and therefore improve water quality as well as increase rainfall infiltration and contributing to soil moisture recharge. Catchment wide changes in livestock density can contribute to reduce flood risk. The EC (2014) reports that reduced livestock numbers can decrease runoff rates by up to 50% and increase infiltration by up to 400%. It may also lead to a reduction in pollutant loads and increased filtration due to greater vegetation and infiltration.

Barriers and constraints

There are no significant barriers if the policy mechanism for intervention exists.

Co-benefits

Reduced impacts on air quality, water quality by removing potential excess nutrient from farming systems.

Risks and trade offs

Significant risk of displaced production and impacts on farm profitability.

References

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A.1.4 Livestock health

A.1.4.1 Herd fertility

Measure description

Reduced fertility means fewer production animals are produced from each breeding animal and thus the greenhouse gas (GHG) emissions intensity per unit of end product is increased. Reproductive fertility can be reduced as a result of infectious disease, e.g., the Bovine Rhinotracheitis (IBR) virus may cause poor fertility (Skuce et al., 2017). However, poor fertility may be due factors other than disease (Skuce et al., 2017).

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[141] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Effect of mitigation measure

Improving herd fertility improves the GHG emission efficiency of production as it decreases the number of herd replacements required and can reduce GHG emissions in a herd by up to 20% (Garnsworthy, 2004; cited in Bell et al., 2015). For dairy herds, the overall emissions intensity of the herd is very sensitive to cow fertility.

Abatement potential

Because poor fertility is often a consequence of disease, overall estimates of GHG abatement arising from improved herd fertility are not available. However, it can be possible to make an estimate based on the reduction in suckler animals needed for a same amount of production, and their GHG emissions, because of improved herd fertility.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.024 to 0.050 t CO_2e/head/y.[142]

Overall emissions impact

Since there are a number of diseases and metabolic issues that can reduce livestock fertility (Bell, et al., 2015; Skuce et al., 2016), there is great uncertainty over the potential effectiveness of this mitigation measure at national or regional level. There are also very few published reports of emission reductions achieved, emission reductions arising from improved herd fertility tend to be incorporated with estimates of abatement from improved disease control. Potential emission reductions from improved disease control were reported by Frelih-Larsen et al., (2014) to range from a 1.5% reduction in emissions intensity from the beef herd to a 22% reduction in emissions intensity for sheep in Scotland.

Displacement effect

Displacement effects are unlikely as improving livestock health should improve productivity and hence overall production.

Permanence

Since viral, bacterial and parasitic pathogens can reduce herd fertility, and fertility is not strongly heritable, reductions in GHG emissions from increasing stock fertility will not be maintained if animal health is allowed to deteriorate.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of animal reproductive rates and allowing farm visits for verification.

Measurement of emissions are not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emission factors for use with activity data.

Barriers and constraints

Bell et al. (2015) considered that since fitness traits such as fertility were of only low heritability, the emissions intensity of dairy systems may be harder to achieve by improving fertility than selection for a production trait such as improving feed efficiency.

Co-benefits

Improving herd fertility, by reducing the number of breeding animals needed, will reduce other emissions, such as ammonia and leaching of nitrate to watercourses from the breeding herd.

Risks and trade-offs

The improved productivity arising from improving herd fertility may disadvantage smaller producers whose resources do not allow them to invest in improved livestock health and subsequently obtain improved fertility.

References

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[142] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

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A.1.4.2 Reduction in endemic disease

Measure description

Livestock diseases that cause long-term impairment of health may indirectly increase GHG emissions from livestock production due to reduced performance, decreasing output and hence increasing the ratio between emissions and output, leading to greater GHG emissions per tonne of produce. Lameness, mastitis, infertility in cattle and calf pneumonia are among the most common conditions that can, if not correctly and promptly treated, cause considerable production losses (Martineau et al., 2016).

Effect of mitigation measure

The assessments of effectiveness of reducing endemic disease in livestock are variable, due to the multi-factorial nature of the conditions and the criteria adopted to define success. However, it is generally agreed that some improvements to the incidence and/or severity of these conditions are possible on most livestock, and in particular, dairy cattle. Moreover, it may be the case that larger production units are better able to implement such improvements due to the economies of scale, enabling greater investment in monitoring stock health and responding to problems. This mitigation measure is considered with respect to its potential for reducing emissions of primarily CH_4 but also N_2O.

Abatement potential

Emission reductions will depend on the specific disease, the efficacy of the intervention and the extent to which this operation encourages uptake of the disease intervention (Frelih-Larsen et al., 2014).

The effectiveness is likely to vary considerably depending upon the current state of herd health. Three diseases, one from each the major livestock sector, were considered more cost-effective and feasible to control by Skuce et al. (2016). These were: neosporosis (beef cattle), infectious bovine rhinotracheitis (IBR; dairy cattle) and parasitic gastroenteritis (PGE; sheep).

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.024 to 0.73 t CO_2e/head/y.[143]

Overall emissions impact

Potential emission reductions were reported by Frelih-Larsen et al., (2014) to range from a 1.5% reduction in emissions intensity from the beef herd to a 22% reduction in emissions intensity for sheep in Scotland. Since there are several livestock health issues that can be potentially addressed via this mitigation measure, either individually or together, there is great uncertainty over the potential effectiveness of this mitigation measure. There are also relatively few published reports of emission reductions achieved.

Displacement effect

Displacement effects are unlikely as improving livestock health should improve productivity and hence overall production.

Permanence

Improvements in herd health may not be permanent as new epizootics could reduce livestock health and productivity.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing veterinary and production records and allowing farm visits for verification.

Adaptation effect

Disease control actions can reduce farm vulnerability to new diseases. Livestock health can also be improved through better housing, including sprinklers and ventilation systems in buildings and shading trees and infrastructures on the farm. Improving livestock housing can help reduce impact on productivity by preventing

[143] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

increased heat stress associated with gradual increases in average temperatures and extreme heat events. The investment in and maintenance of new technology for animal housing, such as new cooling systems, can be high; however, the cost of planting trees for shading can be lower and have benefits for biodiversity. Ventilation and sprinklers can lead to higher energy use and GHG emissions as well as higher water use.

Barriers and constraints

While the techniques for improving disease management are well understood by veterinary professionals, not all farmers will necessarily be aware of the options or recognise the opportunities to use them. Implementation at farm level depends on the farmer being able to identify that a health problem exists and being willing to call on veterinary services to resolve it. The financial position of the farm may also be a barrier. In some cases, farmers will know they have a treatable problem but, due to cash flow limitations, may not be able to afford mitigating activities even though it could prove cost-effective in the long term.

Co-benefits

Improving livestock health is not considered to lead to any other substantial environmental benefits or risks in addition to the climate mitigation benefits from increased efficiency of production (Martineau et al., 2016).

Risks and trade-offs

The improved productivity arising from improved stock health does not necessarily lead to a reduction in emissions, unless the market demand for a product remains static which would be a false assumption as the market will react to price variation triggered by supply variation (Martineau et al., 2016). Improved productivity, by increasing output from healthier herds, may disadvantage smaller producers whose resources do not allow them to invest in improved livestock health.

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A.1.5 Livestock feeding

A.1.5.1 Feed additives for ruminant diets

Measure description

There are a several materials which may be added to livestock feeds in order to reduce methane (CH_4) emissions. Such additives may work directly, by reducing the conversion of carbohydrate to CH_4 or indirectly, by improving animal performance and thereby reducing emissions per kg of product (Martineau et al., 2016).

Effect of mitigation measure

The use of feed additives can change net greenhouse gas (GHG) emissions as described below.

- Hydrogen produced in the rumen through fermentation can react to produce either CH_4 or propionate. By adding propionate precursors (e.g., fumarate) to animal feed, more hydrogen is used to produce propionate and less CH_4 is produced (Moran et al., 2008).
- Increasing the fat content of the diet has been shown to proportionally reduce enteric CH_4 emissions. Standard ruminant diets contain 1.5 to 3% dry matter (DM) fat, which corresponds to the fat content of forages (Frelih-Larsen et al., 2014). Cereal-based concentrates also typically contain c. 2 to 3% fat. An additional fat supplementation of 2 to 4% fat to increase the total fat content to 5 to 6% was evaluated by Frelih-Larsen et al., (2014). The evaluation reported that some farmers already use supplementary fat in the diets, but there is potential for additional uptake. There are differences among fat sources in terms of their effect on land use and land use change, these differences need to be taken into account. There are three mechanisms by which fat reduces enteric CH_4 emissions. First,

the increased amount of fat replaces other energy sources in the diet, mainly carbohydrates. While carbohydrates are digested in the rumen, fats are digested in the intestine and do not contribute to enteric CH_4 emissions. Second, medium chain fatty acids (e.g., those in coconut and palm kernel oil) and unsaturated fatty acids (e.g., those in linseed, rapeseed, sunflower, soybean) selectively reduce the numbers of some of the rumen microbes, thus reducing CH_4 emissions. Rumen-protected fat products and long-chain saturated fatty acids do not have these effects. Third, unsaturated fatty acids also act as a hydrogen sink in the rumen, reducing CH_4 production. However, this is a less important effect compared with the other two mechanisms (Frelih-Larsen et al., 2014).

- Probiotics are microbes used to divert hydrogen from methanogenesis towards acetogenesis in the rumen, resulting in a reduction in CH_4 produced by enteric fermentation. There is an added benefit in that acetate is a source of energy for the animal and therefore can improve overall productivity of the animal. These additives can be used in diets with high grain content.
- Ionophore antimicrobials (e.g., monensin) can improve the efficiency of livestock production by decreasing the dry matter intake (DMI) and increasing performance and decreasing CH_4 production (Moran et al., 2008). This option may be used for beef and dairy cattle.
- A recent development (e.g., Wesemael et al., 2019) has been to include the feed additive 3-nitrooxypropanol (3-NOP) to ruminant diets. This additive blocks the last step of methanogenesis in the rumen by oxidizing the enzyme methyl-coenzyme M reductase (Duin et al., 2016; cited in Wesemael et al., 2019).

Abatement potential

- Moran et al., (2008) reported that increasing the percentage of propionate (at the expense of acetate) by 25% reduced CH_4 emissions by c. 22%. Milk yield increased by 15%.
- Enteric CH_4 emissions are reduced by approximately 5% for each 1% increase (i.e., from 2% of dietary intake to 3% dietary intake) in the fat content of the diet (Frelih-Larsen et al., 2014 and references cited therein). Nutritional and practical aspects impose a limit of 5 to 6% dry matter (DM) total fat content.
- There is variation in the extent to which probiotic additives reduce CH_4 emission. Moran et al., (2008) used an abatement efficiency of 7.5%. They also estimated an improvement in production of 10%.
- The effect of ionophores on production and/or CH_4 is variable. Hristov et al. (2014) concluded that they can reduce CH_4 emissions from ruminants by 5%.
- Wesemael et al. (2019) reported reductions in CH_4 emissions from the inclusion of 3NOP to dairy cattle diets ranging from 7% to 60%.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.071 to 0.32 t CO_2e/head/y.[144]

Overall emissions impact

Feed additives can reduce enteric CH_4 emissions at a territorial level (an absolute change in emissions) and some additives (propionate precursors, probiotics and ionophores) can reduce emissions per unit of production (Moran et al., 2008; Frelih-Larsen et al., 2014).

Displacement effect

Displacement may occur if the large-scale use of fat supplements leads to an increased demand for vegetable oils, leading to increased production in regions where GHG emissions per tonne of crop produced are greater than in the EU.

Permanence

Increasing the fat content of diets may be expected to lead to permanent reductions in GHG emissions from ruminant livestock for as long as the fat content of the diet remains elevated.

[144] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing feed records and allowing farm visits for verification.

Measurement of ruminant CH_4 emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Barriers and constraints

Although the technology is well developed, some of the feed additives may not be available to farmers. For example, the use of ionophores in livestock feed is currently prohibited in the EU and other additives are not suitable for organic farms. There may also be public concern about using probiotics (microbial inputs) in livestock feed (Martineau et al., 2016).

A key consideration is the delivery of feed additives and their applicability/practicality in pasture-based systems. The delivery of feed additives in a housed environment, as part of a controlled ration, its relatively straight forward but controlling intake in the field presents a significant challenge.

Co-benefits

Some feed additives can increase production (Moran et al., 2008; Frelih-Larsen et al., 2014).

Risks and trade-offs

3 NOP presents promising results but is not yet registered in the EU. The application process of registration in the EU is underway for at least 1 feed producer. There are no known direct environmental benefits of this measure in addition to the effect on GHG emissions.

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Two ways to supplement 3-nitrooxypropanol

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A.1.5.2 Optimised feed strategies

Measure description

This mitigation measure aims to optimise dietary intake by closely matching feed intake to the energy and rb requirements of farm livestock. Livestock are often fed diets with more crude protein or more metabolisable energy (ME) than they need, to safeguard against a loss of production from a protein deficit through inaccurate analysis and/or formulation of the diet. For many years, nutrition of farm livestock was managed to maximise the output of end products such as milk and meat, with little or no attention to pollutants such as ammonia (NH_3) or methane (CH_4). Many materials are used as livestock feeds; availability and cost have been the main factors determining the choice of feed constituents, together with their ability to meet the nutritional needs of livestock. Surplus N is not utilised by the animal and is excreted, providing a substrate for emissions of NH_3 and nitrous oxide (N_2O). The use of feeds which are not easily digested by livestock increases total energy intake and greater emissions of CH_4 (Martineau et al., 2016).

Wesemael et al. (2019) reported reductions in CH_4 emissions from the inclusion of 3NOP to dairy cattle diets ranging from 7% to 60% in literature, with reductions of 21-24% from their own work.

Effect of mitigation measure

Optimising livestock feed intake can reduce emissions in two principal ways.

Mitigation of CH_4 emission by optimising ruminant feeding strategies is based on three basic approaches. First, by selecting feed to reduce the production of the volatile fatty acids (VFA) acetate and butyrate which provide CH_4 precursors, and by increasing the propionate VFA which consumes CH_4 precursors. Second, by increasing the rate of passage through the rumen thereby altering microbial populations and VFA production patterns and shift some digestion to the intestines. Third, feeding better-quality diets to increase milk production per cow or growth of beef cattle, which will decrease CH_4 emissions per unit of product (Knapp et al. 2014).

Matching the crude protein (CP) intake of livestock feeds to meet the animals' needs will reduce N excretion thereby reducing the pool of N available for emission as NH_3 and N_2O and pollution of water courses by nitrate (NO_3^-) (Frelih-Larsen et al., 2014).

Abatement potential

The potential of optimising feeding strategies to reduce CH_4 emissions from ruminant production will depend upon current dietary practice, and it is likely to be lower in more developed countries. Knapp et al. (2014) estimated a range of between 2.5 and 15% in such countries, a range likely to be possible within the EU. Sajeev et al. (2017) reported reductions of 19% in NH_3 emissions from cattle farming for each 10 g per kg reduction in crude protein in the livestock diet. For pigs, a reduction of 8% in NH_3 emissions for each 10 g per kg reduction in CP has been reported (Webb et al., 2014). The lesser potential of emission reductions from reducing CP in pig and poultry production is considered to be due to the greater attention already given to feed optimisation in pig and poultry farming and also due to the specific physiology of ruminants to efficiently recycle nitrogen in situations of low protein intake (Sajeev et al., 2017).

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.036 to 0.22 t CO_2e/head/y.[145]

Overall emissions impact

Optimising feeding strategies will impact emissions at a territorial level (an absolute change in emissions) and have an effect on emissions intensity (emissions per unit of production).

Each of the ways that feeding strategies can change net GHG emissions will change absolute emissions.

Changes in feeding strategies can affect production, and therefore influence emissions intensity. The effect of feeding strategies on production can be positive or negative, and on average is considered neutral.

Displacement effect

A displacement effect can occur when grass silage is replaced by maize silage due to the conversion of grassland into arable land with the subsequent evolution of CO_2 from the soil (Vellinga and Hoving, 2011). If land prone to soil erosion is converted from grass to maize production, soil erosion may be increased with subsequent impacts on water quality.

[145] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Permanence

When NH_3, N_2O and CH_4 emissions from livestock production are reduced, these reductions may be considered permanent. In contrast, release of CO_2 from cultivated soils previously under grass, will not continue indefinitely but will come to an equilibrium.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing feed records and allowing farm visits for verification.

Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emission factors and stock change factors for use with activity data.

Adaptation effect

Alternative feeds and more diverse forage crops can diversify feed sources and reduce farm exposure to collapse in local fodder production due to droughts.

Barriers and constraints

The area of land on which forage maize will grow imposes constraints on the amount of maize silage available for cattle feed. There are two constraints here: landform, forage maize is not a suitable crop on land prone to soil erosion; climate, not all parts of the EU are warm enough for the cultivation of forage maize. Although this may be possible with the development of new, earlier maturing genotypes, it may not necessarily be desirable from an environmental or aesthetic perspective.

Co-benefits

Optimising feeding strategies, by reducing N excretion from livestock, will not only reduce emissions of NH_3 and N_2O but also reduce the potential for NO_3^- leaching following application of manures to land.

Risks and trade-offs

Providing feeding strategies are optimised, i.e., they do not compromise production, there are no risks. Over the last 20 years there have been substantial reductions in the CP intake of pigs and poultry without reductions in output from the adoption of improved feeding strategies. Trade-offs will arise mainly due to release of CO_2 from grassland converted to the production of maize silage and, in some locations, an increase in soil erosion and pollution of watercourses from run-off.

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Webb J, Broomfield M, Jones S, Donovan B. 2014. Ammonia and odour emissions from UK pig farms and nutrient leaching from outdoor pig production. A review. Science of the Total Environment, 470-471, 865-875.

A.1.5.3 Optimised forage/grazed crop utilisation

Measure description

Improving forage quality is an effective way of decreasing enteric CH_4 emissions (Hristov et al. 2011). Forage quality can be improved by harvesting or grazing less mature forages, through the selection of genetic strains or species that have superior digestibility, and through proper storage, especially ensiling, to conserve digestible nutrient content, improve dietary utilisation, and increase feed efficiency (Knapp et al. 2014).

Effect of mitigation measure

Optimised forage/grazed crop utilisation can change net greenhouse gas (GHG) emissions in four principal ways.

For a given unit of gross energy intake (GEI), ensiled forages have been shown to produce less CH_4. than dried forages. Maize and whole-crop small-grain silages may yield less CH_4 than grass silage, probably due to differences in carbohydrate composition and digestibility, albeit further work is needed using direct *in vivo* comparisons and whole-farm GHG analyses to quantify all of these potentialities (Knapp et al. 2014).

Some energy-rich forage crops, such as forage maize, require substantially less N fertiliser input than conserved grass. This reduces GHG emissions in three ways. First, the reduced N fertiliser requirement of such forage crops reduces the need for N fertiliser and thereby reduces the GHG emissions arising from N fertiliser manufacture. Second, reducing the amounts of N fertiliser applied to land reduces both direct emissions of N_2O to the atmosphere following N fertiliser application and will also reduce indirect emissions following NH_3 emissions and nitrate leaching arising from N fertiliser use. Third, the protein content of forages that require less N fertiliser is generally less than that of grass and hence both N intake and N excretion by livestock will be reduced thereby further reducing direct and indirect emissions of N_2O (Martineau et al., 2016).

The use of clover/grass pastures is a well-established practice and can produce forage yields as great as those obtained using intensively N fertilised all-grass swards. By reducing N fertiliser use the GHG emissions arising from N fertiliser manufacture can be reduced together with reducing direct and indirect N_2O emissions following the application of N fertiliser to land (Martineau et al., 2016).

The use of forage crops may also be improved by increasing the quality of forages by better management of harvesting and storage or pasture management Knapp et al. (2014).

Abatement potential

Hristov et al. (2013) reported the potential for CH_4 emission reductions to be “low to medium” (but are not quantified).

For this measure we did not find quantitative evidence for the mitigation effect and therefore we assume no mitigation for this measure.[146]

Overall emissions impact

Hristov et al. (2013) considered the approach to be effective with no adverse effects on the livestock and with an overall benefit to the environment.

Displacement effect

The need to increase production of non-grass forages is likely to reduce the area needed for grassland. Reducing the need for grass (and hence grassland) will reduce the incentive for converting arable land to grassland thereby reducing the potential to encourage C sequestration in soil by converting arable to grassland.

Permanence

Hristove et al. (2013) considered the CH_4 reductions attainable by optimising forage use to be long term.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

[146] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data.

Adaptation effect

Alternative feeds and more diverse forage crops can diversify feed sources and reduce farm exposure to collapse in local fodder production due to droughts.

Barriers and constraints

A major barrier to optimising forage utilisation may be the requirement for greater management input which may be limited by labour availability. Both soil type, climate and weather at crucial times of the year may also make optimising forage utilisation difficult. Hristov et al. (2013) noted the critical effect of maturity on grass silage digestibility; each 1-week delay in grass harvest reduced digestibility by 3 to 3.5 percentage points.

Co-benefits

Livestock production can be increased by improved forage utilisation. Hristov et al. (2013) reported a 10 g/kg increase in digestible OM concentration of grass silage DM could increase 1) daily milk yield of lactating dairy cows by 0.37 kg, 2) daily carcass gain of beef cattle by 28 g/head, 3) daily carcass gain of finishing lambs by 10 g/head, 4) lamb birth weight by 0.06 kg, and 5) ewe BW post-lambing by 1.45 kg.

Risks and trade-offs

The need to increase production of non-grass forages is likely to reduce the area needed for grassland. Converting grassland to tillage land will lead to mineralisation of soil organic matter and evolution of CO_2 thereby reducing the amount of C stored in the formerly grassland soil (Martineau et al., 2016).

On average the effect of zero tillage on production is negative (Pittelkow et al., 2015).

References

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A.1.5.4 Breeding lower emissions animals

Measure description

This mitigation action is to breed ruminants with reduced emissions of methane (CH_4) per tonne of product.

Effect of mitigation action

Historically, selection for efficiency of production in ruminant species has also led to reductions in emissions of CH_4 (e.g., Capper et al., 2009). In many cases this has been achieved through selection of production traits and traits related to the efficiency of the entire production system (e.g., fertility and longevity). The impact of selection on these traits is twofold:

1. Reducing the number of animals required to produce a fixed amount of output. This leads to a reduction in emissions of CH_4 per kg of meat or litre of milk produced.
2. Increasing the efficiency of production will help reduce the finishing period for meat animals, therefore reducing emissions per unit output. Moran et al., (2008) reported that the efficiency of beef production systems was paramount in reducing the GHG emissions per unit output; intensive concentrate-based systems produced the least emissions. While this study did not consider the externalities of the system such as the carbon cost of producing concentrate diets, some energy-rich crops, such as forage maize, require substantially less N fertiliser input than conserved grass. There is also a significant

breed difference suggesting that bigger breeds of cattle produced less emissions/unit output than the smaller, traditional, breeds.

3. There is also potential to select animals that emit less methane CH_4 than the average and develop ruminant breeds with reduced emissions of CH_4 per tonne of product (Hristov et al., 2013).

Abatement potential

The UK Defra Project AC204 (Genesis Faraday Partnership, 2008) reported that the improvement in livestock species has resulted in a 0.8 to 1.2% per annum decrease in emissions per year from species the pig, poultry and dairy sectors, that each of which readily adopt genetic improvements, whereas the beef and sheep sectors have been slower to utilise livestock with improved genetics through the population (i.e., pigs, poultry and dairy cattle).

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.00030 to 0.035 t CO_2e/head/y.[147]

Overall emissions impact

Martineau et al. (2016) estimated the greatest absolute reductions in annual CH_4 emissions from livestock breeding would be found in those countries with the greatest numbers of ruminant livestock (France and Germany). However, the greatest reductions in CH_4 emissions per head of livestock were estimated for Poland, Denmark, Estonia and Lithuania.

Displacement effect

Displacement effects can occur when output is decreased, through increases in production and emissions in other locations, driven by market demand. Since reductions in CH_4 emissions per ton of product have been achieved by improving animal performance, continued efforts along these lines are unlikely to cause displacement.

Permanence

Emission reductions by utilising breeds that emit less CH_4 per ton of product are likely to be permanent providing those breeds continue to be used.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors for use with activity data. Measurement of the impact is likely to relate to the ability to measure and monitor the emissions from animals and recalculating emissions factors for lower methane animals. This requires scientific studies and publications to develop an evidence base to support changes in emissions factors.

Adaptation effect

N/A

Barriers and constraints

Breeding programmes for low CH_4 emissions in ruminants have only recently started and there are several technical barriers to be overcome, including maintaining lower levels of CH_4 emissions during the lifetime of the animal as this is also influenced by the microbial population of the rumen, not just the genotype of the animal (Martineau et al., 2016).

Co-benefits

Since reductions in CH_4 emissions per ton of product have been achieved by improving animal performance, further improvements should increase farm output and profit (Capper et al., 2009).

Risks and trade-offs

At this stage in development, it is not possible to assess what, if any, other environmental benefits, or risks are likely to arise from selectively breeding ruminants for lower methane emissions, in addition to the climate mitigation effects (Martineau et al., 2016). Dewhurst (2019) noted that when animals are selected for improved

[147] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

performance, e.g., milk yield, this can lead to health problems, e.g., reduced fertility in Holstein-Friesian dairy cows.

References

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A.1.5.5 Crop breeding for varieties that use N more efficiently

Measure description

Some crops use N more efficiently than others. Notably, legumes can fix atmospheric nitrogen through symbiotic relationships with bacteria in the soil, whereas other crop species cannot do this. There is a continuing effort to breed cereal and other non-leguminous crops to fix nitrogen (Mahmud et al., 2020), but there is not yet any commercial application. Opportunities to breed crops with a lower N requirement were also reviewed however, limited evidence was available.

Effect of mitigation measure

The effect of this mitigation measure will be similar to that for M14, sub measure “Legumes in a crop rotation and increased legume share in grass mixes”.

Abatement potential

The mitigation potential is expected to be similar to that for M14, sub measure “Legumes in a crop rotation and increased legume share in grass mixes”, but without risk of emissions leakage through displacing non-legume crops.

We estimate the mitigation potential per ha to be in the range 0.021 to 0.46 t CO_2e/ha/y.[148]

Overall emissions impact

Decreased emission of N_2O will decrease total greenhouse gas emissions at a territorial level.

Displacement effect

None.

Permanence

Soil organic carbon storage is not strongly affected by use of nitrogen fixing crops, so this is not relevant.

[148] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement requirements
Measurement of the activity depends on farmer co-operation in sharing records of farm activities and can be verified by inspection during farm visits.

Adaptation effect
Adaptation effects will need to be assessed when this mitigation measure becomes commercially available.

Barriers and constraints
The main barrier is that varieties that fix nitrogen are not yet available.

Co-benefits
Co-benefits will need to be assessed when this mitigation measure becomes commercially available.

Risks and trade offs
Risks and trade-offs will need to be assessed when this mitigation measure becomes commercially available.

References
Mahmud K, Makaju S, Ibrahim R and Missaoui A. 2020. Current Progress in Nitrogen Fixing Plants and Microbiome Research. Plants, 9: 97.

A.1.5.6 Legumes in a crop rotation and increased legume share in grass mixes

Measure description
Legumes are plants that can fix atmospheric nitrogen through symbiotic relationships with bacteria in the soil. This reduces the need for manufactured nitrogen fertilisers, including in following crops that are not legumes (Martineau et al., 2016). Grain legumes can be included in a crop rotation, such as peas or field beans. Forage legumes (e.g. red clover, alfalfa) can be grown in an arable crop rotation, either as a perennial crop for a period of (e.g.) 2 to 5 years, or as part of a species mix with grasses in a perennial ley. Legumes may also be grown with cereal crops and then be used for grazing after the cereal crop is harvested

Effect of mitigation measure
Use of legumes in rotations or in species mixes with grass decreases the need for manufactured nitrogen fertiliser, thereby decreasing soil emissions of nitrous oxide as a consequence of nitrogen applications, both in the legume crop and in following crops as residues from the legumes are broken down. There are also avoided emissions from the manufacture of inorganic nitrogen fertilisers.

Abatement potential
Jeuffroy et al., 2013 showed that N_2O emissions decreased by 20–25% through including one legume crop (peas) in a three-year rotation.

Feliciano *et al.,* (2013) considered that inclusion of clover in grassland can potentially reduce greenhouse gas emissions by 15 to 32%.

We estimate the mitigation potential per ha to be in the range 0.021 to 0.46 t CO_2e/ha/y.[149]

Overall emissions impact
Decreased emission of N_2O will decrease total greenhouse gas emissions at a territorial level.

Displacement effect
The inclusion of legume crops in a rotation can result in displacement of arable crop production with displaced emissions. However, this is uncertain, and quantification is complex.

There is no displacement effect of increasing the legume share in grass mixes.

Permanence
Soil organic carbon storage is not strongly affected by use of legume crops, although this depends on the crop replaced by the legume crop.

[149] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016), and this can be used to estimate the areas of crops by species.

Adaptation effect

Crop diversification (including annual crop type mixes and switches to perennials) and longer crop rotations spreads the risk of losing an entire year's production, as different crops respond differently to weather and climate (EEA, 2019). More diverse crops diversify also farm income, contributing to more resilient farm systems. Mixed production systems such as agro-pastoral, agro-silvo-pastoral systems, double-cropping systems and mixed crop-livestock systems can increase land productivity and efficiency in terms of use of water and other resources, protect against soil erosion and lead to enhanced nutrient use efficiency (EEA, 2019).

Barriers and constraints

The main barrier is lost income from the crops that are replaced by legume crops which may have higher margins. Whole farm planning is needed to manage the changes in outputs.

Co-benefits

In arable rotations, this mitigation measure can offer opportunities to reduce the incidence of pests, weeds and diseases and may also increase biodiversity (Martineau et al., 2016).

Risks and trade offs

Care is needed to avoid large emissions from displaced crops, and more research is needed to predict and quantify the displaced emissions.

References

EEA (2019). Climate change adaptation in the agriculture sector in Europe (No. 4/2019).

Feliciano, D., Hunter, C., Slee, B. and Smith, P. (2013) Selecting land-based mitigation practices to reduce GHG emissions from the rural land use sector: A case study of Northeast Scotland, *Journal of Environmental Management*, 120: 93-104.

Jeuffroy MH, Baranger E, Carrouée B, de Chezelles E, Gosme M, Hénault C, Schneider A, and Cellier P. 2013. Nitrous oxide emissions from crop rotations including wheat, oilseed rape and dry peas, Biogeosciences, 10: 1787–1797.

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A.1.5.7 Improved Rice Cultivation (Alternate Wet and Dry Techniques)

Measure Description

By altering irrigation practice to provide alternate periods when the soil is wet and dry (Alternate Wet and Dry (AWD) techniques), periods of aerobic conditions in the soil are created thereby reducing methane (CH_4) emissions.

Effect of Mitigation Action

The conventional way to grow irrigated rice is to flood paddy fields, maintaining standing water throughout crop growth, then drain water from the fields 1–2 weeks before harvesting (Bouman et al., 2007; cited in Thakur et al., 2018). The International Rice Research Institute (IRRI) has developed rice husbandry techniques to reduce water use by between 10 and 40% (Lampayan et al., 2015; cited in Oo et al., 2018). The reduction in water use is achieved by AWD during rice growth. By reducing the time rice is grown under flood irrigation emissions of CH_4 are also reduced. A disadvantage of AWD is that emissions of nitrous oxide (N_2O) can be increased. However, during rice cultivation emissions of CH_4, expressed as CO_2 equivalent, are much greater than those of N_2O and in practice any increases in N_2O emissions from AWD are outweighed by the reductions in CH_4 emissions (Oo et al., 2018 and references cited therein).

Abatement potential
Oo et al.(2018) recorded GHG reductions of c. 20-40% but cited reductions of up to 90% reported by other workers.

Based on mitigation of 20-40%, we estimate the mitigation potential per ha to be in the range 0.028 to 1.4 t CO_2e/ha/y.[150]

Overall emissions impact
The overall impact of AWD on GHG emissions is likely to be small since the area of irrigated rice grown within the EU (450 × 10^3 ha) is only c. 0.8% of the total cereal area (57 × 10^6 ha).

Displacement effect
Displacement effects can occur when yield is decreased, through increases in production and emissions in other locations, driven by market demand. While the impacts of AWD on rice yield have been inconsistent, yield increases have been recorded as well as decreases (Oo et al., 2018). Hence, displacement is likely to be small. However, AWD does not appear to have been tested under European conditions.

Permanence
Reductions on CH_4 emissions from AWD are likely to be permanent as long as the practice is maintained.

Measurement requirements
Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data. However, the application of AWD varies greatly from farm to farm; the exact schedule often finalised for the convenience of the farmer (Thakur et al., 2018). Hence in the absence of a standard operating procedure monitoring the effectiveness of AWD will be difficult.

Adaptation effect
AWD reduces irrigation needs in the post flowering period and can therefore lead to net savings in water use. Most water savings occur during dry season cultivation and in water scarce areas, when AWD avoids permanent flood conditions in paddy fields. Higher water productivity can increase water security to rice farmers, if it does not result in an expansion of cultivated areas. It also increases the resilience of the crop to water and heat stress during the post vegetative period as AWD favours root development and modify grain-filling rate (Thakur et al., 2018).

Barriers and constraints
In order for farmers to successfully adopt AWD simple irrigation indices need to be developed. The IRRI have made some progress in this (Oo et al., 2018).

Co-benefits
Reduction of CH_4 emissions is a co-benefit of AWD since the practice was developed in order to reduce water use during rice cultivation. However, should AWD be promoted to reduce GHG emissions there will therefore be a benefit in reduced water consumption.

Risks and trade offs
Such modified rice growing techniques have been shown to both increase and decrease grain yield per hectare (Oo et al., 2018) and water use is reduced there do not appear to be serious risks or trade-offs.

References
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[150] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Thakur AK, Mandal KG, Mohanty RK, Ambast SK. 2018. Rice root growth, photosynthesis, yield and water productivity improvements through modifying cultivation practices and water management Agricultural Water Management 206, 67–77.

A.1.6 Relevant measures in other groups

Most, perhaps all, of the measures in section A.2 (Carbon stock change) can have consequences for non-CO_2 GHG emissions (N_2O and CH_4), although there is high uncertainty regarding the size and direction of change. Measures that involve a change of land use (including land fallowing of arable land) can influence N_2O emission (through changes in N inputs), but these changes may be compensated for by displacement effects (activities that stop because of land use change may occur elsewhere instead).

Changes to peatland management may also have consequences for non-CO_2 GHG emissions (N_2O and CH_4). The relationship between peatlands and wetlands and greenhouse gas (GHG) emissions is complex. The fluxes of CO_2, CH_4 and N_2O vary depending on the condition and hydrological status of the wetland.

Use of cover crops, changes to cultivation practices, retention of crop residues, mulching and avoidance of compaction can all influence N_2O emissions, through changes to soil water status and N inputs.

A.2 Carbon stock change

A.2.1.1 Conversion of arable land to grassland to sequester carbon in the soil

Measure description

This mitigation measure involves the conversion of arable/tillage land to permanent grassland (grass which is no longer cultivated and has a perennial and permanent grass sward).

Effect of mitigation action

Cultivation is a major source of CO_2 emissions through oxidation of soil organic matter. By stopping cultivation of rotational grass, emissions are reduced, and soil organic carbon (SOC) is maintained.

Converting arable (tillage) land and annual crops to grassland has the potential to reverse the losses of carbon dioxide from soils resulting from the oxidation of organic matter. Converting to a perennial grass sward allows carbon stocks to build. The CLIMSOIL project (Schils *et al.,* 2008) concluded that grassland soils generally accumulate carbon (C), although with a large uncertainty. IPCC guidelines for calculating carbon stock change in cropland converted to grassland provides a range of default factors for the carbon stock change for different soil types. Accumulation of carbon stock is averaged over 20 years. Assumptions in IPCC guidelines state that the accumulation of carbon stock is fastest in the early years of conversion, reducing over a 20-year period, at which point it reaches equilibrium.

The rate of sequestration is likely to be highly variable and will depend on several factors such as the baseline level of soil organic matter/soil organic carbon, soil type, climatic factors and the nature and management of the grass ley that is used. A review of grassland C stock data found soil C stocks calculated to a depth of 30 cm ranged from 8.8 to 353 t C ha^{-1} (per hectare).

Abatement potential

The following examples were found:

- A recent study for UK government (awaiting publication) calculated that carbon stock change rates in grassland following cultivation show a theoretical rate (using Landscape DNDC) of C accumulation in grasslands within the first 5 years of 1.8% year-1 (yr-1, i.e. per year), reducing to rates of 1.1% year-1 over 0 to 10 years.
- Verhagen (2002) calculated carbon fluxes (using the CESAR model) under the 'business as usual' scenario in the 2008 to 2012 commitment period, as 0.52 t C ha-1 yr-1 in grasslands and 1.44 t C ha-1 yr-1 for grasslands converted from arable land use.
- Conant et al. (2017) showed conversion from cultivation increased grassland C by 0.87 t C ha-1 yr-1.
- Post and Kwon (2000) estimated average rates of C accumulation for grassland establishment to be 0.33 t C ha-1 yr-1.

- Rates of sequestration do not continue at a uniform rate and are likely to diminish significantly over time. It is likely that an equilibrium point would be reached at which any C gained by the system would be matched by losses through respiration and turnover (Smith 2014).

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 1.2 to 5.3 t CO_2e/ha/y.[151]

Overall emissions impact
There is a clear benefit of converting arable to grass in terms of enhancing annual carbon sequestration rates. However, these do not continue in perpetuity and there is a need to maintain and protect the carbon store by avoiding cultivation practices in the future. Current assumptions (IPCC) assume emissions equilibrium is reached at 20 years. The net effect is also likely to be diminished by the likelihood of livestock emissions resulting from grazing the converted land.

Displacement effect
Land converted to grassland is likely to have a displacement effect as arable crop production will cease making way for grassland systems. The full displacement effect will depend on the crop type and ultimate market – which could be livestock feed.

Permanence
Permanence is potentially an issue as the sequestration rates diminish over time and the carbon stock stored needs to be protected from cultivation.

Measurement requirements
This measure should be relatively easy to collect data on and monitor using LPIS and/or remote sensing technology.

Adaptation effect
The conversion of arable land into grassland can contribute to reduce soil compaction, preserve and improve soil structure and re-establish healthier soil functions. It can increase infiltration rates, which contributes to increasing soil moisture content and groundwater recharge. Compared to arable land, runoff attenuation can reach 50 to 66% on grassland used for grazing, and up to 100% on more natural meadows used for haying (EC, 2014). Conversion also generally involves reducing pesticide and fertiliser use and increasing surface roughness with the grass which impedes run-off and wind and rain erosion (OECD, 2014). Pollutant leaching and pollution load in rivers are also reduced.

Conversion to permanent grassland and pastures will entail greater benefits over temporary ones. Because vegetation cover becomes permanent (compared to arable land), conversion may increase evapotranspiration and reduce groundwater recharge. Large scale conversion should consider the impact on catchment water budgets.

Barriers and constraints
Low direct capital cost of sowing grass in place of an arable crop but depending on the scale of change, it could mean a whole system change with the introduction of livestock and the associated costs. Profitability per Ha of grass crops vs arable crops tends to be lower, however this could be a cost-effective measure on marginal land, such as field margins.

Co-benefits
Introducing grassland into areas of dominantly arable cropping can have biodiversity benefits. When appropriately positioned there can also be positive effects on water quality.

Risks and trade offs
Reduced profitability, displacement in production, increased methane emissions from enteric fermentation.

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A.2.1.2 Grassland management to enhance C sequestration

Measure description

This measure reviews activities that can be adopted to maintain and enhance carbon sequestration in grassland.

Effect of mitigation measure

- **Cultivation** is a major source of CO_2 emissions through oxidation of soil organic matter. By stopping cultivation of rotational grass, emissions are reduced, and soil organic carbon (SOC) is maintained.
- In addition to maintaining SOC through reducing cultivations, other management practices impact on the rates of sequestration in grassland. Reports reviewed share a general agreement that management practices do impact on rates of sequestration, these include, species diversity (including legumes), moderate stocking densities, and the addition of organic manures and synthetic fertilisers.
- The greatest potential for enhanced sequestration is in degraded soils, however the protection of soil carbon stocks in non-degraded situations is incredibly important.
- **Fertilisation**: Reports reviewed look at the effect of specific activities such as the addition of synthetic fertiliser or organic manures, however these studies find it difficult to disaggregate between activities in combination. The basic principle of this measure is that the optimum conditions for grass growth (plant productivity) should be created while minimising the risk of any nutrient losses to the environment. This creates the conditions for optimum biomass accumulation both above and below the ground, increasing the likelihood of creating stable carbon pools in soil.
- The addition of organic manures has an additional benefit as it introduces (imports) organic matter into the soil which can be stored. Positive impacts of manure application on SOC may exceed the impacts of manufactured fertilisers (Jones et al. (2006)) Soussana et al. (2007) assessed nine grassland sites and demonstrated that carbon storage was positively related to nitrogen supply, but this was from a combination of synthetic and organic fertilisers.
- **Species diverse swards:** Legumes are known to increase SOC through N fixation and corresponding increases in productivity (Mortenson et al., 2004) which also reduces rates of N fertilisation required. Deep-rooting perennial species may help to enhance SOC stocks at depth (Carter and Gregorich, 2010). Increased plant diversity can also increase carbon (C) inputs into the microbial community (Steinbeiss et al., 2008) although the diversity needs to have a positive impact on productivity.

Note: as previously explained renovation and reseeding of grassland to establish species can also lead to release of SOC (Schils et al., 2005).

Abatement potential

The following examples were found:

- Buckingham et al., (2013) found positive changes in grassland soil C stocks brought about through slurry or manure applications (0.7 to 15 t C ha^{-1}) due to the direct applications of additional organic matter and the nutrient contribution optimised grass growth and led to biomass accumulation both above and below the ground
- Jones et al. (2006) reported C storage of 15.7- 48.3 t C ha^{-1} following application of manure over a six-year period.
- Smith et al. (2008) reports a potential for both cropland and grassland of -0.62 – 6.20 t t C ha^{-1} yr^{-1} for application of manure or biosolids.
- A meta-analysis by Conant et al. (2001) reports that fertilisation in general (manures and manufactured fertilisers) can increase SOC by 0.3 t C ha/y. The review highlighted that improved grassland management, fertilisation, sowing legumes and improved grass species, irrigation and conversion from cultivation all tend to lead to increased soil C, at rates ranging from 0.105 - 1 t C ha^{-1} yr^{-1}.
- Conant et al., 2001 reported that improved grazing management, which involves introducing grazing or maintaining a moderate grazing intensity, can increase SOC by 0.35 t C ha^{-1} yr^{-1}.
- Carter, M.R., Gregorich, E.G., (2010) Carbon and nitrogen storage by deep-rooted tall fescue (Lolium arundinaceum) in the surface and subsurface soil of a fine sandy loam in eastern Canada.
- Sowing legumes on grasslands can increase SOC by 0.75 t C ha^{-1} yr^{-1} .(Conant et al., 2001)

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.39 to 3.7 t CO_2e/ha/y.[152]

Overall emissions impact

Overall, the results for management of grassland to enhance rates of sequestration are positive. However, disaggregation of the effectiveness to a single measure is more challenging.

Carbon sequestration rates also vary with time and age of grassland and are dependent on the baseline C stock. Powlson et al (2012) showed that SOC accumulation declines in long term experiments (>50 years) with farm manure applications as a new equilibrium is approached.

Displacement effect

Productivity gains may reduce without cultivation in some circumstances such as highly productive ryegrass swards, however gains may be made in other circumstances when productivity improvements are made.

Permanence

Permanence is potentially an issue as the sequestration rates diminish over time and the carbon stock stored needs to be protected.

Measurement requirements

Measuring the impact of management activity is difficult and would require field scale measurement and monitoring over many years. However, models could be used to predict the effects with supporting ground truthing activities.

Adaptation effect

Due to their rooted soils and their permanent cover, meadows and pastures provide runoff attenuation and greater infiltration, thus good conditions for the uptake and storage of water during temporary floods (EC, 2014). Appropriate management of grasslands and pastures (e.g. controlled field machinery operations to avoid soil compaction, reducing livestock density) can also contribute to improve soil structure, reduce wind and water soil erosion, and protect water quality by trapping sediments. Increased organic carbon and biomass in grasslands contribute to more stable yields for livestock farming systems.

Barriers and constraints

Farmers use cultivation as a means of sward renewal to maintain and increase productivity. Reducing cultivation could lead to a reduction in productivity in grassland systems.

[152] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Co-benefits

Improved soil health, reduced costs of cultivation, more diversity in the sward for biodiversity.

Risks and trade offs

Very few risks if implemented appropriately. This includes ensuring the right levels of nutrients are applied and that environmentally sensitive land is not 'improved'.

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A.2.1.3 New agroforestry

Measure description

Agroforestry systems combine trees and shrubs with crop and livestock production systems. There are two main types of agroforestry systems:

- Silvo-arable agroforestry: the inclusion of trees in crop production systems, trees are grown in-field and often in rows which are large enough to allow machinery access to the crop.
- Silvo-pastoral agroforestry: the inclusion trees in grazing pasture systems.

Agroforestry is a general term for the inclusion of trees in farming systems and can include hedgerow and boundary features. For the purposes of this review, we are focussing on in-field agroforestry activities as boundary features are covered in other mitigation measures.

Effect of Mitigation measure

The accumulation of above ground woody biomass in trees stores carbon sequestered from the atmosphere. The inclusion of trees and shrubs also increases below ground biomass stores in soils.

Abatement potential

The following examples were found:

- Frelih-Larsen *et al.,* (2014) reported that agroforestry sequesters 138 kg carbon per hectare per year. Additionally, 'experiments in Vézénobres (France, Mediterranean climate, sandy loam soil) indicate that poplars (140 trees/ha) of 13 years' old have, on average, sequestered 540 kg C/tree in the trunk and 60 kg C/tree in the root system. This parcel has a potential of sequestering 6.5 t C ha^{-1} yr^{-1}) in the trees itself'

(Aertsens *et al.,* 2013) while suggesting an average of 2.75tC ha^{-1} yr^{-1}. However, 'the type of agroforestry systems and their capacity to sequester C vary globally' (Oelbermann *et al.,* 2004).

- Soil carbon sock change varies considerably and is dependent on a number of climatic and soil conditions. Feliciano et al (2019) reported a result for temperate agroforestry systems ranging from -8 t C/ ha^{-1} yr^{-1} to 8tC ha^{-1} yr^{-1}.
- Kay et al (2019) found a range of carbon stock change from agroforestry systems of between 0.09 and 7.29t C ha^{-1} yr^{-1}. At the lower end, this included boundary features such as hedgerows. The higher end relates to higher density, faster growing tress species.
- Kay et al, table 3 provides a full list of sequestration rates for a variety of agroforestry systems in different bioclimatic regions.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.33 to 27 t CO_2e/ha/y.[153]

Overall emissions impact

Agroforestry is known to have an important role in carbon sequestration (Oelbermann *et al.,* 2004; Aertsens *et al.,* 2013; Baah-Acheamfour *et al.,* 2014). These systems can store more C than conventional arable systems (Baah-Acheamfour *et al.,* 2014). Although, Povellato *et al.,* (2007), found whilst the agroforestry sector acts as a sink for CO_2, it may also be a source of N_2O and CH_4 emissions.

Displacement effect

The displacement effect is likely to be highly variable depending on the circumstances in which agroforestry systems are implemented.

Ray et al (2013) (cited in Kay et al. 2019) reported that there may be a trade-off between the introduction of agroforestry on arable and grassland and food production. However, Nair and Garrity, 2013 (cited in Rivest *et al.,* 2013) states that agroforestry has the ability to maintain, or even increase, tree and crop productivity under climate change whilst also providing benefits for other ecosystem services.

Permanence

The permanence of the sequestered carbon is also highly dependent on the agroforestry system and ultimately depends of the purpose for which the woody biomass has been produced. For example, agroforestry could be high density (400 stems/ha) poplar; harvested at 15 (first cut) and 25 years. This has a high sequestration potential annually (2.78 – 6.35 t C/ha year (Kay et al. 2019)), however the permanence depends on the use of the harvested wood product. If this material is used as biomass fuel (burnt) then sequestered carbon is released back into the atmosphere. While this is preferable to burning fossil fuels, the sequestered carbon in the woody biomass is not permanent.

In other systems, trees may be planted to deliver high nature and cultural benefits, often broadleaved and unharvested. In this system, numbers of stems (50 – 300) may be fewer and rates of sequestration may be slower (0.59 – 2.83 t C/ha year) but there is greater permanence of the carbon sequestered. It is important to note that rates of sequestration will decline as trees reach maturity and the permanence of the carbon stock is dependent on the ongoing management of the wood.

Measurement requirements

Sequestration rates are well understood for woody biomass products and calculated measurements of the effect can be achieved through modelling and can be detected in the inventory, provided accurate activity data is available. Activity data should be straightforward to collect as there is a physical feature available for measurement. Remote sensing could be deployed for measurement of activity data.

Remote sensing may also enhance the accuracy of measurement of biomass accumulation as technologies advance to identify species and densities of woody biomass.

Adaptation effect

Adopting agroforestry on cropland and grasslands can reduce soil erosion and the transmission of pollutants as the trees act as barriers against the eroding effect of rain and wind. In doing so, they can contribute to reduced overland run-off and increased infiltration, thereby contributing to reduced flood risk downstream while

[153] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

recharging soils in water. Trees can also act as buffers for extreme heat and frosts (Burgess et al., 2017). Leaves and small branches can act as fodder bank to feed animals in especially dry years, reducing reliance on external sources of fodder. Agroforestry can improve timber quality of previously monoculture tree production and increase their resilience to strong winds, pests and diseases as trees benefit from fertilisation applied to associated crops and the annual ploughing of soil for crops encourage tree roots to go deeper (Burgess et aL 2017). Overall agroforestry can increase farm economic resilience by diversifying farm income.

Barriers and constraints

Farmers need to be quite motivated to adopt this practice (Aertsens et al., 2013) as the introduction of agroforestry requires significant changes to crop husbandry and farm management.

Barriers include:

- A perception that the impact on productivity is significant
- Reluctance to change the physical characteristics of the landscape
- Perceptions of increasing difficulties in field operations

It is expected that some 50 million ha of pastureland would be available in Europe for the introduction of agroforestry (Aertsens et al., 2013). However, when agroforestry is carried out, cultural practices carried out for annual crops may need to be altered (Calfapietra et al., 2010). Thus, farmers may not choose to implement this mitigation measure.

Co-benefits

Co -benefits are likely to include:

- Reduction in soil erosion
- Reduction in NO_3^- leaching
- Pest control
- Increased biodiversity
- Creation of a cooler microclimate
- Wind speed reductions
- Enhanced soil moisture
- Increased water use efficiency
- Aesthetic value (this could also be perceived as a risk depending on landscape and perspective)
- More resilient to climate change than monocultures
- Biomass production
- Reduction in dependency on timber products imported
- Reduction in flood risk
- More diverse soil microbial communities

George *et al.,* (2012) also argues that agroforestry will alleviate dryland salinity as well as stabilising agricultural systems.

Agroforestry may result in a decrease in deforestation: Dixon (1995; cited in Oelbermann *et al.,* 2004) ‘estimated that for each hectare of sustainable agroforestry production, up to 5 ha of deforestation could be prevented’.

Rivest *et al.,* (2013) suggest that agroforestry will bring increased microbial substrate use efficiency and microbial resilience which would increase crop productivity and improve tolerance to severe water stress, particularly in heavier soils with older trees.

Risks and trade offs

Risks include the displacement effect previously explained.

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A.2.1.4 Afforestation / avoiding deforestation

Measure description

For the purposes of this summary, the IPCC definition is used which states that afforestation describes forest planting activities on sites that have not been forested within the last 50 years, while reforestation refers to sites that have been stocked by forest plants within the last 50 years (SFC, 2010).

In the context of sequestration, it is assumed that measures taken in relation to forestry in Europe are permanent changes. This means that land that is afforested will remain forest. However, permanence will depend on the management, harvest and use of wood products.

This measure also includes afforestation through natural regeneration. This is where agricultural areas are left to regenerate naturally without active planting or stocking with trees.

We also review the role of preventing deforestation in protecting carbon stock and sequestration.

Effect of Mitigation measure

The IPCC states that afforestation sequesters carbon dioxide from the atmosphere through the accumulation of above ground woody biomass in trees and in dead organic matter carbon pools and to a lesser extent, increases below ground biomass stores in soils, which tend to accrue more slowly. However, on sites with low initial soil carbon stocks (e.g., after prolonged cultivation), afforestation can yield considerable soil carbon accumulation rates.

It is also important to note that the process of forest establishment due to the emissions associated with it. This arises from the soil and from machinery. Biomass clearing and site preparation prior to afforestation may lead to short-term carbon losses on that site (IPCC). The emissions from soil can be significant on high organic matter soils and should be avoided.

Preventing deforestation: Protecting Forest from all harvest typically results in maintained or increased forest carbon stocks, but also reduces the wood and land supply to meet other societal needs. The requirements for harvesting and management vary depending on the types of forestry activity and the uses of the product. If forest areas are replanted, then the result is continued sequestration. This is part of a sustainably managed forest production system.

Abatement potential

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 8.8 to 21 t CO_2e/ha/y.[154]

Overall emissions impact

The emissions effect of tree planting is generally positive, however emissions from soil cultivations and machinery should also be taken into consideration. Emissions from degraded soils that have previously been cultivated will be significantly less and can accrue more SOC. Post and Kwon (2000) report rates of 1 to 1.5 t CO2/ yr cited in the IPCC chapter 9 guidelines.

The UK Marginal Abatement Cost Curve (Eory et al 2015) factored in a range of parameters to their abatement potential calculations, including losses on cultivation/establishment and sequestration over a 100yr period based on a species mix of Sycamore, Beech, Birch, Oak and Douglas Fir. Management included some thinning. The abatement rate was calculated on the Forestry Commission Woodland Carbon Code. Using the 100yr horizon, the study factored in the different phases of establishment and growth including the initial period when emissions from soil exceed what is sequestered by trees, through the periods where the highest rates of sequestration occur (10 – 40 years) and when sequestration slows as trees reach maturity. The 100yr abatement potential per ha was calculated as 238.5 t C ha providing an average annual abatement potential of 2.39t C ha^{-1} yr^{-1} - this is based on the UK woodland carbon code (Forestry Commission).

Lamb et al. (2016) states a mean annual sequestration range of 2.9 to 4.7 t C ha^{-1} yr^{-1} for broadleaved species (sycamore, ash, birch) and 3.0 to 5.7 t C ha^{-1} yr^{-1} . These figures represent a 40yr period after planting.

The rates of sequestration for naturally regenerated woody biomass is significantly less as more time is required to establish the stand of trees although sequestration rates are likely to peak at a similar rate once a stand of trees has been established. Lamb et al. assumed a 16-year delay in the establishment of woody biomass on natural regenerated land and their assumptions resulted in an annual rate of carbon sequestration in soils and biomass under natural regeneration of 0.6 t C ha^{-1} yr^{-1} during the shrub phase increasing to 2.4 t C ha^{-1} yr^{-1} after ~35 years as woodland gradually becomes established.

We assume no additional sequestration takes place when preventing deforestation as the baseline includes the forested area which is protected by climate commitments.

Displacement effect

Planting trees on agricultural land can lead to a reduction in agricultural output and a consequent displacement of production and emissions (Eory et al. 2015).

Permanence

The assumptions made in the abatement potential area that no harvesting takes place within 100years. Permanence is variable depending on the management, harvesting and use of any harvested wood products.

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As stated in the introductory paragraph, we assume that forest land will remain forest land and that even areas that are clear felled will be replanted.

Measurement requirements

Sequestration rates are well understood for woody biomass products and calculated measurements of the effect can be achieved through modelling and detected in the inventory provided accurate activity data is available. Activity data should be straight forward to collect as there is a physical feature available for measurement. Remote sensing could be deployed for measurement of activity data.

Remote sensing may also enhance the accuracy of measurement of biomass accumulation as technologies advance to identify species and densities of woody biomass.

Adaptation effect

Forests can soak up excess rainwater, preventing run-offs and damage from flooding. Afforestation in headwaters or as riparian buffers can contribute to soak up excess nutrients, increasing infiltration, slowing water and thus decreasing sediment inputs to surface waters. By releasing water in the dry season, forests can also help provide clean water and mitigate the effects of droughts. The EEA (2015) estimates that, compared to basins with a forest cover of 10%, total water retention is 25% and 50% higher in water basins where the forest cover is more than 30% and 70%, respectively. There is also a risk that total water consumption increases since forest may use more water than crops (OECD, 2014). Targeted afforestation at a small scale (e.g. riparian buffers, water intensive crops, intensive livestock and arable areas) in order to maximise multiple benefits may hence be more preferable than large scale afforestation (EC, 2014). However, where protecting strategic catchment for drinking water supply purposes, large scale afforestation may be preferable.

Forestry can be used on less productive land such as slopes and rocky slopes, reducing erosion risks while increasing the production value of that land. In the Mediterranean basin, increasing land use forest cover can help combating soil erosion and desertification due to a regime of monsoon-type storms and droughts (EC, 2014).

Once trees have taken root, they are much more resistant to droughts and floods compared to agricultural crops. Forestry can thereby contribute to diversify and strengthen farm incomes and can be complementary to crop production systems. However, the establishment of single species plantations or intensive commercial production, unlike native or mixed forests, can lead to soil erosion and degradation of water quality.

Barriers and constraints

Many farmers need a significant extra incentive to encourage afforestation and to compensate for perceived opportunity costs of reducing agricultural production. This incentive may also have to compensate for any loss in land capital values (Bell and Greaves, 2010).

It is challenging to make farmers recognise the potential cost savings gained through reductions in their labour requirements by planting more trees. Farming is often more of a lifestyle than a business. This means that farmers are often prepared to devote time to the business without full financial recognition for their work. The average age of farmers is increasing and those nearing retirement are likely to be most willing to recognise the benefits of tree planting in reducing labour requirements (Bell and Greaves, 2010).

Co-benefits

Afforestation and woodland planting have the potential to deliver multiple co-benefits These include protecting biodiversity, enhancing water quality, delaying and reducing flood flows, preventing landslides, protecting landscape values, soil fertility and downstream agricultural land, enhancing air quality, providing shade and shelter, and preventing erosion caused by wind, water and desertification (SFC, 2010).

Natural regeneration leads to the same benefits to a lesser or greater extent to afforestation depending on the specific circumstances.

Risks and trade offs

Afforestation can increase risk of fires, as dead biomass accumulates and is potential fuel.

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A.2.1.5 Woodland and forestry management

Measure description

Woodland forestry contributes to climate change mitigation by conserving and increasing carbon stocks in forests (including above- and below-ground biomass, deadwood, litter, and soil), producing renewable materials that can be used to substitute fossil fuels and materials that are energy-intensive to produce; and storing carbon in harvested wood products.

Effect of Mitigation measure

Forest management activities influence on-site carbon stores, fluxes, and sequestration, both positively and negatively, either directly, by maintaining forest carbon stocks through forest conservation, transferring carbon from ‘‘live growing stock’’ to the ‘‘product’’ pools (e.g., thinning, final harvesting), or indirectly by altering growth conditions of trees (e.g., liming, fertilising). The effects can happen quickly (e.g., thinning) or evolve slowly (e.g., fertilisation). Activities may: affect the current stand (e.g., thinning regime) or future stands (e.g., regeneration); or be transient (e.g., minimizing site preparation, planting).

The emissions and sequestration rates of forests change over time depending on growth rates and associated accumulation of biomass and the decline of carbon sequestration in ageing forests. Mature forests may eventually reach an equilibrium at which relatively little further sequestration takes place. Therefore, the mitigation potential from forest management has limits (SFC, 2010).

Abatement potential

The following examples were found:

- Managed vs unmanaged woodland: the management of woodland allows wood products to be removed and either the carbon is stored or used as fuel. The management of woodland encourages further growth of the woodland as it is thinned. Natural England (NERR43) state that unmanaged forestry can achieve sequestration rates of 6 t C ha^{-1} yr^{-1} while managed forestry can achieve 22 t C ha^{-1} yr^{-1}. These estimates are for woodland during the 10 – 40 years when growth is at its fastest. However, this evidence seems to conflict with other evidence.
- Other evidence suggests that the rate of sequestration is not enhanced by management such as thinning or felling. However, woodland management means that the carbon stock can be transferred into harvested wood products (substitution) which is likely to reduce the needs for other materials in the economy, such as substituting fossil fuels with biomass. Selective interventions aimed at carbon management (Forest Research 2003) involved low level harvesting of certain trees. “As a general guide, selective intervention and carbon reserve management (minimal intervention) will usually result in higher, long term carbon stocks within a woodland ecosystem. However, substitution has the potential to provide long term reductions in C due to the impacts beyond the forest in terms of displacing fossil fuels and maintaining a carbon stock in harvested wood products”.
- Wood contains an equivalent of about 0.9 t of CO_2/m^3, which is stored in harvested wood products throughout their lifetime. At the end of their life cycle, most wood products can be recycled, thereby extending the carbon storage effect, and/or used as fuels to substitute fossil fuels. A meta-analysis has

shown that for each tonne of carbon in wood substituting for non-wood products, GHG emissions are reduced by approximately 2.1 tonnes of carbon (Sathre and O'Connor 2010).

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 8.4 to 16.8 t CO_2e/ha/y.[155]

Overall emissions impact

In general, a forest stand acts as an emission source directly after final harvesting or thinning. Harvesting at small scales, retaining canopy cover and/or early reforestation can limit loss of carbon. Close-to-nature forestry with longer rotation periods maintains relatively higher soil-carbon stocks. Whole tree harvesting increases the amount of harvested biomass by up to 40%, but can lead to losses of nutrients, and carbon losses in soil (particularly after stump extraction) and acidification unless appropriately compensated (e.g., through ash recycling). Selection of appropriate species mixtures can increase the overall production of forests. An important objective is to stabilize stands against biotic and abiotic disturbances, for example, to avoid large-scale loss of soil carbon (e.g., from drainage or wildfires) (SFC, 2010).

In managing forest for carbon, there is a number of variables to assess which include site conditions, productivity, vulnerability to natural events (wind and fire etc) and the uses of the harvested wood products (Forest Research 2003).

Displacement effect

There is no displacement effect.

Permanence

Permanence will vary depending on the use of the harvested material.

Measurement requirements

Activity data for different management approaches is required along with a detailed understanding of the effect of the management on sequestration rates and indirect impacts of the use of the harvested wood products. This can be a complicated area as evidenced by the lack of quantitative data in this summary.

Adaptation effect

Forests can be vulnerable to heatwaves, droughts, fires, pests and diseases brought by climate change. Diversity of tree species enhances forest resilience and increases the options available to forest managers to learn from climate change and respond accordingly (Isoard and Winograd, 2013). Forest management strategies should support a higher diversity of species either by natural processes or by planned adaptation measures. Other active woodland and forestry management include landscape planning, changes in management intensity, appropriate rotation periods, and salvaging dead timber. For example, improved forest regeneration can include adaptation measures that combine optimal choice of tree species, changing the spacing of trees, and even shifting planting season to enhance drought resistance.

Barriers and constraints

Barriers to encouraging management of woodland are in relation to the cost benefit and skills available on farms.

Co-benefits

The conservation of existing primary forests provides important opportunities for protecting carbon stocks, preventing future GHG emissions, and conserving biodiversity. Most of the carbon in a primary forest is stored in older trees or the soil.

Risks and trade offs

Land-use activities that involve clearing and logging reduce standing carbon stocks, cause collateral losses from soil, litter and deadwood and reduce biodiversity and thus ecosystem resilience. This creates a carbon debt which can take decades to centuries to recover, depending on initial conditions and the intensity of land use (AHTEGBC, 2009).

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A.2.1.6 Hedgerows and woody field margins

Measure description

Hedgerows are woody boundary features common in many European countries. They are highly variable in terms of their age, species composition, size and density which all have an impact on their ability to sequester carbon dioxide. The management of hedgerows also varies and includes:

Mechanical cutting by flail: when the growth achieved over the year is removed in the autumn/winter maintaining the hedge at a uniform size and shape. This can happen annually or in a 2- 3-year rotation

Coppicing: when the hedges are allowed to grow up for 10- 15 years and the woody biomass is removed at the base and the hedge regenerates from new base shoots.

Traditional hedge laying: again, the hedge is allowed to grow but instead of being coppiced, the larger woody material is removed and a proportion of the woody material is used to reform a living boundary by cutting through 90% of the stems (pleached) and weaving it in to a new hedge as shown in the figure **Error! Reference source not found.**below.

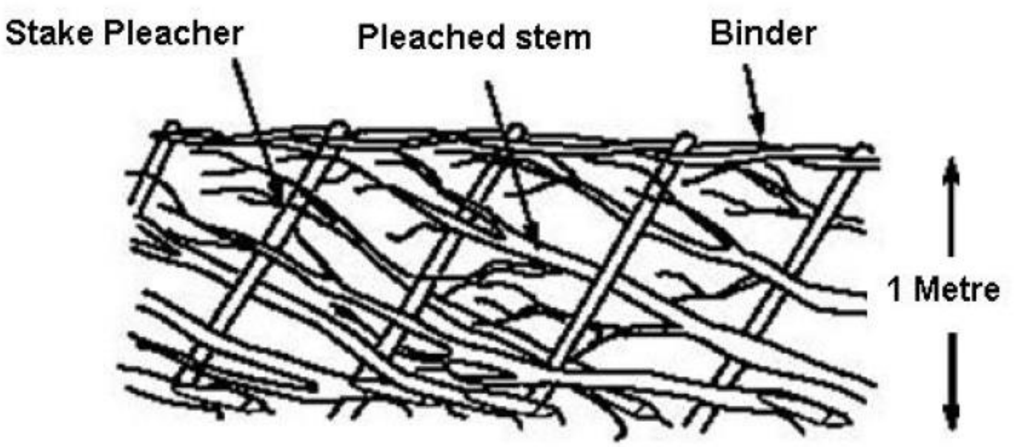

Diagram of a laid hedge.

Effect of Mitigation measure

Hedgerows play an important role in maintaining/enhancing biodiversity and creating wildlife corridors. They also act as a carbon store in both the above ground woody biomass and below ground soil carbon stores.

Hedgerow management is likely to have an impact on their capability to sequester carbon dioxide from the atmosphere. For example, the regular (often annual) removal of new growth limits the ability to accumulate biomass year-on- year. This management effect leads to the assumption that many mature hedgerows are in carbon equilibrium (not accruing any additional carbon in the form of above ground biomass)

New planting of hedge rows provides an opportunity for additional biomass accrual and associated carbon sequestration.

Abatement potential

The following examples were found:

- Results based on an assessment of existing LIDAR data in Ireland suggested that hedgerows and non-forest woodland could sequester 0.66 to 3.3 tCO_2 ha^{-1} $year^{-1}$ (Teagasc).

- A literature review of carbon stock and sequestration rates (Crossland 2015) found that estimates of carbon stock in hedgerow biomass ranges between 5 tC ha and 45 t C ha and below ground SOC stocks range from 3 – 136.8 t C ha. These estimates were based on modelling (Falloon et al., 2004; Warner, 2011; Robertson et al., 2012).
- Limited evidence was found relating to the management effect on C sequestration and the impacts of utilising wood products in hedges following management such as coppicing and laying or simply allowing hedges to grow to be wider and higher. Modelling conducted by Crossland in 2015 suggested that sequestration rates of unmanaged hedges ranged between 2.74 and 12.19 t C ha^{-1} $year^{-}$.
- New planting of hedgerow (Falloon et al. 2004) accrue 1 t C ha^{-1} $year^{-}$for 5 years and soil carbon increasing at 1.23%/yr until equilibrium.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 2.4 to 12 t CO_2e/ha/y.[156] However, activity data to allow this to be monitored are unlikely to be available in most Member States.

Overall emissions impact

Overall emissions impact of hedgerows is likely to be positive but highly variable depending on age, size, management and species composition.

Displacement effect

There is no displacement effect.

Permanence

Permanence will vary depending on the on-going management and the use of the harvested material.

Measurement requirements

Activity data for different management approaches is required along with a detailed understanding of the effect of the management on sequestration rates and indirect impacts of the use of the harvested wood products. This can be a complicated area as evidenced by the lack of quantitative data in this summary. There is the potential for remote sensing to assess overall hedge size and possibly the biomass density.

Adaptation effect

Forests can be vulnerable to heatwaves, droughts, fires, pests and diseases brought by climate change. Diversity of tree species enhances forest resilience and increases the options available to forest managers to learn from climate change and respond accordingly (Isoard and Winograd, 2013). Forest management strategies should support a higher diversity of species either by natural processes or by planned adaptation measures. Other active woodland and forestry management include landscape planning, changes in management intensity, appropriate rotation periods, and salvaging dead timber. For example, improved forest regeneration can include adaptation measures that combine optimal choice of tree species, changing the spacing of trees, and even shifting planting season to enhance drought resistance.

Barriers and constraints

Existing hedgerows are protected but there are cultural barriers in changing management of them. New hedgerows would need to be incentivised to cover all capital costs and offset perceptions of the inconvenience of creating smaller land parcels on increasing the width of boundaries

Co-benefits

Hedgerows provide a valuable habitat and wildlife corridors.

Risks and trade offs

Risks are minimal.

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[156] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

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A.2.1.7 Peatland/wetland maintenance and conservation

Measure description

The conservation of peat is a measure to preserve the carbon stored in wetland/peatland soils, i.e. it aims to avoid its loss through drainage. Appropriate land and water management is necessary to maximise climate benefits obtainable from peatland/wetland.

Effect of mitigation measure

Conserving peatland maintains its potential for sequestering carbon (C) in soil and reducing emissions of methane (CH_4) and nitrous oxide (N_2O).

The relationship between peatlands and wetlands and greenhouse gas (GHG) emissions is complex. The fluxes of CO_2, CH_4 and N_2O vary depending on the condition and hydrological status of the wetland. The amount and type of GHG emissions depend on the water saturation in the soil, climatic conditions and the nutrient availability. The drainage of wetlands and peatlands exposes organic carbon to the air, decomposition of the organic material occurs and emits CO_2. Drained organic soils with resultant low water tables continue to degrade and to emit CO_2, until either drainage is reversed, or all peat is lost. However, soils that remain saturated create anaerobic conditions and can release CH_4 and N_2O. Soil temperature can increase significantly following drainage, further increasing the rate of C losses from peat soils.

Abatement potential

The net GHG stock change factors for near-natural peatlands vary between -2.8 and -0.7 t CO_2eq ha^{-1} $year^{-1}$ (Artz et al., 2012; cited in Feliciano et al., 2013).

By ensuring that peatland is not drained (either by maintaining undrained condition, or by reversing drainage), in CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 2.6 to 10 t CO_2e/ha/y.[157]

Overall emissions impact

Conserving areas of peatland is very important in preventing a significant increase of emissions from these areas. The greatest areas of peat remaining are in Finland followed by Sweden (Martineau et al., 2016).

Displacement effect

Conservation of existing peatland should not lead to displacement.

Permanence

As long as the peatland remains as peatland, the C sequestered is likely to remain in the peat. However, under a warmer climate and changes in rainfall patterns undrained peatland may desiccate leading to GHG emissions as the peat mineralizes.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

Peatlands and wetlands act like natural sponges: they store rainfall and water from other sources and slowly release water, thereby regulating water flow through the catchment. A study in Finland showed a case study wetland could reduce peak flows by up to 38% and reduce stream discharge by up to 47% (EC, 2014). Peatlands and wetlands can thus contribute to reducing flood risk downstream and increasing base flows in

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[157] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

the dry season. In coastal areas, wetlands can support protection against sea storms and surges. Peatland and wetlands can also contribute to maintain local microclimates and work as buffers against temperature extremes. However, they are also vulnerable to climate impacts such as droughts. Some lowland peatlands may need to be actively managed to preserve their effectiveness.

In addition, conserving a network of peatland and wetlands allows numerous plant and animal species to adapt and reshape their distribution in response to changing climatic conditions, improving the overall large-scale resilience and biodiversity of ecosystems.

Barriers and constraints

Techniques to conserve peatland and wetland are well understood and practical guidance is readily available, for example, Joosten et al., (2012).

Although it has been reported that opportunity costs of not converting the peatland to conventional agricultural production may be high if the peatland has the potential to become productive arable land (for example vegetable production on peat soils in north-western Europe) (Martineau et al., 2016), remaining active peatlands fall under the protected habitat types of the EU habitats directive and should not be available for draining and using for agriculture.

Co-benefits

There are other potential environmental benefits of conserving peatlands. These include:

Significant biodiversity gains from the conservation of threatened habitats. This will help to meet EU Biodiversity Action Plan targets and Member State obligations for the conservation of Natura 2000 habitats and species.

Maintaining good water quality by preventing conversion to arable or intensive grassland and consequent increases in diffuse pollution from fertilisers, livestock manure and excreta and soil cultivation.

Maintained water retention and storage, with benefits for flood risk management downstream and/or on floodplains.

Reduced fire risk and reduced GHG emissions from burning dried peat as a fuel and from burning vegetation on subsequently drained upland peat soils.

Risks and trade offs

Given the value of peat and wetlands for biodiversity and regulation of water, as well as the potential for carbon sequestration, there do not appear to be any significant risks or trade-offs from conserving existing peat and wetlands.

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A.2.1.8 Peatland/wetland restoration

Measure description

Restoration of peat requires re-wetting of former peat or wetland through blockage of drains or drainage channels. Following restoration, appropriate land and water management is necessary to maximise climate benefits.

Effect of mitigation measure

Restoring peatland increases its potential for sequestering carbon (C) in soil and reducing emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

The relationship between peatlands and wetlands and greenhouse gas (GHG) emissions is complex. The fluxes of CO_2, CH_4 and N_2O vary depending on the condition and hydrological status of the wetland. The amount and type of GHG emissions depend on the water saturation in the soil, climatic conditions and the nutrient availability. The drainage of wetlands and peatlands exposes organic carbon to the air, decomposition of the organic material occurs and emits CO_2. Drained organic soils with low water tables continue to degrade and to emit CO_2, until either drainage is reversed, or all peat is lost. Saturated soils, however, can create anaerobic conditions and can release CH_4 and N_2O, depending on methods used and management; overall the outcome of rewetting is positive for climate.

Restoration of wetlands help to reduce GHG emissions from decomposition of peat and restoring the natural water table of wetlands. With an increased water table in organic, carbon-rich soils, accumulation of organic substances is greater than the decomposition, which facilitates the conservation and accumulation of peat and reduces the carbon release from these soils (Frelih-Larsen et al., 2014).

Abatement potential

- The GHG abatement will depend on the degree of previous drainage and the current land use intensity. Frelih-Larsen et al., (2014) reported a potential range of mitigation from wetland restoration of 3.1 to 7.8 t CO2 eq ha-1 year-1.
- Artz et al. reported a net potential benefit from peatland restoration of 9 t CO2 eq ha-1 year-1 on damaged sites and much smaller emissions savings on less damaged areas.
- Artz et al citing Couwenberg et al 2011 states that emissions from cultivated peat range from 5.5 to 24 t CO2 eq ha-1 year-1 likely current average emissions range of 9.2 – 15 CO2 eq ha-1 year-1.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 11 to 33 t CO_2e/ha/y.[158]

Overall emissions impact

The overall impact of restoring peatland is significant in countries with large areas on organic soils (i.e. drained peatlands). The areas with the greatest potentials for restoring peat are in Ireland, Germany, northern Europe and countries around the Baltic (Martineau et al., 2016). Schulte et al. (2013) identified peatlands and wetlands as net sources of GHG in Ireland due to earlier drainage. Restoration by rewetting has the potential to turn peat/wetlands into a net sink.

Displacement effect

There is a risk of displacement if the production of arable or livestock products are displaced, causing land use change (LUC). This could be especially serious if the LUC takes place in regions with abundant peatlands and/or wetlands.

Permanence

As long as the peatland remains as peatland, the C sequestered is likely to remain in the peat. However, under a warmer climate and changes in rainfall patterns, restored peatland may desiccate, leading to GHG emissions as the peat mineralises.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

Peatland and wetland restoration can provide additional buffer from coastal storm surges, reducing wave damage and floods, and stabilising shorelines, water supplies and local microclimates (EC, 2014). Creating a

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network of many small wetlands, targeted for example, in heavily drained agricultural catchments (e.g. large areas of intensive livestock production), can store a large amount of water and contribute to reduce flood and erosion damages on agricultural fields along a catchment. Wetlands can also directly contribute to increasing the resilience of the wider rural economy, through provisioning ecosystems services in the form of harvests of fish, animals, and plants.

Barriers and constraints

Techniques to restore peatland and wetland are well understood and practical guidance is readily available, for example Joosten et al., (2012). Some restoration can be relatively simple (such as blocking drainage channels) but because changes to drainage systems affect the whole of a hydrological unit, if this is a large area restoration or conservation, work may involve multiple parcels of land and several different owners or managers.

The restoration of peatland and wetland on existing agricultural land involves significant long-term changes in land use and farming systems, both on the restored peatland area and possibly on buffer zones needed to protect it from nutrient run-off if there is intensively managed farmland nearby. Investment may be required for new drainage infrastructure and there may be additional costs of specialist machinery, advice and management skills. The restoration costs will include the opportunity costs of ceasing conventional agricultural production, which may be very high if the starting point is productive arable land (for example vegetable production on peat soils in north-western Europe) (Martineau et al., 2016).

There may be opportunities to develop new economic uses for the restored peatland, for example by introducing paludiculture. The use of Phragmites australis for bioenergy or as a building material illustrates the technical and economic feasibility of paludiculture, and a database of potential paludiculture plants in one part of Germany identified 184 wetland species native to the area, with a wide range of possible uses including for energy, raw materials, medicine and animal fodder (Abel et al., 2013).

Co-benefits

There are other potential environmental benefits of restoring peatlands (Martineau et al., 2016). These include:

- Significant biodiversity gains from the restoration of threatened habitats. Hence peat conservation will help to meet EU Biodiversity Action Plan targets and Member State obligations for the conservation of Natura 2000 habitats and species.
- Improved water quality as a result of reductions in diffuse pollution from fertilisers after conversion of arable or intensive grassland to wetland/peatland.
- Improved water retention and storage, with benefits for flood risk management downstream and/or on floodplains.
- Reduced fire risk and reduced GHG emissions from burning dried peat as a fuel and from burning vegetation on drained upland peat soils.
- Reduced risk of erosion of drained organic soils.

Risks and trade offs

There are also risks to the environment and potential increases in GHG emissions including:

Potential transfer of emissions from CO_2 to CH_4, if rewetting peat soils increases CH_4 emissions, but in the longer term the continued carbon capture is likely to outweigh this effect.

The use of rewetted peatland for some (but not all) paludiculture crops may conflict with some biodiversity objectives.

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A.2.1.9 Lowland drained peatland/wetland appropriate use

Measure Description

The appropriate use of lowland peatland/wetland, characterised by acidic conditions, will reduce emissions of CO_2 and N_2O and allow continued agricultural use of the peat without re-wetting.

Effect of mitigation measure

Maintenance of existing permanent pastures on peat soils may be among the few options available. Acid peatland has limited agricultural potential, but grass will make satisfactory growth at pH values of <5.5 on peat soils. However, most lowland peat soils are used to grow high value fruit and vegetable crops, many of which require a pH above 5.5 on peat soils and therefore require liming. The addition of lime stimulates microbial activity and mineralisation which lead to emissions of CO_2 and N_2O. This means that the most appropriate crops to grow on lowland peats will be those that do not need lime (grass) and respond to only small amounts of N fertiliser.

Abatement potential

The net impact on GHG emissions will depend upon the amounts by which lime and N fertiliser applications are reduced.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.33 to 1.3 t CO_2e/ha/y.[159]

Overall emissions impact

The overall impact of the appropriate use of lowland peatland is likely to be small since in most EU countries proportion of farmed land composed of peatlands is small (Martineau et al., 2016).

Displacement effect

The cessation of growing legumes, brassicas and other crops that require relatively large amounts of liming will lead to those crops being grown elsewhere, thereby increasing lime and N fertiliser use on other soils.

Permanence

Under a warmer climate and changes in rainfall patterns, soil moisture deficit will increase leading to greater GHG emissions as the peat mineralises.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

[159] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

Peatland and wetland restoration can provide additional buffer from coastal storm surges, reducing wave damage and floods, and stabilizing shorelines, water supplies and local microclimates (EC, 2014). Creating a network of many small wetlands, targeted for example, in heavily drained agricultural catchments (e.g. large areas of intensive livestock production), can store a large amount of water and contribute to reduced flood and erosion damages on agricultural fields along a catchment. Wetlands can also directly contribute to increasing the resilience of the wider rural economy, through provisioning ecosystem services in the form of harvests of fish, animals, and plants.

Barriers and constraints

The need to restrict cropping on lowland agricultural peat soils would mean avoiding crops such as brassicas, which need large amounts of lime and N fertiliser, altogether. While legumes such as peas and beans may be grown without N fertiliser, legumes usually need a pH of at least 6.0. These restrictions would mean that the choice of crop would be limited to carrots, celery and a few other vegetables. These restrictions would greatly reduce the cropping options on farms and reduce income. Some types of fruit also require relatively small amounts (<100 kg/ha) of N fertiliser, dessert apples, strawberries.

Co-benefits

The potential environmental benefits of appropriate use include maintenance of good water quality by limiting diffuse pollution from fertilisers, livestock manure and excreta and soil cultivation.

Risks and trade-offs

Given the value of peat and wetlands for biodiversity and regulation of water, as well as the potential for carbon sequestration there do not appear to be any significant risks or trade-offs from lowland drained peatland/wetland appropriate use.

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A.2.2 More diverse and longer crop rotations

A.2.2.1 Land fallowing of arable cropland

Measure description

Land fallowing of arable cropland is the practice of setting aside arable land for a period of time (typically ranging from one to five years) before it is cultivated again.

Effect of mitigation measure

There is limited evidence that land fallowing of arable cropland mitigates greenhouse gas emissions, when taking into account fluxes of CO_2, CH_4 and N_2O. Bare fallow can be worse in greenhouse gas terms than land managed as grassland or in an arable rotation (Alliance Environnement and Thünen-Institut, 2017).

Bare soil can be a greater sink for methane than soil on which a crop is grown (Liebig et al., 2010). The net flux of CO_2 depends on whether the fallow land is vegetated (e.g., by allowing weeds to grow) and the characteristics of the vegetation. N_2O emissions will be lower than on fertilised arable land.

Abatement potential

The abatement potential strongly depends on whether the fallow land is vegetated. On balance, it is not clear that there is abatement potential from this measure, particularly when accounting for displaced emissions.

In view of the lack of evidence for an overall mitigation effect, we assume no mitigation for this measure.[160]

Overall emissions impact

Changes in emissions following fallowing of a proportion of arable land on a farm will change emissions at a territorial level.

Displacement effect

The avoided emission of the greenhouse gas N_2O can be displaced to another location, through market drivers that lead to increased production in another place, to compensate for decreased production when land is fallow.

Permanence

There is no evidence for measurable increases in stored carbon.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016).

Adaptation effect

Fallow land can have lower water use than arable crops. However, there is poor evidence for an adaptation benefit, and there can be decreased water use efficiency in rain-fed systems, with impaired soil quality, compared with arable land (Farahani et al., 1998; Wienhold et al., 2006).

Barriers and constraints

The main barrier is lost yield.

Co-benefits

Fallow land can have lower water use than arable crops.

Risks and trade offs

Soil erosion is a risk.

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A.2.2.2 Catch/cover crops

Measure description

Catch crops and cover crops both decrease the area and/or duration of bare soil, and this has been used as an measure to reduce GHG emissions and SOC loss (Abdalla et al., 2014).

Cover crops provide soil cover between the harvest of one crop and the planting of the next crop, for example, between late summer harvest of a cereal crop and spring sowing of the next arable crop. Cover crops take up

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mobile nutrients, such as nitrate, and hence reduce pollution of watercourses; they also can protect soil against erosion. A cover crop can be undersown in the previous crop, sown before harvest, or sown post-harvest (Petersen et al., 2011).

Catch crops are also grown between other main crops and can provide a commercial harvest (e.g. for anaerobic digestion feedstock). The benefits for nutrients and soil are similar to those provided by cover crops, and the terms catch crops and cover crops are sometimes used interchangeably. Such crops can be annual, biennial, or perennial herbaceous plants grown in a pure or mixed stand during all or part of the year (Abdalla et al., 2014).

Effect of mitigation measure

Catch/cover crops may increase or decrease N_2O emissions and change the timing of these emissions. Whether there is an increase or decrease can depend on the effect of the practice on the application rate of N fertiliser across the rotation (Jarecki et al., 2009): decreased N losses can decrease the fertiliser N requirements. Whether there is an increase or decrease in N_2O emissions can also depend on the quality and N content of the catch/cover crop residues, with greater emissions from leguminous residues.

Soil organic carbon inputs are increased by cover/catch crops due to the increased productivity of biomass and the duration of vegetation cover (Abdalla et al., 2014; Poeplau and Don, 2015). This increase in SOC persists beyond the duration of the cover crop (Poeplau and Don, 2015).

Abatement potential

In a recent review of the impacts of cover crops on net greenhouse gas balance, Abdalla et al. (2019) reviewed studies at 372 sites and concluded that cover crops could mitigate the net greenhouse gas balance by 2.06 (± 2.10) t CO_2e ha^{-1} $year^{-1}$.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range -0.040 (this negative value indicating an increase in emissions) to 15 t CO_2e/ha/y.[161]

Overall emissions impact

Decreased emission of N_2O, and increased removal of CO_2 into soil organic matter will decrease total greenhouse gas emissions at a territorial level.

Displacement effect

There is no strong evidence of leakage, or displaced emissions from this mitigation measure. In some circumstances, use of cover crops can decrease the yield of the following crop (Abdalla et al., 2019) and where this happens there is potential for the lost production to be displaced, with associated emissions leakage. However, with appropriate selection of cover crop species, and good agronomic practice, yields can be increased (Abdalla et al., 2019), so the displacement effect can be avoided.

Permanence

The effect on stores carbon in soil organic matter can be reversed, e.g., by reverting to a rotation without cover/catch crops.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016).

Adaptation effect

Cover crops can reduce the risk of soil wind and rain erosion and degradation exacerbated by climate change, reduce the amount of nitrogen fertilisation required (use of nitrogen fixing crops), help consume the remaining nitrogen load and avoid nitrate leaching. When linked with precision farming, cover crops reduce the need for fertilisation, as well as increasing organic matter in the soil and ensuring less destruction of the structure by compaction and an increase in the microbiome (EEA, 2019). In terms of quantity, cover crops and switching to perennials may increase consumptive water use and reduce groundwater recharge, in turn potentially reducing groundwater discharges to rivers during dry periods (OECD, 2014). In places where there is no competition for water, the use of green cover with native flora also benefits the infiltration and retention of water

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and the development of beneficial microbial masses and biodiversity linked to the aesthetic and cultural value of the vineyards (EEA, 2019).

Barriers and constraints

The period between harvest of a main crop and planting of the next must be long enough, and have suitable climatic conditions, to allow a cover/catch crop to be established.

There is a cost to a farmer of establishing a cover/catch crop.

Co-benefits

Co-benefits include decreased nitrate leaching (Abdalla et al., 2019) and greater soil organic carbon (Abdalla et al., 2019) with associated improvement in soil properties. Other benefits include prevention of water and wind erosion, better nutrient efficiency and correction of saline soil (Gabriel et al., 2013; Abdalla et al., 2014; Poeplau and Don, 2015).

Risks and trade offs

The removal of cover/catch crops by pesticides may decrease water quality (Ferrant et al., 2013).

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A.2.3 Cultivation practices on arable land (zero tillage & minimum tillage)

A.2.3.1 Zero tillage

Measure Description

Zero tillage cultivation is sometimes referred to as “no-till” and is the practice of growing crops without soil tillage. Tillage aids drilling (sowing of seed using a seed drill) or planting and weed control. Where zero tillage cultivation is practiced, weeds must be controlled in alternative ways, and advanced farm machinery is often used to establish the crop (Smith et al., 2007).

Effect of mitigation measure

Zero tillage can change net GHG emissions in four principal ways.

- Decreased soil disturbance changes the dynamics of soil organic carbon gain, loss and distribution with depth. The potential for an increase in soil organic carbon is greatest in semi-arid areas such as Spain, Portugal, Greece and Cyprus (Mottershead et al., 2019). In other EU climatic conditions, sequestration is highly uncertain and in many cases soil organic carbon (C) content is unchanged, although the distribution of C within the soil profile is altered (Martineau et al., 2016). Some of the uncertainty in the GHG balance is because zero tillage systems are frequently combined with periodical tillage (Smith et al., 2007).

- Less energy is used for soil cultivation, decreasing GHG emissions from fuel combustion (Smith et al., 2007).
- Zero tillage can decrease N_2O emissions in rainfed Mediterranean conditions (Plaza-Bonilla et al., 2018), but the effect on N_2O emissions in other conditions is inconsistent (Smith et al., 2007) and therefore uncertain.
- Zero tillage may also change the emissions and uptake of CH_4 by soil (Bayer et al., 2012), but the net effect of these changes in EU climates is uncertain. Undisturbed soil is usually a sink for CH_4 through bacterial oxidation of methane, but tillage reduces the strength of this sink. Adoption of a zero-tillage system has the potential to restore the strength of the CH_4 sink but this is uncertain and could take many years or decades (Bayer et al., 2012).

Abatement potential

Mottershead et al. (2019) reported a net abatement potential of 0.0121 to 0.0359 t ha^{-1} $year^{-}$ CO_2e. Based on this review, we estimate the mitigation potential per ha to be in the range 0.012 to 0.036 t CO_2e/ha/y.[162]

Overall emissions impact

- Any decrease in emissions through the introduction of zero tillage will be an absolute decrease in emissions and will have an effect on emissions intensity (emissions per unit of production) if the change in yield is not directly proportional to the change in emissions. Each of the ways that zero tillage can change net GHG emissions will change absolute emissions.
- Changes in agricultural practices such as a change from inversion tillage (ploughing) to zero tillage can affect production, and therefore influence emissions intensity. The effect of zero tillage on production can be positive or negative, and on average is negative (Pittelkow et al., 2015). Compared with inversion tillage, zero tillage performs best for crop yields in dry climates without irrigation (Pittelkow et al., 2015).

Displacement effect

Displacement effects can occur when yield is decreased, through increases in production and emissions in other locations, driven by market demand. Where zero tillage decreases yield, this is likely to occur.

Permanence

Where zero tillage increases soil organic carbon, removing carbon dioxide from the atmosphere, this sequestered soil carbon can be emitted as carbon dioxide in the future. The permanence of the removals depends on continued implementation of the zero-tillage practice.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

No tillage or minimum tillage reduces soil disturbances while leaving more residues on the field. Short term losses in yields are usually counterbalanced by long term soil fertility, soil moisture content and overall soil storage capacity, reducing needs for irrigation and enhancing farm resilience against water scarcity and droughts (OECD, 2014). The EC (2014) reports no-till may increase soil water retention in the upper soil layer by 6 to 12% compared to ploughing, and runoff by up to 40%. However, effectiveness is very dependent on the soil type. In terms of wider benefits, no or minimum tillage enhances soil drainage and improves soil biodiversity (EEA, 2019). No tillage may lead to an increasing need for pest control products if it is not

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associated with significant changes in farm operations, such as different crop rotations to break pest and disease cycles.

Barriers and constraints

Zero tillage offers overall cost savings (Martineau et al., 2016), but the upfront capital cost of field machinery for drilling seed directly into an uncultivated soil surface may be a barrier. Farmers may also need advice to provide them with the knowledge and skills for a change to a zero-tillage system.

Soil type can be a constraint as zero tillage is better suited to self-structuring soils with significant clay content than to sandy soils (Martineau et al., 2016).

Co-benefits

Zero tillage can increase yields in some circumstances, decrease soil erosion (this also influences soil organic carbon dynamics), decrease input costs, and sustain long-term crop productivity (Pittelkow et al., 2015). Zero tillage can also reduce dust formation during dry weather (Martineau et al., 2016).

Risks and trade offs

Farmers practicing zero tillage do not have soil inversion as part of their weed control strategies, and often additional weed control activities are needed, such as additional herbicide applications. Zero tillage may require increased application of slug pellets, and there can be increased carry-over of fungal disease from crop residues left on the soil surface (Martineau et al., 2016).

On average the effect of zero tillage on production is negative (Pittelkow et al., 2015).

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A.2.3.2 Minimum tillage

Measure description

Minimum tillage is here defined as crop production without soil inversion by ploughing - often using tine or disc cultivation instead. Less energy is required to carry out cultivation compared with a system that uses ploughing. Ploughing aids weed control, so where minimum tillage is introduced, the weed control practices are also likely to change.

Effect of Mitigation measure

Minimum tillage can change net GHG emissions in four principal ways.

- Decreased soil disturbance changes the dynamics of soil organic carbon gain, loss and distribution with depth. Gain in soil organic carbon (removal of CO_2 from the atmosphere) depends on crop yields and is likely to occur only where crop yields are increased (Martineau et al., 2016). Crop yields may be increased by minimum tillage in dry areas, but in most EU regions, crop yields are likely to be similar or less with minimum tillage, compared with plough-based systems (Martineau et al., 2016). Some of the uncertainty in the GHG balance is because minimum tillage systems are frequently combined with periodical tillage (Smith et al., 2007).
- Less energy is used for soil cultivation, decreasing GHG emissions from fuel combustion (Smith et al., 2007).
- Minimum tillage can decrease N_2O emissions in rainfed Mediterranean conditions (van Kessel et al., 2013), but the effect on N_2O emissions in other conditions is inconsistent and uncertain (Smith et al., 2007).
- Minimum tillage may also change the emission and uptake of CH_4 by soil (Bayer et al., 2012, by analogy to zero tillage), but the net effect of these changes in EU climates is uncertain. Undisturbed soil is usually a sink for CH_4, but tillage reduces the strength of this sink. Adoption of a zero-tillage system has the potential to restore the strength of the CH_4 sink but this is uncertain and could take many years or decades (Bayer et al., 2012). We expect that minimum tillage can have similar effects.

Abatement potential

Mottershead et al. (2019) reported a net abatement potential of 0.0059 to 0.0180 t ha^{-1} year^{-1} CO_2e. Based on this review, we estimate the mitigation potential per ha to be in the range 0.0059 to 0.018 t CO_2e/ha/y.[163]

Overall emissions impact

Any decrease in emissions through the introduction of zero tillage will be an absolute decrease in emissions and will have an effect on emissions intensity (emissions per unit of production) if the change in yield is not directly proportional to the change in emissions.

Changes in agricultural practices such as a change from inversion tillage (ploughing) to minimum tillage can affect production, and therefore influence emissions intensity. The effect of minimum tillage on production can be positive or negative: yields may be increased by minimum tillage in dry areas, but in most EU regions, crop yields are likely to be similar or less with minimum tillage, compared with plough-based systems (Martineau et al., 2016).

Displacement effect

Displacement effects can occur when yield is decreased, through increases in production and emissions in other locations, driven by market demand. Where minimum tillage decreases yield, this is likely to occur.

Permanence

Where minimum tillage increases soil organic carbon, removing carbon dioxide from the atmosphere, this sequestered soil carbon can be emitted as carbon dioxide in the future. The permanence of the removals depends on continued implementation of the minimum-tillage practice.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing field records and allowing farm visits for verification.

[163] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement of emissions and soil organic carbon stock change is not practical for monitoring farm activities. These measurements can be made in scientific studies and used to estimate emissions factors and stock change factors for use with activity data.

Adaptation effect

No tillage or minimum tillage reduces soil disturbances while leaving more residues on the field. Short term losses in yields are usually counterbalanced by long term soil fertility, soil moisture content and overall soil storage capacity, reducing needs for irrigation and enhancing farm resilience against water scarcity and droughts (OECD, 2014). The EC (2014) reports no-till may increase soil water retention in the upper soil layer by 6 to 12% compared to ploughing, and runoff by up to 40%. However, effectiveness is very dependent on the soil type. In terms of wider benefits, no or minimum tillage enhances soil drainage and improves soil biodiversity (EEA, 2019). No tillage may lead to an increasing need for pest control products if it is not associated with significant changes in farm operations, such as different crop rotations to break pest and disease cycles.

Barriers and constraints

Minimum tillage offers overall cost savings (Martineau et al., 2016), but the upfront capital cost of different field machinery may be a barrier. Farmers may also need advice to provide them with the knowledge and skills for a change to a minimum-tillage system.

Soil type can be a constraint as minimum tillage is better suited to self-structuring soils with significant clay content than to sandy soils (Martineau et al., 2016).

Co-benefits

Minimum tillage can increase yields (in some circumstances, decrease soil erosion (this also influences soil organic carbon dynamics), conserve soil moisture and reduce dust formation during dry weather; there can also be decreased input costs (by reducing labour and fuel inputs and by reducing wear on machinery), the size of which depends on the extent to which the number of cultivations is reduced (Martineau et al., 2016).

Risks and trade offs

Farmers practicing minimum tillage do not have soil inversion as part of their weed control strategies, and often additional weed control activities are needed, such as additional herbicide applications. Minimum tillage may require increased application of slug pellets, and there can be increased carry-over of fungal disease from crop residues left on the soil surface (Martineau et al., 2016).

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A.2.4 Soil organic carbon and soil fertility improvement

A.2.4.1 Retention of crop residues on fields

Measure Description

Crop residues may be removed from a field, to be used in various ways, for example, for livestock bedding, livestock feed, or bioenergy feedstock. Leaving residues in the field, to be incorporated into the soil, or left on the surface, can influence greenhouse gas emissions. Usually when residues are retained in the field, they are chopped and incorporated.

Effect of mitigation measure

Retention of crop residues can decrease the need for nitrogen fertiliser applications, with associated savings in emissions from soil and from manufacture of fertilisers. However, residues that are removed are often returned to land after use (e.g., straw is returned in farmyard manure), with the nutrients (Frelih-Larsen et al., 2014; Martineau et al., 2016).

Retention of crop residues can help to increase soil organic carbon, with associated removal of carbon dioxide from the atmosphere. (Frelih-Larsen et al., 2014; Martineau et al., 2016).

Abatement potential

Mottershead et al. (2019) reported abatement potential of 0.11 to 2.2 t CO_2e. Based on this review, we estimate the mitigation potential per ha to be in the range 0.11 to 2.2 t CO_2e/ha/y.[164]

Overall emissions impact

Changes in emissions following retention of crop residues will have an overall emissions impact at a territorial level.

Displacement effect

Effects on yields of crops are expected to be small, with increases or decreases depending on the agronomic circumstances and climate (Martineau et al., 2016). Therefore, there is not expected to be a displacement effect.

Permanence

Increases in organic carbon stored in soil are not necessarily permanent and depend on maintenance of the practice in the future.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm activities and can be verified by inspection during farm visits.

Adaptation effect

Retention of crop residue and increasing soil organic carbon can contribute to enhance soil water retention. This increases the availability of water for crops during the dry season and resilience against droughts. Improving soil fertility through management of soil organic carbon can help stabilise crop yields under varying climate conditions, thereby contributing to increase overall crop farm resilience.

Barriers and constraints

The main barrier is competition with other uses of residues.

Co-benefits

Co benefits can include less soil erosion, conservation of moisture in semi-arid areas, and can save costs by reducing labour and fuel inputs and by reducing wear on machinery (Martineau et al., 2016).

Risks and trade offs

Leaving crop residues on the soil surface may require increased application of chemicals for slug control, and there can be increased carry-over of fungal disease. Care needs to be taken to avoid inhibiting germination of small-seeded crops, and management of weeds may be changed.

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[164] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

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A.2.4.2 Mulching, ridge and furrow

Measure Description

Ridges and furrows are formed and covered with plastic sheeting or other mulching materials such as straw. The purpose is to harvest and store rainwater. The covered ridges are rainwater harvesting zones, and the furrows are planting zones. This mitigation measure is used in semi-arid climates, where water is limiting (Wang et al., 2016).

Effect of mitigation measure

This mitigation measure changes crop growth, biomass accumulation, soil temperature and therefore soil processes involved in emission and removal of carbon (i.e. soil organic matter increase or decrease), and emission of nitrous oxide.

Productivity may be increased (Cuello et al., 2015; Wang et al., 2016), which can have indirect effects on greenhouse gas emissions.

Abatement potential

There is no evidence providing values of the abatement potential. Use of plastic mulch increases emission of nitrous oxide and methane, and decreases storage of soil organic carbon, with the effect of a net increase in greenhouse gas emissions (Cuello et al., 2015).

In view of the lack of evidence for an overall mitigation effect, we assume no mitigation for this measure.[165]

Overall emissions impact

Changes in emissions will have an overall emissions impact at a territorial level.

Displacement effect

An increase in yields may have indirect effects on production and greenhouse gas emissions elsewhere. However, this is uncertain and quantification is complex.

Permanence

Not applicable.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm activities and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of the application of this practice.

Adaptation effect

Techniques such as mulching (i.e., a layer of organic material applied to the surface of an area of soil), ridges and furrows are particularly beneficial under drier conditions, by slowing run off, conserving moisture and improving soil structure. Adopting such soil conservation practices may have some beneficial effects on soil biodiversity particularly in the topsoil zone (EEA, 2019).

Soil water retention can also be protected and increased with landscape level operations such as terraces.

Barriers and constraints

The main barrier is expected to be the cost of additional field operations (forming the ridges and laying/retrieving mulch), and purchase of mulch materials.

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[165] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Co-benefits

Increased crop yields.

Risks and trade offs

There is a high risk of increased greenhouse gas emissions, and environmental impacts associated with plastic usage.

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A.2.4.3 Appropriate timing of field operations to avoid soil compaction

Measure description

Soil wetness affects soil strength and the degree of compaction of soil when it is trafficked. Therefore, avoidance of field operations when the soil is wet decreases the risk of compaction, with benefits for crop production and greenhouse gas emissions. This is good agricultural practice with many advantages for farm productivity.

Effect of mitigation measure

Soil compaction changes biological activity and results in anaerobic conditions, leading to increased release of methane from decomposing organic matter (Martineau et al., 2016). Avoidance of compaction also avoids fuel combustion in heavy machinery to alleviate the compaction.

Abatement potential

Soil compaction leads to decreased CO_2 emission through physical restriction of gas exchange (Mordhorst et al., 2014).

Ball et al. (1999) reported that control of compaction can minimise soil nitrous oxide and carbon dioxide losses.

However, we have not found estimates of the net change in greenhouse gas emissions from changing the timing of field operations to avoid soil compaction.

In view of the lack of evidence for an overall mitigation effect, we assume no mitigation for this measure.[166]

Overall emissions impact

Changes in emissions will have an overall emissions impact at a territorial level.

Displacement effect

There is not expected to be a displacement effect.

Permanence

Changes in stored soil organic carbon can occur with changes to cultivation practice but increases depend on continuation of the mitigation measure.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm activities.

Adaptation effect

Attention to the timing of field operations can reduce the risk of soil compaction and thereby protect infiltration and water storage capacities.

[166] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Barriers and constraints

The main barrier is the need to consider other drivers of field operation timing, such as crop maturity for harvest, and the availability of farm resources to complete operations while the soil is not too wet.

Co-benefits

Co benefits can include increases in crop production, less soil erosion, and better water infiltration and storage in soil.

Risks and trade offs

None identified.

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A.2.4.4 Relevant measures in other groups

Measures that change productivity of crops (e.g., measures for nutrient management) can also change soil organic carbon stocks, although there is high uncertainty regarding the quantity of stock change.

A.3 Substitution of fossil fuels and fossil materials

A.3.1 Renewable energy

A.3.1.1 Production of biogas using biomass originating from agriculture and forestry, such as manure, crop residues, ligno-cellulosic materials, etc. (substitution effect with fossil-based energy)

Description

Biogas is composed of methane (CH_4) and carbon dioxide (CO_2), with trace amounts of other gases in trace amounts (e.g., hydrogen gas). It is produced by the anaerobic digestion (AD) of organic materials, which include livestock manures, food waste and biomass from crop residues or purpose-grown crops. The biogas produced can be converted into bioenergy in the form of electricity, heat, or transport fuel (De Vries et al., 2012; Hamelin et al., 2011; cited in de Vries et al., 2012). The remaining product after the AD process is a material called 'digestate', composed of water, nutrients and organic carbon. It can be recycled as organic fertilizer for crop cultivation to substitute for mineral fertilizer.

Effect of mitigation action

Biogas production from manures and agricultural and forestry biomass can change net GHG emissions in a two principal ways.

4. The replacement of fossil fuels by any form of renewable energy, including biogas, reduces net GHG emissions to the atmosphere.
5. Using livestock manures as a feedstock for biogas reduces GHG, CH_4 and nitrous oxide (N_2O), emissions generated during manure storage. Although AD generates CH_4, net emissions are reduced as the CH_4 is captured and converted to be used as an energy source, offsetting carbon dioxide emission from fossil fuels.

Abatement potential

The following examples were found:

- The abatement potential of biogas production depends on the type of fossil fuel that the biogas replaces. In assessing the sustainability of biogas produced from grass as a transport biofuel, Korres et al. (2010; cited in Schulte et al. 2013) highlighted that a 60% reduction in GHG emissions in displacing diesel on a whole life cycle basis can be readily achieved.

- Frelih-Larsen et al. (2014) reported abatement rates ranging from 600 to 1250 g CO_2e/kWh, for anaerobic digestion of manure, by substitution of fossil-generated energy and avoiding methane emission during storage of manure. Globally, Jain S et al. (2019) reports a potential to offset 930 to 1260 million tonnes CO_2e/annum by collecting manure from livestock and producing biogas via AD.
- The impact of biogas plants GHG emissions must be assessed on a case-by-case basis because of differences in direct methane emission, use of heat, amount and type of feedstocks, nitrous oxide emission from energy crop cultivation, and digestate management (Paolini et al., 2018).
- There is additional abatement potential from upgrading the biogas to biomethane. The upgrading technology generates a co-product of CO_2 which can be captured and used to offset fossil fuel generated CO_2 used in industries such as food and beverage. (IEA, 2020)
- Globally the use of select crop residues can mitigate GHG emissions equivalent to 865 to 1,100 million tonnes CO_2e/annum by avoiding emissions from the production of fossil-generated energy and heat and those from burning of crop residues in the field, Jain S et al. (2019).

In CO_2 equivalent units, we estimate the mitigation potential per kWh to be in the range 0.00060 to 0.0013 t CO_2e/kWh.[167]

Overall emissions impact

The overall emissions impact of biogas production from livestock manures is limited by the amount of substrate which will depend on the livestock population of the member state or region. The amount of substrate can be increased by co-digestion with organic wastes such as by-products from food processing (de Vries et al., 2012), but the availability of these will also be limited. The use of crops such as silage maize and/or grass can further increase the amount of feedstock available (e.g. Schulte et al. 2013).

Displacement effect

The key potential displacement from biogas production arises from the use of land to grow crops such as grass or maize for AD feedstocks. Growing crops for feedstocks rather than for food or forage risks displacing production elsewhere. De Vries et al. 2012 found that of the additional biomass feedstocks assessed, roadside grass gave the best overall environmental performance.

Permanence

By replacing fossil fuels biogas can provide permanent reductions in GHG emissions.

By replacing synthetic and mineral fertiliser, digestate can provide permanent reductions in GHG emissions

Measurement requirements

Measurement of the activity in relation to feedstock depends on farmer co-operation in sharing records and allowing farm visits for verification.

Measurement of emissions is not currently practical. However, measurements and modelling made in scientific studies can be used to estimate abatement when combined with activity data.

Adaptation effect

N/A

Barriers and constraints

Barriers to the production of biogas include the capital costs of installing an AD plant and the need for an assured user of the gas produced.

Biogas plants need to be located in an area where it is commercially viable for feedstock supply and product (biogas and digestate) use.

Co-benefits

Nitrogen immobilization in soil from digestate has been found to be only half that of undigested slurry, due to less easily-decomposable C in the digested slurry (Webb et al., 2013 and references therein). Therefore, there is potential for greater N availability for crop growth after digestion, providing losses of ammonia are contained.

[167] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Recirculation of nutrients (nitrogen, phosphorous and potash) and organic matter in wastes through AD Jain S et al. (2019)

AD produces baseload energy for sustained energy use. Biogas and biomethane can be stored and used when needed acting as a 'battery' in comparison to other intermittent renewable energy sources such as wind and solar.

Risks and trade offs

Trade-offs will occur when crops are grown for the purpose of AD potentially leading to displacement of crop production for human and livestock feeds.

In addition, while emissions of CH_4 from subsequent storage of digestate are potentially less than from undigested manure this is not always the case. If digestate is stored when warm or if the digestion process has not been completed, leaving CH_4 precursors, then CH_4 emissions may be greater from stored digestate than from undigested slurry (Rodhe et al., 2015).

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A.3.1.2 Solar and wind energy production on farmland (substitution effect with fossil based energy)

Description

Solar energy production on farmland is achieved by installation of solar photovoltaic (PV) panels and associated inverters and transformers, usually containerised, and served by access tracks, to generate electricity that is fed into the local electricity network (or occasionally direct to a large local customer) via a power line. Large installations are ground mounted in fields, or can be floating arrays, and smaller installations can be on the roofs of farm buildings.

Schemes usually need around 12 m^2 per kW installed, and ground mounted cover around half the land area. Schemes can be from 5 to several hundred MW, using a few, to tens of hectares of land. Suitable fields include flatter, less undulating landscapes, south facing is helpful but north facing is more challenging. It is helpful if the fields are not divided by heavy hedging and trees. Shading can be problematic and has a significant effect on output and is to be avoided (a 1% shade can have a more than 10% impact on generation, depending on wiring layout). In the EU the solar irradiation in stronger in the south than the north with a marked impact on project economics. Typically solar might generate at full load equivalent for 12% of the hours in the year. It generates much more in the summer than winter, and nothing at night.

Wind energy production on farmland is achieved by the installation of one or more wind turbine(s) in a suitable location, with connection to an electricity network or local customer via a power line and served by access tracks. Turbines vary from 60 m to the tip, to 130 m to the tip and are increasing in size. A tower can be 3-8 m in diameter but the foundation can sterilise land across a 20m radius. A turbine usually has a crane pad next to it for installation and maintenance. Single turbines are rare except for landowner projects. Commercial developer-owned wind farms can have 5-50 turbines.

A suitable location includes an area that allows a good laminar flow of wind. Turbulence is unhelpful to generation. Trees and buildings and sharp changes in landscape can cause turbulence many times higher than their actual height. Wind needs a separation of at least 600 m from dwellings for noise and visual impact. The power in the wind is proportional to the cube of the windspeed, so wind regime is critical. Wind tends to generate more in the winter than in the summer. Typically, a 1 MW machine might generate at full load equivalent for 25%-30% of the hours in the year. In practice wind generates at a portion of its capacity for 97% of the hours in the year.

The correlation between when wind generates and when solar generates is low, and slightly negative (i.e. on a sunny clear day when solar is generating towards its peak, wind tends to generate little. In the winter, in a storm when wind is towards peak then solar is at its lowest). There is also benefit in widely spread portfolio on the system, so that as a weather front moves across, its impact does not affect all installations at the same time. The system is thus less intermittent than any given single installation.

Effect of mitigation action

Solar and wind energy production on farmland substitutes electricity that otherwise would be generated by a mix of other technologies. In practice, it is marginal generation by fossil fuel production that is substituted (Thomson and Harrison, 2015). However, use of coal generation is declining, so the marginal fuel is increasingly gas, and particularly in the winter. In the summer the extent of solar installation is such that the need for new nuclear generation is reduced.

Abatement potential

For renewables the safest approach over the long term is to assume new generation displaces the average on the network (or possibly the average non-renewable on the network).

Emissions factors vary by Member State and are updated annually. Emissions factors include uncertainty, build rates (especially of renewables) and wind and solar conditions can vary actual output. Electricity demand varies with weather so the balance provided by fossil plant (coal and gas) can vary.

For wind energy production, Thomson and Harrison (2015) reported a value of 550 g CO_2e/kWh, based on substitution of marginal generation capacity in the UK in 2012. Although the emissions factor for grid generation is falling in EU member states, the emissions factor for marginal generation will change less over time, so values for 2012 may still be relevant.

Data from a study by Pehl et al. (2017) suggest that wind and solar energy generation will save 66 to 107 g CO_2e/kWh compared with fossil fuel carbon capture and sequestration plants, in a projection for 2050. This study used a life cycle assessment approach integrated with integrated energy/economy/land-use/climate modelling.

In CO_2 equivalent units, we estimate the mitigation potential per kWh to be in the range 0.066 to 0.11 t CO_2e/kWh.[168]

Displacement effect

For solar arrays on farmland there is some displaced production, which is highly variable depending on the use and productivity of the land before installation of solar generation (much of it is low quality land), and the

[168] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

use of land after installation (much of it can continue to be used for grazing, especially sheep, and sometimes geese).

Some landscapes with large ground-mounted solar installations are converted to wildflower meadow to support pollinators, so whilst there can be a direct loss of agricultural land, there can be improvements in agricultural output close by (Semeraro et al 2018).

For wind turbines on farmland there will be very little displaced production. This is first because wind turbines and their access tracks don't themselves take up much land, and land can continue in its original use, and second, many wind locations are landscapes where sheep and cattle (including highland cattle) graze, or moorland or mountain. There are wind installations in forestry land as well, where the area around the turbine has been cleared.

Permanence

By substituting fossil fuels, use of solar and wind energy production on farmland can provide permanent reductions in greenhouse gas emissions. Solar installation can have a lifetime of 35 years or more. It is too soon to see any solar farm sites re-developed.

Wind is closer to a 20-year lifetime, but the UK is now seeing many of its older wind installations re-turbined, with fewer much larger turbines with a significant increase (perhaps a factor of two or three) in wind generation.

Measurement requirements

Measurement of the activity can depend on farmer co-operation in sharing records of installations and allowing farm visits for verification.

Adaptation effect

N/A

Barriers and constraints

Barriers to further progression of solar and wind on agricultural land include:

- The constrained nature of the electricity network. Most networks were designed to be supplied in a top-down way from large central power stations, not from multiple, relatively small, embedded generators. Networks are adapting to become an internet of connected assets. This requires investment and a key issue is who pays. This is a combination of the network owner (and thus customers) and project developers. If early reinforcement is needed for a given project a developer needs to pay.
- The planning framework. The planning system is conservative and sees preservation of the current landscape as a greater priority than mitigating impacts on the future landscape. Wind in particular can be thought of as causing damage to the landscape in visual terms and has faced tougher challenges. Solar is easier to hide in the landscape and sees a much higher proportion of successful applications. Because of local opposition, landowners can be subject to local aggravation, but this usually disappears as people get used to the new landscape. Community ownership or community benefit funds are key strategies for bringing the community together.
- At a certain point however, the landscape or grid has to be considered full. But just as that point is reached there are new opportunities to go further. One key opportunity is to co-locate wind and solar on the same site. There is already an intrusion into the landscape from the first form of generation, there is already a willing landowner, and a grid connection. As noted, wind and solar tend not to generate at the same time, so if the network is full to new solar generation, it may not be full to new wind and vice versa.

Co-benefits

Usually, a solar farm array or a wind turbine is installed on a part of a landholding, leaving much of the existing agricultural business unaffected. Usually, the costs of developing and installing the asset is borne by a private renewable energy developer, with the landowner receiving an option payment during the period of development and a lease payment for the land during the lifetime of the asset. The lease payment is usually significantly higher than the agricultural income the land would provide. Payments usually have a floor below which they will not fall, and are usually linked to inflation and or electricity price. There is usually a requirement for the developer to set up a bond to pay for restoration of the land back to its virgin state at the end of the lease, but we have so far reached the end of few leases without some form of renewal or re-turbining. There is usually therefore a considerable benefit both in income, in farm diversification, and in long term financial security for the landowner.

As a result the agricultural sector and its land agents have become very familiar with the need and opportunities of renewable energy development and the sector has professionalised over the last two decades to a significant extent. There is a ready market in developable sites.

5.4.1.1.1.1 Risks and trade offs

There are few trade-offs, though installation of wind turbines on high-carbon soils risks additional emissions and loss of any abatement effect, though risks can be managed (Thomson and Harrison, 2015).

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A.3.1.3 Production of energy (electricity, heat) using woody biomass originating from agriculture and forestry, such as perennial woody and herbaceous biomass crops (SRC, miscanthus, switchgrass, common reeds, cardoon, etc.), crop residues, etc.

Measure Description

Biomass is converted to energy through bioenergy conversion technologies, by combustion, and/or using combined heat and power plants (CHP).

Effect of mitigation action

Growing energy crops absorbs carbon, removing it from the atmosphere and storing it in the soil and plants/trees. When used to produce energy (electricity and heat) the carbon is returned to the atmosphere, and substitutes greenhouse gas emissions from fossil fuels.

Abatement potential

The abatement potential of converting biomass to energy is dependent on the scenario. Emission reduction will be dependent on a number of factors, including type of energy crop used, whether there was significant land use change and distance of feedstock production from an energy conversion plant. As an example, a study by Wang et al., (2014) found bioenergy as a feedstock for CHP can reduce carbon emissions by up to 30% compared to a power station using a fossil fuel.

In CO_2 equivalent units, we estimate the mitigation potential per kWh to be in the range 0.00017 to 0.00035 t CO_2e/kWh.[169]

Overall emissions impact

The overall emissions impact will vary as described above, but the overall impact will be a reduction in emissions if the biomass feedstock production is managed correctly.

Displacement effect

Growing crops for feedstocks rather than for food or forage risks displacing production elsewhere, with associated emissions.

Permanence

By replacing fossil fuels, biomass can provide permanent reductions in GHG emissions.

[169] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Measurement requirements

Measurement of the feedstock production depends on farmer co-operation in sharing records and allowing farm visits for verification.

Adaptation effect

Adoption of perennial woody and herbaceous biomass crops such as miscanthus instead of cereal crops can reduce dependence on crop water demand and use of fertilisers and plant protection products, leading to greater resilience to water scarcity and droughts and prevent the deterioration of water quality. Developing bioenergy and bio-material production onto marginal land covered by semi-natural grass or trees may on the other hand increase soil disturbance, pesticide application and fertiliser inputs, with negative implications on water quantity and quality (OECD, 2014).

Barriers and constraints

Barriers to the production of energy crops will include the capital costs of installing bioenergy conversion technologies and the need for an assured purchase of the energy. Energy crops may not be favoured by landowners as they tend to be much taller than traditional crops, therefore can have a negative impact on the landscape character (Lovett et al., 2014). The time taken for the crop to become established (5+ years) and to make profit on the capital expenditure is also likely to be a barrier for landowners.

Co-benefits

The management practices associated with these energy crops involves long harvesting cycles and low fertiliser use which have positive environmental impacts. There is much evidence that these practices enhance biodiversity and are beneficial for flora and fauna (Bates, 2018). Low impact management also positively impacts water quality due to less fertiliser use and therefore less leaching into nearby water sources (Bates, 2018). Wang et al., (2015) reported that energy crops have been found to restore degraded soils so are suitable to be grown on land where conventional crops cannot grow.

Risks and trade offs

Availability of suitable land to grow energy crops may be limited and there is the potential for competition to arise with food and fodder, causing direct and indirect land use changes (Lovett et al., 2014; Akkari et al., 2018).

During the growing season, miscanthus and short rotation coppice have been found to have high water use, which can have a negative impact in water stressed areas (Bates, 2018).

The emission reduction depends on the crops being in close vicinity to the energy conversion plant.

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A.3.1.4 Production of biofuels/advanced biofuels using biomass originating from agriculture and forestry (substitution effect with fossil fuels, especially in the transport sector)

Measure Description

Liquid biofuels, usually biodiesel or bioethanol, are produced from biomass, from plant oils (e.g. biodiesel from oilseed rape), from sugars or starch, or from lignocellulosic biomass or woody crops, or other crop or forest residues. Biofuels produced from lignocellulosic biomass or agricultural residues, are usually referred to as second generation biofuels or advanced biofuels.

Effect of mitigation action

Biofuels substitute fossil fuels, especially for road transport, and thereby greenhouse gas emissions from use of fossil fuels are substituted by greenhouse gas emissions from biofuel production, which are usually lower.

Abatement potential

Abatement potential is variable, factors impacting abatement include the type of fuel, the energy input into growing the feedstock and whether there is indirect land use change. It has been estimated by ePURE that the average certified greenhouse gas emission savings of renewable ethanol against fossil fuel were 71% in 2018 (ePURE, 2019). A 2018 study by Akkari et al. found first generation biofuels have only a 50% chance of achieving a 50% greenhouse gas abatement potential, while second generation biofuels have a 80-90% chance of achieving a 50% abatement potential. This study also found that the conversion of forestry to produce crops for biofuels is likely to result in negative GHG savings, in comparison, converting grassland has a 60% chance of achieving a 50% GHG reduction compared to fossil fuels.

Based on our review (Akkari et al., 2018; ePURE, 2019) we estimate that the emissions savings range from 50% to 71% of the fossil carbon in fossil fuels displaced by additional biofuels.

Overall emissions impact

In theory, biofuels should be carbon neutral, but assessing the greenhouse gas impact is complicated due to several factors such as land use change and harvesting techniques.

Displacement effect

For production of biofuels/advanced biofuels using biomass originating from agriculture and forestry there is some displaced production of food crops. There can be, therefore, displaced emissions from agricultural production in another place.

Permanence

By replacing fossil fuels, biofuels can provide permanent reductions in GHG emissions.

Measurement requirements

Measurement of the activity depends activity data for production and use of biofuels, including data from farms on areas of crops grown for this use.

Adaptation effect

N/A

Barriers and constraints

There are no significant barriers from a from business perspective. The main barriers are the need to meet sustainability criteria in the Renewable Energy Directive, and technical constraints to the use of biofuels in engines.

Co-benefits

Forest and agriculture residues that would otherwise be considered waste material after harvest are used, resulting in less waste material. Advanced biofuels do not use food crops, therefore reduce the competition with food production.

Risks and trade offs

Risks include the displacement of production of crops to another place due to the introduction of biofuel crops, which can lead to direct and indirect land use change. Direct land use change occurs in the region where the feedstock is grown, and indirect land use change occurs to compensate for the loss in production in the area. Changes in land use has such an impact as areas of croplands may become more heavily intensified or land such as forestry and pastures may be converted to grow crops. This causes an increase in emissions released, for example if the biofuel industry progresses rapidly, land such as forests may be cleared and converted to produce crops for biofuel to keep up with the demand. As a result, emission reduction targets are unlikely to be achieved due to the amount of carbon released during forest clearance – which will be much higher than can be counteracted by the growth bioenergy crops and use of biofuel.

References

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ePURE. 2019. Average certified emissions savings of renewable ethanol 2018. 05 September 2019. https://epure.org/resources/statistics-and-infographics/

FAO, 2008. *Forests and energy.* [Online] Available at: http://www.fao.org/3/a-i0139e.pdf

A.3.1.5 Production of materials using biomass from agriculture and forestry, such as woody biomass or crop derived products (e.g. straw) (substitution effect with fossil based materials)

Measure Description

There are many materials that can be produced using biomass from agriculture and forestry. Here we use the example of materials for building construction, in particular, greater use of timber framed construction techniques, and use of engineered wood products such as glue laminated timber.

Effect of mitigation action

Materials that can be produced using biomass from agriculture and forestry can be used in place of alternatives such as masonry and steel. The mitigation action includes substitution and displacement of alternative materials, and carbon sequestration in the materials from biomass.

Abatement potential

The UK Committee on Climate Change (2018) estimated that use of timber materials in a timber-framed house resulted in abatement of 3.2 t CO_2e per tonne of biomass.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 8.4 to 26 t CO_2e/ha/y.[170]

Overall emissions impact

This mitigation action will have an overall emissions impact.

Displacement effect

Crops or forests grown for biomass can displace crops that would otherwise be grown, leading to displaced emissions from production (e.g., of food crops) in another place.

Permanence

By substituting other materials, use of biomass-derived products can provide permanent reductions in greenhouse gas emissions. However, the sequestration of carbon in biomass-derived products is not permanent, as this carbon can be lost at the end of the life of the product, e.g., at the time of building demolition.

Measurement requirements

Measurement of the activity requires activity data and supplier records from users of the materials.

Adaptation effect

N/A

Barriers and constraints

Barriers can include perceived risks associated with fire safety of timber structures, indoor air quality and thermal performance (Spear et al., 2019).

Co-benefits

Co-benefits depend on the materials used and the type of application.

Risks and trade offs

There are perceived risks associated with fire safety of timber structures, indoor air quality and thermal performance (Spear et al., 2019).

[170] From Ricardo calculations, expert judgement, literature review

References

Committee on Climate Change. 2018. Biomass in a low-carbon economy. 3. Supporting charts and data. https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/

Spear M, Hill C, Norton A and Price C. 2019. Wood in Construction in the UK: An Analysis of Carbon Abatement Potential. Report commissioned for the Committee on Climate Change, London, UK. Report reference: BC-1383-2018-ES

A.3.1.6 Energy Efficiency

Measure Description

Energy efficiency incorporates measures that could be taken to reduce energy use on farm while maintaining output. Energy efficiency encompasses fuel for stationary and mobile machinery, electricity and heat for buildings and drying harvested crops.

Effect of Mitigation Action

Energy efficiency focusses specifically on the reduction of CO_2 emissions from fuel and electricity usage. The fuel usage emissions are not reported within the agriculture inventory (Category 3) so can be overlooked in terms of the potential to reduce emissions from agriculture. Emissions from fuel use in agriculture are reported on under category 1 which includes emissions from stationary and mobile machinery activities. As a proportion of emissions from the agriculture sector, the emissions from fuel use represents 14% of emissions from agriculture across the EU27, but there are significant variations between member states which are dependent on their farming systems (3% - 34%) (EEA) emissions inventory data 2017).

A Marginal Abatement Cost Curve (MACC) for agriculture energy emission in the UK (Defra EC0103) found that the activities with the greatest emission were:

- Field operations 1571 kt CO_2, (35% of total)
- Heating 1208 kt CO_2, (27% of total), of both greenhouses and livestock buildings.
- Grain drying 886 kt CO_2, (19% of total).

No other activities accounted for more than 5% of total emissions.

This information is indicative and the proportion of emissions from activities will vary by member states depending on farming activities and systems. For example, heating and ventilation for housed livestock such as poultry and poultry and for horticultural crops may be a higher proportion in countries specialising in these systems.

Abatement potential

Output from the UK MACC model indicates that with the adoption of cost-effective abatement techniques there is potential to reduce GHGs arising from energy use on farms by 26% by 2030 (from a 2010 baseline) in addition to the reduction in emissions predicted from decarbonisation of the electricity supply.

The greatest cost-effective reductions may be made by the protected horticulture sector (560 kt CO2), arable (326 kt CO2) and poultry (177 kt CO2) sectors, with the remaining sectors accounting for c. 8% of the potential reduction. There are very few opportunities for cost-effective reduction in the beef and sheep sector which has an estimated abatement potential of just 2% of the 2030 total (Defra EC0103).

To provide an Indicative abatement potential for cultivation Alluvione *et al.* found that Zero tillage (ZT) reduced energy use in arable rotations in Italy by 11%. However, cautioned that if yields are reduced, which can be a consequence of ZT, the energy requirement per tonne of crop may not be reduced. The appropriateness of zero tillage is likely to be specific to climate and soil variables.

Based on the evidence reviewed above we estimate that the mitigation potential ranges from 2% to 26% of energy use on farms.

Displacement effect

There is unlikely to be displacement effects associated with energy efficiency measures.

Permanence
Once changes are made than the effect should be permanent as the investment has been made in the new technologies which will be cost effective.

Measurement requirements
The response can be measures through the reduction in reported fuel and electricity usage. Allocating the effect to specific technologies implemented will be difficult unless additional data collection activities are undertaken.

Adaptation effect
N/A

Barriers and constraints
Like with any activity that requires new equipment, initial capital cost will be the greatest barrier. Even when payback periods look favourable, it can sometimes be challenging to secure finance for investment or there might be a reluctance to take on debt to finance the investment required.

Co-benefits
Energy efficiency measures is likely to have a positive impact on running costs as it reduced fuel and electricity costs.

Risks and trade offs
There are no obvious risks or trade-offs.

References
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A.4 Climate resilience measures

A.4.1 More diverse and longer crop rotations

A.4.1.1 Rotations with perennial forage crops

Measure description
Perennial forage crops can be included in rotations that comprise a sequence of annual crops, such as cereals, oilseed rape, and/or vegetables. The perennial crops would typically be grass (e.g., to make hay or silage) or alfalfa and be incorporated for a duration of 1–3 years (Frelih-Larsen et al., 2014).

Effect of mitigation measure
The effect of this mitigation measure is to increase soil organic carbon, and to decrease use of nitrogen fertilisers with savings in emissions of nitrous oxide from soil (Martineau et al., 2016).

Abatement potential
Abatement potential was reported by Frelih-Larsen et al. (2014) as 0 to 1.2 t CO_2 ha^{-1} yr^{-1} for removal of carbon into soil organic matter, and a saving of 0.7 t CO_2 ha^{-1} yr^{-1} of N_2O emissions from soil and CO_2 emissions from field operations. However, it is not clear whether the sequestration estimate is across the whole rotation, or just for the perennial crop phase.

Franzluebbers et al., (2014) showed that inclusion of perennial forage crops in a rotation, compared with a rotation that did not include a perennial crop, increased soil organic carbon over several rotations, indicating that at least some of the increase in soil organic carbon was not lost during the annual cropping part of the rotation.

In CO_2 equivalent units, we estimate the mitigation potential per ha to be in the range 0.7 to 1.9 t CO_2e/ha/y.[171]

Overall emissions impact

Changes in emissions following an increase in perennial cropping will have an overall emissions impact at a territorial level.

Displacement effect

The inclusion of perennial forage crops in a rotation can result in displacement of arable crop production with displaced emissions. However, this is uncertain, and quantification is complex.

Permanence

Increases in organic carbon stored in soil is not necessarily permanent and depends on maintenance of the practice in the future.

Measurement requirements

Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits. Images from remote sensing could be used to determine extent of ground cover at intervals through the year (Martineau et al., 2016), and this can be used to estimate the areas of crops by species.

Adaptation effect

Crop diversification (including annual crop type mixes and switches to perennials) and longer crop rotations reduce the risk of losing an entire year's production, as different crops respond differently to weather and climate (EEA, 2019). More diverse crops diversify also farm income, contributing to more resilient farm systems. Mixed production systems such as agro-pastoral, agro-silvo-pastoral systems, double-cropping systems and mixed crop-livestock systems can increase land productivity and efficiency in terms of use of water and other resources, protect against soil erosion and lead to enhanced nutrient use efficiency (EEA, 2019).

Long and diverse crop rotations may have a positive impact on the rate of accumulation of soil organic matter, pore morphology and connectivity, and water absorption (EC, 2014). Through increased infiltration and decreased runoff, crop rotation contributes to reducing flood risks and to providing groundwater recharge. It can deliver a range of ecosystem services such as more efficient nutrient cycling and improved soil structure and quality, leading to reduced nutrient leaching, improved soil fertility, and more stable yields.

Barriers and constraints

The main barrier is lost yield of arable crops and a change in the farming system to produce forage. Whole farm planning is needed to manage the changes in outputs.

Co-benefits

Co benefits can include decreased leaching of nutrients and pesticides, increased biodiversity as a result of crop diversity increase, less soil erosion, and better water infiltration and storage in soil (Frelih-Larsen *et al.,* 2014).

Risks and trade offs

Care is needed to avoid large emissions from displaced crops, and more research is needed to predict and quantify the displaced emissions.

References

EC (2014) Selecting, designing and implementing natural water retention measures in Europe: capturing the multiple benefits of nature-based solutions. European Commission, Brussels.

EEA (2019). Climate change adaptation in the agriculture sector in Europe (No. 4/2019).

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[171] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

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Martineau H, Wiltshire J, Webb J, Hart K, Keenleyside C, Baldock D, Bell H, Watterson J. 2016. Annexes to: Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming. Specific contract number 340202/2014/688088/SER/CLIMA.A.2 implementing Framework Contract CLIMA.A.4/FRA/2011/0027.

A.4.1.2 Intercropping/ crop combination

Measure description
Intercropping, or crop consociation, is the production of multiple crops in close proximity, and simultaneously.

Effect of mitigation measure
We have not found evidence that intercropping is an effective greenhouse gas mitigation measure, except in the case of legumes intercropped with other species, for example, in grass swards. This is covered under MA14.

Abatement potential
Although there is evidence that intercropping has more efficient utilisation of resources and increased productivity, compared with the same crops grown separately (Lithourgidis et al., 2011), we have not found clear evidence of greenhouse gas abatement potential.

In view of the lack of evidence for an overall mitigation effect, we assume no mitigation for this measure.[172]

Overall emissions impact
No clear evidence.

Displacement effect
Intercropping can result in displacement of other crops with displaced emissions. However, this is uncertain, and quantification is complex.

Permanence
Where soil organic carbon is increased, this is not necessarily permanent, and depends on continued use of the practice.

Measurement requirements
Measurement of the activity depends on farmer co-operation in sharing records of farm activities and crop rotations and can be verified by inspection during farm visits.

Adaptation effect
Intercropping can provide pest control services by acting as a break against their dispersal and by providing a genetic pool of potential predators. It can therefore reduce pest protection products application, reducing farm costs and benefiting water quality. Carefully chosen varieties can increase their respective yields and resilience to climate extreme, for example by providing structural support. For example, the EC (2014) reports that by implementing avoiding bare soil (under other crops, between rows), intercropping can contribute to increasing water infiltration (4 times in Mediterranean vineyards with grass compared to no grass) and reducing runoff (20 to 55% in the Sahel compared to sole crops). Intercropping can diversify fodder production as well as crop production and farm income. Under climate change, intercropping can therefore increase farm resilience to pest and disease spread and climate variability. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight.

Barriers and constraints
The main barrier is a change in the farming system to different crops. Whole farm planning is needed to manage the changes in outputs.

[172] From DG CLIMA study CLIMA.A3/C3/C1/SER/2019/0014 - Lot 2: Support to the assessment of the Climate ambition of CAP Strategic Plans

Co-benefits

In addition to co-benefits of growing legumes (see MA 14), intercropping can increase soil conservation (less erosion through greater ground cover), provide lodging resistance for crops susceptible to lodging, reduce pest incidence, provide insurance against crop failure or unstable market prices (Lithourgidis et al., 2011).

Risks and trade offs

The main trade-off is that extra work is needed during crop management and harvest (Lithourgidis et al., 2011), with economic consequences.

References

EC (2014) Selecting, designing and implementing natural water retention measures in Europe: capturing the multiple benefits of nature-based solutions. European Commission, Brussels.

Lithourgidis AS, Dordas CA, Damalas CA and Vlachostergios DN. 2011. Annual intercrops: an alternative pathway for sustainable agriculture. Australian Journal of Crop Science, 5: 396–410.

A.4.1.3 Relevant measures in other groups

Many other measures can also influence resilience to climate change. For example, some measures reduce water requirements, such as:

- Improved rice cultivation,
- Manure applications (through better soil water holding capacity),
- Most carbon stock change measures (through better soil water holding capacity, and through changed land use).

Measures that increase land use diversity can influence resilience to climate change through improved biodiversity.

A.5 Cross-cutting measures

A.5.1 GHG emissions assessment and eco design

Measure description

This mitigation measure is about measuring and benchmarking GHG emissions for farms using GHG assessment tools and calculators to help identify the greatest sources of emissions (hotspots) and identify and implement measures to reduce emissions.

Effect of Mitigation measure

GHG emissions auditing and measurement at a farm scale promotes effective data collection and management. These data can help provide a baseline of emissions from which the effectiveness of mitigation activities can be assessed. There are several tools and assessments available to ‘carbon footprint’ agricultural production activities. These assessments can use different parameters for their assessments with some choosing a full life cycle assessment approach and other only looking at the farm impacts.

Outputs also can vary depending on the nature of the data they are set up to process, many now offer the ability to assess emissions intensity by farm enterprise providing a GHG per unit of production output ((kg/CO2e per kg product). Martineau et al. (2019) conducted an assessment of the effectiveness of tools to promote GHG emissions reduction measures and reports that “the use of farm-scale carbon calculators will help identify measures to reduce emissions and improve efficiency, which will often have an overall positive impact on farm business profitability”.

Martineau et al. also make clear that using a farm scale’s emissions measurement tool is not, in itself a GHG mitigation measure, but, where recommendations are implemented, it can be an important component of developing a GHG emissions reduction strategy and is an essential element of measurement and benchmarking.

Aggregation of data from GHG emissions assessments can also provide an important evidence resource from which to develop and design policies and measures. In Scotland and Ireland, RDP funded activity has seen the development of a large data base of emissions information from which national governments can use as a resource to target the most appropriate policies and measures to implement.

Abatement potential

Overall emissions impact

As stated previously the use of a GHG emissions assessment tool is not a mitigation measure but it is an effective tool in identifying the areas to address and possible measures that will be effective. Frelih-Larsen et al., (2014) stated that 'generally, drawing up and implementing an action plan at farm level can result in a GHG emissions reduction potential of at least 10% (AgriClimateChange network of farms) for a wide range of farming systems in Europe (dairy milk farms, cereals, olives, vineyards, etc.)'.

The Frelih-Larsen et al., (2014) report goes on to say that 'the mitigation effect could be 10% average reduction potential in a 3-year period (AgriClimateChange 2013), or 20% reduction potential in a 5 year action plan (Holmes et al., 2008)'.

Wiltshire et al. 2019 conducted a comparative analysis and SWOT analysis of available GHG emissions tools and found that the tools analysed had a robust approach to measuring emissions and emissions intensity however, the complexity, variability and uncertainty relating to measuring carbon sequestration presented challenges. The study concluded that while estimates of sequestration from above ground woody biomass provided some indicative results, other results relating to soil carbon stock change are unreliable.

Based on the evidence reviewed above we estimate that the mitigation potential ranges from 3.3% to 10% of GHG emissions from agriculture.

Displacement effect

There is no displacement effect associated with undertaking GHG emissions assessment.

Permanence

Changes made to farm practices as a result of undertaking an emissions assessment are likely to have a positive impact on productivity/profitability and thus be maintained.

Measurement requirements

The use of an emissions assessment is a measurement tool and can be used to assess the effectiveness of farm scale activity and also aggregate effects if data is structure and collected appropriately.

Adaptation effect

N/A

Barriers and constraints

The main barriers relate to the administration needed in data collection and inputting into the tools available.

There are also constraints which may result in low uptake: such as uncertainty over quantification of emissions, large time requirements, a lack of data quality, and a lack of incentives to use the tools (Kaetsch and Osterburg, 2015).

The following bullet points are cited in Frelih-Larsen *et al.,* (2014):

High number of data required for the carbon audit, variability of farm records across EU

Economic barriers (absence of national investment subsidies program etc.) and technical barriers (insufficient technical advice).

Farmers would be willing to do a carbon audit only if they had financial incentives

Farmers seemed more ready to address practices that produced carbon dioxide emissions, particularly the use of energy and fuel on the farm

Co-benefits

The most significant co-benefits are productivity and profitability as the process of doing a carbon audit tends to lead to greater resource efficiency. This will also result in reductions in other pollutants being lost to the environment such as reactive N to air and water.

Frelih-Larsen et al., (2014) point out that reducing emissions may reduce costs and increase resource efficiency, thereby benefitting the wider business. Evidence of reducing emissions can also be used on product labelling; this may be a further incentive for farmers.

Risks and trade offs

Cost in time and advisory input is likely to be required. There is some uncertainty between different data processing methodologies.

References

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Wiltshire et al. 2019 A framework for benchmarking greenhouse gas emissions intensity in Scottish farming. Report to Climate Exchange & Scottish Government.

APPENDIX 2 PAMS FROM MEMBER STATES' NATIONAL AIR POLLUTION CONTROL PROGRAMMES (NAPCP)

The following table provides examples of PaMs reported by EU Member States following European Commission Implementing Decision (EU) 2018/1522 of 11 October 2018 laying down a common format for national air pollution control programmes (NAPCPs) under Directive (EU) 2016/2284 of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants[173].

PaM Name	PaM Description	Pollutants	Sector	Objective
Incentives to reduce consumption of inorganic fertilizers and implement the Code of Good Agricultural Practice	Financial incentives for replacing inorganic fertilizers with organic fertilizers, upgrading technologies of organic fertilizer use and implementing measures of the Code of Good Agricultural Practice related to air pollution abatement.	NOx;NH3	Agriculture	Improved livestock management and rearing installations Low-emission application of fertilizer/manure on cropland and grassland
Review of requirements for storage and handling of manure and slurry	Amendment of environmental requirements for manure and slurry management with respect to the storage and handling of manure and slurry (except for small and very small-scale farms).	PM2.5;NMVOC;NOx;NH3	Agriculture	Improved animal waste management systems
Review and revision of technical and technological solutions for the farm animal housing	Amendment of the design requirements for pig farms, cattle buildings, sheep farms, poultry farms, fur farming and rabbit farms with regard to available new technical and / or technological solutions to manage emissions to air. Such requirements should not apply to small and very small farms.	NMVOC;NOx;PM2.5;NH3	Agriculture	Other agriculture
Legal regulation of the use of ammonium carbonate fertilizers	Legal prohibition of the use of ammonium carbonate fertilizers.	NOx;NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Establishment of common rules for the operation of farm animal housing	Common mandatory technical and / or technological operational requirements of the control and reduction of emissions to air from housing of pigs, cattle, birds and other animals. Such requirements should not apply to small and very small farms.	NOx;NH3	Agriculture	Other agriculture

[173] NECD policies and measures database — European Environment Agency (europa.eu)

PaM Name	PaM Description	Pollutants	Sector	Objective
Development of Code of Good Agricultural Practice	Establishment and application of revised code of good agricultural practice expected to mitigate negative impacts of agriculture on soil, water condition, ambient air and climate.	NOx;NH3	Agriculture	Other agriculture
Promoting replacement of lagoon-type storage facilities by cylindrical-type storage facilities	The financial support will be provided within the Rural Development Programme (in accordance with Common Agriculture Policy), to promote step-by-step transition to cylindrical-type manure storage facilities	NH3	Agriculture	Improved animal waste management systems
Decreasing the time during which the manure shall be incorporated within the soil after spreading	In the intensive rearing farms of poultry and pigs, corresponding to category A permit, as well as in the cattle farms having number of animals above 300, the liquid manure shall be incorporated within the soil within 4 hours after spreading. The solid manure in the intensive rearing farms of poultry and pigs, corresponding to category A permit, shall be incorporated within the soils within 4 hours after spreading. Additionally, PaM corresponding to dairy farms with more than 300 animals. The solid manure shall be incorporated within the soil within 12 hours after spreading (general case). The financial support to implement the measure will be provided within the Rural Development Programme (in accordance with Common Agriculture Policy).	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Providing direct incorporation of liquid manure within the soils	The financial support will be provided within the Rural Development Programme (in accordance with Common Agriculture Policy), to ensure providing direct incorporation of liquid manure within the soil.0	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Promote effective manure management outside the animal house	The financial support will be provided within the Rural Development Programme (in accordance with Common Agriculture Policy), to ensure covering stores for liquid manure.	NH3	Agriculture	Improved animal waste management systems
Capacity building and more efficient performance of State Environmental Service	This measure is introduced to evaluate previous performance of State Environmental Service and to develop new strategy for capacity building and more efficient performance of State environmental Service to ensure better control of polluting activities and reduce emissions caused by industrial activities and combustion plants.	PM2.5;NMVOC;NOx;BC	Agriculture; Industrial Processes; Waste manageme	Improved animal waste management systems Improved control of fugitive emissions from industrial processes

PaM Name	PaM Description	Pollutants	Sector	Objective
			nt; Energy Supply	Improved livestock management and rearing installations Improved wastewater management systems Installation of abatement technologies Waste incineration with energy use
Revision of the natural resource tax rates set for air pollutants	The envisaged amendments will provide motivation to implement emission reduction technologies (including energy efficiency improvements)	PM2.5;BC;NH3;NMVOC; NOx	Cross-cutting	Multi-sectoral policy
Strengthen control on protection of water and soil from pollution with nitrates caused by agricultural activity	The measure ensures that the fertilization plans in line with the foreseeable nutrient requirement of the receiving cropland/grassland are prepared, the manure and slurry are incorporated as well as other requirements are performed in accordance with the requirements defined by relevant Cabinet of Ministers Regulation No 834 (23.12.2004) "Regulation Regarding Protection of Water and Soil from Pollution with Nitrates Caused by Agricultural Activity".	NH3	Agriculture	Improved animal waste management systems Improved livestock management and rearing installations Other activities improving cropland management
Promoting the development of biological dairy farming	Biological dairy farming ensures lower specific ammonia emissions per dairy cow, compared to conventional dairy farming. The financial support will be provided within the Rural Development Programme (in accordance with CAP)	NH3	Agriculture	Other agriculture
Promoting evolve of the newest technologies to provide precision fertiliser application. Providing financial support.	The measure ensures effective (optimal) application of nitrogen fertilizers. The financial support will be provided within the framework of national Rural Development Programme (in accordance with CAP).	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland Other activities improving cropland management
Preparing crop fertilisation plans to provide optimal fertilisation (in line with the foreseeable nutrient	The measure ensures effective (optimal) application of nitrogen fertilizers. The financial support will be provided for the implementation of the fertilization plans (in those territories in which such mandatory plan is not required), within the framework of	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland

PaM Name	PaM Description	Pollutants	Sector	Objective
requirement) in those territories, in which mandatory requirement for the plan is not stated. Providing financial support	national Rural Development Programme (in accordance with Common Agriculture Policy).			;Other activities improving cropland management
Replacing urea-based fertilisers by ammonium nitrate-based fertilizers in the additional fertilizing	The financial support will be provided within the Rural Development Programme (in accordance with CAP) to ensure replacing urea-based fertilisers	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Introduction of papilionaceous (leguminous) plants in the crop rotation to provide accumulation of atmospheric nitrogen in soil. Providing financial support.	The measure ensures effective (optimal) application of nitrogen fertilizers. The financial support will be provided within the framework of national Rural Development Programme (in accordance with CAP).	NH3	Agriculture	Other activities improving cropland management
Development of new Air Quality Action plan for Riga city for 2021.- 2025.	Development of new Air Quality Action plan for Riga city for 2021.-2025. and assessment of progress made by measures arising from existing plan and propose new measures for the next 5 years	PM2.5;BC;NOx	Cross-cutting	Multi-sectoral policy
Strengthen control on implementation special requirements for the performance of polluting activities in animal housing	The measure ensures that the construction of manure and slurry storage facilities are provided in accordance to the requirements defined by relevant Cabinet of Ministers Regulation No 829 (23.12.2014) "“Special Requirements for the Performance of Polluting Activities in Animal Housing”	NH3	Agriculture	Improved animal waste management systems Improved livestock management and rearing installations
Developing and implementing feeding management plans for poultry and pigs. Providing financial support for these plans’ implementation	The measure provides decrease in ammonia emissions simultaneously ensuring necessary amount of nourishing substances for animals. The measure ensures that emission limit values do not exceed emission levels associated with the best available techniques.	NH3	Agriculture	Other agriculture
Ensure implementation of requirements set in new	The measure decreases the ammonia emissions. The measure ensures that emission limit values for these polluting activities,	NH3	Agriculture	Improved livestock management and rearing installations

PaM Name	PaM Description	Pollutants	Sector	Objective
best available techniques for intensive rearing of poultry and pigs	corresponding to A category permit, do not exceed emission levels associated with best available techniques. Measure foresees revision of existing permits and application of stricter emission requirements and providing inspections.			
Use of revenues (at least 70%) of Natural Resource Tax for co-financing environmental protection (including emission reduction) measures	The measure establishes additional source of financing for air emissions reduction measures	SO2;PM2.5; NOx;BC;NM VOC;NH3	Cross-cutting	Multi-sectoral policy
MAG-5: Hydro-technical interventions and systems for protection against natural disasters	The construction of drainage, irrigation and flood, droughts and other natural disaster prevention systems, besides the direct benefits of production costs reduction and quality of drinking water improvement, can also reduce the loss of nutrients due to leaching, resulting in a reduced need for nitrogen and mineral fertilizers usage.	NOx;N2O;P M10;CO2;P M2.5;NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland ;Other activities improving cropland management
MAG-3: Improvement of Livestock Plants and Animal Waste Management System	Covering storage (liquid) manure - creating a natural layer (crust) with natural (straw) or (porous) artificial material. This measure reduces direct emissions of methane and ammonia, although to a lesser extent they improve the nitrification process (porous material) and cause a slight increase in nitrogen oxide emissions.	NMVOC;NH3 ;NOx;PM10; CH4;N2O;P M2.5;CO2	Agriculture	Improved animal waste management systems ;Improved livestock management and rearing installations
MAG-4: Improvement of the Application Method of Mineral Fertilizers	The application of new slow releasing fertilizers suitable for corn and wheat cultivation (fertilizers coated with polymers) reduces the need for fertilizer application per hectare (due to lower nitrogen losses) with unchanged or increased yields. Further reduction of NH3 emission is possible by reducing the urea application to other types of mineral fertilizers.	N2O;PM2.5; NH3;PM10;N Ox	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
MAG-2: Anaerobic decomposition of manure and bio-gas production	With the introduction of a bio-gas emission reduction plant, elimination of methane emissions resulting from the disposal of used garbage and the production of electricity from renewable sources is achieved. The measure is related to measures in Renewable Sources in Electricity and Heat Production and Construction of Co-generation Plant from the Energy Sector.	N2O;CH4;N H3;CO2	Agriculture	Improved animal waste management systems

PaM Name	PaM Description	Pollutants	Sector	Objective
MAG-1: Changes in livestock and pigs diet and the quality of fodder	Specific sub-measures within this group of measures relate to the improvement of livestock breeding, livestock production and animal nutrition. The measures also relate to the potential reduction of nitrogen compounds and ammonia emissions from intestinal fermentation and manure management.	NH3;PM10;NOx;CH4;PM2.5;N2O;NMVOC	Agriculture	Improved animal waste management systems Improved livestock management and rearing installations
MCC-2: Support for Documentation Creation to Provide Additional Financial Resources for More Effective Implementation of Air Quality Improvement Action Plans	The NEC Directive foresees that assistance in the planning and implementation of air quality improvement action plans can be achieved by co-financing through the LIFE and EU Structural Funds programs. Consequently, it is proposed to carry out the necessary technical analysis and preparation of project documentation for funding applications from the Structural Funds for the cycle (envelope) of financing the period 2021-2027.	NH3;NMVOC;PM10;NOx;PM2.5;CO2;CH4;SO2	Cross-cutting	Multi-sectoral policy
MCC-1: Support for increasing the administrative, technical and management capacities of local communities	The problem in cities is coordinated by multi-sectoral actions, namely closeness and financial rigidity, and there are no common funding sources for a holistic approach. Support should be given to increasing the administrative, technical and managerial capacities of local communities in the implementation of air quality improvement action plans. This can be achieved through a LIFE project that will help cities to more effectively implement and monitor progress and strengthen national and local co-ordination.	CO2;SO2;CH4;NMVOC;NOx;NH3;PM10;PM2.5	Cross-cutting	Multi-sectoral policy
MAG-6: Introduction of new cultivars, varieties, and species	Encouraging the development, education and application of technologies at national and regional level, encourage transitions and adaptation of the entire production chain for production of new crops or facilitate and encourage the use of cultivars and varieties that are more resistant to drought and disease and have lower carbon footprint.	PM10;PM2.5;N2O;NOx;NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland Other activities improving cropland management Other agriculture
Incentive to reduce the use of nitrogen fertilizers	Decrease of the consumption of nitrogen fertilizers by applying mandatory standards under cross-compliance. It applies to the 1st pillar and to the beneficiaries of the agro-environment and areas subject to natural conditioning of the 2nd pillar. Monitoring of GHG in the monitoring systems of policies and measures to incentivize the reduction of the use of nitrogen fertilizers (with reference to the	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland

PaM Name	PaM Description	Pollutants	Sector	Objective
	Code of Good Agricultural Practices) and the National Emission Ceilings Directive, using methodologies compatible with the emissions inventory.			
Ammonia requirements in environmental approval of livestock farms	Ammonia emissions from stables are regulated in environmental approvals of the establishment, expansion, or conversion of livestock farms. For livestock farms (all types of livestock) with a total emission of more than 750 kg of ammonia-N requirements are made to the effect that emissions must not exceed a maximum emission corresponding to the use of best available technique (BAT). In addition, limit values have bet set for the maximum ammonia deposition from livestock farms on protected habitats. Requirements for ammonia reduction may be met by establishing low-emission stables or environmental technology. Today around half of all livestock farms are subject to an environmental approval. Since the mechanism of the legislation is that livestock farms must have an environmental approval for expansions, conversion, or establishment a larger share of livestock farms will over time be regulated by environmental approvals and the resulting ammonia requirements. This means that continuously a large propagation of ammonia reducing technology will be seen. In 2018 efforts were launched to update the knowledge base behind the establishment of permitted levels for the emission of ammonia from different stable designs (BAT levels). The update is expected to contribute to emission reductions applying the principles of BAT.	NH3	Agriculture	Improved livestock management and rearing installations
Reduced emissions from inorganic fertilizers	It will be made more attractive to farmers to use those types of inorganic fertiliser that have the lowest emissions of ammonia to the air, so that emissions of ammonia from inorganic fertiliser are reduced. This will be done by requiring that sulphur acid ammonia and urea (both in solid and liquid form), which have a particularly high ammonia evaporation compared with other inorganic fertilisers, will be spread in a manner reducing evaporation	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland

PaM Name	PaM Description	Pollutants	Sector	Objective
	(injection, deep placement or by adding urease inhibitor to a sufficient extent). These two types of fertilisers today account for some 3 percent of the total sale of fertiliser in the Member State stated in tonnes of nitrogen, while they account for 10 percent of total emissions from inorganic fertiliser. By setting requirements for the use of these two types of fertilisers, emissions from inorganic fertiliser are expected to be reduced by approx. 900 tonnes a year. This measure is expected to be implemented in 2019 through an amendment of the Statutory Order on Livestock Manure.			
Other measures within agriculture	A number of the measures to be launched to reduce climate gases from agriculture will potentially have a positive impact on ammonia emissions. This applies to the efforts for promoting precision farming, establishment of a re-parcelling fund of EUR 150 million, and the set-aside scheme for organic soil. Furthermore, in 2018 the government has allocated EUR 90 million for climate research in the agricultural field.	CH4;NH3	Agriculture	Other agriculture
Committee on ammonia reducing measures	As part of the process of the climate and air proposal it was considered to set requirements for the reduction of ammonia emissions in connection with the spreading of livestock manure. Studies showed that there is a major potential for ammonia reduction to be gained from regulating spreading further, but also that the measure will be relatively burdensome for agriculture, a burden it would be difficult to compensate for. It was therefore decided to set up a committee looking further into possibilities and proposing a balanced solution liable to contribute to the reduction of ammonia emissions without hampering the competitiveness of the industry. The committee will be set up in early 2019 and is expected to table preliminary recommendations for initiatives in the fall of 2019 in view of a subsequent political decision. After this, initiatives must be further refined and implemented. The initiatives presented by the committee must be able to put the Member State in a position to comply with our emission reduction commitments.	NH3	Agriculture	Other agriculture

PaM Name	PaM Description	Pollutants	Sector	Objective
	To support the work of the committee and secure concrete follow-up on the recommendations EUR 160 million has been allocated for, among others, pilot projects or the establishment of subsidy schemes in view of reducing ammonia emissions from agriculture. Ammonia reductions further to this measure will depend on the design of the initiatives that are concretely implemented as a follow-up on the recommendations of the committee. As mentioned, however, the initiatives are to ensure that the reduction target for ammonia is attained.			
Improved animal housing	EUR 2.4 million has been allocated in 2019 for the establishment of an EU financed subsidy scheme under the EU Agricultural Fund for Rural Development for investments in new slaughter pig stables promoting the propagation of ammonia and greenhouse gas reducing technology, such as slurry acidification installations.	NH3;CH4	Agriculture	Improved livestock management and rearing installations
Improved management of manure	Low emission of manure on cropland	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Reducing NH3 emissions from pig and poultry houses with an air scrubber	(1) Monitoring system on air scrubbers Inspection reports from the Flemish Environmental Inspectorate show that air scrubbers in pig houses are not always operated correctly, as a result of which the statutory annual average removal efficiency of 70% is not achieved. On the other hand, well-functioning and well-dimensioned air scrubbers that are carefully monitored can achieve a removal efficiency of 95%, which is considerably better than the minimum annual average removal efficiency of 70%. A solution to remedy the lack of technical follow-up and therefore the non-compliant operation of the air scrubbers is to make the use of an electronic monitoring system mandatory. This system is already being used in the Netherlands and Germany and keeps track of when and with which parameters the air scrubber is in use.	NH3	Agriculture	Improved livestock management and rearing installations ;Other agriculture

PaM Name	PaM Description	Pollutants	Sector	Objective
	o We require the installation and use of an electronic monitoring system for new air scrubbers or extensions of existing air scrubbers that are taken into use from 1 January 2020. Existing air scrubbers: o At the latest mid-2019, we will complete the analysis to evaluate the technical and economic feasibility of the generic implementation of electronic monitoring in existing air scrubbers. Attention will be paid to (1) an estimate of realistic cost prices for the purchase, installation and maintenance, (2) the technical feasibility of installing an electronic monitoring system in all existing air scrubbers and (3) the concrete way in which the government will use the data from the electronic monitoring to check the proper functioning of the air washer. o At the latest at the end of 2019, a decision will be taken on whether or not to introduce the obligation to install an electronic monitoring system at existing air scrubbers. We also record the concrete modalities and timeframes. (2) Air scrubbers with a removal efficiency of at least 80 %: From 2019, new air scrubbers in Flanders are required to submit a measurement and dimensioning report showing what minimum removal efficiency (70% - 75% - 80% - …) they can guarantee. Based on the measurement reports received and the operation of the air scrubbers in practice, we will gain a clearer view of the actual removal efficiencies. Because it is currently insufficiently clear whether there are enough suppliers of air scrubbers with a guaranteed minimum removal efficiency of 80%, we will periodically (annually) carry out an evaluation of the available air scrubbers on the market. Based on this periodic evaluation, we will decide when a switch to a minimum removal efficiency of 80% is justifiable, or an increase to 75% as an intermediate step. "			

PaM Name	PaM Description	Pollutants	Sector	Objective
Reducing NH3 emissions from the application of animal manure and fertilizers	(1) Stricter conditions for low-emission application of slurry The measure means that we are working towards an increased application rate of the most efficient techniques for low-emission application of manure. In doing so, we aim to: • Drag hoses are no longer used on grassland, or at least as little as possible. • The proportion of manure injection will be increased from 26% to 50%. • 50% of the spread manure is incorporated as soon as possible instead of after two hours. (2) Better regulations for the use of urea as fertilizer Elaboration of a proposal to arrive at better regulations for the use of urea as fertilizer. A ban (complete or for types of crops and soils) on the use of urea is one of the possibilities.	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Anchoring knowledge about air pollution	Knowledge building on limiting (exposure to) air pollution • for spatial designers • in departments responsible for policy on mobility and public works • with construction professionals • at schools around indoor air	NOx	Cross-cutting	Multi-sectoral policy
Developing expertise on air pollution	We are continuing to improve the emission inventory. We improve knowledge about (local) traffic data in function of emission and air quality modelling. We are gaining better insight into the air quality in street canyons. We better map out the specific locations of attention. We are exploring options to reduce non-exhaust emissions. We are gaining better insight into UFP emissions from aircraft engines and road traffic. We are strengthening our knowledge about the greening of freight transport. We acquire more	NOx	Cross-cutting	Multi-sectoral policy

PaM Name	PaM Description	Pollutants	Sector	Objective
	knowledge about BC. We are acquiring more knowledge about the relationship between indoor air and outdoor air			
We are strengthening the set of instruments and the implementation of plans and projects	We strengthen the environmental instruments We work together efficiently and effectively in the implementation of existing instruments We are committed to strengthening enforcement	NOx	Cross-cutting	Framework policy ;Multi-sectoral policy
Collaboration between regional government and local authorities	We work with local authorities to improve air quality We support local projects that improve air quality We facilitate the collection of local traffic data for emission and air quality modelling We optimize the available tools and information We ensure a better dissemination of the available information We integrate air quality into other local instruments We support local authorities in informing and sensitizing the population We support the local authorities in coherent enforcement action	NMVOC;NOx ;BC;SO2;PM 2.5	Cross-cutting	Multi-sectoral policy
Adapt manure application techniques to limit nitrogen emissions and losses	Reduce the time between incorporation of effluents and spreading using techniques adapted to the type of surface: meadow or crop. Use techniques close to the ground which reduce losses by volatilization.	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Reduction of NH3 emissions from mineral fertilization.	Replace mineral fertilizers with fertilizers in a less emissive form and/or reduce the time for burying or by reducing the quantities spread.	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Develop "low" emission buildings for large pig and poultry farms, new or subject to major renovations.	Capture the ammonia present in the air of livestock buildings using a filtration system, ventilation, air washing. The abatement technique is free and leaves room for technical innovations.	NH3	Agriculture	Improved animal waste management systems ;Improved livestock management and rearing installations
In the event of a spring or seasonal pollution peak,	Limit (avoid) the spreading of nitrogenous fertilizers in the event of a spring peak in pollution by particles (ammonium nitrate) or impose	NH3	Agriculture	Improved animal waste management systems

PaM Name	PaM Description	Pollutants	Sector	Objective
limitation of ammonia evaporation resulting from the spring spreading of nitrogen fertilizers on the fields.	the burying within 4 hours of fast-acting organic fertilizers (liquid manure, soft manure, effluents from poultry, drippings) rather than slow-acting organic fertilizers (cattle or pig manure and manure compost) or mineral fertilizers which lead to significant volatilization of ammonia.			;Low-emission application of fertilizer/manure on cropland and grassland
Prohibition of the burning of household green waste, the maintenance of parks and gardens by professionals and green waste of agricultural origin.	Permanent ban on the burning of plant waste outdoors: branches, hedge trimmings, garden waste, grass, straw or crop residues. The measure targets households, professionals in the maintenance of parks and gardens, the agricultural sector and forest waste. Exception possible for phytosanitary reasons, to preserve biodiversity, for traditional celebrations such as "great fires" at the end of winter and as part of preventive programs aimed at avoiding forest fires.	PAHs;HCB;PM10;PM2.5	Waste managegment	Improved landfill management ;Other waste
Cover for urine container	All urine containers that currently have flood blankets instead use roofs as coverage	NH3	Agriculture	Improved animal waste management systems
Use fertilizer within the same day	Apply the fertilizer that is currently spread on unsown land without degradation within the same day and carry out faster degradation (within 4 hours) of the fertilizer that is currently degraded within the same day.	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Replace widespread with band spread	Replace broadband with broadband in areas where it is possible and where it is not already in use	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Further promotion of anaerobic digestion for the treatment and management of animal waste	Further promotion of anaerobic digestion for the treatment and management of animal waste; Promotion of anaerobic digestion in existing biogas plants; Encouragement of new biogas plants to exploit organic waste from livestock breeding	NH3	Agriculture	Improved animal waste management systems
Establishment of a national advisory code of good agricultural practices to control ammonia	The establishment of a national advisory code of good agricultural practices to control ammonia, taking into account the UNECE Framework Code for Good Agricultural Practice for Reducing Ammonia Emissions of 2014. More detailed description is provided in the Annex 1 (chapter 6.2) of NAPCP.	NH3	Agriculture	Improved animal waste management systems ;Improved livestock management and rearing installations ;Low-emission application of

PaM Name	PaM Description	Pollutants	Sector	Objective
				fertilizer/manure on cropland and grassland ;Other activities improving cropland management
Fast incorporation of mineral fertilizer spread to the arable land	The possibilities of limiting NH3 emissions from the use of mineral fertilizers are based on the principle that the surface where NH3 emissions can occur should be as small as possible. Therefore, the measure includes the use of the fast incorporation of mineral fertilizer tillage method. More detailed description is provided in the Annex 1 (chapter 6.3) of NAPCP.	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Low-emission manure storage technologies: covered liquid manure storages ("tight" lid, tent, or roof structure)	The aim of this measure is to increase the number of covered liquid manure tanks. More detailed description is provided in the Annex 1 (chapter 6.3) of NAPCP.	NH3	Agriculture	Improved animal waste management systems
Low-emission manure spreading technologies: injection of liquid manure	The aim of this measure is to increase the usage of low-emission manure spreading techniques, especially promoting the use of techniques of slurry injection. More detailed description is provided in the Annex 1 (chapter 6.3) of NAPCP.	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Prohibition of the use of ammonium carbonate fertilisers	This PaM includes prohibition of the use of ammonium carbonate fertilisers. More detailed description is provided in the Annex 1 (chapter 6.3) of NAPCP.	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Manure incorporation (A4)	Solid manure incorporation using different techniques and timings for different terrains	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Fertilizers incorporation (A1)	Urea based fertilizers incorporation	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Effluent incorporation (A3)	Effluent incorporation using different techniques and timings	NH3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland

PaM Name	PaM Description	Pollutants	Sector	Objective
Effluent spreading techniques (A2)	Regulation on effluent spreading techniques in case of low slope terrains	NH_3	Agriculture	Low-emission application of fertilizer/manure on cropland and grassland
Ban on new lagoons (A5)	Ban of construction of new lagoons	NH_3	Agriculture	Improved animal waste management systems
Floating covers (A6)	Natural floating cover of manure	NH_3	Agriculture	Improved animal waste management systems

APPENDIX 3 FINANCING OPTIONS

A.6 CAP

The funding of the CAP became streamlined in this new programming period, with more movement between the two pillars and more flexibility for each Member State to allocate funding depending on their needs within the CAP Objectives. Member States are however required to allocate 40 % of the overall financial envelope of the CAP to climate objectives and at least 30% of the total EAFRD contribution to the CSPs for interventions addressing the specific environmental and climate-related objectives, including Bioenergy. Much of this funding is expected to be results-based.

A.6.1 European Agricultural Fund for Rural Development (EAFRD)

Key areas

Supporting rural development interventions such as conversion to and maintenance of organic farming, Natura 2000 and forestry measures, among others.

Volume of Funding

EUR 95.51 billion, of which EUR 8.07 billion under NGEU

Objectives and scope

The EAFRD finances the CAP's contribution to the EU's rural development objectives:

- improving the competitiveness of agriculture,
- encouraging sustainable management of natural resources and climate action,
- achieving a balanced territorial development of rural economies and communities.

As one of the funding mechanisms of the CAP, the fund also supports the 10 objectives of the CAP.

Components

All components are incorporated into the CSPs which outline interventions that Member States want to support through CAP funding, including the EAFRD.

Type of management

Management is shared between the European Commission and Member States national and regional authorities.

Types of funding

The funding is largely through Rural Development Programmes and can also provide investment support for rural enterprises and projects through financial instruments, such as loans, guarantees, or equity.

Targeted beneficiaries

Targeted beneficiaries can include farmers and forest owners, but this can extend to public authorities, economic and social partners, local action groups, and relevant bodies representing civil society.

Types of Projects

There are a broad range of projects that can be supported under the EAFRD, such as long as they are meeting the ten CAP objectives and the needs identified by the Member State. Support for rural development has been simplified under the new CAP, with the selection of 20 rural development "measures" and 64 "sub-measures", being simplified into 8 broader "types of interventions".

Eligibility Criteria

To be eligible, you must meet the following conditions each year:

- direct payments are not granted if the total amount due and/or the area of land eligible for payment is too small (the exact threshold varies from country to country).
- only farmers with a holding located in the EU and undertaking an agricultural activity can receive direct payments.

- Farmers need to comply with statutory management requirements and good agricultural and environmental conditions as determined by their Member State or region and go beyond these requirements.

Detailed eligibility criteria for all supported activity should be found within the CSPs.

Useful links and resources

- European agricultural fund for rural development (EAFRD) (europa.eu)
- New CAP: 2023-27 (europa.eu)
- CAP strategic plans by country (europa.eu)

A.6.2 European Agriculture Guarantee Fund

Key areas

Farmer income support schemes, market measures, eco-schemes.

Volume of Funding

EUR 291.09 billion

Objectives and scope

To help the EU's farmers to provide a secure supply of safe, healthy, and affordable food.

As part of funding the CAP, the EAGF also contributes to the 10 CAP objectives.

Components

The majority of the EAGF measures will be implemented through the CSPs, produced by each Member State, approved by the EC, and published on the EC's website. The EAGF will implement support via direct payments and sectoral interventions. Direct payments provide income support to farmers, while sectoral interventions are measures that support and stabilise agricultural markets.

There is also financing under the EAGF which supports activity outside of the CAP, including private and public storage measures and the EU school scheme.

Eco-schemes are voluntary tools to be offered by Member States to farmers to support various action that goes beyond conditionality and other relevant obligations and can contribute to climate resilience. These supported actions may focus on climate change mitigation, including the reduction of greenhouse gas emissions from agricultural practices, and the maintenance of existing carbon stores and enhancement of carbon sequestration; and, on climate change adaptation, including actions to improve resilience of food production systems and animal and plant diversity for stronger resistance to diseases and climate change.

Type of management

Management is shared between the European Commission and Member States national and regional authorities.

Types of funding

Direct payments are made to farmers. The fund also provides sectoral interventions for market support.

Targeted beneficiaries

Targeted beneficiaries can include farmers, forest owners, and other land managers.

Types of Projects

The EAGF does not finance projects but provides direct payments.

Eligibility Criteria

To be eligible, you must meet the following conditions each year:

- direct payments are not granted if the total amount due and/or the area of land eligible for payment is too small (the exact threshold varies from country to country).

- only farmers with a holding located in the EU and undertaking an agricultural activity can receive direct payments.
- only land suitable for agricultural production is considered as agricultural area (i.e., arable land, permanent crops and permanent grassland).
- Farmers need to comply with statutory management requirements and good agricultural and environmental conditions as determined by their MS or region.

As part of the new CAP from 2023, specific eligibility criteria for the different interventions supported under the fund should be included in the CSPs, which are available online.

Useful links and resources

- European agricultural guarantee fund (EAGF) (europa.eu)
- New CAP: 2023-27 (europa.eu)
- CAP strategic plans by country (europa.eu)

A.6.3 Cohesion Fund (CF)

Key areas

Trans-European transport networks, energy efficiency, renewable energy, intermodal transport, transport infrastructure, environmental infrastructure.

Volume of Funding

EUR 48 billion

Objectives and scope

The CF encourages investments in priority trans-European transport networks and investments related to energy or transport that benefit the environment in terms of energy efficiency, the use of renewable energy, developing transport and supporting intermodal transport.

Components

With relation to the NECP the CF supports a greener, low-carbon transition towards a net-zero carbon economy and resilient Europe by promoting a clean and fair energy transition, green and blue investment, the circular economy, climate change mitigation and adaptation, risk prevention and management, and sustainable urban mobility. The CF more specifically focuses on:

- promoting energy efficiency and reducing greenhouse gas emissions.
- promoting renewable energy and developing smart energy systems, grids and storage.
- promoting climate change adaptation and disaster risk prevention and resilience.
- promoting access to water and sustainable water management.
- promoting the transition to a circular and resource-efficient economy.
- enhancing the protection and preservation of nature, biodiversity and green infrastructure, including in urban areas, and reducing all forms of pollution.

Type of management

The CF is a fund in which management is shared between the European Commission and national and regional authorities in certain EU Member States. The Member States' authorities in charge of the administration of the CF choose which projects are to be supported (through grants and/or via financial instruments, e.g., a loan, equity or a guarantee).

Types of funding

Member States can use the contribution from the CF to provide support to beneficiaries in the form of grants, financial instruments or prizes, or a combination thereof. Financial instrument products may include loans, guarantees, equity or quasi-equity. Moreover, MAs can tailor financial products according to their needs and capabilities or structure the financial instrument based on terms and conditions provided by the European Commission for 'off-the-shelf' instruments.

Targeted beneficiaries

Research and academia, NGOs and civil society, large enterprises, SMEs, public authorities (specific Member State only, which is detailed in the 'Eligibility section' below).

Types of Projects

Investments in the environment, most of which are related to climate and low carbon transportation between Member States.

Funding from the Cohesion fund can contribute to actions under the RePowerEU plan, which is the European Commission's plan to make Europe independent from Russian fossil fuels well before 2030, in light of Russia's invasion of Ukraine. REPowerEU is a plan for

- saving energy,
- producing clean energy,
- diversifying our energy supplies.

It is backed by financial and legal measures to build the new energy infrastructure and system that Europe needs. Member States can draw on funds from CF, as well as other NECP relevant funds including RRF, EAFRD, and Innovation Fund (see relevant sections in Appendix 3 for more information on these funds).

Eligibility Criteria

The Cohesion Fund is only for EU Member States with a GNI per capita below 90% of the EU-27 average. This currently (2023) includes: Bulgaria, Czechia, Estonia, Greece, Croatia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania, Slovenia, and Slovakia.

A.6.4 European Regional Development Fund: Investment for jobs & growth goal

Key areas

Innovation, SME competitiveness, digitalisation, energy efficiency, renewable energy, energy network, climate change mitigation and adaptation, disaster risk management, access to water, circular economy, waste management, nature protection, biodiversity, mobility, transport infrastructure, employment, education, skills, social inclusion, access to healthcare, culture, sustainable tourism.

Volume of Funding

EUR 274 billion

Objectives and scope

The ERDF's objective is to strengthen economic, social, and territorial cohesion in the EU by correcting imbalances between its regions. The ERDF principally aims to enable EU countries and regions to become more competitive and smarter (through innovation, the development of an inclusive digital society and support for SMEs), greener (through a reduction in greenhouse gas emissions, improved water and waste management, protection of the environment, preserving biodiversity and reducing pollution), more connected (through enhanced mobility), more social (via support for effective and inclusive employment, enhancing the role of culture and sustainable tourism) and 'closer to citizens' (fostering sustainable urban development).

Components

Support through the ERDF is related to five policy objectives, one of which is relevant to NECPs. This is:

- Policy Objective 2 – a greener, low-carbon transition towards a net-zero carbon economy and resilient Europe by promoting a clean and fair energy transition, green and blue investment, the circular economy, climate change mitigation and adaptation, risk prevention and management, and sustainable urban mobility.

Of the 5 policy objectives, Member States are required to concentrate at least 30 % of their allocation to this policy objective.

Type of management

Management of the ERDF is shared between the European Commission and MSs national and regional authorities. The Member States' authorities choose the projects to be supported. The ERDF operates according to the co-financing principle (i.e., whenever a project is to receive funding, the Member States' authorities must also provide funding from their own budget). The maximum co-financing rate varies according to the development level of the region concerned.

Types of funding

Member States can use the contribution from the ERDF to provide support to beneficiaries in the form of grants, financial instruments or prizes, or a combination thereof. Financial instrument products may include loans, guarantees, equity or quasi-equity. Moreover, MAs can tailor financial products according to their needs and capabilities or structure the financial instrument based on terms and conditions provided by the European Commission for 'off-the-shelf' instruments.

Targeted beneficiaries

The country's authority will decide which project promoters are eligible. For example, you may be eligible if your organisation is an SME, a large enterprise, a research organisation, a public authority, an NGO, or a civil society organisation.

Types of Projects

Each country or region will specify different types of projects to support. Generally, the support from the ERDF covers:

- investments in infrastructure
- activities for applied research and innovation, including industrial research, experimental development, and feasibility studies
- investments in access to services.
- productive investments in SMEs and investments aiming to safeguard existing jobs and create new jobs.
- investments in equipment, software, and intangible assets.
- investments in networking, cooperation, the exchange of experiences, and activities involving innovation clusters, including between businesses, research organisations and public authorities.
- investments in information, communication, and studies.

Eligibility Criteria

Certain rules may be applied, such as:

- Limits on time-period – there are limits on the period during which operations and expenditure can take place.
- Scope of intervention – there are restrictions on the types of activities that can be co-financed.
- Exclusion of certain cost categories
- Location of operations
- Durability of operations

A.6.5 European Regional Development Fund: European territorial cooperation goal (Interreg programmes)

Key areas

Environment, climate, sustainable energy, innovation, employment, social, digital, transport, governance and democracy, migration

Volume of Funding

EUR 8 billion from ERDF + EUR 2 billion of external funding

Objectives and scope

The aim of Interreg programmes is to promote cooperation between regions and countries to support their economic and social development and tackle the obstacles of borders. Interreg also reinforces cooperation between the EU's outermost regions and neighbouring countries. The programmes may contribute to any of the five policy objectives of the cohesion policy for 2021–2027, and specifically for NECP related projects PO 2 – a greener, low-carbon transition towards a net-zero carbon and resilient Europe is the most relevant.

Components

There are four types (or strands) of Interreg programmes:

- Interreg A focuses on promoting integrated regional development between neighbouring land and maritime border regions.
- Interreg B promotes cooperation between national, regional, and local partners in transnational programme areas to increase the territorial integration of these areas.
- Interreg C focuses on the reinforcement of the effectiveness of the cohesion policy on a pan-European level and involves neighbouring countries; it promotes networking, innovative approaches, and capacity building with the aim of identifying and transferring good practices and strengthening the exchange of experiences in the field of regional and urban development, as well as analysing development trends in relation to the aims of territorial cohesion.
- Interreg D supports cooperation among the outermost regions themselves and with their neighbouring countries, overseas countries and territories, and regional integration and cooperation organisations to facilitate regional integration and development in their neighbourhood.

Type of management

Management of the ERDF is shared between the European Commission and MSs national and regional authorities. The co-financing rate for Interreg programmes is generally a maximum of 80 %, although with possibilities for higher co-financing rates for Interreg D programmes (outermost regions) and for external cross-border cooperation programmes (see below for further details on the four stands of Interreg).

Types of funding

Grants, financial instruments or prizes, or a combination thereof. The most common type of support is grants.

Targeted beneficiaries

The type of beneficiaries eligible to receive support is decided by the programme's MA. For example, you may be eligible if your organisation is an SME, a large enterprise, a research organisation, a public authority, an NGO or a civil society organisation.

Types of Projects

Interreg A, B and D programmes support cooperation through project funding to jointly tackle common challenges and to find shared solutions in fields including the environment, research, education, and sustainable energy. Examples of projects include developing and integrating green infrastructure, encouraging SMEs to assess and address resource use issues and reducing waste volumes in SMEs and households. Interreg C programmes often support more intangible actions such as capacity building and the exchange of experiences, mostly among public authorities.

Eligibility Criteria

Eligibility criteria will depend on the type (strand) of Interreg programme, and the content set out in each specific programme. General criteria include the type of organisation and a minimum size of the consortium, while information on specific criteria for each project can be found on the Interreg website.

Useful Links and Resources

Interreg website
Interreg project database

A.6.6 Horizon Europe

Key Areas

Horizon Europe tackles climate change helps to achieve the UN's sustainable development goals, and boosts the EU's competitiveness and growth. The programme facilitates collaboration and strengthens the impact of research and innovation in developing, supporting, and implementing EU policies while tackling global challenges. It supports the development and improves the sharing of knowledge and technologies. It creates jobs, fully engages the EU's talent pool, boosts economic growth, promotes industrial competitiveness, and optimises investment impact within a strengthened European research area.

Volume of funding

Horizon Europe has a budget of EUR 95.5 billion for 2021–2027. This includes EUR 5.4 billion from NextGenerationEU plus an additional reinforcement of EUR 4.5 billion. Of this budget, 35 % will contribute to climate change objectives.

Objectives and scope

The first strategic plan set out the key strategic aims for the targeting of investments in the programme's first 4 years: promoting an open strategic autonomy by leading the development of key digital, enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations; restoring Europe's ecosystems and biodiversity, and sustainably managing natural resources to ensure food security and a clean and healthy environment; making Europe the first digitally enabled circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems; creating a more resilient, inclusive and democratic European society that is prepared for and responsive to threats and disasters, addressing inequalities and providing high-quality healthcare, and empowering all citizens to act in the green and digital transitions.

Components

The programme consists of three pillars and one part, which correspond to its main priorities.

Pillar I: excellent science. This pillar aims to increase the EU's global scientific competitiveness. It supports frontier research projects defined and driven by top researchers through the European Research Council. It also funds fellowships for postdoctoral researchers, doctoral training networks and exchanges for researchers through the Marie Skłodowska-Curie Actions programme and invests in world-class research infrastructures.

Pillar II: global challenges and European industrial competitiveness. This pillar supports research relating to societal challenges and reinforces technological and industrial capacities through clusters. It sets EU missions, with ambitious goals tackling some of our greatest problems. It also includes activities pursued by the Joint Research Centre, which supports EU and national policymakers by providing independent scientific evidence and technical support. This pillar is broken down into six clusters, each of which is made up of individual expected impacts linked by overarching themes.

1. health
2. culture, creativity, and inclusive society
3. civil security for society
4. digital, industry and space
5. climate, energy, and mobility
6. food, bioeconomy, natural resources, agriculture, and environment.

Further to this, the Horizon Europe research and innovation programme has now introduced EU missions for 2021–2027 (including the ocean mission). These missions represent commitments to solving some of the greatest challenges facing our world. Each mission operates as a portfolio of actions – such as research projects, policy measures or even legislative initiatives – to achieve a measurable goal that could not be achieved through individual actions. These missions contribute to the goals of the European Green Deal, Europe's beating cancer plan and the sustainable development goals. The EU Missions relevant to the NECPs and Land Use sector are:

1. Adaptation to climate change – supporting at least 150 European regions and communities to become climate resilient by 2030.
2. Restoring our ocean and waters by 2030.
3. 100 climate-neutral and smart cities by 2030.
4. A soil deal for Europe – 100 living laboratories and lighthouses to lead the transition towards healthy soils by 2030 (see Types of Projects below for more information on the Soil Deal for Europe mission).

Pillar III: Innovative Europe. This pillar aims to make Europe a frontrunner in market-creating innovation via the European Innovation Council (EIC). It also helps to develop the overall European innovation landscape through the European Institute of Innovation and Technology, which fosters the integration of the knowledge triangle of education, research and innovation. The EIC aims to identify and support breakthrough technologies and game-changing innovations with the potential to scale up internationally and become market leaders. It supports all stages of innovation, from research and development on the scientific underpinnings of breakthrough technologies, to the validation and demonstration of breakthrough technologies and innovations to meet real-world needs, to the development and scaling up of start-ups and SMEs. All EIC awardees, as well as selected applicants, have access to a range of EIC business acceleration services providing access to leading expertise, corporate entities, investors, and ecosystem actors. The EIC also undertakes additional activities, such as the giving of prizes.

Part 1: widening participation and strengthening the European research area. This part of Horizon Europe increases support for EU Member States in their efforts to make the most of their national research and innovation potential.

<u>Type of management</u>

The programme is implemented through direct management or indirect management by the funding bodies. Funding under the programme is provided by means of indirect actions in any of the forms laid down in the financial regulation40; however, grants are the main form of support under the programme. The programme also supports investments in European partnerships that involve collaborations with Member States or industry. A significant part of Pillar II of Horizon Europe will be implemented through institutionalised partnerships, particularly in the areas of mobility, energy, the digital sector, and the bio-based economy, which will also have separate work programmes.

<u>Types of funding</u>

Horizon Europe offers grants as the main funding model, complemented with dedicated financial instruments, when appropriate.

<u>Targeted beneficiaries</u>

Any legal entity, regardless of its place of establishment, including legal entities from non-associated non-EU countries or international organisations (including international European research organisations), is eligible to participate (whether it is eligible for funding or not), provided that the conditions laid down in the Horizon Europe regulation41 have been met, along with any other conditions laid down in the specific call topic. To be eligible for funding, applicants must be established in the EU, associated countries or low- or middle-income countries. The associated countries are Armenia, Bosnia and Herzegovina, Georgia, Iceland, Israel, Kosovo, Moldova, Montenegro, North Macedonia, Norway, Serbia and Turkey, and association negotiations are currently being processed with Albania, the Faroe Islands, Morocco, Tunisia, Ukraine, and the United Kingdom.

<u>Types of Projects</u>

The following activities are generally eligible for grants under Horizon Europe:

- Research and innovation actions. These are activities that aim primarily to establish new knowledge or to explore the feasibility of a new or improved technology, product, process, service, or solution. This may include basic and applied research, technology development and integration, testing, or demonstration and validation of a small-scale prototype in a laboratory or simulated environment.
- Innovation actions. These are activities that aim to produce plans and arrangements or designs for new, altered, or improved products, processes, or services. These activities may include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication.

- Coordination and support actions. These are activities that contribute to the objectives of Horizon Europe
- Programme co-fund actions. This is a programme of activities established or implemented by legal entities managing or funding research and innovation programmes, other than EU funding bodies. Such a programme of activities may support networking and coordination, research, innovation, pilot actions, innovation and market deployment, training and mobility, awareness raising and communication, and dissemination and exploitation. It may also provide any relevant financial support, such as grants, prizes and/or procurement. The actions may be implemented by the beneficiaries directly or by providing financial support to third parties.
- Innovation and market deployment actions. These are activities that embed an innovation action and other activities that are necessary to deploy an innovation action on the market. This includes the scaling up of companies and Horizon Europe blended finance.
- Training and mobility actions. These are activities that aim to improve the skills, knowledge, and career prospects of researchers, based on mobility between countries and, if relevant, between sectors or disciplines.

An example of an NECP relevant Horizon funded project is the European Joint Programme Cofund on Agricultural Soil Management, that contributes to key societal challenges including climate change, water, and future food security. This cofund can fund research and innovation into carbon farming and sequestration, and climate change mitigation and adaption.

A Soil Deal for Europe is one of the five missions of Horizon Europe, and of key relevance for NECPs. The mission's goal is for 100 living labs and lighthouses to lead the transition to healthy soils in Europe by 2030. Under this, there are set out 8 specific objectives and 4 transversal operational objectives. The 8 specific objectives are:

1. Reduce land degradation relating to desertification
2. Conserve and increase soil organic carbon stocks
3. No net soil sealing and increase the reuse of urban soils
4. Reduce soil pollution and enhance restoration
5. Prevent erosion
6. Improve soil structure and habitat quality for soil biota and crops
7. Reduce the EU global footprint on soils
8. Increase soil literacy in society across Member States

While the 4 operational objectives are:

1. Build capacities and the knowledge base for soil stewardship (The R&I programme)
2. Co-create and upscale place-based innovations to improve soil health in all places (living labs and lighthouses)
3. Engage with the soil user community and society at large (Soil literacy, communication, citizen engagement)
4. Track progress towards the mission's goal and develop an integrated soil monitoring system for the EU

A key component of the mission is a network of 100 living labs and lighthouses, which is to be built up gradually. The living labs are to be real-life sites in rural or urban areas in which people from various sectors and backgrounds experiment and test solutions in a co-creative manner. Each lab is composed of a group of sites (e.g., farms, forest stands, urban green areas) working together at regional or sub-regional level. Lighthouses are individual sites (such as a single farm) of exemplary performance with regards to a certain practice. These are places for demonstrations, training, and communication of good practices.

Eligibility Criteria

Eligibility to participate: Any legal entity, regardless of its place of establishment, including legal entities from non-associated non-EU countries or international organisations (including international European research organisations), is eligible to participate (whether it is eligible for funding or not), provided that the conditions laid down in the Horizon Europe regulation have been met, along with any other conditions laid down in the specific call topic.

Eligibility for funding. To be eligible for funding, applicants must be established in the EU, associated countries or low- or middle-income countries. Specific cases are set out in Annex A of the Horizon work programme. Beneficiaries must register in the participant register before submitting applications. Legal entities forming a consortium are eligible to participate if the consortium includes at least one independent entity established in a Member State and at least two other independent legal entities established in different Member States or associated countries. Projects must comply with ethical principles and applicants must complete an ethics self-assessment. Projects involving classified and/or sensitive information must go through a security appraisal to authorise funding. Legal entities from Member States and associated countries that are public bodies, research organisations or higher education establishments (including private research organisations and higher education establishments) must have a gender equality plan to be eligible.

A.6.7 Innovation Fund

Key areas

The Innovation Fund annually provides grants for projects to invest in the deployment of next-generation technologies for the EU's transition towards climate neutrality. It is open for project proposals from individual businesses and consortia, including SMEs and mid-caps across all EEA Member States. The Innovation Fund supports both large-scale (capital expenditure above EUR 7.5 million) and small-scale projects (capital expenditure under EUR 7.5 million).

Volume of Funding

The Fund is made from revenues from the EU ETS between 2020 and 2030. Assuming a price of EUR 75/tCO2, the fund may amount to about EUR 38 billion.

Objectives and scope

The Innovation Fund is a key funding instrument for delivering the European Green Deal. The overall goal for each funded project is to contribute to greenhouse gas reduction, decarbonise Europe and support its transition to climate neutrality. For that, the Innovation Fund seeks to:

- create the right financial incentives for new investments in the next generation of technologies for the EU's transition to climate neutrality.
- boost growth and competitiveness by empowering companies with a first-mover advantage to become global leaders in innovative clean technologies.
- support innovative low-carbon technologies in taking off and reaching the market.

Components

The Innovation Fund focuses on highly innovative technologies and large flagship projects that can provide significant emission reductions when deployed and operated. It provides grants to a varied project pipeline, in all EU Member States, Iceland and Norway, in the following eligible sectors relevant to land use:

- energy-intensive industries including products substituting carbon-intensive ones.
- renewable energy generation.
- energy storage.
- construction and operation of carbon capture and storage.

A.6.8 InvestEU programme

Key areas

InvestEU support is deployed under four policy windows, which represent important policy priorities for the EU and bring high EU added value:

1. sustainable infrastructure (EUR 9.9 billion)

2. research, innovation, and digitisation (EUR 6.6 billion)

3. SMEs (EUR 6.9 billion)

4. social investment and skills (EUR 2.8 billion).

Volume of Funding

The InvestEU Fund is expected to mobilise more than EUR 372 billion of public and private investment through an EU budgetary guarantee of EUR 26.2 billion that backs the investment of implementing partners such as the EIB Group and other international financial institutions or national promotional banks. The InvestEU programme also features the option of establishing Member State compartments for each policy area. This means that EU countries may contribute additional funds to the EU guarantee's provisioning or to the InvestEU Advisory Hub by voluntarily channelling a part of their resources from the funds under shared management, such as cohesion policy funds or funds from RRF allocations to address specific national priorities.

Objectives and scope

The InvestEU programme is a critical instrument for boosting green growth, innovation, and job creation in Europe. InvestEU will provide the EU with crucial long-term funding by leveraging substantial private and public funds in support of sustainable recovery. It will help mobilising private investments for the EU's policy priorities, such as the European Green Deal. InvestEU also supports activities of strategic importance to the EU, such as enhanced resilience and strengthening strategic value chains.

Components

There are three pillars:

Pillar 1: InvestEU Fund is expected to mobilise funds in support of investment by implementing partners who are expected to contribute approximately EUR 6.55 billion (25 %) in risk-bearing capacity. The guarantee is provisioned at 40 %, meaning that EUR 10.5 billion of the EU budget is set aside in case calls are made on the guarantee, the rest being contingent liability. The EU budgetary guarantee can be used by the implementing partners to cover their direct financing of eligible projects or to provide guarantees to financial intermediaries who in turn provide loans or equity to the final beneficiaries.

Pillar 2: InvestEU Advisory Hub will connect project promoters and intermediaries with advisory partners, who work together to get projects to the financing stage. It provides advisory support to help with the preparation, development, structuring and implementation of investment projects, including capacity building and market development.

Pillar 3: InvestEU Portal links investors and project promoters. The Portal provides a list of pre-checked projects, allowing qualified investors to screen projects before choosing which to invest in.

Type of management

The EU budgetary guarantee available under the InvestEU Fund is implemented via 'implementing partners. The main partner is the EIB Group (the EIB and the EIF), which will be responsible for implementing 75 % of the EU guarantee. The EU budgetary guarantee will be open also to national promotional banks and institutions and other international financial institutions (such as the European Bank for Reconstruction and Development).

Types of funding

The InvestEU Fund provides a EU budgetary guarantee (of around EUR 26.2 billion) to support implementing partners to increase their capacity to bear risk and provide financing (in the form of debt or equity) to final beneficiaries addressing EU policy priorities. Implementing partners can provide financing directly to final recipients or indirectly through private or public financial intermediaries. Financial products to be deployed under InvestEU may take the form of general products or thematic financial products. General financial products must support one or more policy areas covered under each policy window and can include either debt or equity interventions. Thematic financial products must focus on clearly defined, higher level EU added-value policy areas and involve a higher risk profile of the financing and investment operations than general products.

Targeted beneficiaries

Project promoters should apply directly to implementing partners, which will offer tailor-made financing solutions based on the financial products supported by the EU budgetary guarantee. The final beneficiaries can be natural or legal persons established in an EU country or eligible non-EU country, including:

- private entities such as special-purpose vehicles or project companies, large corporates, mid-cap companies (including small midcap companies) and SMEs.
- public sector entities (territorial or not but excluding operations with entities giving rise to direct Member State risk) and public sector type entities.
- mixed entities, such as public–private partnerships and private companies with a public purpose.
- non-profit organisations.
- SMEs, small mid-cap companies, microfinance enterprises and social enterprises may also apply through financial intermediaries of the implementing partners, which are selected through calls for expressions of interest by InvestEU implementing partners.

Types of Projects

All projects guaranteed through InvestEU fall under one of the four policy priorities listed above under 'Key areas. Eligible projects supported through InvestEU fall under the following main areas (of relevance to NECPs and the Land Sector):

- the development of the energy sector in accordance with the Energy Union priorities (e.g., energy security and clean energy) and the commitments taken under the 2030 agenda for sustainable development and the Paris Agreement
- sustainable and safe transport infrastructures, mobility solutions and innovative technologies in accordance with EU transport priorities and the commitments taken under the Paris Agreement.
- the environment and resources (e.g., water, waste management, the restoration of ecosystems and biodiversity, and the decarbonisation of energy production).
- sustainable agriculture, forestry, fishery, aquaculture, and other elements of the wider sustainable bioeconomy.

Eligibility Criteria

To benefit from InvestEU financing, potential projects must,

- address market failures or suboptimal investment situations for final recipients that are deemed economically viable.
- achieve additionality by preventing the replacement of potential support and investment from other public or private sources.
- achieve a multiplier effect and, where possible, crowd-in private investment.
- contribute to the EU policy objectives and fall within the scope of eligible areas laid out in Annex II of the InvestEU regulation.
- be consistent with the InvestEU investment guidelines.

A.6.9 Just Transition Fund

Key areas

Productive investments in SMEs, creation of new firms, research and innovation, digitalisation and digital connectivity, environmental rehabilitation (including land), clean/renewable energy, circular economy, upskilling and reskilling of workers, job-search assistance and active inclusion of jobseekers' programmes, transformation of existing carbon-intensive installations when these investments lead to substantial emission cuts and job protection.

Volume of Funding

EUR 7.5 billion under the MFF for 2021–2027 + EUR 10 billion from the European Recovery Instrument for 2021–2023This budget may be voluntarily increased by the Member States by transferring resources from the ERDF and ESF+ under certain conditions. Funds are also available through the PSLF: EUR 1.5 billion of grants, financed from the EU budget, with EUR 10 billion of loans from the EIB, to mobilise between EUR 25 billion and EUR 30 billion of public investment.

Objectives and scope

This is an EU funding tool for regions dependent on fossil-fuel- and greenhouse-gas-intensive industries to help them transition to achieve at least a 55 % reduction in emissions by 2030, and climate neutrality by 2050. Specifically, the JTF will alleviate the socioeconomic costs triggered by the climate transition, supporting the economic diversification and reconversion of the regions concerned, helping people to adapt to the changing labour market. The JTF is the first pillar of the Just Transition Mechanism (JTM). The JTM is a key tool to ensure that the transition towards a climate-neutral economy happens in a fair way, leaving no one behind. The JTM includes two other pillars.

1. A scheme under InvestEU (the InvestEU Just Transition Scheme) aims to mobilise private investments (see Section 4.2.10 on the InvestEU Fund for more details).

2. A public sector loan facility (PSLF) generates public investment through preferential lending conditions. The PSLF targets public sector institutions and consists of a grant component and a loan and advisory support component. The grant component is managed by the European Commission (the Directorate-General for Regional and Urban Policy and CINEA) and the loan component is managed by a financing partner. The grant component has an EU budget of EUR 1.495 billion and the loans are provided by the EIB with a total value of EUR 10 billion. Dedicated advisory support is available under the InvestEU Advisory Hub, with a budget of EUR 2.5 million to support the preparation, development and implementation of projects, as well as for strengthening the capacities of beneficiaries and loan scheme coordinators. The PSLF is delivered through a call for proposals managed by CINEA.

Components

- Environment (e.g., land restoration, the circular economy, sustainable mobility and green infrastructure)
- Energy (e.g., renewable energy, energy efficiency and upgrading of district heating)
- Innovation (e.g., research and innovation activities in universities and digitalisation)
- Social (e.g., job upskilling and reskilling, social inclusion and education).

Type of management

Management is shared between the European Commission and MSs national and regional authorities.

Types of funding

A mix of primarily grant financing from the fund with the opportunity to access private investments through InvestEU and public financing through the EIB.

Targeted beneficiaries

The type of beneficiaries eligible to receive support is decided by the programme's MA. For example, you may be eligible if your organisation is an SME, a large enterprise, a research organisation, a public authority, an NGO or a civil society organisation.

Types of Projects

Interreg A, B and D programmes support cooperation through project funding to jointly tackle common challenges and to find shared solutions in fields including the environment, research, education, and sustainable energy. Examples of projects include developing and integrating green infrastructure, encouraging SMEs to assess and address resource use issues and reducing waste volumes in SMEs and households. Interreg C programmes often support more intangible actions such as capacity building and the exchange of experiences, mostly among public authorities.

Eligibility Criteria

The Member States and the Commission will identify the territories and sectors eligible for funding under the JTF (i.e., the territories that are expected to suffer the most from the transition to climate neutrality). The project selection criteria are identified individually by the Member States.

A.6.10 LIFE: Programme for the environment and climate action

Key areas

Circular economy and waste, air quality and pollution prevention and control, nature and biodiversity protection, conservation and restoration, sustainable use and protection of water and marine resources, climate change mitigation and adaptation, clean energy and environmental and climate governance, energy efficiency.

Volume of Funding

EUR 5.4 billion

Objectives and scope

The general objective is to contribute to the shift towards a sustainable, circular, energy- efficient, renewable energy-based, climate-neutral and resilient EU economy, in order to protect, restore and improve the quality of the environment, including the air, water and soil, and to halt and reverse biodiversity loss and to tackle the degradation of ecosystems, including by supporting the implementation and management of the Natura 2000 network, thereby contributing to sustainable development. The LIFE programme is also intended to support the implementation of the EU's general action programmes on the environment. Constituting 100% contribution to the objectives and targets of the European Green Deal, LIFE is the only EU programme dedicated exclusively to the environments, nature conservation, and climate action.

Components

The LIFE programme is made up of four subprogrammes:

1. nature and biodiversity
2. circular economy and quality of life
3. climate change mitigation and adaptation
4. clean energy transition.

Type of management

LIFE is a directly managed fund through calls for proposals/tenders. The programme is managed by the European Commission and the bulk of grants are delegated to CINEA.

Types of funding

The predominant form of funding used by the LIFE programme is grants, broadly constituting about 85 % of the total budget. Grants can co-finance up to 95 % of project costs, as outlined below, depending on the type of projects, and can be either action grants or operating grants. Other forms of funding include procurement contracts, prizes and technical assistance for investment operations.

Targeted beneficiaries

Eligible beneficiaries fall within one of the following categories:

- a public or private legal entity registered in the EU or an overseas country or territory linked to it
- a non-EU country associated with the LIFE programme
- a legal entity created under EU law or any international organisation.

Natural persons are not eligible to apply. Legal entities established in a non-EU country that is not associated with the LIFE programme may exceptionally be eligible to participate when this is necessary for the achievement of the objectives of a given action to ensure the effectiveness of interventions carried out in the EU. However, those legal entities must, in principle, bear the cost of their participation.

Types of Projects

The LIFE programme funds environment-specific and environment-integrated projects in the form of grants, prizes and procurement and may also finance technical assistance for investment operations.

Projects supported by action grants under the LIFE programme may fall within five project types. These types are:

- standard action projects (SAPs)
- strategic nature projects (SNAPs)
- strategic integrated projects (SIPs)
- technical assistance (TA)
- other actions (OA)

SAPs aim to:

- develop, demonstrate, and promote innovative techniques, methods and approaches
- contribute to the knowledge base and to the application of best practices
- support the development, implementation, monitoring, and enforcement of the relevant Union legislation and policy, including by improving governance at all levels, through enhancing capacities of public and private actors and the involvement of civil society
- catalyse the large-scale deployment of successful technical and policy related solutions for implementing the relevant Union legislation and policy by replicating results, integrating related objectives into other policies and into public and private sector practices, mobilising investment and improving access to finance

SIPs aim to support the full implementation of the following plans and strategies:

- Circular Economy: National or Regional Circular Economy Action Plans, Strategies, Roadmaps or similar
- Waste: National and regional Waste Management Plans (WMPs) and/or Waste Prevention Programmes (WPPs)
- Water: River basin management plans (RBMPs), Flood Risk Management Plans (FRMPs) or Marine Strategies
- Air: Air quality plans pursuant to the Ambient Air Quality Directive or National Air Pollution Control Programmes (NAPCP)

SNAPs aim to implement:

- Prioritised Action Frameworks (PAF) and/or
- other plans or strategies adopted at international, national, multiregional, or regional level by nature and biodiversity authorities, that implement EU nature and/or biodiversity policy or legislation

The LIFE programme can furthermore support the functioning of non-profit entities active in the field of environment and climate action (including energy transition). Grants may, under certain conditions, also finance activities in overseas countries or territories of Member States or support international agreements to which the EU is a party.

Eligibility Criteria

The LIFE regulation lays down the basic rules for the fund, including its main eligibility criteria. One important criterion is the need to co-finance projects. The co-finance rates are as follows

- obligatory for LIFE projects, the co-finance rate can be at most 60 % for SNAPs, SIPs, and standard action projects.
- for standard action projects under the nature and biodiversity subprogramme, the co-finance rate can be up to 75 %.
- for non-profit entities, the co-finance rate can be up to 70 %.
- other actions financed under the clean energy transition subprogramme can be co-financed up to 95 %.

A.6.11 Recovery and Resilience Facility (RRF) funding Recovery and Resilience Plans (RRPs)

Key areas

The RRF has six pillars: the green transition; digital transformation; smart, sustainable and inclusive growth; social and territorial cohesion; health, economic, social and institutional resilience; and policies for the next generation.

Volume of Funding

Up to EUR 723.8 billion (in current prices)

Objectives and scope

The RRF's primary objective is to respond to the economic and social impacts of the COVID 19 pandemic. The funding will also contribute to the sustainable improvement of the EU's economies and societies. As such, the RRF regulation sets explicit expenditure targets: 37 % for the climate transition and 20 % for the digital transition.

Components

There are seven areas for investment, the first three of which are relevant to the NECPs.

1. Power up – the frontloading of future-proof clean technologies and the acceleration of the development and use of renewables.

2. Renovate – the improvement of the energy efficiency of public and private buildings.

3. Recharge and refuel – the promotion of future-proof clean technologies to accelerate the use of sustainable, accessible and smart transport and of charging and refuelling stations and the extension of public transport.

Type of management

The RRF is a performance-based instrument from which funds will be disbursed to Member States upon fulfilment of agreed milestones and targets as set out in the RRPs. The Member States prepare RRPs, to be approved by the European Commission, before the MSs implement the plans.

Types of funding

The RRF regulation specifies grants and loans as forms of payments; however, Member States may implement projects under different modalities. For example, funding from the RRF can be provided to a financial intermediary, to which the final beneficiaries apply.

Targeted beneficiaries

The beneficiaries will vary according to the nature of the projects, the topic to be addressed and the concrete funding scheme. In many cases, the final beneficiaries are public bodies; however, oftentimes, public bodies act as an intermediary. The selection of beneficiaries is partly done a priori (i.e., in the case of public bodies), while, in other cases, beneficiaries are selected through calls for proposals.

Types of Projects

The RRF regulation does not specify project types; allowing Member States to define the projects. As the RRF supports largely public beneficiaries, a broad range of support for public infrastructure (including public buildings, but also zero- and low-emission vehicles and other infrastructure for sustainable public transport, etc.), government funding programmes (e.g. individual support for zero- and low-emission vehicles and support for renewable energy) and government-sponsored programmes (e.g. support for material acquisitions for teachers and support for educational programmes) is implemented. Member States must ensure that all supported measures respect the DNSH principle as prescribed by the RRF regulation. As such, your project once selected has to be aligned with these requirements as defined by the RRP of your Member State.

Eligibility Criteria

The eligibility criteria are likely to differ between Member States and between measures, due to the expected use of intermediaries. Certain criteria will be consistently applied, such as certain safeguards for DNSH. The limits and criteria can include, inter alia, limits on the scope of interventions, cost categories, the durability of projects, types of beneficiaries, the mandatory involvement of types of partners and the size of supported industries.

APPENDIX 4 LIST OF RELEVANT LEGISLATION

Agriculture	
Common Agriculture Policy	Various delegated and implementing acts to implement the Common Agricultural Policy, including the Strategic Plan Regulation 2021/2115/EU and CAP Horizontal Regulation
Nitrate Directive – 1991/676/EEC	Nitrate Directive 1991/676/EEC

LULUCF	
Land Use, Land Use Change, and Forestry (LULUCF) Regulation – 2018/841	LULUCF Regulation 2018/841

Other	
Industrial Emissions Directive – 2010/75/EU	Industrial emissions Directive 2010/75/EU (Recast of IPPC Directive 2008/1/EC and Large Combustion Plant Directive 2001/80/EC) and its associated Best Available Technique Reference (BREF) Documents
National Emissions Ceiling Directive – 2016/2284	Directive 2016/2284 on the reduction of national emissions of certain atmospheric pollutants
Water Framework Directive – 2000/60/EC	Water Framework Directive 2000/60/EC
Medium Combustion Plant Directive – 2015/2193	Medium Combustion Plant Directive 2015/2193

Energy Supply	
Renewable energy financing mechanism – 2020/1294	Commission Implementing Regulation (EU) 2020/1294 on the Union renewable energy financing mechanism
Internal electricity market	Directive (EU) 2019/944 on common rules for the internal market for electricity and the Regulation on the internal market for electricity (EU) 2019/943
Renewable Energy Directive (RED) – 2018/2001	RED directive 2009/28/EC and RED recast (Directive 2018/2001)
Geological Storage CO2 Directive – 2009/31/EC	Directive on the geological storage of CO2 2009/31/EC
Risk-preparedness in electricity sector – 2019/941	Regulation (EU) 2019/941 on risk-preparedness in the electricity sector
Electricity Market Regulation – 2019/943	Regulation (EU) 2019/943 on the internal market for electricity (as amended)
Trans-European Networks for Energy (TEN-E) Regulation – 347/2013	Regulation (EU) 347/2013 on guidelines for trans-European energy infrastructure (as amended)

Waste	
Waste Management Framework Directive – 2008/98/EC	Waste Management Framework Directive 2008/98/EC (as amended)
Waste Incineration Directive – 2000/76/EC (**no longer in force**)	Waste Incineration Directive 2000/76/EC
Landfill Directive – 1999/31/EC	Landfill Directive 1999/31/EC (as amended)

Horizontal	
Governance of the Energy Union and Climate Action – 2018/1999	Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action
Effort Sharing Regulation (ESR) – 2018/842	Effort Sharing Regulation EU 2018/842 and implementing decision on ESR Annual Emission Allocations
EU Emissions Trading System (ETS) – 2003/87/EC	EU ETS directive 2003/87/EC (as amended) and its implementing legislation
European Structural and Investment Funds	Provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund under the Multiannual Financial Framework

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