

International scan of GHG mitigation policies in agriculture

Revised report

12/03/2019

Prepared by:

Benjamin Henderson^a and Clara Frezal^b

^a. OECD, Paris (Agriculture and Resource Policies Division)

^b. OECD consultant, Paris

Report prepared for New Zealand's Interim Climate Change Committee (ICCC).

Contents

BACKGROUND	4
AUSTRALIA	5
Paris Agreement and Nationally Determined Contributions - relevance to agriculture	5
Background on agricultural and GHG emissions	5
Mitigation policies directly targeting agricultural emissions	5
Other policies with indirect impacts on agricultural emissions	9
Research and knowledge transfer	10
Industry-led initiatives directly targeting agricultural emissions	11
IRELAND	12
Background on agricultural and GHG emissions	12
EU targets and policies - relevance to Irish agriculture GHG mitigation	12
National mitigation policies – relevance to agriculture	17
Existing national environmental programmes	18
Industry-led initiatives directly targeting agricultural emissions	19
Research and knowledge transfer programmes	20
Issues of national level policy coherence with agricultural GHG mitigation	20
THE NETHERLANDS	22
Background on agricultural GHG emissions	22
EU targets and policies - relevance to Dutch agriculture GHG mitigation	22
National mitigation and agricultural policies targeting agricultural emissions	23
Industry-led initiatives directly targeting agricultural emissions	27
Social pressures and animal welfare policies' impact on agricultural emissions	28
Research and innovation programmes	29
FRANCE	30
Background on agricultural GHG emissions	30
EU targets and policies - relevance to French agriculture GHG mitigation	30
National mitigation and agricultural policies targeting agricultural emissions	31
Industry-led initiatives directly targeting agricultural emissions	36
Research, development and innovation projects	36
THE UNITED-STATES	38

Background on US agricultural GHG emissions	38
Federal policies and programmes that affect agricultural emissions	38
Background on California agricultural production, GHG emissions, and related policy challenges	38
California's mitigation targets and policies directly targeting agricultural emissions	39
Other policies with indirect impact on agricultural emissions in California	41
California's research and innovation programmes	43
CANADA	44
Paris Agreement and Nationally Determined Contributions - relevance to agriculture	44
Background on agricultural GHG emissions	44
Mitigation policies directly targeting agricultural emissions	44
Other policies with less direct impacts on agricultural emissions	46
Industry-led initiatives that affect agricultural emissions	47
Research programmes	48
BRAZIL	49
Paris Agreement and Nationally Determined Contributions - relevance to agriculture	49
Background on agricultural production, GHG emissions, and related policy challenges	49
National mitigation targets and policies for emissions from agriculture and LULUCF sectors	49
Other policies with indirect impacts on agricultural emissions	56
Industry-led initiatives directly targeting agricultural emissions	58
Research programmes	59
CHINA	60
Paris Agreement and Nationally Determined Contributions - relevance to agriculture	60
Background on agricultural production, GHG emissions, and related policy challenges	60
National mitigation policies targeting agricultural emissions	60
Agricultural policies contributing to the mitigation of agricultural emissions	61
Other policies with indirect impacts on agricultural emissions	64
Research programmes	65
REFERENCES	66
ANNEXES	79

BACKGROUND

The purpose of this study is to provide an outline of the policies that a selection of countries is using to address agricultural GHG emissions, for New Zealand's Interim Climate Change Committee (ICCC).

The countries to be covered in this policy scan include: Australia, Canada, Ireland, France, Netherlands, and the US (focusing on California).

The policy scope of the scan includes: policies directly targeting agriculture emissions; other non-climate change policies (environmental or otherwise) which may have a significant impact on agricultural emissions; and industry-led initiatives, with significant mitigation ambitions.

AUSTRALIA

Paris Agreement and Nationally Determined Contributions - relevance to agriculture

Australia has committed to an economy-wide reduction in its greenhouse gas emissions of 26-28 percent below 2005 levels by 2030, in its Nationally Determined Contribution (NDC) submitted to the UNFCCC in 2015. All UNFCCC national inventory sectors are covered by this commitment, including the Agriculture and LULUCF (Land-use, land-use change and forestry) sectors, although no sector-specific targets have been set. According to Government's own emissions projections report released on 21 December (Commonwealth of Australia, 2018a), Australia is on track to miss its Paris Agreement target by a vast margin, with emissions in 2030 projected to be 563 MtCO₂eq – a reduction of only 7% on 2005 levels. The Australian Government reviewed its climate change policies in 2017, in light of the 2030 emission reduction target and as an input to the development of a long-term mitigation strategy by 2020. This strategy will explore opportunities for emission reductions across all sectors of the economy, including agriculture.

Background on agricultural and GHG emissions

According to Australia's most recent national GHG inventory report (Commonwealth of Australia, 2018b), agriculture generated 69.1 Mt CO₂e of GHG emissions in 2016, accounting for 13% of national emissions. In contrast the LULUCF sector was a net sink of 24.1 Mt CO₂e in 2016. The majority of agriculture's emissions were CH₄ from enteric fermentation (72%), followed by N₂O from agricultural soils (19%), then mainly CH₄, but also N₂O from manure management (5%). Although agricultural emissions have declined by 9.2% between 2005 and 2016, most recent inventory figures indicate a 2.1% increase in emissions over the year to March 2018 above emissions in 2016 (Commonwealth of Australia, 2018c).

From a mitigation policy perspective, potential challenges for Australia include the dominance of extensive cattle and sheep grazing systems that are responsible for enteric CH₄, the main source of national agricultural GHG emissions. These production systems are not particularly well-suited to the type of management practices (e.g. dietary additives and intensive feed management) currently available to reduce this major emission source. On the other hand, the large land areas occupied by grazing and other forms of agriculture provide potential for carbon sequestration in soils and particularly in biomass from vegetation management and from land-use change.

Mitigation policies directly targeting agricultural emissions

The Emission Reduction Fund

The Direct Action Plan is the centrepiece of Australia's climate change mitigation efforts, which mainly relies on the Australian Government's Emission Reduction Fund (ERF) to directly fund abatement for a range eligible activity including livestock management, revegetation, savannah fire management, waste management and energy efficiency, to reduce emissions and sequester carbon (Commonwealth of Australia,

2019a). This fund is an opt-in scheme, meaning that only those farmers who choose to participate in the scheme are exposed to the price mechanism. The fundamental design of the ERF is that taxpayers fund abatement undertaken voluntarily by individual emitters.

Landowners and farmers who adopt abatement projects using approved ERF methods can generate Australian Carbon Credit Units (ACCUs) which can be sold, either to the government through a competitive reverse auction or to third parties, to provide alternative or additional income streams. The methods approved under the ERF must meet strict integrity requirements including in relation to additionality. Projects must register with the Clean Energy Regulator to be able to generate ACCUs. The Direct Action policy also includes a safeguard mechanism, which aims to ensure that emission reductions purchased through the ERF are not offset by increased emissions elsewhere in the economy. The safeguard mechanism covers large non-agricultural emitters and is enforceable by the Clean Energy Regulator (Australian Government, 2016).

Since April 2015, the Fund has been used to contract a total abatement portfolio of 193 MtCO₂e across all ERF sectors¹ over eight auctions (the most recent in December 2018), with the average price per tonne of abatement across all auctions ranging between 10 and 14 AUD t CO₂e⁻¹. Of this total portfolio, 18.1 MtCO₂e have been contracted in the agricultural sector. This total abatement will be delivered across an unspecified number of years, making it difficult to estimate the annual emission reduction that this mechanism will achieve. The overwhelming majority of the contracted abatement is from sequestering carbon in soils in grazing systems and is still scheduled to be delivered, which explains most of the discrepancy between total contracted abatement and abatement delivered (Table 1). It is worth noting that carbon sequestration from changes in land use, and changes in land management within existing land uses, along with all other eligible activities in the ERF can in principle be reported in the Australian National Greenhouse Gas Inventory. In contrast, the only soil carbon changes that are reported in the New Zealand national inventory are those associated with land use change. Soil carbon stocks and the potential for soil carbon sequestration is very different between the two countries, with Australia having much lower stocks and carbon depleted soils.

Table 1. Emission Reduction Fund agriculture projects and abatement

Method	Registered projects	Contracted projects	Contracted abatement (ktCO ₂ e)	Abatement delivered (ACCUs issued)
Beef cattle herd management	3	1	184	24
Destruction of methane biogas (piggeries)	1	1	35	17
Destruction of methane from manure in covered ponds (dairy)	1	0	0	0
Destruction of methane from manure in piggeries	13	9	858	44
Sequestering carbon in soils in grazing systems	42	10	16,725	0
Measurement of soil carbon sequestration in agricultural systems	1	1	300	0
Total	61	22	18,102	483

Source: Department of the Environment and Energy, Australian Government

Note: This table does not include the results from the most recent (December 2018) auction

The ACCUs issued include delivery from Government-contracted projects and registered projects without a contract. Businesses can register a project, start their abatement activity and begin earning ACCUs before entering into a contract with the Government through the auction process. Some registered projects may never win a government contract and will instead seek sale of their ACCUs to non-government sources of demand including other firms covered by the safeguard mechanisms, along with secondary market purchasers such as entities with ERF contracts that source ACCUs to help deliver on their contracts (P Ryan

¹ Agriculture; vegetation management; energy efficiency; mining, oil and gas; industrial facilities; transport; waste and waste water.

2018, personal communication, 11 December). Furthermore, the total amount of abatement under registered projects exceeds the contracted amount. For instance, of the total 55.73 MtCO_{2e} of ACCUs issued by 31 October 2018, 36.75 MtCO_{2e} (exactly two thirds) were from contracted projects, with the rest from registered but uncontracted projects. It was not possible to extract a breakdown by project category, including for agriculture specifically, because these data are not publicly available.

There has been a further 125.5 MtCO_{2e} contracted in land vegetation projects (Clean Energy Regulator, 2018), with a breakdown of project types provided in Table 2. Many of these projects have been undertaken on land that was being used for agricultural production, although none of the abatement directly counts towards the reduction of agricultural emissions. Of the various vegetation projects listed in Table 2, the eligibility criteria of following project types are explicitly specified for land that is cropped or grazed: Avoided Clearing of Native Regrowth; Reforestation and Afforestation; Native Forest from Managed Regrowth; Measurement Based Methods for New Farm Forestry Plantations. The eligibility criteria of the Human-Induced Regeneration of a Permanent Even-Aged Native Forest - 1.1 project type, refers to grazing as one type of mechanism suppressing forest regeneration. While the criteria for Avoided Deforestation, Plantation Forestry, and Reforestation by Environmental or Mallee Plantings refer to landholders in general (many of which will be agricultural).

Table 2. Emission Reduction Fund vegetation projects and abatement

Method	Registered projects	Contracted projects	Contracted abatement (ktCO _{2e})	Abatement delivered (ACCUs issued)
Avoided Deforestation	58	56	25,739	14,005
Designated Verified Carbon Standard Projects	3	1	772	419
Avoided Clearing of Native Regrowth	3	2	354	232
Reforestation and Afforestation	19	6	652	1,254
Human-Induced Regeneration of a Permanent Even-Aged Native Forest - 1.1	243	166	92,131	10,062
Measurement Based Methods for New Farm Forestry Plantations	1	0	0	0
Native Forest from Managed Regrowth	35	21	3,513	2,133
Quantifying Carbon Sequestration by Permanent Mallee Plantings using the Reforestation Modelling Tool	1	0	0	0
Reforestation by Environmental or Mallee Plantings – FullCAM	23	9	1,819	205
Plantation Forestry	11	5	531	0
Quantifying Carbon Sequestration by Permanent Environmental Plantings of Native Species using the CFI Reforestation Modelling Tool	12	1	21	52
	408	267	125,531	28,361

Source: Department of the Environment and Energy, Australian Government

Note: This table does not include the results from the most recent (December 2018) auction

There has also been 13 MtCO_{2e} of abatement contracted in savannah burning projects under the ERF. Some of the savannah fire management projects are on agricultural land, but a substantial proportion are on land managed by Indigenous land managers for other purposes (P Ryan 2018, personal communication, 7 December).

Table 3. Emission Reduction Fund savannah fire management projects and abatement

Method	Registered projects	Contracted projects	Contracted abatement (ktCO _{2e})	Abatement delivered (ACCUs issued)
Savannah fire management	73	49	13,020	5,992

Source: Department of the Environment and Energy, Australian Government

Note: This table does not include the results from the most recent (December 2018) auction

Of the initial 2.55 billion AUD allocated to the ERF, there is only 226 million AUD remaining and no commitments for the future of the Fund have been made.

Scale of impact and limitations of the ERF

Without knowledge about the schedule of delivery for the various abatement projects in the pipeline for the Fund it is difficult to a precise measure of its impact relative to the agriculture sector's 69.1 MtCO_{2e} of annual emissions. For instance, if the total 18.1 MtCO_{2e} contracted over the past five years were delivered over a 10-year period, the annual abatement rate would be 1.81 MtCO_{2e} or 2.6% of annual emissions. Given the high percentage of projects sequestering soil carbon, this timeframe is likely to be longer and the relative annual emission reductions lower. More details from Clean Energy Regulator are however needed to provide a more precise calculation. As mentioned, a large proportion of the vegetation projects which have contracted a substantial 125 MtCO_{2e} of ACCUs over the past five years have occurred on land used previously for agriculture (i.e. these actions support land-use change).

There has been some criticism of the ERF from the very small number of peer reviewed studies that have commented on the policy including by Freebairn (2016) and Burke (2016). One criticism that both these studies make about abatement subsidies, including schemes such as the ERF, is that they cannot guarantee additionality, because the authors argue that they will inevitably pay for some activities that would have occurred anyway. This issue of additionality applies to any market-based instrument which relies on a business as usual baseline (e.g. baseline and credit emission trading schemes), but not to cap and trade emission trading schemes (ETS) such as the New Zealand ETS. However, not all project types under the ERF pose the same risks of non-additionality. Projects based on avoided deforestation on agricultural land arguably pose relatively high risks in this regard, because it may not be possible to guarantee that a landholder would in fact have cleared the land without participation in the ERF. However, one of the eligibility conditions for this type of project is that the "landowner must have received consent before 1 July 2010 to clear the forest for the purposes of converting the land to cropland or grassland in perpetuity". Satisfying this condition provides some degree of certainty that the project is additional. For other projects, such as those involving the flaring of manure methane from piggeries do not involve risks of non-additionality because payments are based on the measured quantity of biogas sent to a combustion devise.

Furthermore, the ERF contains three strong tests of additionality: assessing the newness of the projects, whether or not they are already required by existing regulations and whether or not they already have access to other government funding. However, we have not evaluated the extent to which these have been enforced. Also there is no test whether new projects might have become economically viable in their own right because of changing market conditions or changes in the cost of technologies. Perhaps a bigger concern is the potential lack of permanence from soil carbon sequestration projects which dominate the agriculture portfolio, as the ERF accepts projects with a 25- or a 100-year permanence period and allows for projects with a 100-year permanence period to convert to a 25-year permanence period (DoEE, 2014). A 20% reduction in the number of ACCUs issued to a project is applied if the 25-year option is selected, for covering the potential cost to the Government of restoring carbon stocks after the project finishes. This is additional to the 5% risk reversal buffer, bringing the total discount to 25%. If a disturbance (e.g. fire) causes a decline in the amount of carbon stored, the carbon stock to restored or ACCUs equivalent to the loss must be

relinquished or returned to the Clean Energy Regulator. The monitoring and reporting period for projects depend on the project methodology used. For example, projects estimation sequestration of soil carbon using default values need to monitor the Carbon Estimation Areas (CEAs) on their properties every six months to ensure the maintenance of ground cover. Whereas soil carbon sequestration projects based on soil sampling must submit a report to the Clean Energy Regulator every six months to five years (Clean Energy Regulator, 2019). The costs of measurement and reporting are incurred by the participating landholders.

Despite the possible limitations of the ERF, it is a notable for the scale of its funding, and for being the world's first national level market-based instrument that directly targets a broad scope of GHG abatement sources in the agriculture and LULUCF sectors.

Competitiveness and leakage implications of the ERF

According to economic theory, the use of an abatement subsidy will not have the same negative consequences on agricultural production as an emission tax or ETS with auctioned permits, because unlike the latter policies it does not impose additional costs on producers, which could cause (prevent) marginally profitable producers to exit (or stop from entering) the agricultural sector. This finding is backed up by ex-ante modelling of mitigation policies in agriculture including from OECD (2019) and Golub et al. (2013). However, this policy approach relies on taxpayers funding abatement actions by individuals, and hence follows the 'beneficiary pays' rather than the 'polluter pays' principle. Whether such a policy is economically viable and publicly acceptable depends on a range of factors, including the scale of emissions reductions that need to be achieved and relative magnitude of different emission sectors.

Nevertheless, some of the ERF vegetation projects outlined above that involve establishing non-agricultural vegetation on land that would otherwise be used for grazing or cropping activities will, by design, cause agricultural output to fall. This effect has not been quantified, but if the scale of this supply reduction were sufficient to increase agricultural commodity prices it could cause production and emissions to increase in elsewhere in either domestic or international markets.

Other policies with indirect impacts on agricultural emissions

National Landcare Program

The National Landcare Program is a large-scale voluntary program designed to improve natural resource management, agricultural sustainability and biodiversity outcomes. Some specific issues tackled by the program include land and soil degradation, vegetation loss, pests, water and fire management. The Australian Government invested 1 billion AUD in the Landcare Program from July 2014 to June 2018 and will invest a further 1 billion AUD in the next phase from July 2018 to June 2023 (Commonwealth of Australia, 2019b). This includes 450 million AUD for the Regional Land Partnerships program, which aims to deliver six outcomes including reduction of threats to Ramsar sites; threatened species management; invasive species management; soil, biodiversity and vegetation management; and adaptation to climate change) (Commonwealth of Australia, 2019c). None of these outcomes directly involve the mitigation of GHG emissions, but it is possible that activities improving soil management could have soil carbon sequestration benefits.

Energy emissions, efficiency and renewables

There are national agencies and programs that encourage research and development, as well as sector-wide investment in energy efficiency and renewable energy, which agriculture can participate in to lower its energy-related emissions. This includes the Clean Energy Finance Corporation (CEFC), which is an

independent Australian Government agency working to increase commercial investment in these areas (Commonwealth of Australia, 2017). The Renewable Energy Target (RET) scheme of the Australian Government also provides incentives large scale and small scale renewable energy systems (Commonwealth of Australia, 2019d). In addition, the Australian Renewable Energy Agency provides funding to researchers, developers and businesses that have demonstrated the feasibility and potential commercialisation of their project (Commonwealth of Australia, 2019e). Even if agricultural producers achieve high adoption rates of renewable energy technologies it will not have much of an impact of overall agricultural GHGs emissions, because GHG emissions from energy use in the agriculture sector are minor compared to agricultural non-CO₂ emissions from animals and soils in Australia.

Research and knowledge transfer

The Australian Government set up and funded a number of research, development and outreach programmes for the mitigation of agricultural GHGs over the past decade. The main program was the Carbon Farming Futures (CFF) programme that ran from 2012 to 2017, and which the Government invested over 145 million AUD in 200 projects (DAWR, 2017). It was comprised of four main components. The most significant of these, in terms of its scale and focus, was the Filling the Research Gap (FtRG) programme, which supported research into emerging mitigation technologies in agriculture, practices for sequestering carbon or reducing GHG emissions from the land use sector and assisting farmers to adapt to climate change. There were 89 projects worth 80 million AUD that were funded by the programme, covering: livestock methane research; manure management research; nitrous oxide research, soil carbon research, modelling and farm systems research; and adaptation research (DAWR, 2017). The FtRG programme also included a national survey of land management practices, which helped provide a benchmark for methodology development and additionality testing in the ERF.

The FtRG programme built on the Climate Change Research Program which ran from 2008 to 2012, which received 46.2 million AUD and supported more than 50 projects, delivered in collaboration with industry groups, research providers, universities and state governments, bringing the total investment amount, including partner contributions to 130 million AUD. Research outputs from this programme underpinned a number of methodologies applied under the Carbon Farming Initiative, the predecessor to the ERF.

Another component of the CFF programme is Action on the Ground, which provided 43 million AUD to 87 grants assisting land managers and farmers to conduct on-farm trials of mitigation technologies on over 530 properties (DAWR, 2017). The CFF programme also included an Extension and Outreach component, which used extension services to transfer knowledge about managing GHG emissions from agriculture and other land uses, and it also supported participation of land holders in the ERF. In this component 24 projects worth 22.4 million AUD were funded from 2013 to 2017 (DAWR, 2017). The final component of the CFF was the Conservation Tillage Refundable Tax Offset, which provided farmers with a 15 per cent refundable tax offset for the purchase of conservation seeding equipment (DAWR, 2019). No future extensions of the CFF programme have been announced by the Australian Government as far as we are aware of.

Australia is also a member of Global Research Alliance on Agricultural Greenhouse Gases (GRA), and is a partner country of the Global Methane Initiative (GMI). The Australian Government's Department of Agriculture and Water Resources is also a partner of the Climate Change Research Strategy for Primary Industries (CCRSPI), which is multi-stakeholder collaboration between governments (federal, state and territory), rural research and development corporations and CSIRO (Lovett and McCluskey, 2017). Its main activities are to share information on research activities through stocktake exercises and to identify emerging research priority areas. CCRSPI identified 589 projects with a life-of-project value of 549 million AUD in 2011-12, of which CCRSPI partners support 483 projects worth 491 million AUD. Only 30% of this value was targeted at climate change mitigation (CCRSPI, 2019). More recent figures are on CCRSPI projects are not yet published.

Industry-led initiatives directly targeting agricultural emissions

In 2017, Meat and Livestock Australia (MLA) commissioned the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to investigate whether the Australian red meat industry could become carbon neutral by 2030 (Mayberry et al. 2018). The conclusion of this study was in the affirmative and based on this report the Australian red meat and livestock industry has declared its commitment to this target (Meat & Livestock Australia, 2017).

Mayberry et al. (2018) identified a number of pathways in which different rates of assumed effectiveness for options reducing animal GHG emissions, determined the quantity of carbon sequestration required for the industry to reach its carbon neutrality goal. Mayberry et al. (2018) concluded that the most promising mitigation options are land management (e.g. reduced deforestation, sequestration of carbon in trees from afforestation/reforestation and improved forest management, and savannah burning management), and the reduction of enteric methane with feed additives and vaccines. All of the mitigation options identified are eligible for funding by the ERF, however, with the ERF budget nearly exhausted and no commitment from government about its future, it is not possible to determine the extent to which red meat industry's mitigation ambitions will be supported or incentivised by national government climate policies. It is also worth noting that no proof of concept exists yet for a methane vaccine, and other feed additives (such as the marine algae *Asparagopsis taxiformis*) are not yet commercially available and tested as methane mitigation option.

The Australian dairy industry has also committed to reducing the intensity of GHG emissions from milk manufacturers' use of fuel and electricity by 30%, from the baseline level of 178.7 tCO₂e per ML in 2010/2011, to 125.8 tCO₂e per ML in 2020 (ADIC, 2015). The approach of the Australian Dairy Industry Council (ADIC) has so far been to set a target for emissions from manufacturing, while supporting projects to reduce GHG emissions on dairy farms. Given that manufacturing emissions on account for 5% of GHG emissions from dairy farming and dairy manufacturing combined (ADIC, 2015), the 2020 emission intensity target excludes the overwhelming majority of the sector's emissions.

In the event that the ERF is either discontinued or not sufficiently scaled up, and another effective national level policy instrument fails to emerge in its place, it is not clear how the industry can create the economic incentives needed to meet its own carbon neutrality goal. Although there will be certainly be reputational benefits for the sector from achieving this goal which could deliver international and domestic marketing benefits, it is unlikely that these alone will provide enough incentives to mobilise such an ambitious and well-coordinated outcome.

IRELAND

Background on agricultural and GHG emissions

According to the 2018 EU GHG Inventory report, agriculture generated 19.25 Mt CO_{2e} of GHG emissions in 2016, accounting for 31% of national emissions. In addition, the LULUCF sector was a net source of 4.9 Mt CO_{2e} in 2016. The majority of agriculture's emissions were CH₄ from enteric fermentation (58%), followed by N₂O from agricultural soils (29%), then mainly CH₄, but also N₂O from manure management (10%) (EEA, 2018a). Although agricultural emissions have declined by 2.7% between 2000 and 2016, more recent figures from the Environmental Protection Agency (EPA) indicate a 3% increase in emissions from the agricultural sector between 2016 and 2017 (EPA, 2018a).²

From a mitigation policy perspective, potential challenges for Ireland include the dominance of cattle and sheep livestock production that are responsible for enteric CH₄, which is the main source of national GHG emissions. There is a limited availability of cost-effective mitigation options for this emission source.

EU targets and policies - relevance to Irish agriculture GHG mitigation

The 2020 Energy and Climate Package and the 2030 Energy and Climate Framework

Member states' contribution to GHG emission reductions is regulated by EU policies (Box 1). Although no sector-specific target has been set for agriculture at the EU-level, GHG emissions from the agricultural sector are regulated by the Effort Sharing Decision (ESD); together with emissions from other non-ETS sectors (i.e. the transport, building and waste sectors).³

Under the ESD, Ireland has committed to:

- Cut its GHG emissions from non-ETS sectors by 20% by 2020 (from 2005 levels) (EU, 1995-2019a).

Member states benefit from some flexibilities in meeting their annual emissions allocation (AEAs) for the period 2013-20: overachievement in a given year can be carried over subsequent years up to 2020. Up to 5% of AEAs are tradable between member states for the period 2013-19 (EU, 1995-2019b).

- Cut its GHG emissions from non-ETS sectors by 30% by 2030 (from 2005 levels).

The same flexibilities apply for the period 2021-30. In addition, Ireland benefits from the following flexibilities in meeting its 2030 ESD target: 4% of the target is achievable through the use of banking/borrowing of EU ETS allowances and 5.7% is achievable via offsetting non-ETS emissions with net emission reductions from the LULUCF sector (EU, 1995-2019c). The level of flexibilities is higher for Ireland than for most other EU states as: a) the ratio of Ireland's non-ETS/ETS emissions is higher than in most member states b) the share of agricultural emissions in total Irish GHG is higher than in most member states. Agriculture accounts for 44% of non-ETS emissions in Ireland and this is expected to increase to 48% by 2020 (Teagasc, 2018).

Ireland has not met its ESD annual targets both in 2016 and 2017, and projections suggest that non-ETS emissions will only be 0% to 1% below 2005 levels in 2020 (EPA, 2018b).⁴ Ireland will have to buy

² According to the EPA, agricultural GHG emissions amounted to 19.6 Mt CO_{2e} in 2016 and to 20.2 Mt CO_{2e} in 2017 (EPA, 2018a).

³ The ESD covers the following gases: CO₂, CH₄, N₂O, HFCs, PFCs, SF₆ and NF₃.

⁴ In 2017, emissions from non-ETS sectors were 2.95 Mt above the annual limit (EPA, 2018).

allocations from other member states who have achieved greater emission reductions than those set in their targets or will be exposed to fines in the order of EUR 450-600 million/year until it complies with its commitments (Downing, 2018).⁵

The Common Agricultural Policy (CAP)

In recent years, the CAP has made an increasingly significant contribution to the environmental sustainability of the European agri-food sector. The current CAP programme (2014-20) provides substantial support to climate change mitigation in the agricultural sector through its two pillars (Box 2).

Almost 90% of measures in Ireland's RDP have GHG emission reducing elements (IFA, 2018). In particular, for the period 2014-20, EUR 1.53 billion have been allocated to agri-environmental and climate measures (AECMs); for a total RDP funding of EUR 4 billion. It makes AECMs the biggest RDP measure for Ireland in budgetary terms (EU, 1995-2019e).

Box 1. EU's GHG mitigation policies

- *2020 Climate and Energy package (2008)*

The package sets the target of reducing GHG emission by 20% from 1990 levels in the EU territory. The emissions trading system (ETS) is the key tool for cutting GHG emissions (CO₂, N₂O and PCFs namely) from the power, industry and aviation sectors. For sectors not covered by the ETS (i.e. transport, buildings, agriculture and waste), EU countries have taken on binding annual targets for cutting emissions under the ESD. The targets differ according to national wealth – from a 20% cut for the richest countries to a maximum 20% increase for the least wealthy; although all member states are expected to make efforts to limit their emissions. The national ESD targets will collectively deliver a reduction of around 10% in total EU emissions from non-ETS sectors by 2020 (compared to 2005 levels). The ESD covers the six GHG controlled by the Kyoto Protocol (i.e. CO₂, CH₄, N₂O, HFCs, PFCs, SF₆) plus NF₃ (EU, 1995-2019a).

- *2030 Climate and Energy framework (2014)*

In line EU's commitment under the Paris Agreement, the framework contains a binding target to cut emissions in EU territory by at least 40% below 1990 levels by 2030. For non-ETS sectors, they would need to cut emissions by 30% (from 2005 levels) under the ESD (EC, 2014).

- *2050 long-term strategy (2018)*

Defines a roadmap for achieving a net zero GHG emission economy by 2050. The strategy gives a central role to innovation in meeting this carbon-neutrality objective. For the agricultural sector it focuses on: precision farming's potential in optimising fertiliser and plant protection products application, the treatment of manure in anaerobic digesters, and ways to maximize carbon sequestration and storage in agricultural land (EC, 2018).

- *The LULUCF Regulation (2018)*

Includes GHG emissions and removals from LULUCF into the 2030 climate and energy framework. The actions of forest owners and farmers to secure carbon stored in forests and soils will thus contribute to achieving the EU's commitment under the Paris Agreement (i.e. reduce GHG by at least 40% by 2030 compared to 1990 levels). The "no debit" rule sets a binding commitment to each member state to ensure that accounted emissions from the

⁵ Fines imposed due to the failure of meeting 2020 GHG reduction and renewable energy commitments (Ireland has committed to obtain 16% of its energy from renewable sources by 2020).

LULUCF sector are entirely compensated by an equivalent removal of CO₂ from the atmosphere through actions in the sector (EU, 1995-2019d).

Among the various programmes funded via the RDP, the following have the potential to contribute to GHG emission reductions in the Irish agricultural sector (Table 4):

Table 4. RDP funded programmes with a significant GHG mitigation potential

Measures and sub-measure	Total allocation 2014-20 (EUR)
Measure 1 - Knowledge transfer and information actions	125 800 000
Sub-measure 1.1 (Knowledge transfer groups and M10 Training)	125 800 000
Measure 4 - Investments in physical assets	425 000 000
Sub-measure 4.1 (TAMS II)	395 000 000
Measure 10 - Agri-environment-climate	1 531 005 630
Sub-measure 10.1 (GLAS, BDGP, The Burren Programme & Transitional AEOS/REPS)	1 531 005 630
Measure 11 - Organic farming	56 000 000
Sub-measures 11.1 & 11.2 (The Organic Farming Scheme)	56 000 000

Source: DAFM, 2017a

1. Green, Low Carbon, Agri-Environment Scheme (GLAS)

GLAS incentivises agricultural production methods to address issues of climate change, water quality and biodiversity loss. The scheme supports low-carbon agriculture through a range of cross-cutting measures and promotes the delivery of targeted environmental advice and best practice at farm level. It includes actions such as low input pastures, minimum tillage and low emissions manure spreading techniques. The payment consists in a minimum of EUR 5,000/year for a period of 5 years, up to EUR 7,000/year for farmers who “take on particularly challenging actions which deliver an exceptional level of environmental benefit” (referred to as GLAS+) (DAFM, 2017a).

Box 2. The Common Agricultural Policy’s contribution to GHG mitigation

Pillar I: Direct Payments and Market Measures

Green Direct Payments: 30% of direct payments of the CAP 2014-20 are conditional on the respect of the following criteria: a) maintaining permanent grassland, b) diversification of crop rotation, and c) devoting a certain portion of arable land to biodiversity-friendly practices and features. These three criteria have climate mitigation and/or adaptation benefits by protecting soil carbon pools under permanent grassland and encouraging landscape resilience through crop diversification and establishment of ecological focus areas (EFAs).

Pillar II: The Rural Development Programme

At least 30% of the budget of each RDP must be devoted to voluntary measures that are beneficial for the environment, and 20% must have cross-cutting impacts that address climate change. Agri-environmental and climate measures (AECMs), in particular, reward farmers for a wide range of practices which go beyond those of cross-compliance and the green direct payments scheme. AECMs can cover climate change, water, soil, air, biodiversity and landscapes issues as well as genetic diversity. AECMs account for 23% of 2014-20 total RDP funding. Other RDP measures also have important potential in reducing GHG and ammonia (NH₃) emissions. This is the case for measure 11 on organic farming or measure 4 on investment on physical assets, which includes the construction of or improvements to manure storage facilities, nutrient storage or low emissions slurry spreading equipment.

Pillars I and II: Cross-compliance is a mechanism that links elements of both pillars to farmers' compliance with various basic standards. The system includes two types of requirements:

- **Statutory Management Requirements (SMRs)**: thirteen requirements arising from non-CAP EU legislation in the field of the environment, food safety, animal and plant health and animal welfare.

- **Good Agricultural and Environmental Condition (GAEC)**: seven EU standards relating to management of water, soil and landscape features.

Failure to meet the previous standards can result in a reduction of Pillar I direct payments or Pillar II area-based payments. The most relevant cross-compliance standards with regard to climate change are SMR 1 on the Nitrates Directive, GAECs 1-3 on water protection, and GAECs 4-6 on soil protection. The cross-compliance standard with the most direct link to air quality is SMR 10 on pesticides.

CAP Post-2020 is expected to have a “higher environmental and climate ambition” according to the European Commission (EC) proposal made in November 2017. In particular, the EC has mentioned the possibility to have all payments conditional on the respect of minimum environmental standards/practices.

Sources: Institute for Climate Economics (2018), MEDDE (2015)

2. Organic Farming Scheme (OFS)

The scheme promotes organic agriculture as an alternative farming system, contributing to improving soil quality, and mitigation and adaptation to climate change. The OFS, which started under the previous RDP programme (2007-13), sets the following targets: 16,000 ha in conversion and 46,880 ha in maintenance by 2020. As of 2016, the target for conversion was exceeded by 50% and the target for maintenance was exceeded by 2.4%. But despite the increase in the share of UAA under organic farming in Ireland since 2010, this share remains very low compared to other member states. Under the 2014-20 OFS, the standard rate of payment is EUR 220/ha for conversion with a maintenance rate of EUR 170/ha. Higher rates of EUR 300 and EUR 200, and EUR 260 and EUR 170 apply for horticulture and tillage operations, respectively. In addition, a top-up of EUR 30/ha is included for red-clover (DAFM, 2017a). The OFS is expected to contribute to GHG mitigation by enhancing ecosystems, diversifying crop and livestock production and fostering the use of organic fertilisers known for having a positive impact on soil carbon.

3. Targeted Agricultural Modernisation Schemes (TAMS II)

The scheme supports capital investment in a number of target areas which promote, among other things, sustainability. In particular, EUR 10 million have been invested on low emissions slurry spreading equipment with the objective of reducing GHG and NH₃ emissions from the agricultural sector. An additional EUR 70.7 million have been invested in farm nutrient storage in order to improve water management, e.g. to reduce nutrient loss from farms (DAFM, 2017a). According to Teagasc (2018), TAMS II has the potential to reduce GHG emissions by 102kt CO₂e/year between 2021 and 2030 and should have an even larger impact on reducing NH₃ emissions.

4. Beef Data and Genomics Programme (BDGP)

The BDGP aims to reduce GHG emissions by improving the maternal genetics of the beef herd. Farmers participating in the programme commit - for a period of 6 years - to carry out a specific set of actions designed to better the climate performance of the suckler herd. These actions include (DAFM, 2017a):

- record keeping and event recording;
- genotyping;
- a replacement strategy: animals identified as being of superior genetic merit, with lower associated GHG emissions, are utilised as replacement stock on participating herds; and

- completion of the carbon navigator, an online tool developed by Teagasc and Bord Bia which estimates the % reduction in farms GHG emissions resulting from the implementation of sustainable farm practices.⁶

Programme participants receive an annual payment of EUR 142.5/ha for the first 6.66 payable hectares under the scheme, and EUR 120 per payable hectare after that (DAFM, 2017a). Overall, the BDGP could contribute to cut GHG emissions by 110 kt CO₂e/year between 2021 to 2030 (Teagasc, 2018).

Both the BDGP and GLAS benefit from the knowledge and information programme of the RDP (measure 1). This knowledge transfer (KT) programme further supports and reinforces GLAS and BDGP by enhancing environmental knowledge and best practices among participants through training and introductory courses. According to Teagasc (2018), KT programmes have a significant potential in reducing GHG emissions, with estimated reductions in the order of 4.7 to 6.1 Mt CO₂e/year for AFOLU measures for the period 2021-30.

Overall, the 2014-20 RDP programme is expected to reduce GHG emissions in the Irish agricultural sector by 1.5 Mt CO₂e between 2017 and 2020 (i.e. 0.5 Mt CO₂e/year) and by 10 Mt CO₂e between 2017 and 2030 (i.e. 0.8 Mt CO₂e/year) (Table A.1) (DCCAE, 2017).

The cross-compliance standard with the most impact on agricultural GHG emissions is the 1991 Nitrate Directive (ND), which aims to lower manure surplus and associated emissions. This regulation has significant synergies with reducing N₂O emissions and improving nitrogen-use efficiency. If fully implemented, it could cut N₂O emissions across the EU by 6% by 2020 (from 2000 level) (EC, 2010). The ND requires each member state to establish a national action programme (NAP) – which should be reviewed at least every four years- setting: a) a limit on the amount of livestock manure applied to the land each year, b) periods when land spreading of organic and synthetic fertilizer is prohibited due to risk, and c) capacity levels for the storage of livestock manure. Member states can choose to apply their NAP only to “nitrate vulnerable zones” (i.e. territories draining into waters that are or could be affected by high nitrate levels or eutrophication) or to the all territory. Ireland chose the 2nd option. In addition, Ireland’s NAP includes legally binding phosphorus and nitrogen application limits for all crops. In 2018, Ireland obtained a derogation from the EU to increase the application limit for livestock manure from 170kgN/ha/year to 210kgN/ha/year (DHPLG, 2016).

The EU milk quota (under Pillar I of the CAP) also helped containing Irish GHG emissions by limiting the number of dairy herds held in Ireland. Its removal in 2015 led to an upsurge in GHG emission in the agricultural sector (see last section).

The National Emission Ceilings Directive (NEC) for ammonia (NH₃)

Agriculture is responsible for over 90% of NH₃ pollution in the EU. Two EU directives regulate NH₃ emissions in member states (Box 3). Under the NEC, Ireland has first committed to keep its NH₃ emissions below 116 kilotons for the period 2010-19. Ireland has exceeded its NH₃ emissions ceiling for the first time in 2016. Then, under the new NEC, Ireland has committed to reduce its NH₃ emissions by 1% between 2020 and 2029 and by 5% by 2030 (compared with 2005 level).⁷ Projections suggest that Ireland’s NH₃ emissions will exceed agreed commitments both in 2020 and 2030 (EEA, 2018b). NH₃ is not itself a GHG, however

⁶ The Carbon navigator focus on five efficiency measures: a) increased Economic Breeding Index (EBI), b) longer grazing season, c) improved nitrogen use efficiency, d) improved slurry management, and e) energy efficiency (Teagasc, n.d).

⁷ Ireland has also committed to reduce its ammonia emissions by 1% by 2020 (using 2005 as base year) under the Gothenburg Protocol; stricter than its commitment under the NEC.

indirect N₂O emissions from NH₃ volatilization are a significant source of GHG emissions. Therefore, regulations controlling NH₃ emissions will also affect N₂O emissions.

Box 3. EU polices targeting NH₃ emissions

- *The National Emission Ceilings Directive* (2001)

This EU Directive sets upper limits for each member state for the total emissions in 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (i.e. NO_x, NMVOCs, SO₂, and NH₃). The NEC has been updated in 2016 setting reduction commitments for 2020 and 2030 and adding PM_{2.5} to the list of pollutants to be monitored. It also ensures that the emission ceilings for 2010 set in the earlier directive remain applicable until the end of 2019 (EEA, 2018c).

Also, the EC has expressed its intention to see CH₄ emissions monitored and is currently considering measures to reduce CH₄ emissions in the EU. The potential inclusion of CH₄ emissions and the targets on NH₃ emissions have been particularly discussed due to their implications for the agricultural sector. Indeed, agriculture is responsible for 40% of CH₄ emissions in the EU, and over 90% of NH₃ pollution (Institute for Climate Change Economics, 2018).

- *The Industrial Emission Directive* (2010)

It is the main EU instrument regulating pollutant emissions from industrial installations. It aims to minimize pollution from point sources. In the agricultural sector, it covers intensive rearing of poultry or pigs: a) with more than 40,000 places for poultry; b) with more than 2,000 places for production pigs (over 30 kg), or c) with more than 750 places for sows. These installations are required under the directive to apply control techniques for preventing NH₃ emissions according to best available technology (BAT (EU, 2010).

National mitigation policies – relevance to agriculture

National Mitigation Plan (2017)

As set out in the *National Policy Position* (2014), the long-term vision of Ireland for the agriculture and land-use sector, including forestry, is based on an approach to carbon neutrality which does not compromise capacity for sustainable food production.⁸ Carbon neutrality is presented as a horizon point for 2050 rather than as a binding target as it is acknowledged that it would be very difficult to achieve in the short run. As the agricultural sector has a limited mitigation potential, the Irish mitigation plan also considers the opportunities of abatement through carbon sequestration and fossil fuel substitution (DCCAE, 2017).

According to Teagasc (2018), almost 50% of Irish agricultural GHG emissions could be abated between 2021 and 2030 through:

1. agricultural mitigation of CH₄ and N₂O emissions: using efficiency and technical measures, and by reducing agriculture upstream emissions.⁹

⁸ The *National Policy Position on Climate Action and Low Carbon Development* (2014) sets the target of cutting GHG emissions by at least 80% (compared to 1990 levels) by 2050 across the electricity generation, building and transport sectors; and promotes, in parallel, an approach to carbon neutrality in the agriculture and land-use sector (DCCAE, 2013).

⁹ Efficiency measures include: dairy EBI, optimised live weight gain, improved material traits, extended grazing, and improved nitrogen-use efficiency. Technical measures include: fertiliser formulation, crude protein and fat in diets, manure additives and land spreading management of animal manures (Teagasc, 2018).

2. land-use and land management to enhance carbon sequestration: mainly through afforestation (see afforestation scheme below) but also via optimal management of grassland, water table manipulation on organic soils and tillage management.
3. offsetting via fossil fuel displacement: development of biofuel and bioenergy crops, forestry utilisation in heat and power generation, and adoption of grass-based anaerobic digestion.

Table 5 summarizes the opportunities for abatement in the Irish agricultural sector for the period 2021-30 using the updated version of the Marginal Abatement Cost Curve (MACC).

Table 5. Summary of the mean potential GHG mitigation for the period from 2021-2030 and the maximum mitigation in the year 2030

	Mean CO ₂ e saving 2021-2030	CO ₂ e saving in 2030
MACC Category	Mt yr ⁻¹	Mt yr ⁻¹
Agricultural Mitigation	1.85	3.07
Land Use Mitigation (Carbon sequestration land management & land-use change)	2.97	3.89
Energy - Fossil Fuel Displacement	1.37	2.03
Total	6.19	8.99

Source: Teagasc (2018)

However, even when assuming the full uptake of these existing options over the period 2021-30, Ireland is projected to fall short of meeting its 2030 target for non-ETS emissions by 3.46 Mt CO₂e/year in 2030 (Teagasc, 2018).

Existing national environmental programmes

Origin Green (2012)

Origin Green is a voluntary initiative led by the Irish Food Bord (i.e. Bord Bia) which brings together the government, the private sector and the food industry in an effort to improve the environmental performance of farms and food manufacturers.

Under the programme, independent auditors perform a sustainability assessment at the farm level based on the following criteria: GHG emissions, biodiversity, water conservation measures, energy efficiency and soil management. A feedback report assessing the farm performance and comparing it with similar farms is sent to farmers following each audit, with reassessments every 18 months (Origin Green IRELAND, n.d). Origin Green benefits from a very high coverage rate. To date, the carbon footprint of over 50,000 beef farms has been assessed under the programme and certified dairy farms represent almost 100% of Ireland dairy farms (Teagasc, 2018). Ireland is the first country in the world to assess the footprint performance of farms on a national scale.

In 2016, the average carbon intensity of participating beef farms was estimated at 11.58 kgCO₂e/kg of beef (2% lower than in 2014), and 1.14 kgCO₂e/kg of milk for dairy farms (6% lower than in 2014); with significant degree of variation observed between farms. It has been estimated that bringing beef and dairy farms currently running behind the average to the average could reduce emissions by over 1.4 Mt CO₂e/year; representing 7% of total emissions from Irish agriculture (Bord Bia, 2017).

In addition, all eggs produced in Ireland are already part of the Sustainability Egg Quality Assurance Scheme. By mid-2019, 98% of pig meat and 95% of broiler meat produced in Ireland will come from farms certified under Origin Green sustainability programmes (IFA, 2018).

Animal-By Product (ABP)

The Department of Agriculture, Food and the Marine (DAFM) is encouraging the innovative use of ABP such as tallow as a substitute for imported heavy fuel oil, poultry litter as a biomass energy source or the replacement of conventional fertilisers by organic residue agri-fertiliser (DCCAE, 2017). According to Teagasc (2018), the use of ABP could reduce agriculture GHG emissions by 0.14 Mt CO₂e/year between 2021 and 2030.

Afforestation scheme (1990)

It is a 100% state funded scheme that encourages landowners to convert land from agricultural production into forestry. Its main objective is climate change mitigation. Other objectives are to provide: commercial timber; a sustainable source of biomass for energy production; and woodland habitat and biodiversity benefits. Forests also supply a number of ecosystem services related to recreation, and air and water quality, with positive effects on quality of life (DCCAE, 2017).

Grants covering the entirety of establishment costs are provided, along with 15 annual premium payments based on foregone income. Ireland had less than 1% forest cover in 1900, but it has since increased to 11% as a result of the scheme and the country plans to expand forest cover to 18% by 2050; with the majority of this expansion to be undertaken by farmers (DCCAE, 2017).¹⁰ According to DAFM, over 13,000 farmers received a forestry payment in 2016 (DAFM, 2017b).

This policy has significant mitigation potential: afforestation since 1990 (i.e. all new forests planted since 1990 and up to 2020) is expected to remove a net 4.5 Mt CO₂/year from the atmosphere over the period 2021-30.¹¹ The cost of the afforestation programme to the state for the period 1990-2030 is estimated at EUR 3.2 billion. In addition to carbon sequestration, these forests will provide wood for timber products and sustainable biomass.

Industry-led initiatives directly targeting agricultural emissions

Smart Farming Programme (2014)

Smart Farming is a voluntary resource efficiency programme led by the Irish Farmers' Association, in collaboration with the EPA. It supports the measurement, monitoring and improvement of the environmental performance of farms by performing farm assessment and providing farmers tailored advice from experts.

In particular, farmers participating in the programme receive the following set of environmental indicators for their farms (IFA, 2017):

- A carbon reduction strategy based on the carbon navigator.
- A nutrient management plan is completed based on soil testing. Maps indicating the existing soil fertility levels, and liming and fertiliser requirements are provided.
- An analysis on the quality of the water from the domestic water well and quality of the silage is performed. Recommendations are made regarding feed management strategies arising from the results of the silage tests.

¹⁰<https://www.agriculture.gov.ie/media/migration/forestry/forestpolicyreviewforestsproductsandpeople/00487%20For%20Review%20-%20web%202022.7.14.pdf>

¹¹ This estimate is based on the current method of accounting in EU Decision 529/2013.

In 2017, an average reduction of 10% in GHG emissions has been observed on participating farms. The three following measures have been identified as having the more impact on GHG reduction (IFA, 2017):

1. Increasing genetic merit through the Economic Breeding Index (EBI), a profit index helping farmers to source the most profitable bulls and cows for breeding (it is part of the carbon navigator).
2. Improving calving rates, particularly in suckler herds.
3. Improving nitrogen efficiency on farms.

Research and knowledge transfer programmes

Ireland is investing significantly in agriculture GHG mitigation research and KT programmes. Research is mainly funded by the DAFM and is performed by Teagasc and a number of Irish universities.¹² Ireland is putting efforts in enhancing the links between research, KT programmes and policy in order to maximize farms' uptake of new abatement measures.

DAFM's funding to GHG mitigation research projects is mainly channelled through the Research Stimulus Fund (RSF); a fund supporting sustainable and competitive agricultural practices (Table A.2). DAFM also funds the *Agricultural Greenhouse Gas Research Initiative for Ireland*, a research programme which brings together researchers, students and professionals working to develop mitigation solutions for Irish agriculture. Research efforts are concentrated on: a) N₂O emissions, b) carbon sequestration, c) CH₄ and the rumen microbiome, and d) integrated land management. The programme received an initial funding of EUR 1.5 million in 2012 and is coordinated by Teagasc (AGRI-I, 2016).

In 2018, Teagasc spent EUR 4 million in GHG emissions research and KT programmes coming from a combination of external and internal funding. The two KT programmes with the highest mitigation potential are: the carbon navigator, and the online nutrient management planning tool. The latter assists farmers to optimise nutrient inputs on a paddock by paddock basis, hence reducing overuse of fertilisers. This tool helps farmers in meeting regulatory requirements from the EU Nitrate Directive (Teagasc, 2018).

Finally, the Irish agricultural sector benefits from Ireland's active participation in EU and international research groups, including: the EU Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI); the GRA and the Global Alliance for Climate Smart Agriculture; and FAO's Livestock Environmental and Assessment Performance (LEAP). All these research groups have a strong focus on collaborative agricultural GHG mitigation.

Issues of national level policy coherence with agricultural GHG mitigation

One of the policies with the biggest impact on GHG emissions from agriculture in Europe was the CAP's milk quota (1984-2015), which led to a strong reduction in animal numbers in the dairy sector. Since its removal in 2015, Ireland has enacted a number of policies aimed at boosting national milk production. This is the case of *Food Harvest 2020*, which sets the target of increasing milk production by 50% by 2020 (using the average of the years 2007-09 as a baseline). National ambition to increase milk production has led to an increase in the number of dairy cows and of GHG emissions from the Irish agricultural sector. Between 2015 and 2016, agricultural emissions have increased by 2.7%, mainly driven by an increase in dairy cow numbers (+6.2%). Even if agricultural production has gained some efficiency in recent years, Ireland is far from achieving full decoupling (EPA, 2017).

Strategies such as *Food Harvest 2020* and *Food Wise 2025* that seek to grow the contribution of the Irish agri-food sector to the Irish economy will make it even more challenging for Ireland to meet its 2020 and

¹² Teagasc is a national body providing agriculture and food research, advisory and training services.

2030 GHG reduction commitments. EPA estimated that emissions from the agriculture sector will increase by 12% by 2020 on current levels as the removal of milk quotas and the impacts of expansion under the Food Harvest 2020 plan come into effect (EPA, n.d).

THE NETHERLANDS

Background on agricultural GHG emissions

According to the 2018 EU GHG Inventory report, agriculture generated 19.17 Mt CO₂e of GHG emissions in 2016, accounting for 10% of national emissions. In addition, the LULUCF sector was a net source of 6.7 Mt CO₂e in 2016. The majority of agriculture's emissions were CH₄ from enteric fermentation (46%), followed by N₂O from agricultural soils (29%), then mainly CH₄, but also N₂O from manure management (24%). Agricultural emissions have declined by 15% between 2000 and 2012, but they started increasing again in 2012; plus 9% over the period 2012-16 (EEA, 2018a).

From a mitigation perspective, potential challenges for the Netherlands include the dominance of intensive cattle production that are responsible for enteric CH₄, which is the main source of national agricultural GHG emissions. With dairy production already at a highly efficient level by global standards, further reductions in enteric CH₄ may be difficult to achieve through existing practices.

EU targets and policies - relevance to Dutch agriculture GHG mitigation

The 2020 Energy and Climate Package and the 2030 Energy and Climate Framework

Under the Effort Sharing Decision (ESD), the Netherlands has committed to:

- Cut its GHG emissions from non-ETS sectors (i.e. transport, buildings, agriculture and waste) by 16% by 2020 (from 2005 levels) (EU, 1995-2019a).
- Cut its GHG emissions from non-ETS sectors by 36% by 2030 (from 2005 levels).

The Netherlands benefits from the following flexibilities in meeting its 2030 ESD target: 2% of the target is achievable through the use of banking/borrowing of EU ETS allowances and 1% is achievable via offsetting non-ETS emissions with net emission reductions from the LULUCF sector. In addition, flexibilities available over the 2013-20 period remain applicable (EU, 1995-2019c).¹³

The Netherlands has overachieved its 2016 and 2017 ESD annual targets by 11.6 and 10 percentage points (ppt) respectively and is thus on good track to meet its 2020 commitment. According to projections from the European Environmental Agency (EEA), the Netherlands will overachieve its 2020 ESD target by 10 ppt with existing measures in place and by 11 ppt if additional measures are implemented (EEA, 2018c).

In addition, CO₂ emissions from energy use in the greenhouse horticulture sector—one of the biggest agricultural sectors in the Netherlands—are regulated under the ETS.

The Common Agricultural Policy (CAP)

The Dutch rural development programme (RDP) has an important environmental component. For the period 2014-20, EUR 518 million have been allocated to agri-environmental and climate measures (AECMs); for a total RDP funding of EUR 1.69 billion. It makes AECMs the 2nd biggest RDP measure for the Netherlands in budgetary terms (EU, 1995-2019f).

¹³ Overachievement in a given year can be carried over subsequent years up to 2030. Up to 5% of annual emissions allocation are tradable between member states for the period 2021-29.

In particular, the Dutch RDP put a strong emphasis on enhancing ecosystems (priority 4 of the RDP), with 56% of the total budget allocated to improving landscapes, stimulating biodiversity and improving water and soil management on 6% of the agricultural land. However, the government has chosen not to include specific measures on promoting resource efficiency and the transition to a low-carbon economy (priority 5 of the RDP). The Dutch vision is that innovation is the key to strengthen the competitiveness and sustainability of the agricultural sector. Innovative sustainable investments under the RDP are expected to contribute to environmental and climate objectives (EU, 1995-2019f).

The Statutory Management Requirement (SMR) with the most impact on GHG emissions and on national policy in the Netherlands is the 1991 Nitrate Directive, which aims to lower manure surplus and associated emissions. The Directive sets a maximum threshold for the use of animal manure of 170 kg of nitrogen per hectares per year. The Netherlands has received a derogation from the EU which allows farmers to apply up to 250 kg N/ha/year, if based on cow manure (Van Grinsven and Bleeker, 2017). The Netherlands has incorporated requirements from the Nitrate Directive into its own policy framework regulating manure and fertilizers use (see section on the Dutch manure and fertilizer policy).

The EU milk quota also contributed to reduce GHG emissions in the Dutch agriculture by limiting the number of dairy herds held in the Netherlands. After its removal in April 2015, the number of dairy cows increased resulting in an increase of direct GHG emissions. Since then, regulation on manure management and nitrogen and phosphate content in manure have been used to limit animal numbers and thus CH₄ and N₂O emissions. In January 2018, a trading system for phosphate emissions has been introduced in the dairy sector. The number of allowances is set at the situation in July 2015, minus 8.3%, to bring phosphate production levels back to what they were when the milk quota was in place (Backus, 2017). This will result in a reduction of the dairy herd which will naturally lead to lower GHG emissions from cattle (see section on the Dutch manure and fertilizer policy).

The National Emission Ceilings Directive (NEC) for NH₃

In 2016, the agricultural sector was responsible for more than 85% of total NH₃ emissions in the Netherlands (NEA, 2018). The Netherlands has first committed to keep its NH₃ emissions below 120 kt for the period 2010-19 under the NEC. Then, under the new NEC (2016), it has committed to reduce its NH₃ emissions by 13% between 2020 and 2029 and by 21% by 2030 (compared with 2005 level).¹⁴ The Netherlands has kept its NH₃ emissions below 120 kt since 2012 and is expected to meet both its 2020 and 2030 NH₃ emissions reduction targets (EEA, 2018b). A number of national policies contribute to the reduction of NH₃ emissions in the agricultural sector (see section on the Dutch manure and fertilizer policy).

National mitigation and agricultural policies targeting agricultural emissions

Climate-change mitigation efforts for agriculture in the Netherlands focus particularly on the livestock and the greenhouse horticulture sectors, which together account for 90% of agricultural GHG emissions (Ignaciuk and Boonstra 2017).

GHG emission reduction targets for Dutch agriculture

1. The Clean and Efficient Agro Sectors Covenant (2008)

¹⁴ The Netherlands has also committed to reduce its ammonia emissions by 13% by 2020 (using 2005 as base year) under the Gothenburg Protocol.

Part of the *Clean and Efficient Programme* (2007), the agro covenant is the main policy framework for the Dutch agricultural sectors (i.e. arable farming, horticulture and livestock farming). Drawn up by the government in collaboration with the different agricultural sectors, it specifies targets for energy consumption and savings, energy from sustainable sources, and GHG emissions; with the associated action plans.

In particular, it sets the following GHG emissions reduction targets to be achieved by 2020 (EZK, 2017):

- a reduction in CO₂ emissions of 3.5 to 4.5 Mt as compared to 1990.
- a reduction in non-CO₂ GHG emissions (i.e. CH₄ and N₂O emissions) of 4 to 6 Mt CO₂e as compared to 1990 (correspond to an emission reduction of 25-30%).

Regarding CH₄ and N₂O emissions reduction, the following set of measures is specified (EZK, 2017):

- Measure for reducing nitrogen inputs on farms such as precision soil cultivation using GPS. In 2017, the government and businesses invested EUR 10 million (EUR 2 million from the Ministry of Economic Affairs and EUR 8 million from businesses) available for a period of four years in a pilot programme for precision agriculture using innovative technologies such as satellite data and drones (Government of the Netherlands, 2017).
- Measures for cattle feed to reduce CH₄ emissions.
- Measures for manure storage to reduce CH₄ emissions.

The non-CO₂ emission reduction target has already been achieved by 2013, albeit entirely due to the reduction of N₂O emissions. The reduction in N₂O emissions was largely due to the reduced application of artificial nitrogen fertiliser. Methane emissions, however, have increased due to the increase in the number of dairy cattle (WUR, 2015).

A new document reassessing the objectives of the agro covenant was supposed to be published in 2018. Partners are currently also making plans for the period up to 2030 and 2050.

2. The 2018 National Climate Agreement (proposal)

The Dutch National Climate Agreement aims to translate Paris Agreement objectives into clear GHG emission reduction targets for five sectors of the economy, including the agriculture and land use sector. During the consultation process, each sector platform (involving organisations, experts and companies) has been responsible for defining the instruments and measures required to achieve a 49% cut in GHG emissions by 2030 (compared with 1990 levels). In addition, they had to propose additional measures required to reach a 55% reduction in national GHG emissions by 2030 (Klimaatakkoord, 2018). The Dutch Climate Agreement proposal sets ambitious targets that exceed the EU 2030 target of 40%.

For the agriculture and land use sector, responsible parties have considered an emission reduction target of 3.5 Mt CO₂e by 2030, mainly coming from: a reduction in livestock CH₄ emissions (in particular dairy cattle and pigs via manure and feed measures), increased carbon sequestration in grasslands, agricultural soils and forests, and CO₂ emission reductions in the greenhouse horticulture sector (via energy savings and sustainable production of energy). Additional measures have been identified that could deliver up to 5.1 Mt CO₂e emission reductions in the Dutch agriculture by 2030 (Table 6).

Table 6. Emissions reduction breakdown in the agriculture and land use sector

Theme	Objective	Formulated ambition & measures
Remit		
Methane & livestock farming	1 Mt	Methane reduction ambition: 1.1 Mt CO ₂ e:

		- pig farming: 0.3 Mt through voluntary termination and buying up rights, as well as sty modifications; - dairy cattle farming & dairy: "Animals and Feed" and "Manure Storage and Fertilisation": 0.8 Mt methane in CO _{2e} N ₂ O reduction: 0.2 Mt
Smarter land use	1.5 Mt	Total ambition: 1.8 – 2 Mt: approx. 1.0 Mt peat grassland; 0.5 Mt farmland outside peat grassland; 0.3-0.5 Mt forests, trees and natural areas.
Greenhouse as a Source of Energy	1 Mt Additionally	1.8 Mt: - energy savings, incl. through "new-style cultivation"; - CO ₂ and sustainable heat system (incl. new geothermal energy sources); - modernisation of greenhouses & regional approach; - electrification & frontrunner approach.
Total	3.5 Mt	4.9-5.1 Mt

Source: Klimaataakkoord (2018)

Investments in the order of EUR 2-4 billion have been considered over the period 2019-30 to support the underlying measures (Klimaataakkoord, 2018). The proposal is waiting for government's approval. The Dutch Climate Agreement should be signed by May 2019.

Policies supporting reduction in agricultural GHG emissions

Two main type of policies support GHG emission reductions in the Dutch agricultural sectors. The Dutch Manure and Fertilizer policy fosters N₂O and CH₄ emission reductions in the livestock and crop farming sectors by regulating manure production and manure and mineral fertilizer application. In addition, a number of policies encourage CO₂ emission reductions in the greenhouse horticulture sector by supporting energy efficiency measures and on-site renewable energy production.

1. The Dutch Manure and Fertilizer management policy

High livestock density in the Netherlands has creating problem for controlling mineral surplus in manure; with associated negative environmental consequences. Since the beginning of the 80's, the Dutch government has developed a whole policy framework for reducing nitrogen and phosphorus losses from fertilisation to improve water quality. The Dutch manure and fertilizer policy is part of the national application of the Nitrate Directive (1991). This policy is also important for achieving other policy targets such as GHG emission reductions. The implementation of the *Manure and Fertilizer Act* delimits the total head of livestock - directly through a cap on pig and poultry number and indirectly by limiting manure production and application- and thus has a significant impact on agricultural N₂O and CH₄ emissions. Regulations have evolved over time in form (from command-and-control to market-based instruments for instance) and stringency, but significant restrictions remain on: animal numbers, manure production and application, phosphate and nitrogen content in manure, and fertilizer use.

a) Policies controlling livestock number

The livestock production quota system for pigs and poultry: in 1998, the *Pig Production Restructuring Act* replaced the system of manure production rights by pig production rights, a quota system based on the

average number of pigs held in 1995-96. Under this system, one pig production right equals to 7.4 kg of phosphate of annual manure production. Pig quotas can be traded. However, if a farmer wants to end pig production, he can only sell a share (from 40-60%) of his pig quota to farmers who need additional quotas in order to increase production. The remaining quotas have to be handed over to the government so the national pig herd decreases. Pigs quota have been reduced several times since 1998 (OECD, 2001). In 2001, manure production rights were also converted to animal-based rights for the poultry sector (based on the average volume in 1995-97). This policy has been proven successful in containing livestock number. In 2015, full quota utilisation (106% for poultry and 100% for pigs) and high prices for pig and poultry quotas indicated an expansion in livestock numbers, with a 10% increase in poultry number over the period 2012-15. Without this policy, livestock numbers and GHG emissions from manure would have been even larger (Van Grinsven and Bleeker, 2017).

Land-related expansion for dairy farms: in 2016, the Netherlands introduced a regulation setting a maximum livestock units per unit of land on dairy farms. Dairy farmers who increase the number of cows on their farm and consequently produce more phosphate must demonstrate that they have enough land for its application (Backus, 2017). This regulation, which aims to counter the decoupling of animal farming from farmland, is expected to limit dairy farm expansion and thus the increase in the number of dairy cows in the Netherlands.

Tradable phosphate rights for dairy farms: since January 2018, a system of tradable phosphate rights has been introduced in the dairy sector. Dairy farmers have been allocated phosphate right based on the number of cattle held on July 2015, less a generic reduction of 8.3%. The phosphate rights are tradable. However, when a transaction occurs 10% of the traded rights are withheld and kept in a “phosphate bank” (Government of the Netherlands, 2017). In addition, dairy farms that have grown on recent years have been assigned monthly targets for reducing their number of dairy cows, thus also cutting phosphate production. Farms that fail to meet their target will have to pay a large penalty, while farms that do meet their target will receive a bonus. Bonuses are also available for producers who quit dairy farming. Feed tracking also contributes to lower phosphate content in cows manure (Government of the Netherlands, n.d).

b) Policies regulating nitrogen and phosphate content in manure

Until 2005, a nutrient accounting system – the *Mineralen Aangiftesysteem* (MINAS) – was used to track nitrogen and phosphate content in manure and to compute levies on surplus nutrients being generated by farms. Levies were imposed on nitrogen and phosphate surpluses above a certain level per hectare. The objective was to bring nutrient inputs and outputs into balance at farm level (Backus, 2017). According to researchers from WUR, MINAS was the most cost-effective policy for reducing N₂O emissions (ADEME, 2012). Since 2006, it has been replaced by soil- specific nitrogen and phosphate application standards which have been lowered step-wise to meet the targets of the Nitrate Directive.

c) Policies regulating manure application

Seasonal restriction on spreading manure: Since 1991, farmers are only allowed to spread manure onto grassland and arable land during the winter time; with rules varying depending on the types of manure and soil. This regulation induced livestock farmers to invest in manure storage facilities. Currently, every livestock farm must have manure storage capacity for at least six months (Backus, 2017). In addition, application with low-emissions machines became obligatory.

d) Other manure management policies

Compulsory manure injection: Since 1992, it is compulsory to inject all manure that spread on all grasslands and sandy soils or plough fields within 24 hours of application. This measure aimed to reduce NH₃ emissions through more efficient nitrogen-use and lower fertilizer use but might lead to additional N₂O emissions.

Other requirements for reducing NH₃ emissions include: covering all manure storage facilities, building low-emission animal housing systems when old ones have to be replaced, and lowering the protein content of animal feed.

Mandatory manure processing: Since 2013, farmers who produce more manure than they can apply to their land are required to either process or export it. The percentage of manure that farmers are required to process is set to increase over time. In the southern part of the country this percentage increased from 10% in 2013 to 60% in 2017 (Backus, 2017).

The above arrangement of policy for controlling animal numbers, the receiving environment, improving manure management, and reducing nutrient surpluses from manure, also have an important potential in reducing manure-based N₂O emissions.

e) Support measures

Flagship farms: Currently, the only measure supporting the Dutch manure and fertilizer policy is the flagship farms educational programme, which is in place since 1987. A pilot programme - Cows and Opportunities - involving researchers and 16 dairy farmers has been introduced to foster sustainability in the dairy sector. The primary objective of the programme is to implement the existing environmental legislation on these 16 farms to get an insight of the economic, environmental and socio-cultural consequences at the farm-level as well as of the actual effectiveness of these regulations. It also aims to spread environmental knowledge and best practices within the sector. The programme – which has been monitored and evaluated over several years- demonstrated that it is possible to meet nitrogen and phosphorus surplus target by taking simple actions.

2. Policies encouraging GHG emission reductions in the greenhouse horticulture sector

Policy instruments supporting CO₂ emission reductions in the greenhouse sector include: a) a sectoral emission trading system, with total allocation declining annually to a level of 4.6 Mt CO₂ in 2020, b) financial incentives for energy savings and subsidies for investment in energy efficiency and renewable energy installations, and c) a specific innovation programme “The greenhouse as an energy source” (EZK, 2017).

Industry-led initiatives directly targeting agricultural emissions

Sustainable Dairy Chain (2013)

Sustainable Dairy Chain is an initiative from the dairy industry (Dutch Dairy Association) and dairy farmers (Dutch Federation of Agriculture and Horticulture). Together, they have formulated goals to achieve a more sustainable dairy sector under four themes: climate and energy, animal welfare and health, maintenance of grazing and environment and biodiversity. In particular, they set the target of cutting GHG emissions from the dairy chain by 20% by 2020 (from 1990 levels), and to achieve climate-neutral growth compared to 2011. They also defined targets relative to phosphorus production and NH₃ emissions.¹⁵ The Sustainable Dairy Chain initiative is promoting the following set of good agricultural practices for reducing GHG emissions in the dairy sector: soil conservation measures, grazing, reduce artificial fertilizer use, improve feed efficiency,

¹⁵ Keep dairy farming phosphorous production at the 2002 level i.e. 84.9 million kg and reduce ammonia emissions by 5 kt compared to 2011 level.

lower young cattle population, growing and feeding corn, and the use of clover as a nitrogen source (Duurzame Zuivelketen, n.d).

“Kringloopwijzer” (2012)

Kringloopwijzer is an online management tool developed by the dairy industry that track the nutrients entering and leaving farms and can help monitor the actual farm level N₂O emissions. It aims to improve farm nutrient-use efficiency by providing indicators such nitrogen and phosphate levels, nitrogen and phosphate surpluses, mineral use and NH₃ emissions. Farmers can then compare their environmental performance with legal standards and with other farms. This monitoring system is already compulsory for farms with a phosphate surplus and it is expected that within a couple of years all farms will be obliged to implement it. Similar systems are developed for the pork sector (Ignaciuk and Boonstra, 2017). Since January 2018, Kringloopwijzer also has a climate module which monitor farms' GHG emissions and provides advice on how to reduce them. Several dairy companies reward farmers for completing the module.

Other incentives by dairy companies

In line with the Sustainable Dairy Chain incentive, a number of Dutch dairy companies have expressed their aim to achieve climate neutrality and have developed their own accounting system for nutrients and GHG emissions. This is the case of Royal Friesland Campina and Vreugdenhil Dairy Foods for instance. The latter is also rewarding its 850 Dutch dairy farmers for making sustainability efforts regarding energy consumption, renewable energy generation, biodiversity and land-related activities. In 2017, 76% of the dairy farmers received a sustainability incentive premium (Vreugdenhil Dairy Foods, n.d).

Social pressures and animal welfare policies' impact on agricultural emissions

There is strong social pressure for animal welfare in the Netherlands. Animal welfare policies affect the regulatory environment within the agricultural sector and can have an impact on the GHG balance (problem of pollution-swapping). A recent OECD publication identifies the following animal welfare regulations as having an influence on GHG emissions in the Dutch agricultural sector (Ignaciuk and Boonstra, 2017):

- Anaesthesia for pig castration: The Netherlands recently made it compulsory to use anaesthesia while castrating pigs. This led to farmers not castrating pigs for the domestic market in order to avoid the potential increase in production costs. Non-castrated pigs can more easily absorb minerals, resulting in a reduction in mineral-rich feed in piglets' diets. This, in turn, led to a decrease in phosphorus and nitrogen levels in pigs' manure, and explains to a large extent why emissions from pig manure stayed stable despite a significant increase in pig population.
- Requirements for animal housing to meet new animal welfare standards: these requirements are expected in many cases to contribute to increased emissions of NH₃, which when converted to N₂O during bio-physical processes can contribute to increased GHG emissions.
- Minimum quota of pasture time for dairy cows: More grazing reduces NH₃ emissions but increases N₂O emissions. Inversely, CH₄ emissions from manure meadow are lower than manure produced in the stable. The final GHG balance is likely to be slightly less favourable for mitigation objective; depending on many locally determined factors.
- Keeping calves with their mothers for the first weeks of their life: this regulation is currently being discussed in the dairy sector. GHG emissions are likely to be lower if young calves are fed with milk rather than milk-replacements. However, these potential mitigation benefits might be counterbalanced by an increase in production.

Research and innovation programmes

In the Netherlands, research on agricultural GHG mitigation is mainly performed by Wageningen University & Research (WUR). WUR has several research programmes on climate change including one on “Climate and Soil” and one on “Climate Smart Agriculture”; both programmes cover agriculture GHG mitigation issues.

WUR also performed GHG mitigation research in its livestock research institute with programmes on “livestock and the environment” – focusing on the environmental effects of livestock farming on soil and atmosphere- and on “Climate-smart livestock farming”. The latter provides practical and applicable knowledge at farm level to reduce GHG emissions from livestock and manure. It also addresses low-emission animal feed and energy transition in the agri-food chain.

In addition, in 2018, WUR starts developing a comprehensive research programme with the aim of cutting GHG emissions from agriculture and land use in the Netherlands. The programme focuses on: a) forest and nature management, b) greenhouse as an energy source, and c) low-emission livestock farming. The Ministry of Agriculture, Nature and Food Quality allocated more than 11 million to this project. The amount is part of the 300 million made available earlier in 2018 by the cabinet to counter the effects of GHG emissions (WUR, 2018).

The Netherlands is an active member of several international research groups with a focus on agricultural GHG mitigation. It is part of the GRA on agricultural GHG since 2011. Dutch participation in the GRA’s research groups is coordinated by WUR. The Netherlands is a world leader on climate smart agriculture research. In 2014, it launched the Global Alliance for Climate-Smart Agriculture (GACSA) during the SGUN’s climate summit in New York. The GACSA aims to encourage partnerships and initiatives in the field of climate-smart agriculture. It currently counts 207 members. Finally, The Netherlands is involved in the Global Agenda for Sustainable Livestock, a multi-stakeholder partnership focused on the sustainable development of the livestock sector worldwide. The Agenda addresses, among other things, climate change mitigation issues in the livestock sector.

FRANCE

Background on agricultural GHG emissions

According to the 2018 EU GHG Inventory report, agriculture generated 76.7 Mt CO₂e of GHG emissions in 2016, accounting for 17% of national emissions. In contrast, the LULUCF sector was a net sink of 36.6 Mt CO₂e in 2016. The majority of agriculture's emissions were CH₄ from enteric fermentation (46%), followed by N₂O from agricultural soils (43%), then mainly CH₄, but also N₂O from manure management (9%). Overall, agricultural emissions have been declining since 2000; with a reduction of 8% over the period 2000-16 (EEA, 2018a).

EU targets and policies - relevance to French agriculture GHG mitigation

The 2020 Energy and Climate Package and the 2030 Energy and Climate Framework

Under the Effort Sharing Decision (ESD), France has committed to:

- Cut its GHG emissions from non-ETS sectors (i.e. transport, buildings, agriculture and waste) by 14% by 2020 (from 2005 levels) (EU, 1995-2019a).
- Cut its GHG emissions from non-ETS sectors by 37% by 2030 (from 2005 levels).

France benefits from the following flexibility in meeting its 2030 ESD target: 1.5% of the target is achievable via offsetting non-ETS emissions with net emission reductions from the LULUCF sector (i.e. corresponds to a limit of 5.8 Mt CO₂e/year). In addition, flexibilities available over the 2013-20 period remain applicable (EU, 1995-2019c).¹⁶

France has overachieved its 2016 and 2017 ESD annual targets by 7 and 1 ppt respectively and is thus well on track to meet its 2020 commitment. According to projections from the EEA, France will overachieve its 2020 ESD target by 6 ppt with existing measures in place (EEA, 2018c).

The Common Agricultural Policy (CAP)

In France, Pillar II of the CAP is managed by regions, allowing to tailor actions to local requirements. This decentralisation of the RDP resulted in the establishment of 21 regional RDP programmes covering the period 2014-20. Overall, these programmes have an important environmental component, with a significant share of the total budget spend on priorities 4 and 5; 55% and 5.5% on average for Metropolitan France.¹⁷ Four regions (Alsace, Bourgogne, Haute Normandie and Nord Pas de Calais) have allocated funds to priority 5D which aims to reduce GHG and NH₃ emissions from agriculture. The majority of regions have spent a share of their total budget on priority 5E (i.e. carbon conservation and sequestration). These two sub-priorities directly contribute to France's mitigation efforts (EU, 1995-2019g).

¹⁶ Overachievement in a given year can be carried over subsequent years up to 2030. Up to 5% of annual emissions allocation are tradable between member states for the period 2021-29.

¹⁷ Priority 4: Restoring, preserving and enhancing ecosystems in agriculture and forestry; priority 5: Resource efficiency and shift to low carbon and climate resilience economy in agriculture, food and forestry sectors.

Under priorities 4 and 5, seven French regions have allocated more than 19% of their total RDP funding (the EU-28 average) to AECMs measures. Measure 11 supporting organic agriculture also benefits from significant funding; ranging from 2.5 to 15.5% of regional RDP budgets (Table A.3).

In addition, a new investment scheme – the *Farm Competitiveness and Adaptation Plan*- has been funded under measure 4 of the RDP (i.e. investment in physical assets). This plan - which mainly targets livestock housing- contributes to CH₄ and N₂O emission reductions through: investments to promote slurry pit covers and effluent management; and investment assistance to reduce the use of mineral fertilizers and to develop leguminous crops (MEDDE, 2017b). This plan benefits from a total funding of EUR 200 million a year for the period 2014-20, coming from EU funds, the French government and local authorities (MAAF, 2016).

As required by the 1991 Nitrate Directive (ND), France has translated its requirements into a national action plan -which is revised every four years- but has also formulated a number of regional action programmes for the period 2014-18. In 2015, France lowered the threshold of pollution of the surface waters from 50 mg -as set in the ND- to 18 mg, resulting in an increase in the number of zones deemed vulnerable i.e. areas to which the regulation applies and that should be carefully monitored (Institute for Climate Economics, 2018).

The National Emission Ceilings Directive (NEC) on NH₃

France is the second largest emitter of NH₃ in the EU after Germany. Under the NEC, France has first committed to keep its NH₃ emissions below 780 kt for the period 2010-19. Then, under the new NEC (revised in 2016), it has committed to reduce its NH₃ emissions by 4% between 2020 and 2029 and by 13% by 2030 (compared with 2005 level).¹⁸ France has kept its NH₃ emissions below the 780 kt ceiling since 2010, however projections suggest that French's NH₃ emissions will exceed agreed commitments both in 2020 and 2030 (EEA, 2018b).

National mitigation and agricultural policies targeting agricultural emissions

GHG emission reduction targets for French agriculture

The *Energy Transition and Green Growth Act* (ETGGA) (2015) is the cornerstone of France's climate policy. It sets the target of reducing national GHG emissions (including agricultural CH₄ and N₂O emissions) by 40% between 1990 and 2030 - in line with EU and Paris Agreement's objectives - and by 75% between 1990 and 2050 (MTES, 2016). The last objective has recently been modified by the 2017 *Climate Plan* which sets the target of achieving climate neutrality by the middle of the century (MEDDE, 2017a).¹⁹

The 2015 *National Low-Carbon Strategy* has been used to translate the ETGGA's objectives into clear emission reduction targets for seven sectors of the economy. The NLCS also provides long-term guidelines and sector-specific recommendations to implement this transition. Carbon budgets i.e. national GHG emissions caps have been set for each sector for the periods: 2015-18, 2019-23 and 2024-28. These emissions ceilings are aligned with EU 2020 and the ETGGA's emission reduction objectives (MEDDE, 2015). The NLCS has been revised in 2018 and take into account the new objective of carbon neutrality in 2050. In addition, it set the 4th carbon budget covering the period 2029-33 and adjusted previous carbon budgets downward to allow France to meet its EU and international mitigation commitments (MEDDE, 2018).

¹⁸ France has also committed to reduce its ammonia emissions by 4% by 2020 (using 2005 as base year) under the Gothenburg Protocol.

¹⁹ The target of achieving carbon neutrality by 2050 has been reaffirmed in the 2018 National Low Carbon Strategy and should be translated into law.

For the agricultural sector, carbon budgets have been allocated as described in Table 7.²⁰ The current allocation corresponds to a GHG emission reduction of 8% by 2023, 13% by 2028 and 20% by 2033, compared to 2015 levels (i.e. the year of the implementation of the strategy).

Table 7. Carbon budgets allocated to the agricultural sector for the period 2015-33

Emissions (annual average) in Mt CO ₂ e	Reference years			1 st carbon budget	2 nd carbon budget	3 rd carbon budget	4 th carbon budget
	1990	2005	2015	2015-18	2019-23	2024-28	2029-33
Agriculture	94	90	89	86	82	77	72
of which N ₂ O	40	38	37	37	35	33	31
of which CH ₄	43	40	40	38	37	34	32
Total (without LULUCF)	546	553	458	442	421	357	299
Total (with LULUCF)	-	-	417	-	383	319	257

Source: MEDDE, 2018

Measures considered to achieve these emission reductions

The 2015 and 2018 NLCSs promotes the move towards alternative agricultural systems that directly, or indirectly, generate less GHG emissions. The strategies mainly focus on agroecology (the NLCS is part of the implementation of the French agroecology project) and precision agriculture. Organic farming is also seen as an effective option. More precisely, the following measures have been formulated to reduce N₂O and CH₄ emissions from the French agricultural sector (MEDDE, 2015 and 2018):

Regarding N₂O emissions reductions, the NLCSs mainly focus on:

- Optimization of the nitrogen cycle to minimize surplus, the increase in low-inputs circuits and the replacement of mineral fertilizers with organic alternatives (including livestock effluents). The 2015 NLCS sets the target of reducing mineral nitrogen by -30 unit of mineral nitrogen/ha in 2035 compared to 2010 level.
- Use of decision support tools throughout the cycle to adapt inputs to crop needs and select plant varieties adapted to a low level of inputs.
- Reduction in protein intake in animal feed. The 2015 NLCS aims to reduce the protein rations provided to over 50% of dairy cattle by 2035. The strategies also promote protein autonomy through the development of leguminous crops.
- Development of organic farming with the target of converting 15% of arable UAA (25% of total UAA) to organic agriculture by 2035.

For CH₄ emissions reduction, the following set of measures has been considered:

- Improvement in livestock manure management and storage (slurry pit cover, biogas flares, development of anaerobic digestion). The 2015 NLCS sets the target of having 40% of usable excrement methanised by 2035.
- Optimization of herd management to reduce unproductive periods or to change products placed on the market (management of health status, reduction of birth mortality, optimization of age at first calving, evolution of fattening systems).
- Reducing enteric CH₄ emissions through adjustments to animal feed (flaxseed, for example) or genetic selection.

²⁰ Carbon budgets include emissions related to fertilizer production and animal feed imports and exports.

The NLCSs also include measures to enhance soil carbon capture such as: increasing soil organic matter return and carbon storage through permanent soil cover, above-ground biomass and reduced tillage; protecting permanent grassland; developing agroforestry and slowing down land artificialisation. In particular, the 2015 NLCS sets the following targets: bringing catch crops to 80% of spring crops by 2035; restricting the reduction in permanent grassland to 490,000 ha between 2010 and 2035; and having 700,000 ha of hedgerows and 120,000 ha of agro-forests by 2035.

Policies supporting reduction in agricultural GHG emissions

A number of policies are supporting the emission reduction targets set in the NLCSs for the agricultural sector. These mainly include: the 2014-20 CAP (see previous section on the CAP), and the French agroecology project and its sub-strategies – which are partly funded by the CAP.

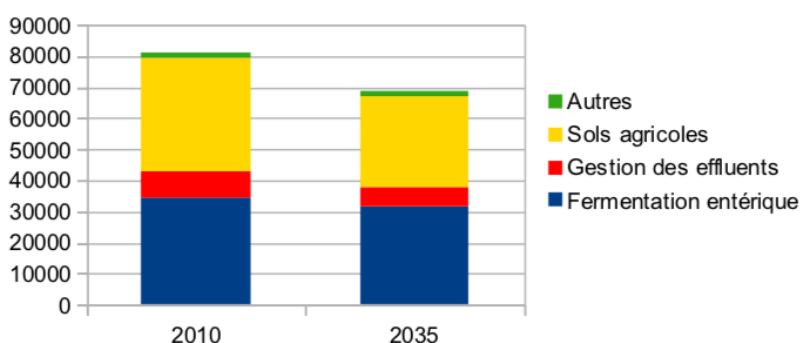
1. The French Agroecology project (2012)

The agroecology project aims to develop solutions combining high economic, environmental, social and sanitary performances based on positive biological interactions and on the use of ecosystem services. The French agroecology project formulates the ambition of having 50% of French farms committed to agroecology by 2025 (MAA, 2017).

Agroecology has the potential to contribute to GHG mitigation in the French agricultural sector. The implementation of the agroecology project could reduce French agricultural GHG emissions by 13% between 2010 and 2035. Most of the reduction are expected to come from reduced enteric CH₄ emissions (mainly through anaerobic digestion); and reduced N₂O emissions from agricultural soils through the substitution of mineral fertilizers with organic alternatives.²¹ Emissions from livestock are also expected to decrease significantly due to a small reduction in cattle population, better use of grass in dairy feed and optimization of animal feed (Figure 1.1). In addition to this, carbon storage is expected to contribute to a reduction of 6.3 MtCO₂e/year in agricultural GHG emissions by 2035 mainly coming from a decrease in the conversion of agricultural lands to urban and associated uses (roads, parking lots, buildings, etc), the implementation of carbon storing practices in arable crops and the development of agroforestry and hedgerows (FAO, 2016).

Figure 1. The mitigation potential of the French agroecology project

Emissions de GES en ktéqCO₂ en 2010 et en 2035 sous AMS2



Source: FAO, 2016

The implementation of the agroecology project has been supported by the creation of ten actions plans. The majority of these plans have a significant mitigation potential.²²

²¹ Organic alternatives include digestates, livestock effluent and legumes.

²² The other plans focus on animal welfare, antibiotic use and bee-keeping.

a) EMAA (energy methanisation self-sufficiency & nitrogen) (2013)

This plan has two complementary focuses: reduce French farmers' dependence on mineral nitrogen by fostering the use of organic nitrogen, and the development of agricultural biogas production. Therefore, it has the potential to contribute to both CH₄ and N₂O emission reductions in agriculture. Example of measures to encourage the use of organic fertilizers include: reduced VAT rate on organic fertilizers (10% against 20% for mineral fertilizers), and a EUR 10 million fund supporting collective projects that aim to reduce nitrogen fertilizer use. Agricultural biogas production is mainly encouraged through financial support for the acquisition of methane digesters, and a feed-in-tariff for electricity generated by methane digesters. The number of biodigesters on farm has increased from 90 at the end of 2012 to 230 in early 2018. France aims to have 1,000 farms with anaerobic digestion units by 2020 (Institute for Climate Economics, 2018). The two objectives of the EMAA plan are also supported by the simplification of administrative procedures, dissemination of knowledge and strong government support for innovation (MAAF, 2013).

b) Protein crops (2014-20)

This plan aims to enhance plant-based protein and leguminous production and promote protein self-sufficiency among livestock farmers. Leguminous crops enrich the soil with nitrogen and thus reduce the need for external inputs such as mineral nitrogen fertilizer; thereby reducing N₂O emissions. Fodder legumes also represent a good alternative to high-protein concentrate animal feed. The development of plant-based protein in France is supported by: a) CAP 2014-20's coupled payments, which provide a total of EUR 49 million to encourage protein, soy and fodder legumes production (individual payments range between EUR 100-200/ha), b) CAP's AECM "systèmes grandes cultures", which requires to have 5% of arable land dedicated to leguminous production (individual payments range from EUR 90-210/ha and can be cumulated with CAP's coupled payments), and c) CAP's greening payments. Livestock farmers' protein self-sufficiency is encouraged through: a) CAP's direct payments, which provide a total of EUR 98 million for fodder legumes production on livestock farms (individual payments range from EUR 100-150/ha), b) EUR 4 million coupled payments for fodder seeds production, and c) the AECM "polyculture élevage". The protein plan also has a strong focus on R&D and training (MAAF, 2014a).

c) Ambition bio 2017 (2013)

This plan contributes to limit N₂O emissions by supporting the development of organic agriculture. Ambition Bio aimed to double the share of organic surfaces by the end of 2017. Financial support is provided through an incentive scheme dedicated to land conversion. A total of EUR 160 million a year is available over the period 2014-20, coming both from EU funds and the French Ministry of Agriculture. This plan also aims to strengthen R&D on organic farming, train farmers and agri-food professionals and adapt regulations (MAAF, 2013). In 2018, the French Ministry of Agriculture launched Ambition Bio 2022; an additional 1.1 billion will be invested to support organic agriculture over the period 2018-22. The programme aims to bring the share of the UAA under organic farming to 15% by 2022 (MAAF, 2018). In 2017, this share was 6%.

d) Agroforestry (2015-20)

By combining crops and livestock production with trees on the farmland, agroforestry can contribute to reduce agricultural GHG emissions through enhanced carbon sequestration. The carbon sequestration potential of agroforestry could range between 0.3 and 1 t CO₂e/ha/year, depending on the type of trees. This agricultural system also contributes to restore soil fertility and thus reduce the need for external inputs. The agroforestry plan mainly aims to improve agroforestry's regulatory and legal framework and strengthen financial support. The CAP 2014-20 provides support to agroforestry through its two pillars. In particular, it offers: a) aid for the first installation of agroforestry systems on agricultural land, and b) support for

hedgerow plantation and maintenance through the AECMs. The agroforestry plan also focuses on developing R&D, training and farm advisory (MAAF, 2015).

e) Seed and sustainable agriculture (2011)

This plan defines concrete action to help the seed industry enhance the sustainability of its modes of production, and foster environmental protection, adaptation to climate change and development of crop biodiversity. It can contribute to limit N₂O emissions by supporting the selection of low-nitrogen plant cultivars and improving resources in terms of leguminous seed varieties (MEDDE, 2017b).

f) Teaching to produce differently (2014-18)

Four-year educational programme supporting the transition of agricultural systems towards agroecology. It focuses on agricultural education and training in alternative production methods that are more economically and environmentally sustainable. This type of programme can contribute to the reduction in GHG emissions in French agriculture by disseminating environmental knowledge and best-practices among students, teachers and agri-professionals (MAAF, 2014b).

2. Economic and Environmental Interest Groups (EEIGs) (2014)

EEIGs are voluntary groups of farmers organised around a multi-year shared project aimed to improve the economic, environmental and social performance of agricultural practices. Set up by the 2014 *Law on the Future of Agriculture, Food and Forestry*, EEIGs contribute to the implementation of the French agroecology project. Therefore, projects' actions must be in line with agroecology principles.

EEIGs benefit from increased aid allocation or preference for aid allocation. Funding comes from European funds (ERDF), the state, local authorities or public bodies (French energy and water agencies for instance). As of February 2018, there were 477 EEIGs granted recognition, gathering 7,500 farms and 9,000 farmers (Chambres d'Agriculture France, 2018).

3. The High Environmental Value Certification (HEV) (2012)

The HEV is a voluntary certification scheme which aims to promote environmentally friendly practices applied by farms. The HEV covers four key areas: a) biodiversity conservation, b) plant protection strategy, c) management of fertilizer use, and d) water management.

Labelling is conditional on the implementation of a number of practices that have a positive impact – or apply minimum pressure- on the environment (i.e. on air, water, soil, climate, biodiversity and landscape). It is also based on a set of quantitative performance indicators; with predefined levels to be met. The certificate is delivered following a farm assessment by an independent certifier body and is valid for a period of three years (MAAF, 2017).

This certification scheme can contribute to GHG mitigation mainly through its criterion relative to fertilizer use which has a direct impact on N₂O emissions. The implementation of practices to enhance biodiversity such as maintenance of permanent grassland or the establishment of ecological surfaces can also mitigate agriculture GHG emissions through increased soil carbon capture/storage (MEED, 2017b).

As of 1st January 2019, there were 1,518 HEV farms in France (MAAF, 2019). HVE farms are mainly horticulture, arboriculture, wine growing and arable farms. To date, there is a relatively low number of livestock farms involved in this labelling process (MAAF, 2017).

Monitoring of the NLCS targets

The first carbon budget—which ended in 2018—was evaluated before the NLCS review. In 2016, emissions from the agricultural sector were 3% above the target defined by the NLCS at 90 MtCO₂e; 40% of which was N₂O and 46% CH₄ emissions. The main reasons for this gap were: an increase in the sale of mineral nitrogen over the period 2014-16 (+ 13000 tonnes); and an increase in livestock number (in particular suckler cows' population was 10% above the reference scenario in 2015) (MTES, 2018). According to the French Energy Agency, agricultural GHG emissions in 2033 will only be 14% below 2015 levels if no additional measures are implemented (MEDDE, 2018).

Industry-led initiatives directly targeting agricultural emissions

Life Carbon Dairy (2013)

In 2013, the livestock institute launched Life Carbon Dairy in collaboration with the French Dairy Interbranch Organization, France Conseil Elevage and the Chamber of Agriculture. The project aims to reduce the carbon footprint of dairy production by 20% over ten years and to develop a climate roadmap for the dairy sector. Supported by EU funds and by the Ministry of Agriculture, this project led to the creation of CAP'2ER, an environmental assessment and decision support tool. CAP'2ER provides the following environmental indicators at the farm level: GHG emissions, energy consumption, biodiversity conservation, water and air quality, and carbon storage. As part of the project, carbon footprint assessment of 3,900 dairy farms spread across 6 French regions has been performed using CAP'2ER. On average, between 2013 and 2016, Carbon Dairy farms had reduced their environmental footprint by 6% and their GHG emissions by 4%; mainly due to a reduction in input use (Brocas, Danilo, 2018).

Due to its success, the programme has been extended to all the territory in 2015 under the name “the low carbon dairy farm”. To date, environmental assessment has been performed in 8,526 dairy farms. It has been estimated that if the 60,000 French dairy farms took part in this process it could cut GHG emissions by 2 Mt of CO₂e over 10 years (CNIEL, 2019).

In addition, similar actions are taken in other livestock sectors. In 2016, France, Ireland, Spain and Italy launched *Life Beef Carbon*; an initiative which aims to reduce beef carbon footprint by 15% over 10 years in four major European beef producers' countries. Carbon footprint assessment of 2,000 pilot farms will be performed using the CAP'2ER tool. In addition, 170 farms (125 of which are located in France) will be closely monitored for 5 years and used to test and promote innovative mitigation practices in the beef sector (IDELE, 2015).

Research, development and innovation projects

France is investing in a number of research, development and innovation projects through its national programme for agricultural and rural development (NPARD), which is funded by a tax on farms turnover.²³ The NPARD funds multi-year projects, transversal actions and pilot projects to foster innovation and good practices in the agricultural sector. It is part of the implementation of the French agroecology project (MAAF, 2018b).

In particular, the NPARD is funding the joint technology networks (JTNs), created in 2006 by the Ministry of Agriculture. JTNs are scientific and technical partnerships aim to enhance collaboration between research,

²³ In 2017, the annual budget of the NPARD was 133 million.

technical institutes, and agricultural education institutions on socio-economic and environmental topics. The network acts as a collaborative R&D project incubator. As of January 2019, there were 22 JTNs benefiting the agricultural sector; a number of them contribute to agricultural GHG mitigation. This is the case of the livestock and environment JTN (2014-19) which aims to reduce the environmental footprint of livestock production. It focuses on the development and use of environmental assessment methods and tools, on emissions reduction from manure management, and on ways to improve nitrogen, carbon and phosphorus recycling (IFIP, 2014). The JTN fertilisation and environment (2007-19) also has an important mitigation potential. Its objective is to identify methods and tools for the sustainable management of biogeochemical cycles and soil fertility in the main French cropping systems, and to encourage their adoption through training, knowledge sharing and transfer. This led to the development of two nutrient management tools: Syst’N and AzoFert (MAAF, n.d)

In addition, various JTNs focus on agroecology, agroforestry, biodiversity and agriculture, and organic farming which can all contribute to GHG emission reductions and increased carbon sequestration. The National Institute of Agronomic Research (INRA) also started, in 2018, a multi-year research programme on organic farming (annual budget of EUR 500,000) (INRA, n.d).

THE UNITED-STATES

Background on US agricultural GHG emissions

According to the US Environmental Protection Agency, agriculture generated 541.2 Mt of CO₂e of GHG emissions in 2016, accounting for 8.3% of national emissions. In contrast, the LULUCF sector was a net sink of 738 Mt CO₂e in 2016. The majority of agriculture's emissions were N₂O from agricultural soils (50%), followed by CH₄ from enteric fermentation (32%), then CH₄ but also N₂O from manure management (15%). Agricultural emissions have increased by 5% between 2005 and 2016 (U.S EPA, 2018).

Federal policies and programmes that affect agricultural emissions

At the federal level, agri-environmental programmes provide funding for the conversion of environmentally fragile cropland to approved conservation uses, including long-term retirement. These programmes also reward crop and livestock farmers for the implementation of conservation practices that reduce environmental pressures such as cover crops and prescribed grazing (e.g. the Conservation Reserve Program). Since the enactment of the 1985 Farm Act, eligibility for most federal commodity programme payments is subject to the establishment of an individual farm plan to protect highly erodible cropland and wetlands. The 2014 Farm Act restored the conservation compliance eligibility requirement for crop insurance premium subsidies that was removed in 1996. The US Department of Agriculture (USDA) also helps farmers mitigate GHG emissions and adapt to climate change by providing educational, technical and financial assistance through various conservation practices and programmes. Beside conservation measures, the USDA supports voluntary actions to reduce CH₄ emissions through agricultural biogas production (USDA, 2014).

The US initially committed to an economy-wide reduction in its GHG emissions of 25-28% below 2005 levels by 2025, in its Nationally Determined Contribution (NDC) submitted to the UNFCCC in 2016. All UNFCCC national inventory sectors were covered by this commitment, including the agriculture and LULUCF sectors. However, in June 2017, the US withdrew from the Paris Agreement.

Background on California agricultural production, GHG emissions, and related policy challenges

Individual states have markedly different mitigation targets, policies and support programmes. Within the scope of this report, we focus on California because it is one of the most ambitious states regarding its progress on implementing mitigation policies in the agricultural sector. In addition, California is of particular interest for New Zealand as it is a significant milk producer and a potential export competitor. California's most ambitious mitigation policies in agriculture target the dairy sector.

According to California Air Resources Board (CARB), agriculture generated 33.8 Mt CO₂e of GHG emissions in 2016, accounting for 8% of state-wide emissions. The majority of agriculture's emissions were CH₄, but also N₂O from manure management (34%), followed by CH₄ from enteric fermentation (33%), then mainly N₂O from agricultural soils (17%). Agricultural emissions have increased by 7% between 2000 and 2016. A notable feature of the agricultural emissions profile in California is the dominance of dairy cattle production, which is responsible for 60% of agricultural GHG emissions. GHG emissions from dairy manure management and enteric fermentation increased by 24% over the period 2000-16 (CARB, 2018).

California accounts for 6% of national agricultural GHG emissions. It is the state with the highest number of dairy cows in the US and the highest dairy CH₄ emissions from manure management and enteric fermentation. Due to the widespread use of flush water lagoon systems for collecting and storing manure, California also has higher per-milking cow CH₄ emissions than most US states. However, milk production feed efficiency at California dairies is among the best in the world, resulting in relatively low enteric CH₄ emissions per gallon of milk (CARB, 2017a).

California's mitigation targets and policies directly targeting agricultural emissions

CARB Offset Credit Scheme (2011)

In 2005, Governor Arnold Schwarzenegger issued Executive Order (EO) S-3-05 which sets the target of cutting state-wide GHG emissions by 80% by 2050 (from 1990s levels). Since then, some shorter-term emission reduction targets have been established. In particular, *California Global Warming Solutions Act* (Assembly Bill No. 32, 2006) sets the target of bringing GHG emissions (including CH₄ and N₂O) to 1990 levels by 2020 with maintained and continued reductions post-2020. A decade later, EO B-30-15 (2015) and Senate Bill 32 (2016) established a new state-wide goal: reduce GHG emissions by 40% by 2030 (from 1990 levels). Finally, in September 2018, Governor Jerry Brown issued EO B-55-18 which aims to achieve carbon neutrality no later than 2045 (Poloncarz and Levine, 2018)

The main instrument to achieve these GHG emission reductions is a *cap-and-trade programme* managed by the CARB. The programme covers electricity generators and large industrial facilities since 2013, and distributors of transportation, natural gas, and other fuels since 2015. As part of this programme, an *offset credit scheme*, allows companies to cover a share of their emissions by credits offset purchases. Up to 8% of the compliance obligation of capped companies can be met with offset credits until 2020, down to 4% for the period 2021-25, and 6% between 2025-30. Credits offset purchase is restricted to projects in five areas including dairy digesters and rice cultivation. Emission-reduction projects should be located in the US and starting from 2021 half of the offsets purchased should come from projects located within the state of California (Center for Climate and Energy Solutions, n.d).

Compliance offset protocols developed by the CARB provide methods to quantify, report, verify, and credit GHG emission reductions from offset projects. Registered projects must be verified by an independent third party as adhering to criteria established in the project protocols. After a project has been positively verified and approved, it is officially registered and can issue offset credits; one offset credit equals to the removal of 1 tCO₂e.

1. Livestock projects

The first livestock offset protocol has been adopted in 2011 and revised in 2014. It credits operators who voluntarily install manure biogas capture and destruction technologies. Dairy cattle and swine farms installing methane digesters to capture emissions from manure and convert it to energy, can thus produce offset credits to sell into the state cap-and-trade market. The protocol focuses on quantifying the change in CH₄ emissions but also accounts for the effects on CO₂ emissions.²⁴ Avoided N₂O emissions are not accounted for under this protocol (CARB, 2014). Since 2014, more than 80 livestock digesters compliance projects have been completed, generating 3.9 million offset credits. About 17% of these projects are based in California. An additional 1.7 million offset credits have been generated by early action projects (CARB,

²⁴ The protocol quantifies CH₄ emissions from: waste treatment and storage, from the anaerobic digester due to biogas collection inefficiencies and venting events, from effluent pond, and from combustion; and CO₂ emissions from support equipment, and from vehicles for land application and/or off-site transport.

2019a).²⁵ Moreover, since 2015, CARB allows Low Carbon Fuel Standard (LCFS) credits for production of vehicle fuel derived from biogas to count toward avoided dairy CH₄ emissions, using the Livestock Offset Protocol. These credits have dramatically increased the financial viability of anaerobic digester investments – with ARB (Air Resources Board) offset credits worth only one tenth of the value of LCFS credits (Lee and Summer, 2018).²⁶ However, fuels produced using manure types not included in the protocol (poultry and beef cattle manure for instance) do not qualify.

2. Rice cultivation projects

The first rice cultivation protocol—adopted in 2015—allows compliance offset credits to be issued for CH₄ emission reductions associated with changes in rice cultivation practices in California and mid-south rice growing regions fields. In particular, three type of rice cultivation activities are eligible under this protocol: a) dry seeding, b) early drainage in preparation for harvest, and c) alternate wetting and drying activities (CARB, 2015). Already, 21 growers on more than 22,000 acres in three different states have signed up to participate in rice cultivation projects (EDF, 2019).

3. Grassland management projects

The Climate Action Reserve—one of California’s offset project registries—recently developed a voluntary grassland protocol which offers farmers and ranchers payment for conservation activities and avoided conversion of grasslands to croplands, thereby protecting carbon stocks. The Reserve also developed a nutrient management protocol which rewards farmers for implementing nitrogen management best-practices leading to N₂O emission reductions. The two protocols have been approved in January 2017 and October 2018, respectively (Climate Action Reserve, n.d).

This offset credit scheme enables emission reduction and technological innovation in the agricultural sector and other outside-of-cap sectors (forestry for instance). In addition, it increases flexibility in the state cap-and-trade market by giving regulated entities another option for compliance and reduces compliance cost as offsets credits are often cheaper than emission allowances (IETA, 2015).²⁷ Since the implementation of the cap-and-trade programme, too few offsets credits have been generated to meet the growing demand.

While California it is on track to meet its 2020 target (i.e. reduce its GHG emissions to 1990 levels by 2020, as specified in the Global Warming Solutions Act), emission reductions will have to increase dramatically for California to meet its 2030 and 2050 commitments (i.e. cut GHG emissions by 40% by 2030 and by 80% by 2050, from 1990 levels), and even more for achieving carbon neutrality by 2045.

²⁵ Voluntary offset projects that have been issued offset credits by approved voluntary registries for GHG reductions that occurred between January 1, 2005 and December 31, 2014 may be eligible to be issued CARB offset credits. These projects are referred to as early action offset projects. Early action projects must meet specific requirements of the cap-and-trade regulation.

²⁶ LCFS is California’s cap and trade scheme for transportation fuels, where fuels are assigned a carbon intensity (CI) that varies depending on their feedstock and how they are produced or manufactured. Producers of fuels with a CI under the annual cap earn credits while producers of higher-carbon fuels like gasoline and diesel incur deficits and are required to buy offsetting credits to meet the annual average CI value. The large price differential between ARB and LCFS credits can mainly be explained by their link to different schemes.

²⁷ This is the case because: a) emission reductions can often be generated less expensively outside of the cap, b) of the risk of invalidation of offset credits the latter are often sell at a discount price compared to allowances. Invalidation can occur - even after offsets have been surrendered for compliance- in case of failure to comply with a given protocol.

Senate Bill No. 1383 on Climate Short-Lived Pollutants (2016)

SB 1383 sets state-wide 2030 emission reduction targets for methane, anthropogenic black carbon, and hydrofluorocarbons gases. In particular, SB 1383 sets the target of cutting dairy and other livestock manure-sourced CH₄ emissions by 40% by 2030 (from 2013 levels). Enteric CH₄ emissions are not covered by this target. The regulation will be phased in the beginning of 2024, however, monitoring and reporting of manure-based CH₄ emissions could start by 2020.

The first short-lived climate pollutant (SLCP) reduction strategy—published in 2017—provides specific direction for CH₄ emission reductions from dairy and livestock manure operations. It focuses on the modification to manure management practices, and particularly on: a) switching from flush water lagoon system to anaerobic digesters or other systems such as solid manure management practices, b) fostering pasture-based dairy management, and c) installing anaerobic digestion systems to produce pipeline-injectable biomethane or renewable natural gas (CARB, 2017a).

The underlying changes to manure management practices will be encouraged through financial incentives, collaboration with the industry to overcome technical, market and regulatory barriers to the development of emission-reduction projects, policies to encourage renewable natural gas production and other market support measures. In particular, SB 1383 calls on CARB to establish energy infrastructure development and procurement policies needed to encourage dairy biomethane projects and calls on California Public Utilities Commission (CPUC) to direct gas companies to implement five dairy biomethane pipeline injection pilot projects. CARB is also required to develop a pilot financial mechanism to reduce the value uncertainty of LCFS offset credits from dairy-related projects and to expand the mechanism to other biogas sources. CDFA estimates that at least USD 100 million/year will be needed over the period 2019-24 to support the development of necessary manure management infrastructure in the form of grants, loans and other incentives (CARB, 2017a).

The strategy also encourages voluntary CH₄ emission reductions from enteric fermentation even if these emissions are not covered by the regulation. Due to the absence of “cost-effective and scientifically valid methods” for reducing enteric CH₄, the focus is put on research and demonstration projects.

Since 2017, USD 250 million—coming from the cap-and-trade programme’s revenues—have already been spent on CH₄ emission reductions from dairy and livestock operations through the Alternative Manure Management and Dairy Digester programmes (see section below). SB 1383’s CH₄ emission reduction target—together with reduction targets for other SLCPs—will assist California in meeting its 2030 GHG emission reduction commitment.

Other policies with indirect impact on agricultural emissions in California

Climate Smart Agriculture programmes

Under the California Climate Investment (CCI) incentive, funding from the cap-and-trade auction proceeds has been used to support a wide range of programmes that contribute to GHG mitigation and deliver other economic, environmental and social benefits. The Legislature allocates money from the Greenhouse Gas Reduction Fund (GGRF) to state agencies for implementing those GHG-reduction programmes (CARB, 2019b). The GGRF revenues currently fund the following climate smart agriculture programmes:

1. The Alternative Manure Management Program (AMMP) (2017)

The AMMP, which is managed by California Department of Food and Agriculture (CDFA), provides financial assistance to California dairy and livestock operations for the implementation of non-digester manure management practices that result in CH₄ emission reduction and other environmental co-benefits. Eligible practices for funding include: composting manure, shifting from liquid flush system to dry scraping, advanced solid separation and improved pasture management. To date, 58 AMMP projects have been funded for a total of USD 31.2 million. These are expected to reduce GHG emissions by 716.8 kt of CO₂e over a 5-year period. Available funding for 2019 will range between USD 19-30 million, with a maximum of USD 750 000 awarded per project. Starting this year, funding will also be available for demonstration projects under the AMMP (CDFA, 2019a).

2. The Dairy Digester Research and Development Program (DDRDP) (2017)

CDFA's DDRDP awards grants for the installation of dairy digesters in California that result in long-term CH₄ emission reduction and minimize adverse environmental impacts. Projects must use methane for renewable energy production or transportation fuel. Current DDRDP projects are expected to lead to a reduction in GHG emissions of 12.9 Mt of CO₂e. Since 2017, significant GGRF revenues have been allocated to the DDRDP; with funding in the order of USD 61-75 million available for 2019 for instance (CDFA, 2019b). However, despite strong government support for the installation of dairy digester in California this technology has not yet experience wide-spread adoption. As of April 2018, there were 20 dairy digesters in operation and six new digesters should open in 2019 (Lee and Summer, 2018).

Both the AMMP and the DDRDP will support the 40% manure-sourced CH₄ emission reduction target set by SB 1383.

3. The Healthy Soils Program (2017)

The programme provides financial incentives to California farmers and ranchers for the implementation of agricultural management practices that sequester carbon, reduce GHG emissions and improve soil health. The most popular practices incentivised thus far are cover crops, compost, mulch, and hedgerow plantings. Since its implementation in 2017, the Healthy Soils Programme has funded 112 projects—including 28 demonstration projects—for a total of USD 6.3 million. In 2019, some USD 15 million will be available—of which USD 5 million are coming from the GGRF—with project grants of up to USD 75,000 per operation. New eligible practices under the 2019 programme include prescribed grazing, application of compost produced on-farm, conservation crop rotation, and range planting (CalCAN, 2019a).

4. The Sustainable Agricultural Lands Conservation (2015)

The programme focuses on GHG emission reductions associated with the conservation of agricultural lands by protecting at-risk agricultural lands from sprawl development. In particular, the GGRF provides funding for permanent agricultural easements on agricultural lands at risk of development and funds local governments to improve farmland conservation policy and programme development. Since 2015, USD 124 million have been invested on 60 easement projects, protecting 90,000 acres of farm and rangeland at risk of urban sprawl or rural ranchette development. This programme could cut GHG emissions by 42 Mt CO₂e over 30 years (CalCAN, 2019b).

5. The State Water Efficiency and Enhancement Program (SWEEP) (2014)

The programme provides grants for the installation of irrigation and water-pumping systems that reduce GHG emissions (CO₂ mainly) and save water on California agricultural operations. Eligible system

components include: soil moisture monitoring, drip systems, switching to low pressure irrigation systems, variable frequency drives, pump fuel conversion and installation of renewable energy that power irrigation systems (solar panels for instance). Since 2014, grants have been provided to 614 projects covering over 113,994 acres for a total funding of nearly USD 63 million. According to CDFA, SWEEP projects have the potential to reduce GHG emissions by 75.4 kt of CO₂e per year and will help save over 101,050 acre-ft of water annually (CDFA, 2019c).

Assembly Bill No. 2377 (2018)

AB 2377 aims to provide technical assistance for farmers and ranchers seeking to implement sustainable farming practices that will lead to a reduction in GHG emissions. The bill requires that 5% of the annual budgets for the SWEEP, AMMP, and the Healthy Soils Programme is used to establish a technical assistance grant of up to USD 100,000 a year available for a maximum of three years. The bill focuses on technical assistance for small and moderately-scaled farms and ranches and demands that at least 25% of the funds available go to socially disadvantaged farmers. Technical assistance includes programme outreach, project design, application assistance, project implementation and reporting (CalCAN, 2019c).

California's research and innovation programmes

California is investing in a number of research programmes which aim to reduce N₂O and CH₄ emissions from agriculture.

In 2009, CARB implemented a N₂O research programme in collaboration with CDFA, California Energy Commission, and California Department of Resources Recycling and Recovery. The programme aims to improve California's N₂O inventory and explore alternative management options that can reduce N₂O and overall GHG emissions from California agricultural lands. The programme mainly focuses on N₂O emissions from nitrogen fertilizer application and explores mitigation strategies and conservation management practices. Since its creation, it has funded eight projects for a total of USD 2.9 million coming from the four state agencies involved. The programme ended in 2016 (CARB, 2017b).

CDFA is also funding various research programmes with important GHG mitigation potential. CDFA manages the *Fertilizer Research and Education Program* (FREP) which provides funding for basic and applied research, education, training and outreach on nutrient and water management practices. Since its creation in 1990, FREP has invested over USD 17 million on more than 220 research and education projects (CDFA, n.d). By promoting reasonable fertilizer use among farmers this programme can contribute to N₂O emission reductions.

The CDFA is also supporting research projects that address GHG mitigation through its *Specialty Crop Block Grant Program* (SCBGP). Results of funded research projects provide knowledge and tools to help growers reduce GHG emissions and increase carbon sequestration (CDFA, 2018a).

Finally, in 2018, CFDA awarded a USD 213,349 research grant to the California Dairy Research Foundation in collaboration with the University of California to study CH₄ emission reduction strategies at California dairies. The research project focuses on understanding the differences in manure management and CH₄ emissions strategies between large and small dairies. Researchers will also examine cost-saving techniques, evaluate emerging technologies, and investigate the economic impacts of methane regulations on California dairy farms. This research project will provide important knowledge to achieve the 40% CH₄ emission reductions set by SB 1383 in an efficient and appropriate manner (CDFA, 2018b).

CANADA

Paris Agreement and Nationally Determined Contributions - relevance to agriculture

Canada has committed to an economy-wide reduction in its GHG emissions of 30% below 2005 levels by 2030, in its Nationally Determined Contribution (NDC) submitted to the UNFCCC in 2015. All UNFCCC national inventory sectors are covered by this commitment, including the Agriculture and LULUCF sectors, although no sector specific targets have been set. The Canadian Government reviewed its climate change policies in 2016, in light of the 2030 emission reduction target and has developed a strategy covering opportunities for emission reductions across all sectors of the economy, including agriculture (see section on mitigation policies).

Background on agricultural GHG emissions

According to Canada's most recent national GHG inventory report, agriculture generated 60 Mt CO₂e of GHG emissions in 2016, accounting for 8.5% of national emissions. In contrast the LULUCF sector was a net sink of 28 Mt CO₂e in 2016. The majority of agriculture's emissions were CH₄ from enteric fermentation (42%), followed by N₂O from agricultural soils (40%), then mainly CH₄, but also N₂O from manure management (13%). Canada's agricultural emissions have decreased by 1% between 2005 and 2016 (Environment and Climate Change Canada, 2018).

Mitigation policies directly targeting agricultural emissions

Pan-Canadian Framework on Clean Growth and Climate Change (2016)

The Pan-Canadian Framework (PCF) sets the target of cutting national GHG emissions by at least 30% by 2030 (from 2005 levels); in line with Canada's NDC under the Paris Agreement. Carbon pricing is a considered as the main instrument to achieve these emission reductions. Provinces are given flexibility regarding which carbon pricing system they want to implement, but they are required by the federal government to set up a system that either prices carbon at CAD 10 per-tonne, rising to CAD 50 per-tonne by 2022, or that meets, under a cap-and-trade system, similar emission reductions. Four provinces—British Columbia, Alberta, Ontario and Quebec—already had a carbon pricing mechanism in place before the implementation of the PCF (Government of Canada, 2018).

The federal backstop is expected to cover about 80% of national emissions. The largest source of uncovered emissions is non-CO₂ emissions from the agricultural sector (Dobson, Winter and Boyd, 2018).²⁸ The

²⁸ At a minimum, carbon pricing should apply to substantially the same sources as British Columbia carbon tax (Government of Canada, 2018). British Columbia carbon tax applies to GHGs associated with the combustion of fossil fuels purchased or used within the province and to burning of combustibles -peat and tyres- to produce energy or heat.

proposed federal system provides exemption from carbon pricing for gasoline and diesel fuel used in farming activities. Similar exemptions already apply in British Columbia and Alberta (AAFC, 2018a).

The federal carbon pricing system will include emission trading and recognition of offset credits. The details of this system are still being developed; regulations should be implemented by spring 2019. Under the proposed federal backstop, a regulated facility that exceeds its annual emissions limit could buy eligible carbon offset credits from the agriculture sector. Credits can be generated from voluntary activities that go beyond “business as usual” practices. Two Canadian provinces already use agricultural carbon offsets as part of their cap-and-trade systems (see next section).

In addition to carbon pricing, the PCF promotes complementary measures to reduce GHG emissions. In the agricultural sector, it mainly focuses on (Government of Canada, 2018):

- Increasing carbon storage in agricultural land through land-use and conservation measures. The strategy encourages the adoption of land management practices like increasing perennial and permanent cover crops and zero-till farming.
- The development and adoption of new technologies to reduce emissions from livestock and crop production. The PCF mainly refers to the use of precision farming and smart fertilizers as well as feed innovation that reduce CH₄ emissions from cattle.

Provincial carbon offset schemes

Two Canadian provinces -Alberta and Quebec- already use agricultural carbon offset schemes as part of their cap-and-trade systems.

Since 2007, Alberta’s farmers can receive money from the sale of carbon offset credits in the province cap-and-trade market by voluntarily implementing agricultural practices that reduce GHG emissions or increase carbon storage in soils. The province currently has 12 agriculture-related offset protocols (Government of Alberta, 2017).

Four of these protocols quantify CH₄ emission reductions from enteric fermentation, and CH₄ and N₂O emission reductions from manure management, through:

- A reduction in the number of days required to get a feeder calf from birth to harvest under the Beef Reduced Age at Harvest protocol (2011).
- Selective breeding of cattle using a genetic marker for low residual feed intake under the Beef Law Residual Feed Intake protocol (2012).
- The implementation of innovative feeding practices and management strategies to increase feed use efficiency under the Reducing Emissions from Fed Cattle protocol (2016). Eligible practices include: performance tracking and cattle sorting improvements, feeding strategies and technologies, and genetic improvement.
- An increase in milk productivity per cow and in feed efficiency, retaining fewer replacement heifers and changes in manure management practices in Alberta dairy farms under the Dairy Cattle protocol (2010). This protocol also considers N₂O and CO₂ emissions reduction from feed production.

The Biogas protocol (2007) also quantifies reduction in CH₄ emissions from anaerobic digestion of animal manure, silage and dead animal stocks.

Finally, two protocols reward Alberta farmers for reducing N₂O emissions from agricultural soils. The Nitrous Oxide Emission Reductions protocol (2015) quantifies N₂O emission reductions from on-farm reduction of nitrogen sources such as fertilizer, manure and crop residues. The Conservation Cropping protocol (2012) quantifies N₂O emission reductions from soils under no-tillage management. It also takes

into account GHG emission reductions from new carbon stored annually in agricultural soils and CO₂ emission reductions from reduced fossil fuel use from fewer passes per farm field.

The other protocols cover CO₂ emissions reduction in the agricultural sector through improved energy efficiency and renewable energy generation.²⁹

Since the implementation of the cap-and-trade system, 13 million offset credits have been generated under the different agricultural offset protocols; one offset credit equals to the removal of 1 tCO₂e in GHG emission reductions. Farmers and intermediaries have earned up to CAD 170 million from the sale of these emission offset credits. Emission offsets were mainly created from reduced tillage management under the conservation cropping protocol, and by generating biogas energy from the digestion of cattle manure (Government of Alberta, 2017).

The price of offset credits in Alberta's carbon market depends on buyers' willingness to pay. An alternative option for regulated companies is to pay per t CO₂e reduction required into a fund dedicated to innovations that reduce GHG emissions. Between 2015 and 2017, carbon price for regulated companies choosing to pay into the fund increased from CAD 15 to CAD 30 (Government of Alberta, 2017).

Since 2015, Quebec also has one agriculture-related offset protocol as part of its cap-and-trade system which reward farmers for "methane destruction from covered manure storage facilities". However, it has not been taken up by any Quebec farmers yet. As of January 2019, no offset credits have been generated under this protocol (Gouvernement du Québec, 2019).

Other policies with less direct impacts on agricultural emissions

The Canadian Agricultural Partnership (CAP) (2018)

The CAP is a CAD 3 billion investment by federal, provincial and territorial governments over five years (2018–23) in the agri-food sector. The Partnership allocated CAD 1 billion to federal activities and programs; and CAD 2 billion to cost-shared programs delivered by provinces and territories to ensure that projects are tailored to meet regional needs (AAFC, 2019a). Environmental sustainability and climate change—including reductions in the sector GHG emission—is one of the six priorities of the CAP.

Federal-provincial investments are used to fund strategic programmes and initiatives in the agricultural sector, including some related to climate change mitigation. Environmental Farm Plans and Environmental Stewardship and Climate Change Programs are used to support on-farm actions in Canadian provinces to reduce the impact of agriculture on the environment and address climate change mitigation and adaptation issues. In particular, these programs help farmers to adopt environmental best management practices (BMPs) by providing payments for the implementation of eligible BMPs and supporting investments in: manure storage facilities; biodigesters; surface water management systems; low pressure nozzles and fuel efficiency upgrades; and equipment for precision nutrient application and reduced tillage seeding (Government of Alberta, 1995-2018), (Government of Yukon, 2018).³⁰

²⁹ Other offset protocols applying to the agricultural sector: Energy Efficiency (2007), Wind Powered Electricity (2008), Solar and Wind Micro-Generation (Distributed Renewable Energy Generation) (2013), Waste Biomass (2014), Biofuel Production and Usage (2014).

³⁰ Eligible BMPs include: implementation of grazing management strategies, improved land application of manure, improved nutrient management; with some variations between provinces.

Federal programs and activities focus on three priorities, including “innovative and sustainable growth” in the sector. This priority is supported by a CAD 690 million investment in two programs—AgriInnovate and AgriScience—over the period 2018-23. The AgriInnovate program (CAD 128 million) funds projects that aim to accelerate the commercialization, adoption and/or demonstration of innovative products, technologies, and processes or services that boost agri-sector competitiveness and sustainability. Priority areas for funding include the adoption of new or world-leading clean technology such as precision agriculture. The programme covers up to 50% of a project cost to a maximum of CAD 10 million (AAFC, 2019b). The AgriScience program (CAD 338 million) funds industry-led research that benefit the Canadian agri-food sector. A number of research clusters and projects funded under the program will address environment and climate change issues, including reduction in agricultural GHG emissions. Research projects will also deal with water and soil management issues, and the transformation of agricultural products into biofuels which can all contribute to GHG mitigation (AAFC, 2018b).

The Low Carbon Economy Leadership Fund (LCEF) (2017)

The LCEF provides CAD 1.4 billion to Canadian provinces that have adopted the PCF for investment in projects that reduce GHG emissions; including projects in the agricultural sector (Government of Canada, 2019). Under the LCEF, Ontario received almost CAD 420 million to support its Climate Change Action Plan, including helping farmers to reduce GHG emissions from their operations. Quebec has been attributed over CAD 260 million to expand actions under the province’s 2013-20 Climate Change Action Plan, including new investment to allow farmers to adopt agricultural best practices that reduce GHG emissions. Alberta received nearly CAD 150 million to support its climate objectives. Alberta’s funded projects will help Albertans, including farmers and ranchers, adopt energy efficiency measures and save money (AAFC, 2018a). Investments under the LCEF will contribute to a reduction in agricultural GHG emissions and support Canada in meeting its 2030 GHG emission reduction target.

Industry-led initiatives that affect agricultural emissions

The 4R Nutrient Stewardship

The 4R Nutrient Stewardship has been developed by the Canadian fertilizer industry in collaboration with the federal government, provincial governments, and academia. It establishes a set of BMPs that support improved nutrient use efficiency and environmental sustainability. More precisely, it provides recommendation for fertilizer application that match crops requirements and minimize nutrient losses from fields. This led to the so-called 4R concept: applying the Right Source of nutrients, at the Right Rate, at the Right Time and in the Right Place. Other complementary agronomic and conservation practices such as no-till farming and the use of cover crops are encouraged to support the 4R nutrient stewardship (Johnston and Bruulsema, 2014). The 4R Nutrient Stewardship has been promoted and applied across Canada through a number of provincial and regional programs and initiatives. It is currently being practiced in four Canadian provinces (Alberta, Manitoba, Ontario, New Brunswick, and Prince Edward Island) (Fertilizer Canada, 2019). By 2020, it is expected that 25% of Canada crop production (covering 20 million acres) will be covered by the program. It is also used outside of Canada.

Nitrogen-specific BMPs under the 4R Nutrient Stewardship have been proven to reduce GHG by at least 25% and increase growers’ profits by as much as CAD 87 per acre (Fertilizer Canada, 2018). The generation of carbon offset credits under Alberta’s N₂O emission reduction protocol is conditional on the implementation of a 4R nitrogen stewardship plan.

Research programmes

Agriculture and Agri-Food Canada (AAFC) manages the *Agricultural Greenhouse Gases Program* (AGGP), which funds research projects that help develop technologies, BMPs and processes that can be adopted by farmers to mitigate GHG emissions in Canada. It also contributes to increase farmers' understanding of GHG emissions. The AGGP focuses on projects that fall under the following priority areas: livestock systems, cropping systems, agricultural water use efficiency and agroforestry. The first phase of the program (2010-15) allocated CAD 27 million to fund 18 agricultural GHG mitigation research projects across Canada. In 2016, an additional CAD 27 million has been allocated to support 20 new research projects over a five year-period. Individual projects can receive up to CAD 2 million of support. The AGGP is Canada's domestic contribution to the GRA on Agricultural Greenhouse Gases (AAFC, 2017).

AAFC also supports research on agricultural GHG mitigation as part of the *Canadian Agricultural Adaptation Program* (CAAP) (2014-19). CAAP funds industry-led projects that help the agri-food sector to respond to emerging issues and develop new ideas, products and market opportunities.

In addition, AAFC performs research into reducing GHG emissions associated with agriculture at its different research centres (AAFC, 2014). AAFC research efforts led to the development of Holos software program. Holos is a free downloadable program that estimates CO₂, N₂O and CH₄ emissions from enteric fermentation, manure management, cropping system and energy use based on information entered for individual farms. This tool also enables to visualize the effect on GHG emissions from a change in farm management practices. Examples of these adjustments include changing livestock feed, reducing tillage or including perennial forages in rotation (AAFC, 2018c). The overall result is a GHG emission estimate for the whole farm that can help farmers identify possible ways to reduce their emissions. Holos is continually being updated with new data and improved features.

Finally, the Canadian federal government is funding a number of research and innovation projects with a focus on agricultural GHG mitigation as part of the CAP (AgriInnovate and AgriScience).

BRAZIL

Paris Agreement and Nationally Determined Contributions - relevance to agriculture

Brazil has committed to an economy-wide reduction in its GHG emissions of 37% below 2005 levels by 2025, in its Nationally Determined Contribution (NDC) submitted to the UNFCCC in 2016.³¹ All UNFCCC national inventory sectors are covered by this commitment, including the agriculture and LULUCF sectors although no sector specific mitigation targets have been set. In its NDC, Brazil considers large scale measures relating to land use change and forests as the one of the main channels to achieve this overall reduction in national emissions. Reductions in GHG emissions from the agriculture and LULUCF sectors have been supported by three national action plans (see below).

Background on agricultural production, GHG emissions, and related policy challenges

According to the Greenhouse Gas Emissions and Removals Estimates, agriculture generated 495 Mt CO₂e of GHG emissions in 2017, accounting for 24% of national emissions. The majority of agriculture's emissions were CH₄ from enteric fermentation (64%), followed by N₂O from agricultural soils (27%), then mainly CH₄, but also N₂O from manure management (4%). Overall, Brazil's agricultural emissions have increased by 28% between 2000 and 2017. In addition, the LULUCF sector was a net source of 955 Mt CO₂e in 2017, accounting for 46% of national emissions. Emissions from the LULUCF sector peaked at 2,903 Mt CO₂e in 2004, down to 886 Mt CO₂e in 2015. However, they started increasing again in 2015; by 12% over the 2015-17 period (SEEG, 2019).

National mitigation targets and policies for emissions from agriculture and LULUCF sectors

GHG emission reduction targets for the Brazilian agriculture and LULUCF sectors

At the 2009 15th COP to the UNFCCC in Copenhagen, Brazil voluntarily agreed to reduce its national GHG emissions by 36.1-38.9% by 2020 in relation to a baseline scenario.³² This was followed by the communication of its *Nationally Appropriate Mitigation Actions* (NAMAs) in Annex II of the Copenhagen Accord, which set out a number of specific actions that will help deliver this overall reduction in national emissions (Gebara and Thuault, 2013). These included: reducing deforestation in the Amazon and the Cerrado biomes, restoring degraded pastures, increasing the use of non-tillage farming, and increasing the use of biofuels (see details below).

Shortly after the COP, Brazil instituted these goals in Law No. 12.187/2009, establishing its *National Policy on Climate Change* (NPCC), which lays out sector-based emission reduction targets, as presented in Table 8. These include a reduction in agricultural GHG by 5-6% by 2020, and a reduction of 24.7% in GHG from the LULUCF sector (compared to projected BAU emissions in 2020).

³¹ Brazil also pledged an indicative target to reduce its GHG emissions by 43% by 2030 (compared to 2005).

³² Baseline scenario = projected GHG emissions in 2020 if no action is taken.

Under the UNFCCC, cutting GHG emissions is voluntary for developing countries.

In December 2010, the Brazilian Government approved Decree 7.390, which regulates the NPCC. Decree 7.390 states that the 2020 targets will be achieved through sectoral plans and initiatives. For the agriculture and LULUCF sectors, these include: a) the Low Carbon Emission Agriculture Plan (ABC Plan); b) the Action Plan to Prevent and Control Deforestation in the Amazon (PPCDAm), and c) the Action Plan to Prevent and Control Deforestation and Fire in the Brazilian Cerrado (PPCerrado). According to government's projections, the PPCDAm is expected to produce between 53.7-57.8% of the total committed emission reduction in 2020. The PPCerrado is expected to produce between 10.2-10.8%, and the ABC Plan between 12.5-16.8% (Gebara and Thuault, 2013).

Table 8. Voluntary agreement for the reduction of GHG emissions by sector, 2010-20

Sectors	Emissions (Mt CO ₂ e)			Total reduction (%)		Reduction (Mt CO ₂ e)	
	Estimate 2005	Projection 2020	Variation (%)	Target 36.1%	Target 38.9%	Target 36.1%	Target 38.9%
Change in land and forest use	1,268	1,404	10.7	24.7	24.7	801	801
Agriculture	487	730	49.7	4.9	6.1	159	199
Energy	362	868	139.8	6.1	7.7	199	248
Industrial processes, waste treatment	86	234	172	0.3	0.4	10	12
TOTAL	2,203	3,235	46.8	36.1	38.9	1,168	1,259

Source: Marques de Magalhães, Lunas Lima (2014)

Policies supporting GHG emissions reduction in the agriculture and LULUCF sectors

1. The Low Carbon Emission Agriculture Plan (ABC Plan) (2010)

In 2010, the Brazilian government launched the ABC plan to provide resources and incentives for farmers to adopt sustainable agricultural practices and technologies. The programme integrates the sectoral plans and targets set by Brazil in its NAMAs and its NPCC. The main objective of this plan is to reduce CO₂, CH₄ and N₂O emissions from agriculture. Besides actions to cut GHG emissions or increase carbon sequestration, the ABC plan establishes a support component for training technicians and farmers, financing for research and development, and monitoring of activities and results (Marques de Magalhães, Lunas Lima, 2014).

The central element of the ABC Plan is the ABC program, a credit initiative that provides low-interest loans to farmers who want to implement sustainable agricultural practices. Eligible practices include no-till agriculture, the restoration of degraded pasture, the planting of commercial forests, biological nitrogen fixation, treatment of animal wastes and the integration of crops, livestock and forest. The programme's ambitious goals encompass rehabilitating 15 million hectares of degraded pastures and increasing the area under zero tillage from 25 million ha to 33 million ha by 2020; as committed by Brazil in its NAMAs. Table 9 summarizes ABC plan's targets and estimated emission reductions associated with their full implementation. Overall, the programme is expected to cut GHG emissions by 133-166 Mt CO₂e/year by 2020.

A total of BRL 197 billion have been allocated to the ABC plan over the period 2010-20; of which BRL 157 billion must be available for rural credit (Marques de Magalhães, Lunas Lima, 2014). Funds are coming from the Bank of Brazil, the Brazilian Development Bank (BNDES), and private funds and banks. At its creation, the ABC programme offered credit of up to BRL 1 billion per beneficiary with an annual interest rate of 5.5% and a repayment period of 12 years. Credit conditions have evolved over time (Observatório ABC, 2017).

Table 9. The Low-Carbon Agriculture Plan strategies and targets

Strategy	Action	Target
No-till systems	The goal is to expand the current 25 million hectares under no-till systems to 33 million hectares.	Reduce GHG emissions by 16-20 Mt of CO ₂ e relative to projected 2020 levels
Degraded Pastures renovation	To transform degraded land into productive areas for the production of food, fibre, meat, and forests. The government aims to recover 15 million acres.	Reduce GHG emissions by 83-104 Mt of CO ₂ e relative to projected 2020 levels
Integrated crop-livestock-Forestry Systems	The system aims to integrate plant, animal, and forestry production in one system. This type of farming systems replenishes the soil, increases farm income, and creates jobs. The goal is to convert 4 million hectares, which are currently used for crops, to an integrated system.	Reduce GHG emissions by 18-22 Mt of CO ₂ e relative to projected 2020 levels
Planted Forests	Planted eucalyptus and pine trees provide future income to the producer and reduce carbon dioxide by releasing oxygen. The goal is to increase the area of 6 million hectares to 9 million hectares of planted forests.	Reduce GHG emissions by 8-10 Mt of CO ₂ e relative to projected 2020 levels
Biological nitrogen Fixation	The government aims to improve the method in the production of 5.5 million hectares.	Reduce GHG emissions by 10 Mt of CO ₂ e relative to projected 2020 levels
Animal waste treatment	Waste from pigs and other animals is collected and used to produce energy (gas) and organic compounds. The goal is to treat 4.4 million m ³ of waste from pig farming and other activities.	Reduce GHG emissions by 6.9 Mt of CO ₂ e relative to projected 2020 levels
ABC Plan		Reduce annual GHG emissions by 133-166 Mt of CO ₂ e relative to projected 2020 levels

Source: Gebara and Thuault (2013)

Note: Targets sets in the ABC Plan are the same than targets set by Brazil in its NAMAs (and its NPCC).

The uptake of the ABC programme has been slow. During the first years of its implementation, the value of contracted credits was far lower than available funds due to the small demand for ABC funds. Starting in 2012, programme uptake started increasing as more financial intermediaries became involved, the interest rate was reduced, technical capacity strengthened and dissemination of information about the programme improved (OECD, 2015). In 2012, 90% of available funds for rural credits have been disbursed. Since then, the number of signed contracts and funds disbursement rate have fluctuated and seem to be correlated with changes in interest rate. Overall, between 2010 and 2017, 54,194 ABC contracts have been signed for a total value of BRL 15.64 billion (correspond to a disbursement rate of 67%). In the past few years, funds available for ABC rural credit have been reduced (Table 10). ABC only accounts for a small part of the total funds available for agricultural credit and subsidies as part of the federal Agricultural and Livestock Investment Plan (CEA Consulting, 2016).³³

³³ For the year 2017-18, the Agricultural and Livestock Plan allocated a total of BRL 190 billion to rural credit, of which only 1% was attributed to the ABC credit programme (i.e. BRL 2 billion). The rest supported marketing policies, rural insurance subsidy, adoption of new technologies, investment in storage facilities etc (Presidency of the Republic of Brazil, 2017).

Table 10. Disbursement of ABC programme funds, 2010-18

Period	Interest rate	Funds available (in BRL million) (a)	Value of contracted credits (in BRL million) (b)	Disbursement rate (b/a)	Number of signed contracts
2010-11	5.5%	2,000	420	21%	
2011-12	5.5%	3,150	1,620	51%	4,808
2012-13	5%	3,400	3,050	90%	11,369
2013-14	5%	4,500	3,030	67%	12,103
2014-15	4.5-5%	4,500	3,660	81%	15,002
2015-16	7.5-8%	3,000	2,050	68%	6,353
2016-17	8-8.5%	2,900	1,810	62%	4,559
2017-18	7.5%	2,130	n.a		n.a
TOTAL		25,580	15,640		54,194

Source: Observatório ABC (2017)

A number of reports discuss reasons for the low uptake of the ABC programme, especially during the first years of its implementation. Identified barriers to the full implementation of the programme include: a) its poor marketing, b) excessive bureaucracy, c) producers' lack of knowledge about the potential benefits of adopting sustainable agricultural practices, d) the lack of technical assistance to train small and medium producers in sustainable agricultural practices, e) little understanding of the program by bank managers and producers, f) difficulty in getting access to credit, and g) too high interest rates compared to alternative programmes (IPAM, 2012).

Since the beginning of the programme, most of the resources available have been concentrated in the Central West and Southeast regions of the country due to the presence of a stronger technical assistance network resulting in greater interest and demand for the programme funds. In contrast, the North and Northeast regions of Brazil - which suffer from vast extension of degraded pastures and a relatively low efficiency of agriculture - have received the lowest share of ABC funds. Most of ABC funds have been invested in pasture recovery (61% in 2016-17), followed by no-till farming, integrated production systems and planted forest (Observatório ABC, 2017).

So far, only programme funds disbursement has been monitored by the ABC Observatory. There is no evaluation of the programme outcomes in terms of its impact on agricultural GHG emissions. However, based on the current rates of adoption of low carbon agricultural practices, Brazil is expected to fall short of its declared NAMAs targets for agriculture by 2020 (Newton et al, 2016) (Table 9).

In its NDC in 2016, Brazil expressed its aims to strengthen the ABC Plan as the main strategy for sustainable agriculture development, including by restoring an additional 15 million hectares of degraded pasturelands by 2030 and enhancing 5 million hectares of integrated cropland-livestock-forestry systems by 2030.

2. The Action Plan to Prevent and Control Deforestation in the Amazon (PPCDAm) (2004)

Targets of the PPCDAm

The PPCDAm was launched in 2004, at the time when deforestation in the Amazon forest was growing significantly. In 2004, deforestation rate in the Amazon reached a historical peak at 27,772 km² up from 18,165 km² in 2001 (Ministério do Meio Ambiente, 2018b). The PPCDAm aims to achieve continuous reduction in deforestation rates in the Amazon. Research demonstrates that cattle farming is responsible for the majority of deforestation in the Amazon biome (Ministério do Meio Ambiente, 2011).

In particular, the following targets have been set:

- Reduce deforestation by 20% between 2004 and 2007 i.e. during the first phase of the programme.
- In its second phase (2008–11), the PPCDAm targeted an 80% reduction in deforestation by 2020 relative to a 1996–2005 baseline; as set in Decree 7,390 regulating the NPCC.
- The third phase (2012–15) focused in areas with less than 25 ha by reinforcing actions of planning and territorial development and fostering sustainable land management activities.
- The fourth phase (2016–20) seeks to align the PPCDAm's objectives with Brazil's 2016 NDC and with the Forest code (see below). It also aims to implement economic and regulatory instruments to control illegal deforestation.

In addition, in its NAMAs, Brazil has committed to reduce its GHG emissions by 564 Mt CO₂e by 2020 through lower deforestation in the Amazon.

Programme's implementation

The PPCDAm's actions have been structured around three main axes:

1. land use, tenure and settlement planning,
2. environmental monitoring and control, and
3. promotion of sustainable production activities.

The first pillar involves instruments for spatial planning and management including the clarification of tenure through registers, cartographic data, and zoning plans, and the creation and consolidation of protected areas. In particular, efforts have been put to develop rural landholdings geo-referencing under the Terra Legal programme. The rewriting of norms aimed at land tenure regularization enabled to combat illegal appropriation of public land. Thousands of irregular land titles for rural properties have been withdrawn. Under pillar I, the PPCDAm also led to the creation of 50 million ha of federal and state protected areas - especially in municipalities under high pressure from deforestation – and the recognition of 10 million ha of indigenous lands between 2004 and 2015 (Ministério do Meio Ambiente, 2018a).

The second thematic line aims to strengthen environmental monitoring and control of deforestation and lands and to reinforce enforcement capacities. Under this pillar, existing systems for detecting deforestation such as PRODES have been updated and a new system, the real time deforestation detection system (DETER), has been developed.³⁴ In addition, sanctions against illegal deforestation have been strongly increased. The federal environment agency, the army and the federal police carried out hundreds of surveillance and inspection operations to detect fraudulent activities. Those resulted in fines or prison sentences for offenders, the seizure of illegally extracted wood and embargoes placed on land being used for illegal activities. The rural environmental registry (CAR) - which enables monitoring of deforestation at the property level - also facilitated effective accountability and punishment. Another important accomplishment under pillar II is the enactment of Central Bank Resolution No 3.545/2008 which made rural credit for agricultural activities in the Amazon biome conditional upon compliance with environmental legislation and legitimacy of land claims (Gebara and Thuault, 2013).

The third pillar seeks to incentivize sustainable production practices, support sustainable forest management, enhance agricultural productivity, and restore degraded areas. Actions under this pillar led to: a) the concession of 842,000 ha of public forests for forest management purposes, b) the issuing, by states, of environmental licenses for settlement projects, c) support to 51,000 families in sustainable land and forest

³⁴ DETER enables an analysis of deforestation dynamics based on satellite images, in intervals of less than 15 days.

management projects under the Bolsa Verde programme³⁵, d) subsidies to 60,000 families to maintain a guaranteed minimum price for natural rubber, Brazil nuts, Babassu and Piassava fibre (socio-biodiversity products) (Ministério do Meio Ambiente, 2018a).

The implementation of the PPCDAm involves the participation of more than a dozen of ministries under the coordination of the Executive Office of the President. Since 2004, more and more responsibilities have been transferred to state governments which have established their own action plans to control deforestation. The private sector has also been gradually involved in the implementation of the programme (Ministério do Meio Ambiente, 2011).

Programme's monitoring

Overall, the PPCDAm has been highly effective in curbing deforestation rate in the Amazon biome. Between 2004 and 2008, the annual deforestation rate fell by 58%, far above the 20% reduction target set for the 1st phase of the programme. Continuous fall in deforestation rates has been achieved after that with a 77% decrease between 2004 and 2011 (i.e. end of the 2nd phase) and an 80% decrease between 2004 and 2014. In absolute terms, this translates into a reduction in the deforested area from 27,772 km² in 2004 to 5,012 km² in 2014 (Ministério do Meio Ambiente, 2018b).

Lower rates of deforestation in the Amazon resulted in a drop in land use change emissions since 2004. The Brazilian government claimed that 610 Mt of CO₂ have been abated by 2017 through lowered deforestation in the Amazon forest. This suggests that Brazil has met its NAMA target (i.e. 564 Mt reduction in CO₂ emissions through lowered deforestation in the Amazon by 2020) 3 years ahead of schedule (Presidency of the Republic of Brazil, 2018a). However, deforestation rate will still have to fall by 20% between 2018 and 2020 for Brazil to meet its NPCC target (i.e. 80% reduction in deforestation relative to a 1996–2005 baseline).³⁶ Reduction in deforestation rates in the Amazon has also been associated with increased cattle production and productivity in priority municipalities as farmers shifted investment from deforestation to capital investments in farming (Kohl and al., 2019).

There is a consensus on the fact that most of the reductions in deforestation rates as part of the PPCDAm can be attributed to command and control actions carried out under pillar II of the programme. The Climate Policy Incentive estimated that they were responsible for the avoidance of 62,100 km² of deforestation from 2005 to 2009, representing 52% of the total deforestation that would have occurred in the absence of these policies. The remaining 48% of avoided deforestation can be attributed to falling agricultural prices (Assunção et al, 2015). The two other pillars of the programme have been implemented less effectively. It is possible that greater reduction in deforestation would have been achieved otherwise.

Nevertheless, there is evidence of a setback in Brazil's efforts to bring down its deforestation rate. Since 2013 some increases in deforestation rates have been recorded, resulting in an upsurge of LULUCF emissions (see section on GHG emissions). Between 2017 and 2018 for instance, deforestation rates in the Amazon biome increased by 13% (Ministério do Meio Ambiente, 2018b).

In its 2016 NDC Brazil has committed to strengthen policies and measures with a view to achieve zero illegal deforestation in the Amazon by 2030 and compensating for GHG emissions from legal suppression of vegetation by 2030.

³⁵ The Bolsa Verde programme was launched by the Brazilian government in 2011. Through this program, families who live in extreme poverty in rural areas can receive income in exchange for maintenance and sustainable use of natural resources. The program aims to provide additional income to 73,000 Brazilian families through the end of 2014.

³⁶ In 2018, the annual deforestation rate in the Amazon was 60% lower than the average over the period 1996-2005 (Ministério do Meio Ambiente, 2018b).

3. The Action Plan to Prevent and Control Deforestation and Fire in the Brazilian Cerrado (PPCerrado) (2010)

Context and targets

The rate of land cover change in the Cerrado biome has been extremely high in the last decades, even higher than in the Amazon. By 2009, the biome had already lost 48% of its forest cover (Gebara and Thuault, 2013). The main reason for forest loss is agriculture expansion, and in particular soybean production and cattle farming. The Cerrado contains 33% of the national cattle herd - with pasture being the most important form of land use change - and is responsible for over half of Brazil's soybean production (The World Bank, 2016). Other threats to the Cerrado biome include charcoal and mining. Wildfires are also a major issue. Although fire is a natural ecological phenomenon in the region, it has been increasingly used illegally by farmers and ranchers to clear natural vegetation (CEA Consulting, 2016).

Recent estimates indicate that deforestation and burning in the Cerrado between 2003 and 2008 resulted in the emission of 1,450 Mt CO₂e (including CH₄ and N₂O), of which conversion to pastures corresponds to 819 Mt CO₂e (or 136.5 Mt CO₂e/year) (The World Bank, 2016).

Launched in 2010, the PPCerrado aims to achieve sustained reduction in deforestation rate and to reduce the occurrence of forest fires and burning in the 2nd largest Brazilian biome. The PPCerrado is based on the National Program of Sustainable Use of the Cerrado and has been integrated into the NPCC. It targets a 40% reduction in deforestation by 2020 (based on the 2002–08 baseline); as set in Decree 7.390 (Gebara and Thuault, 2013). In its NAMAs, Brazil also committed to reduce its GHG emissions by 104 Mt CO₂e by 2020 through lower deforestation in the Cerrado biome.

Programme's implementation

Inspired by the successful experience of the PPDCAm, actions under the PPCerrado are distributed around three pillars:

- 1- Monitoring and control,
- 2- Protected areas and land use planning, and
- 3- Promotion of sustainable activities, including environmental education as a transversal component

The plan is managed by an executive commission which comprises representatives from 17 ministries and is coordinated by the Executive Office of the President. It also involves joint actions and partnerships between the different governmental levels, the private sector and academia.

The first phase of the plan covered the period 2010-11. A revised version of the PPCerrado was launched in 2014 which mainly renewed the commitments of the initial version. In December 2016, the 3rd phase of the project was launched together with the 4th phase of the PPCDAm. It covers the period up to 2020.

The main objective of the PPCerrado's was to establish a satellite-based monitoring system for deforestation and degradation in the Cerrado biome. Unlike in the Amazon, attempts to monitor deforestation in the Cerrado are relatively new. In addition, monitoring in the Cerrado is technically more complex as it is difficult to distinguish between land types in the mosaic savanna environment (CEA Consulting, 2016). The current effort by the Ministry of Environment to monitor forest cover change in the Cerrado suffers from limited financial resources and does not measure deforestation and degradation in real time and with the same level of accuracy than in the Amazon (The World Bank, 2016). Moreover, the government's plan to expand the Amazon's monitoring systems (PRODES and DETER) to the Cerrado biome have been delayed for years. Another objective of the plan under pillar I was to enhance prevention and control of forest fires. The existing system to monitor fires is robust and nearly instantaneous. However, capacity to respond to

fires is mixed and varies by area (CEA Consulting, 2016). Hundreds of command and control and inspection operations have also been carried out as part of the PPCerrado to fight illegal deforestation, resulting in fines in the amount of BRL 75 million between 2010 and 2015 (Ministério do Meio Ambiente, 2018).

Actions under pillar II aims to improve territorial planning by promoting sustainable land use alternatives. This includes actions to create and to consolidate conservation units (i.e. protected areas) and indigenous lands, water resources planning, and the development of an ecological-economic zoning for the biome. Between 2010 and 2015, 14 territorial and environmental management plans have been implemented on indigenous lands. These include support to 18,000 indigenous families in environmental and territorial management projects such as the implementation of agroforestry systems (Ministério do Meio Ambiente, 2018).

Between 2010 and 2015, the following results have been achieved under pillar III of the PPCerrado: a) training of 13,133 producers in sustainable farming technologies, b) training of 2,400 families in forest and community management, c) support to 4,008 families in sustainable land and forest management projects under the Bolsa Verde programme, and d) subsidies to maintain a guaranteed minimum price for four additional Cerrado agricultural products (Ministério do Meio Ambiente, 2018).

Programme's monitoring

The main achievements of the PPCerrado over the period 2010-15 have been communicated before the implementation of the 3rd phase of the plan in 2016 (as described above). Overall, it seems that the 3rd pillar (i.e. promotion sustainable activities) has been most thoroughly implemented, while activities falling under the other pillars have been limited by a lack of financing (Gebara and Thuault, 2013). However, there is no monitoring of the effect of the PPCerrado on GHG emissions.

Data from INPE suggest that deforestation rates in the biome have been declining since the implementation of the programme. In particular, since 2016, the annual deforestation rate in the Cerrado has been more than 40% below the 2002-08 average, suggesting that Brazil has met its NPCC target (Presidency of the Republic of Brazil, 2018c).

In 2018, deforestation reached 6,657 km² in the biome, which corresponds to an 11% decrease in relation to the previous year. This is the smallest deforested area ever recorded in the Cerrado since the beginning of the time series. The deforestation observed in the Cerrado in 2018 is 33% lower than in 2010, the year of the implementation of the plan (Presidency of the Republic of Brazil, 2018b).

Other policies with indirect impacts on agricultural emissions

The Forest Code (1934)

Created in 1934, and revised in 2012, the Forest Code is considered as the main environmental law in Brazil. It regulates land-use and conservation to native vegetation on private properties. In particular, it establishes two main types of lands under environmental protection: permanent protection areas (PPAs) and legal reserves (LRs). The natural vegetation on PPAs should be preserved, meaning that it cannot be used for farming, grazing or any other agricultural activity. PPAs include riparian areas, springs, hilltops, mountain slopes, and mangroves. A LR is defined as a share of rural property, beyond PPAs, which should be set aside for sustainable or conservation activities. The percentage to be held as LR varies from 80% of the farm area in the Amazon to 20-35% in the Cerrado (depending on location), to 20% in the rest of Brazil (The World Bank, 2016). In the Amazon, requirement can be reduced to 50% if over 65% of the state's territory is protected by conservation units or indigenous reservations (Machado and Anderson, 2016).

The 2012 Forest Law involves the creation of the environmental rural registry (CAR); a public registry with data on rural properties and their compliance with the environmental requirements of the Forest Code. Landholders are required to register PPAs and LR on their land in the CAR. As of June 2016, 95% of Brazil's rural properties were registered in the CAR (CEA Consulting, 2016).

Medium and large landholders whose property lack the required amount of remnant vegetation must submit a regularization plan that details how they will achieve compliance. For LR, landholders must either restore degraded areas on the property itself or via an offset through a compensation process in areas of equivalent size in the same biome. Owners of PPAs that have been converted cannot use compensation as a compliance mechanism and must restore the PPA within 20 years (Machado and Anderson, 2016). Smallholders, family farmers and traditional communities are special beneficiaries of the Forest Code and receive, free of charge, government support to restore the degraded PPAs and LR on their lands, through technical assistance, environmental education, provision of seeds/seedlings and appropriate training. Compliance with the environmental legislation of the Forest Code is a prerequisite for small and medium producers to access rural credit available in the ABC Program (The World Bank, 2016).

Across Brazil, the Forest Code protects about 190 million ha of native habitat containing roughly 90 Gt CO₂e. The 2012 update to the Forest Code reduced "environmental liabilities" (i.e., areas that need to be restored) from approximately 50 to 20 million ha (CEA Consulting, 2016).

However, enforcement of the Forest Code has been a major issue. Inadequate enforcement of the regulation has led to the expansion of agriculture into areas not eligible for exploitation. It is estimated that nearly 30 million ha of PPAs and LR across the country require restoration to comply with the Forest Code; and currently over half of Brazilian landholdings (about 2.5 million farmers) are thought to be illegal (The World Bank, 2016). In its NDC, Brazil has considered the enforcement of the Forest Code at federal, state and municipal levels as a key mitigation measure. Indeed, if fully implemented, the Forest Code can contribute to up 1.03 Gt CO₂e (i.e. 85 Mt CO₂e/year) to the ambitious GHG emission reduction target set by Brazil for 2030 (Soterroni et al, 2018).

The National Policy on Agroecology and Organic Production (Pnapo) (2012)

The National Policy on Agroecology and Organic Production (Pnapo) was enacted in 2012 through a participatory process, in which civil society played a leading role. The main instrument for the implementation of Pnapo is the *National Plan for Agroecological and Organic Production (Planapo)*, which is revised every 3 years. The plan involves the participation of nine ministries and focuses on implementing programmes and actions to foster a transition towards organic and agroecological based production systems and promoting conservation and agricultural biodiversity. Planapo is targeted at small agroecological and organic farmers, indigenous and traditional communities, and other groups defined by the State as family farmers (FuturePolicy, 2019).

Its initiatives and targets are organized under four main axes: 1) production, 2) use and conservation of natural resources, 3) knowledge, and 4) marketing and consumption. For the period 2013-15, BRL 2.5 billion have been allocated to Planapo. Most of the budget has been used to support the following initiatives (FuturePolicy, 2019):

- a) The Segunda Agua Programme (BRL 1.4 billion), which supports the deployment of technologies for harvesting and storing rainwater for agricultural purposes on family farms in the Brazilian semi-arid region. It covers technical assistance and courses in managing simplified irrigation systems.
- b) The National School Feeding Programme (BRL 317 million), which supports schools' procurement of organic agricultural products from local farmers.

- c) ATER (BRL 489 million), which provides technical assistance and rural extension, with focus on agroecology.
- d) Education (BRL 109 million) and research (BRL 34 million) on agroecology and organic farming.
- e) Ecoforte (BRL 32 million BRL), a programme that aims to strengthen agroecology and organic farming networks throughout the country by providing direct financial support.
- f) Farmer training in agroecology and organic farming practices (BRL 25 million); and
- g) Seeds (BRL 34 million)

Other supporting policies includes: PRONAF (the National Programme for Strengthening Family Farming) and the Agricultural and Livestock plan's lines of credit which provided a total of BRL 7 billion of credit for agroecological production over the period 2013-15 (CEA Consulting, 2016); The Minimum Price Guarantee Policy (PGPM); and the Food Acquisition Program (PAA).³⁷

Some of the results achieved by the first phase of Planapo (2013-15) in advancing Brazil's agroecological agenda include: assisted 5,300 municipalities to spend 30% or more of their school meal programme budget on purchases of organic and agroecological products from family farmers (some municipalities even reach 100%); trained 7,722 technicians and 52,779 farmers to agroecology and organic farming practices; promoted 24 networks for agroecology; adapted 600 native seeds banks to semiarid conditions; and financed nine projects for seeds for agroecology (FuturePolicy, 2019).

In 2018, Brazil's Pnapo received the Future Policy Silver Award from the World Future Council in partnership with FAO and IFOAM. This award celebrates best policies to scale up agroecology. The Second phase of Planapo (2016-19), has added two strategic axes "land and territory", and "socio-biodiversity" to those already covered by the first cycle. However, it has been facing drastic budget cuts that have hampered its implementation (FuturePolicy, 2019).

Industry-led initiatives directly targeting agricultural emissions

The Brazilian Roundtable on Sustainable Livestock (GTPS) (2007)

The *Grupo de Trabalho da Pecuária Sustentável* (GTPS) was created in 2007 and was formally constituted in June 2009. It is formed by representatives of all actors of the cattle livestock's value chain; including producers, industries, organizations of the industry and associations, retailers, supplies and services providers, financial institutions, civil society organizations, research centres and universities. The goal of the GTPS is to discuss and formulate principles, standards and common practices for adoption by the beef cattle sector in Brazil, thereby contributing to the development of environmentally, socially and economically sustainable livestock production (GTPS, 2019). The GTPS is also part of the Global Roundtable on Sustainable Beef (GRSB), which has similar set of objectives and a broader global membership.

One of the main outcomes of the GTPS is the development of the Sustainable Livestock Indicators Guide (GIPS). It is an online assessment tool which enables users to test their own sustainability performance as well as the one of members of their value chain. It includes sustainability indicators related to: GHG emissions intensity of beef production (including emissions from land use conversion), soil conservation, water consumption, energy efficiency, waste treatment, air quality, deforestation, compliance with the Forest Code's requirements, etc (GTPS, 2016).

³⁷ The PGPM is an income-based policy for agriculture which provides farmers with a minimum revenue per unit of output. The PAA is a public procurement programme which facilitates government's purchases and distribution of agricultural products from local family farmers.

The GTPS also disseminates information on sustainable livestock value chains through training and activities, the organisation of events and meetings, and various publications.

Research programmes

The Brazilian Agricultural Research Corporation (Embrapa)—operating under the aegis of the Brazilian Ministry of Agriculture, Livestock, and Food Supply—conducts a number of research programmes that can contribute to GHG mitigation in the agricultural sector.

Embrapa has a climate change research's portfolio with over 60 projects which encompass: the elaboration of mitigation and adaptation strategies for agriculture, modelling of agroforestry systems, the analysis of social, economic, and environmental risks and sustainability with respect to global climate change. In addition, Embrapa contributes to Brazil's ABC Plan on low carbon agriculture by guiding scientific research on climate change and technologies. Many of Embrapa's decentralized units take part in technology transfer events and action as part of the programme (Embrapa, 2019b). Embrapa also develops technological solutions for low carbon agriculture in Brazil including granular organic mineral fertilizer made from chicken litter and the use of grass and legume (e.g. forage peanuts) mixtures on pastures.

Other research themes linked to the ABC plan include biological nitrogen fixation and Integrated Crop Livestock Forestry Systems. In addition, Embrapa performs research on precision agriculture and agroecological zoning (Embrapa, 2019a).

Embrapa is part of the organizing Committee of the 7th Greenhouse Gas and Animal Agriculture (GGAA) Conference, which will be held in Brazil in August 2019. The GGAA is an international event on GHG emissions generated by animal agricultural practices, which takes place every three years (7th International Greenhouse Gas and Animal Agriculture, 2019). Brazil is also a member country of the GRA on Agricultural GHGs.

CHINA

Paris Agreement and Nationally Determined Contributions - relevance to agriculture

China ratified the Paris Agreement on Climate Change on 3 September 2016. Its NDC includes a commitment to peak CO₂ emissions by 2030 at the latest, lower the carbon intensity of GDP by 60–65% below 2005 levels by 2030, increase the share of non-fossil energy carriers of the total primary energy supply to around 20% by that time, and increase its forest stock volume by 4.5 billion m³, compared to 2005 levels. While the NDC explicitly mentions agriculture, land-use change and forestry, among other sectors, no specific net-emission target has yet been set for the agricultural sector. The only specific quantitative target set for agriculture relates to achieving zero growth in fertiliser and pesticide utilisation by 2020. Other broad objectives concern controlling CH₄ emissions from rice fields and N₂O emissions from farmland, promoting comprehensive utilisation of straw or reutilisation of agricultural waste (UNFCCC, 2015; Climate Action Tracker, 2017).

Background on agricultural production, GHG emissions, and related policy challenges

According to the UNFCCC, agriculture in China generated 655.5 Mt CO₂e of GHG emissions in 2005, accounting for 11% of national emissions. In contrast, the LULUCF sector was a net sink of 421.5 Mt CO₂e in 2005. The majority of agriculture's emissions were CH₄ from enteric fermentation (37%), followed by N₂O from agricultural soils (25%), then mainly CH₄ from rice cultivation (20%), and CH₄, but also N₂O, from manure management (17%). Significantly, China's agricultural emissions have increased by 94% between 1994 and 2005 (UNFCCC, n.d). More recent estimates indicate that agriculture generated 938 Mt CO₂e of GHG emissions in 2012, accounting for 8% of national emissions. According to these more recent figures, the majority of agriculture's emissions were N₂O from agricultural soils (40%), followed by CH₄ from enteric fermentation (24%), then mainly CH₄ from rice cultivation (20%), and CH₄, but also N₂O from manure management (16%) (Dong Hongmin, 2018).

National mitigation policies targeting agricultural emissions

13th Five-Year Work Plan to Control GHG Emissions (2016-20)

The State Council released its 13th Five-Year Work Plan to Control GHG Emissions in October 2016. It sets the target of reducing CO₂ emissions per GDP unit by 18% by 2020 (compared to 2015 levels); in line with China's NDC commitment (LSE, 2016). The plan also looks to strengthen policies controlling for GHG emissions beyond CO₂, such as CH₄ and hydrofluorocarbons (HFCs). It also mentions reducing CH₄ emissions in the agricultural sector (NDRC, 2017).

The 13th Five Year Plan also aims to modernize agriculture production to reduce over-utilisation of land, while aiming to convert 1 million ha of marginal cropland into forest or grassland. In an effort to enhance carbon sequestration, the plan also aims to increase forest coverage to 23.04% over the next five years. Other targets set for the LULUCF sector include: stable arable land at 124.3 million ha by 2020; and ensuring that the grassland vegetation coverage reaches 56% by 2020 (LSE, 2016).

The national Emissions Trading Scheme (ETS) (2017)

In order to achieve reduction in its GHG emissions, China launched its national emissions trading scheme (ETS) in December 2017. However, its implementation will involve infrastructure development and simulation phases, before actual implementation commences (The World Bank, 2018). China's ETS will initially only cover CO₂ emissions from the power sector but, depending on the findings from these initial phases, it might be expanded to other sectors in the future. In addition, the scheme will include an offset mechanism. China informed the OECD that the agriculture sector is expected to be able to generate offset credits for their national ETS. However, at this stage, no further details about the specific GHG emission or abatement sources from agriculture have been provided (OECD, 2019).

Agricultural policies contributing to the mitigation of agricultural emissions

1. MOA's efforts to increase fertilizer use efficiency and foster the use of organic fertilizers

In China, fertilizer overuse is a major issue. The intensity of chemical fertilizer use grew at an average of 2.5% per year, increasing from 265 kg per ha in 2000 to 357 kg per ha in 2013. This use intensity far exceeds the internationally recognized standard to limit the use of fertilizer to 225 kg per ha (Jin and Zhou, 2018).

Since 2005, the MOA has been promoting actions to increase fertilizer use efficiency and foster the replacement of mineral fertilizers by organic alternatives. These include the development of soil test-based fertilization across country. By 2007, these actions had been taken in 1,200 counties to guide farmers in fertilization, and by the end of 2009 this practice had covered more than 1 billion Mu.³⁸ Excessive use of nitrogen fertilizer was reduced by 700 kt in wheat, corn and rape growing regions in 2009 (The People's Republic of China, 2014).

More recently, the MOA introduced its "Action to achieve zero growth in chemical fertilizer by 2020" (2015); in line with China's NDC commitment. It sets the target of achieving annual growth rates of chemical fertilizer use of less than 1% from 2015 to 2019 and strive to realize zero growth of chemical fertilizer use for principal crops by 2020.³⁹ A certain number of measures have been considered to meet this target, including (Jin and Zhou, 2018):

- a) Promote soil testing and formulated fertilization (i.e. fertilizer with a chemical balance tailored to local needs) on a larger scale. Unit area limits for fertilization will be set for each region and each crop according to soil conditions and crop yield potentials, in order to minimize blind fertilization. The MOA aims to have more than 90% of soil testing and formulated fertilization coverage by 2020.
- b) Promote improved fertilization methods by fostering the use of machines for deep fertilization to replace traditional methods of surface application and spraying. Strengthen technical training and guidance services on fertilization methods. The MOA aims to have more than 40% of crop acreage fertilized by machine (an increase of 10%) and to increase application area of integrated irrigation and fertilization to 150 million mu (growth of 80 million mu) by 2020.
- c) Promote application of new fertilizers and new techniques, through scientific research, education, and corporate resources. Increase investments in R&D and channels to access international advanced techniques.

³⁸ Mu is a Chinese unit of area measurement: 1 Mu = 666.7 m².

³⁹ Other policy documents promote reduce use of mineral fertilizers, including: The Agricultural Law (2002), the Environmental Protection Law (2015), the Agricultural Sustainable Development Program (2015–30).

- d) Promote the use of organic fertilizers by giving support to farmers to increase organic fertilizer use. In particular, the MOA sets the target of increasing livestock and poultry manure application rate by 10%, and straw application rate by 25%.
- e) Improve cropland quality, by implementing actions to enhance soil fertility and effectively control acidification, salinization, and pollution.

The plan also aims to enhance chemical fertilizer utilization rate⁴⁰ by at least 1% per year, and to bring the utilization rate of chemical fertilizer for main crops above 40% by 2020 (Jin and Zhou, 2018). In 2017, the national chemical fertilizer use rate of the three major cereal crops, paddy, corn and wheat was 37.8%, 2.6 percentage points higher than in 2015, and zero growth in chemical fertilizer use was achieved ahead of schedule (Ministry of Ecology and Environment, 2018).

In addition, the MOA is taking action to reduce mineral fertilizer use in fruit, vegetable and tea production/crops. In 2017, 100 demonstration counties have been established to foster the use of digestate fertilizers. Each county provides a CNY 10 million subsidy for the implementation of the pilot project (i.e. to conduct basic investigations, for investments in facilities incl. treatment, transportation, application, etc.). The MOA targets a 20-50% decrease in mineral fertilizer use by 2020 in fruit, vegetable and tea production areas (Federal Ministry for Economic Affairs and Energy, n.d).

MOA's efforts to reduce mineral fertilizer use in China's main crops should lower N₂O emissions from agricultural soils.

2. Development of agricultural biogas production in China

The MOA has also been supporting biogas production from treatment of livestock and poultry manure, from straw and agricultural processing waste. This can contribute to reduce manure-based CH₄ emissions. In addition, biogas digestate can be used as a replacement for mineral fertilizer thereby reducing N₂O emissions from agricultural soils.

Key supporting policies for biogas development in China include the 13th FYP on Agricultural Biogas Development in China (2017), and the 13th FYP on Bioenergy Development (2016). The *13th FYP on Agricultural Biogas Development Plan* sets ambitious targets for agricultural biogas expansion as described in Table 11. In particular, the MOA aims to reduce China's GHG emissions by 46 Mt CO₂-e/year by 2020 through increased agricultural biogas and digestate fertilizer production. *The Bioenergy development plan* aims to support bio natural gas production by establishing 160 demonstration counties by 2020. The plan sets the following targets in demonstration counties: increase solid digestate fertilizer consumption to 10 million tonnes and liquid digestate fertilizer consumption to 50 million tonnes by 2020; Bring straw utilization rate above 90% and livestock waste utilization rate above 95% by 2020. The plan also targets a decrease in ammonia nitrogen pollution of 10% (Federal Ministry for Economic Affairs and Energy, n.d).

In addition, in 2016, the MOA launched the *Circular on Announcing the Plan of Investment within the Central Budget for Large-scale Biogas Projects*, which aims to advance rural biogas transformation and upgrading. The plan actively promotes fuel utilization technologies as straw pyrolysis and gasification, straw biogasification, straw curing, and straw carbonization (OECD, 2018). As part of this plan, the MOA will provide a minimum of CNY 2 billion/year to support large scale biogas plants and biomethane projects until 2020 (Federal Ministry for Economic Affairs and Energy, n.d).

Overall, support for agricultural biogas production mainly takes the form of subsidies for the construction of biogas digesters/plants. Between 2003 and 2015, the MOA's construction subsidies for biogas plants

⁴⁰ This refers to the percentage of applied chemical fertiliser utilised by crops.

amounted to CNY 38.5 billion. There is also an output subsidy for electricity generated from livestock and poultry waste and agro and forestry waste (Federal Ministry for Economic Affairs and Energy, n.d).

Other policies are promoting enhanced livestock and poultry waste utilization. The *Work Plan for the National Project of the County-wide Promotion of Livestock and Poultry Excrement Resource Utilization* (2018-2020) launched the implementation of pilot projects for county-wide promotion of resource use of livestock and poultry excrement (Ministry of Ecology and Environment, 2018). *The Opinions on Accelerating the Promotion of the Livestock and Poultry Breeding Waste Resource Utilization* (2017) sets a 75% target for animal manure utilization rate by 2020 and aims to have 95% of small-medium scale animal farms and 100% of large-scale farms equipped with a manure treatment facility by 2020 (Federal Ministry for Economic Affairs and Energy, n.d). In 2017, the comprehensive utilization rate of livestock and poultry excrement reached 70%, and the comprehensive utilization rate of straws and stalks exceeded 82% (Ministry of Ecology and Environment, 2018).

Table 11. Targets sets in the 13th FYP on Agricultural Biogas Development in China (2017)

	Current value (2015)	Target value (2020)
BNG plants	25	197
Scale biogas plants	6,972	10,122
Small and medium scale biogas plants	103,476	128,976
Household digesters (in million)	41.93	43.04
Biogas production (in billion m ³)	15.8	20.7
Digestate fertilizer production (in million tonnes)	71	97.51
Agricultural waste treatment capacity (in million tonnes/year)	2,000	2,080.47
CO ₂ reduction (in million tonnes/year)	28.6	46.22

Source: Federal Ministry for Economic Affairs and Energy (n.d)

3. Promotion of conservation tillage and non-tillage to increase carbon stocks

Since the beginning of the 2000s, the central government has promoted the adoption of conservation tillage through technological innovation and the establishment of demonstration pilot projects in a number of Chinese provinces. The government has been considering providing a subsidy for the adoption of conservation tillage or non-till practices if the environmental benefits observed in demonstration provinces appear to be great enough (Wang, Huang, and Rozelle, 2010).

4. Efforts to reduce methane emissions from rice cultivation

Rice cultivation is one of the major sources of CH₄ emissions in China. Research has demonstrated that irrigation methods used, and the type of rice varieties planted have a direct influence on the rate of CH₄ emissions from paddy fields. The Ministry of Water Resources and the MOA have both supported the expansion of intermittent irrigation over the past decade. Studies have found that compared with flood irrigation, adoption of intermittent irrigation can reduce CH₄ emissions by 30-46% (Wang, Huang, and Rozelle, 2010). Actions have also been taken to promote high-yield rice varieties with lower associated emissions, and rice cultivation in semi-arid areas (The People's Republic of China, 2014).

Other policies with indirect impacts on agricultural emissions

Environmental regulations for pig farming

Recently, the pig sector in China has been strongly impacted by a number of new regulations. The 2015 Environmental Law increased environmental requirements for pig farms and strengthen punishments for farms not meeting these new standards. As a result, many small and medium pig farms have been forced to close (Zhang, 2017).

In addition, the 2015 *Guidance on Adjusting and Optimising the Layout of Pig Farming in South China*, released by the MOA, requires a reduction in pig breeding in South China and the reallocation of some of these farms in the middle-west and north-eastern provinces. This regulation aims to address the environmental concerns in congested areas and waterways across the South, East and Centre of China (OECD, 2018). At the same time, the National Environmental Protection Department had strengthened its control over faecal pollution caused by breeding pigs; set higher requirements around farm infrastructure and imposed stricter rules on documents related to farm running (Zhang, 2017).

Between 2016 and 2017, more than 20 provincial governments set up Development Control Areas (DCAs) within their respective provinces, delineating the “environmental control zones” (or “forbidden zones”) where pig farming operations are prohibited. Preliminary information suggests that by July 2017, such operations conducted in DCAs across 10 provinces led to an overall 20 million heads of pig inventory reduction (OECD, 2018). It is not clear how much of this inventory was relocated or reduced in net terms. The relocation of pig farms to the Northeast is also supported by the MOA guidelines for “Accelerating the Development of Modern Animal Husbandry in the Main Grain Producing Areas of North-eastern China” issued in August 2017.

The designation of “forbidden zones” also affects cattle and poultry farms, although to a lesser extent than pig farms. In all three sectors however, the enforcement of the environmental regulations and farm relocations are pushing towards a consolidation of small- and medium-farms into larger operations which have increased access to capital to invest in environmental control systems and compliance with new regulations (OECD, 2018). It is possible that these improvements could also lower GHG emissions or emission intensities from livestock.

The Environmental Protection Tax (EPT) Law (2016)

The Environmental Protection Tax (EPT) Law took effect on 1 January 2018. The Law had been promulgated by the National People’s Congress (NPC) in December 2016, replacing the previous Pollutant Discharge Fees (PDF). The EPT Law provides guidelines for levying taxes on entities that emit air and water pollutants, solid wastes, as well as noise pollution. Local governments decide the tax rates to be levied, within a range defined by the central government. The tax applies to farms with more than 50 cows or 500 pigs, but it exempts small-scale farms and leaves margins for farmers to reduce their tax bill where pollutant concentration is kept below 50% of emission standards set by local governments (OECD, 2018).

The tax is levied based on the amount of effluent produced/discharged (nitrate levels). For pig farms for instance, the tax rate on water pollution amounts to RMB 1.40 per pig. Farms also face an air pollutant (i.e. ammonia) tax of RMB 1.20 per pollution equivalent (i.e. quantity of the pollutant discharged divided by its pollutant equivalent value). There is also a separate solid waste tax based on ton of waste produced. Farmers can apply for tax exemptions if they install waste treatment plants on their farms that meet wastewater treatment standards. The EPT law encourages reduction in manure production and the conversion of slurry into dried products for organic manure (Godfrey, 2017).

Research programmes

In 2018, China launched two major research projects on GHG emissions mitigation from livestock as part of a research collaboration between Chinese agencies, the Research Program on Climate Change, Agriculture and Food Security (CCAFS), the Sino-Dutch Dairy Development Centre (SDDDC), Wageningen University & Research, the Global Research Alliance on Agricultural GHG and the private sector.

The first research project focuses on improving agricultural emissions accounting methods at the province level. In particular, the project aims to develop a guideline based on Tier 2 methodology to improve measurement, reporting and verification of enteric fermentation and manure management emissions from dairy cattle and manure management emissions from pigs. It will enable provincial governments to use high quality data (in national reports) and will be used as a tool to measure emission reductions from improved livestock practices at the farm level.

The objective of the second research project is to identify sustainable dairy practices, especially from novel feeds (such as lignin degradation of maize or rice straw), that can result in a reduction of GHG emissions from dairy farming; and to provide accurate estimates of emission reductions associated with these changes in dairy practices (White, 2018).

REFERENCES

Abdala Guilherme C (2015), *The Brazilian Amazon: challenges facing an effective policy to curb deforestation*. Brasília, WWF Living Amazon Initiative, http://d2ouvy59p0dg6k.cloudfront.net/downloads/12mar2015_wwf_livingamaz_desafiosdesmatamentobra sil_engl_web.pdf.

ADIC (2015), *Australian dairy industry sustainability framework progress report 2015*. <https://www.dairyaustralia.com.au/-/media/dairyaustralia/documents/industry/manufacturing/industry-sustainability/2015--australian-dairy-industry--sustainability-framework--progress-report-2015.pdf?la=en&hash=002F186FD67BAD7AA35196BE740E53AD02864872>.

Agriculture and Agri-Food Canada (AAFC) (2014), *Evaluation of the Agricultural Greenhouse Gases Program*, <http://www.agr.gc.ca/eng/about-us/offices-and-locations/office-of-audit-and-evaluation/evaluation-reports/evaluation-of-the-agricultural-greenhouse-gases-program/?id=1424977033211>.

Agriculture and Agri-Food Canada (AAFC) (2017), *Agricultural Greenhouse Gases Program Applicant Guide*, <http://www.agr.gc.ca/eng/programs-and-services/agricultural-greenhouse-gases-program/3-apply/applicant-guide/?id=1461260706084>.

Agriculture and Agri-Food Canada (AAFC) (2018a), *Agriculture and Climate Change Policy, Financial Impacts of Carbon Pricing on Canadian Farms*.

Agriculture and Agri-Food Canada (AAFC) (2018b), *AgriScience Program – Projects: Applicant guide*, <http://www.agr.gc.ca/eng/programs-and-services/agriscience-program-projects/applicant-guide/?id=1516993365431>.

Agriculture and Agri-Food Canada (AAFC) (2018c), *Holos software program*, <http://www.agr.gc.ca/eng/science-and-innovation/agricultural-research-results/holos-software-program/?id=1349181297838>.

Agriculture and Agri-Food Canada (AAFC) (2019a), *Canadian Agricultural Partnership*, <http://www.agr.gc.ca/eng/about-us/key-departmental-initiatives/canadian-agricultural-partnership/?id=1461767369849>.

Agriculture and Agri-Food Canada (AAFC) (2019b), *AgriInnovate Program: Applicant guide*, <http://www.agr.gc.ca/eng/programs-and-services/agriinnovate-program/applicant-guide/?id=1515683309209>.

Agricultural Greenhouse Gas Research Initiative – Ireland (AGRI-I) (2016), <http://agri-i.ie/>.

Amazon Environmental Research Institute (IPAM) (2012), *Brazil's "Low-Carbon Agriculture" Program: Barriers to Implementation*,

https://static1.squarespace.com/static/5896200f414fb57d26f3d600/t/58f59dab8419c294a6edc083/1492491693855/brazil%27s_low-carbon_agriculture_program.pdf.

Assunção et al (2015), *Deforestation Slowdown in the Brazilian Amazon: Prices or Policies?*, Climate Policy Incentive, <https://pdfs.semanticscholar.org/5158/1df02d079ca3d2aa4fe2c3d930b5ab6b25af.pdf>.

Australian Government (2016). The Safeguard Mechanism – Overview. www.environment.gov.au/system/files/resources/8fb34942-eb71-420a-b87a-3221c40b2d21/files/factsheet-safeguard-mechanism.pdf [accessed 20 December 2018].

Backus, G. B. C. (2017), “*Manure Management: An Overview and Assessment of Policy Instruments in the Netherlands.*” Prepared for the World Bank, Washington, DC.

Bord Bia Irish Food Board (2017), *Origin Green Sustainability Report 2016*, <https://www.origingreen.ie/globalassets/publications/origin-green-sustainability-report-2016.pdf>.

Brazilian Roundtable on Sustainable Livestock (GTPS) (2019), *Missions and Objectives*, <http://gtps.org.br/en/mission-and-objectives/>.

Brazilian Roundtable on Sustainable Livestock (GTPS) (2016), *Guia de Indicadores da Pecuária Sustentável - 2016*, <http://www.gtps.org.br/wp-content/uploads/2015/09/Guia-de-Indicadores-da-Pecu%C3%A1ria-Sustent%C3%A1vel.pdf>.

Brocas et Danilo (2018), *Émissions de gaz à effet de serre et contributions positives de l'élevage laitier*, https://opera-connaissances.chambres-agriculture.fr/doc_num.php?explnum_id=103344.

Burke P (2016), *Undermined by adverse selection: Australia's Direct Action subsidies*. Crawford School of Public Policy, The Australian National University, CCEP Working Paper 1605, April 2016.

California Air Resources Board (CARB) (2014), *Compliance Offset Protocol Livestock Projects, Capturing and Destroying Methane from Manure Management Systems*, <https://www.arb.ca.gov/regact/2014/capandtrade14/ctlivestockprotocol.pdf>.

California Air Resources Board (CARB) (2015), *Compliance Offset Protocol Rice Cultivation Projects*, <https://www.arb.ca.gov/cc/capandtrade/protocols/rice/riceprotocol2015.pdf>.

California Air Resources Board (CARB) (2017a), *Short-Lived Climate Pollutant Reduction Strategy*, https://www.arb.ca.gov/cc/shortlived/meetings/03142017/final_slcp_report.pdf.

California Air Resources Board (CARB) (2017b), *Research on GHG Emissions in Agricultural Ecosystems*, <https://www.arb.ca.gov/ag/fertilizer/fertilizer.htm>.

California Air Resources Board (CARB) (2018), *California Greenhouse Gas Emissions for 2000 to 2016 - Trends of Emissions and Other Indicators*, https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2016/ghg_inventory_trends_00-16.pdf.

California Air Resources Board (CARB) (2019a), *Compliance Offset Program*, <https://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm>.

California Air Resources Board (CARB) (2019b), *California Climate Investments – About*, <https://ww2.arb.ca.gov/our-work/programs/california-climate-investments/about>.

California Climate Agriculture Network (CalCAN) (2019a), *Climate Smart Agriculture Year End Roundup: New Funding, Program Changes*, <http://calclimateag.org/climate-smart-agriculture-year-end-roundup-new-funding-program-changes/>.

California Climate Agriculture Network (CalCAN) (2019b), *Sustainable Agricultural Lands Conservation Program (SALCP)*, <http://calclimateag.org/salcp/>.

California Climate Agriculture Network (CalCAN) (2019c), *Bill to Help Farmers Fight Climate Change Signed by the Governor*, <http://calclimateag.org/bill-to-help-farmers-fight-climate-change-signed-by-the-governor/>.

California Department of Food and Agriculture (CDFA) (2019a), *ALTERNATIVE MANURE MANAGEMENT PROGRAM (AMMP)*, <https://www.cdfa.ca.gov/oefi/AMMP/>.

California Department of Food and Agriculture (CDFA) (2019b), *DAIRY DIGESTER RESEARCH & DEVELOPMENT PROGRAM*, <https://www.cdfa.ca.gov/oefi/ddrdp/>.

California Department of Food and Agriculture (CDFA) (2019c), *STATE WATER EFFICIENCY & ENHANCEMENT PROGRAM*, <https://www.cdfa.ca.gov/oefi/sweep/>.

California Department of Food and Agriculture (CDFA) (2018a), *2018 Specialty Crop Block Grant Program Project Abstracts*, https://www.cdfa.ca.gov/Specialty_Crop_Competitiveness_Grants/pdfs/2018SCBGP_ProjectAbstracts_Final.pdf.

California Department of Food and Agriculture (CDFA) (2018b), *Small Dairy Climate Change Research*, https://www.cdfa.ca.gov/oefi/research/docs/SmallDairyClimateChange_selectedforaward.pdf.

California Department of Food and Agriculture (CDFA) (n.d), *About FREP*, https://www.cdfa.ca.gov/is/ffldrs/frep/FREP_Fact_Sheets.html.

California Department of Food and Agriculture (CDFA) (2018), *Small Dairy Climate Change Research*, https://www.cdfa.ca.gov/oefi/research/docs/SmallDairyClimateChange_selectedforaward.pdf.

CEA Consulting (2016), *Challenges and Opportunities for Conservation, Agricultural Production, and Social Inclusion in the Cerrado Biome*, <http://www.climateandlandusealliance.org/wp-content/uploads/2016/09/Cerrado-Policy-deforestation-and-emissions.pdf>.

Center for Climate and Energy Solutions (n.d), *California Cap and Trade*, <https://www.c2es.org/content/california-cap-and-trade/>.

Centre National Interprofessionnel de l'Économie Laitière (CNIEL) (2019), *La Ferme laitière bas carbone, une démarche ambitieuse et pragmatique*, <http://www.ferme-laitiere-bas-carbone.fr/decouvrir-le-projet>.

Chambres d'Agriculture France (2018), *La dynamique GIEE se poursuit en 2018*, <https://chambres-agriculture.fr/actualites/toutes-les-actualites/detail-de-lactualite/actualites/la-dynamique-giee-se-poursuit-en-2018/>.

Clean Energy Regulator (2019), Emissions Reduction Fund, <http://www.cleanenergyregulator.gov.au/ERF> (accessed 31 January, 2019).

Climate Action Reserve (n.d), *Protocols*, <http://www.climateactionreserve.org/how/protocols/>.

Climate Action Tracker (2017), *Countries: China*, <http://climateactiontracker.org/countries/china.html>.

Commonwealth of Australia (2018a), *Australia's emissions projections 2018*, Commonwealth of Australia.

Commonwealth of Australia (2018b), *National Inventory Report 2016: Volume 1*. Commonwealth of Australia.

Commonwealth of Australia (2018c), *Quarterly Update of Australia's National Greenhouse Gas Inventory: March 2018*, Commonwealth of Australia.

Commonwealth of Australia (2019a), *About the Climate Solutions Fund - Emissions Reduction Fund*, Australian Government, Department of the Environment and Energy, <http://www.environment.gov.au/climate-change/government/emissions-reduction-fund/about>.

Commonwealth of Australia (2019b), *National Landcare Program Phase Two*, Australian Government, National Landcare Program, <http://www.nrm.gov.au/national-landcare-program>.

Commonwealth of Australia (2019c), *Regional Land Partnerships*, Australian Government, National Landcare Program, <http://www.nrm.gov.au/regional-land-partnerships>.

Commonwealth of Australia (2019d), *The Renewable Energy Target (RET) scheme*, Australian Government, Department of the Environment and Energy, <http://www.environment.gov.au/climate-change/government/renewable-energy-target-scheme>.

Commonwealth of Australia (2019e), *Where we invest*, Australian Government, Australian Renewable Energy Agency, <https://arena.gov.au/where-we-invest/>.

Commonwealth of Australia (2017), *Clean Energy Finance Corporation (CEFC) investment in agriculture*, Australian Government, Department of Agriculture and Water Resources, <http://www.agriculture.gov.au/ag-farm-food/climatechange/cefc>.

CRSPI (2019) *The Climate Research Strategy for Primary Industries*. <http://www.ccrspi.net.au> (accessed 11 March, 2019).

Department of Agriculture, Food and the Marine (DAFM) (2017a), *The 2017 Evaluation on the Implementation of Ireland's Rural Development Programme 2014 -2020*, <https://www.agriculture.gov.ie/media/migration/ruralenvironment/ruraldevelopment/ruraldevelopmentprogramme2014-2020/2017EvaluationofIrelandsRDP180917.pdf>.

Department of Agriculture, Food and the Marine (DAFM) (2017b), *Doyle Launches 2017-18 Forestry Afforestation Programme*, <https://www.agriculture.gov.ie/press/pressreleases/2017/september/title.111621.en.html>.

Department of Communications, Climate Action & Environment (DCCAE) (2017), *National Mitigation Plan*, <https://static.rasset.ie/documents/news/national-mitigation-plan-2017.pdf>.

Department of Communications, Climate Action & Environment (DCCAE) (2013), *National Policy Position on Climate Action and Low Carbon Development*, <https://www.dccae.gov.ie/en-ie/climate-action/publications/Documents/5/National%20Climate%20Policy%20Position.pdf>.

Department of Housing, Planning and Local Government (DHPLG) (2016), *Nitrates Directive*, <https://www.housing.gov.ie/water/water-quality/nitrates/nitrates-directive>.

DAWR (2017), *An evaluation of the Carbon Farming Futures Programme*. Department of Agriculture and Water Resource (Australian Government) and Grosvenor Management Consulting, Canberra. <http://www.agriculture.gov.au/SiteCollectionDocuments/climate-change/carbon-farming/evaluation-carbon-farming-futures-programme.pdf>

DAWR (2019), *Carbon Farming Futures*. <http://www.agriculture.gov.au/ag-farm-food/climatechange/carbonfarmingfutures> (accessed 11 March, 2019).

Dobson, Winter and Boyd (2018), *The Greenhouse Gas Emissions Coverage of Carbon Pricing Instruments for Canadian Provinces*, https://econ.ucalgary.ca/sites/econ.ucalgary.ca.manageprofile/files/unitis/publications/1-8832833/DobsonWinterBoyd_emissions_coverage_July2018.pdf.

DoEE (2014) *The emissions reduction fund: Storing Carbon*. Department of Environment and Energy, Australian Government. www.environment.gov.au/system/files/resources/dcf16dcd-2724-4ed8-96c0-5837a9977604/files/erf-fs-storing-carbon.pdf (Accessed 20 December 2018).

Dong Hongmin (2018), *Tier II MRV of livestock emissions in China: Developing guidance for implementation at the provincial level*, https://ccafs.cgiar.org/fr/node/56397#.XJjLh89Kj_Q.

Downing (2018), *Ireland faces annual EU energy fines of €600m*, News Irish News, <https://www.independent.ie/irish-news/ireland-faces-annual-eu-energy-fines-of-600m-36857141.html>.

Duurzame Zuivelketen (n.d), *Kennisdocument broeikasgassen*, <https://www.duurzamezuivelketen.nl/resources/uploads/2018/04/Kennisdocument-DZK-broeikasgassen.pdf>.

Embrapa (2019a), *About us*, <https://www.embrapa.br/en/international>.

Embrapa (2019b), *Low Carbon Agriculture*, <https://www.embrapa.br/en/tema-agricultura-de-baixo-carbono/sobre-o-tema>.

Environment and Climate Change Canada (2018), *National Inventory Report 1990-2016 - Greenhouse Gas Sources and Sinks in Canada: Executive Summary*.

Environmental Defense Fund (EDF) (2019), *A new crop for rice farmers: Carbon offsets*, <https://www.edf.org/ecosystems/new-crop-rice-farmers-carbon-offsets>.

Environmental Protection Agency (EPA) (2018a), *Ireland's Provisional Greenhouse Gas Emissions 1990-2017*, http://www.epa.ie/pubs/reports/air/airemissions/ghgemissions2017/Report_GHG%201990-2017%20November%202018_Website.pdf.

Environmental Protection Agency (EPA) (2018b), *Ireland's Greenhouse Gas Emissions Projections 2017-2035*, https://www.epa.ie/pubs/reports/air/airemissions/ghgprojections2017-2035/EPA_2018_GHG_Emissions_Projections_Summary_Report.pdf.

Environmental Protection Agency (EPA) (2017), *Action needed as greenhouse gas emissions increase*, <http://www.epa.ie/newsandevents/news/pressreleases2017/name.63280.en.html>.

Environmental Protection Agency (EPA) (n.d), *Ireland's Environmental Agriculture* (factsheet). https://www.epa.ie/media/epa_agriculture_v2.pdf

European Commission (EC) (2018), *A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*, https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf.

European Commission (EC) (2014), *2030 climate and energy goals for a competitive, secure and low-carbon EU economy*, http://europa.eu/rapid/press-release_IP-14-54_en.htm.

European Commission (EC) (2010), *The EU Nitrate Directive* (factsheet), <http://ec.europa.eu/environment/pubs/pdf/factsheets/nitrates.pdf>

European Environmental Agency (EAA) (2018a), *Annual European Union greenhouse gas inventory 1990–2016 and inventory report 2018*, <https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2018>.

European Environment Agency (EAA) (2018b), *NEC Directive reporting status 2018*, <https://www.eea.europa.eu/themes/air/national-emission-ceilings/nec-directive-reporting-status-2018>.

European Environmental Agency (EEA) (2018c), *Trends and projections in Europe 2018- Tracking progress towards Europe's climate and energy targets*, file:///Users/clarafrezal/Downloads/16_2018%20TrendsProjections%20TH-AL-18-018-EN-N%20(1).pdf.

European Union (EU) (1995-2019a), *Effort sharing: Member States' emission targets*, https://ec.europa.eu/clima/policies/effort_en.

European Union (EU) (1995-2019b), *Annual emission allocations 2013-2020 and flexibilities*, https://ec.europa.eu/clima/policies/effort/framework_en.

European Union (EU) (1995-2019c), *Effort sharing 2021-2030: targets and flexibilities*, https://ec.europa.eu/clima/policies/effort/proposal_en.

European Union (EU) (1995-2019d), *Land use and forestry regulation for 2021-2030*, https://ec.europa.eu/clima/policies/forests/lulucf_en.

European Union (EU) (1995-2019e), *Factsheet on 2014-2020 Rural Development Programme for Ireland*, https://ec.europa.eu/agriculture/sites/agriculture/files/rural-development-2014-2020/country-files/ie/factsheet_en.pdf.

European Union (EU) (1995-2019f), *Factsheet on 2014-2020 Rural Development Programme for the Netherlands*, https://ec.europa.eu/agriculture/sites/agriculture/files/rural-development-2014-2020/country-files/nl/factsheet_en.pdf.

European Union (EU) (1995-2019g), *Factsheet on 2014-2020 Rural Development Programme for France*, https://ec.europa.eu/agriculture/rural-development-2014-2020/country-files/fr_en.

European Union (EU) (2010), *DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 November 2010 on industrial emissions*, <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:334:0017:0119:en:PDF>.

Federal Ministry for Economic Affairs and Energy (n.d), *Opportunity and challenges of Biogas market in China*, https://www.oav.de/fileadmin/user_upload/2_Termine/Allgemein/biogas_development_in_China.pdf.

Fertilizer Canada (2019), *4Rs Across Canada*, <https://fertilizercanada.ca/nutrient-stewardship/4rs-across-canada/>?

Fertilizer Canada (2018), *Key Findings of the Canadian 4R Research Network*, https://fertilizercanada-ksiu6qbsd.netdna-ssl.com/wp-content/uploads/2018/08/fc_4R-key-findings2018_en_vf-digital.pdf.

Food and Agriculture Organization (FAO) (2016), *Le projet agro-écologique pour la France: vers une agriculture durable face au changement climatique*, http://www.fao.org/fileadmin/user_upload/gacsa/AF/SC/GACSA-EEAG-Etude_de_cas_France_Agro%C3%A9cologie.pdf.

Freebairn J (2016), “A comparison of policy instruments to reduce greenhouse gas emissions. *Economic Papers*, 35: 204-215.

FuturePolicy (2019), *Brazil’s National Policy for Agroecology and Organic Production (PNAPO)*, <https://www.futurepolicy.org/healthy-ecosystems/brazil-national-policy-agroecology-organic-production/>.

Gebara and Thuault (2013), *GHG mitigation in Brazil’s land use sector: an introduction to the current national policy landscape*, World Resources Institute, https://wriorg.s3.amazonaws.com/s3fs-public/ghg-mitigation-brazil-land-use-sector.pdf?_ga=2.21426811.1590551725.1553520605-1243013630.1551267395.

Godfrey (2017), *Chinese farms face new environment tax*, Global Meat News, <https://www.globalmeatnews.com/Article/2017/01/09/Chinese-farms-face-new-environment-tax>.

Golub, A. et al. (2013), “Global climate policy impacts on livestock, land use, livelihoods, and food security”, *PNAS*, Vol. 110, pp. 20894-20899.

Government of Alberta (2017), *Agricultural Carbon Offsets - An Introduction*, [https://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/cl16248](https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl16248).

Government of Alberta (1995-2018), *Environmental Stewardship and Climate Change – Producer*, https://cap.alberta.ca/CAP/program/STEW_PROD.

Government of Canada (2019), *The Low Carbon Economy Fund*, <https://www.canada.ca/en/environment-climate-change/services/climate-change/low-carbon-economy-fund.html>.

Government of Canada (2018), *Pan-Canadian Framework on Clean Growth and Climate Change – Canada’s Plan to Address Climate Change and Grow the Economy*.

Government of the Netherlands (2017), *European Commission gives green light for dairy cattle phosphate system*, <https://www.government.nl/latest/news/2017/12/19/european-commission-gives-green-light-for-dairy-cattle-phosphate-system>.

Government of the Netherlands (n.d), *Sustainable livestock production*, <https://www.government.nl/topics/livestock-farming/sustainable-livestock-production>.

Government of the Netherlands (2017), *Staatssecretaris Van Dam kondigt Nationale Proeftuin Precisielandbouw aan*, <https://www.rijksoverheid.nl/actueel/nieuws/2017/02/13/staatssecretaris-van-dam-kondigt-nationale-proeftuin-precisielandbouw-aan>.

Gouvernement du Québec (2019), *The Carbon Market – Offset Credits*, <http://www.environnement.gouv.qc.ca/changements/carbone/credits-compensatoires/index-en.htm>.

Government of Yukon (2018), *Programming guide for Yukon*, <https://yukon.ca/sites/yukon.ca/files/emr/canadian-agricultural-partnership-programming-guide.pdf>.

Hyunok Lee and Daniel A. Sumner (2018), *Dependence on policy revenue poses risks for investments in dairy digesters*,

IETA (2015), *Offsets in California's Cap-and-Trade Program*, <https://www.ieta.org/resources/Resources/101s/offsets-in-cas-candt-program-101-mar15.pdf>.

Ignaciuk, Ada, and Boonstra, Carla (2017), *Synergies and trade-offs between agricultural productivity and climate change mitigation and adaptation: Netherlands case study*, OECD, Paris.

Institut de l'Élevage (IDELE) (2015), *Lancement du programme LIFE BEEF CARBON*, <http://idele.fr/linstitut-de-lelevage/publication/idelesolr/recommends/lancement-du-programme-life-beef-carbon.html>.

Institut du porc (IFIP) (2014), *La vie du RMT « Élevages & environnement »*, https://www.ifip.asso.fr/sites/default/files/pdf-documentations/fiche_bilan2014_038.pdf.

Institut national de la recherche agronomique (INRA) (n.d), *Les métaprogrammes de l'INRA – Outils de programmation scientifiques interdisciplinaire*, <https://inra-dam-front-resources-cdn.brainsonic.com/ressources/afile/425594-11290-resource-metaprogrammes-plaquette-fr.pdf>.

Institute for Climate Economics (2018), *Mutualiser les connaissances pour atténuer*, Club Climat Agriculture, Edition 2018.

Jin and Zhou (2018), *Zero Growth of Chemical Fertilizer and Pesticide Use: China's Objectives, Progress and Challenges*, <http://www.jorae.cn/EN/abstract/abstract8825.shtml#>.

Johnston and Bruulsema (2014), *4R Nutrient Stewardship for Improved Nutrient Use Efficiency*, Procedia Engineering, <https://www.sciencedirect.com/science/article/pii/S1877705814011229>.

Klimaatakkoord (2018), *Proposal for key points of the Climate Agreement*. Available at: <https://www.klimaatakkoord.nl/documenten/publicaties/2018/09/19/proposal-for-key-points-of-the-climate-agreement>.

Kohl and al (2019), *Agricultural Productivity and Forest Conservation: Evidence from the Brazilian Amazon*, Published by Oxford University Press on behalf of the Agricultural and Applied Economics Association, <https://academic.oup.com/ajae/advance-article/doi/10.1093/ajae/aay110/5376645>.

Lovett A and McCluskey S (2017), *Climate Research Strategy for Primary Industries 2017-2020 (CRSPI)*. Rural Industries Research and Development Corporation.

Machado and Anderson (2016), *Brazil's New Forest Code: a guide for decision-makers in supply chains and governments*, WWF Brazil, https://c402277.ssl.cf1.rackcdn.com/publications/859/files/original/wwf_brazils_new_forest_code_guide.pdf?1455912714.

Marques de Magalhães, Lunas Lima (2014), *Low-Carbon Agriculture in Brazil: The Environmental and Trade Impact of Current Farm Policies*, Issue Paper No. 54, International Centre for Trade and Sustainable Development, Geneva, Switzerland, <https://www.ictsd.org/sites/default/files/research/Low-Carbon%20Agriculture%20in%20Brazil.pdf>.

Mayberry D, Bartlett H, Moss J, Wiedemann S, Herrero M (2018), *Greenhouse Gas mitigation potential of the Australian red meat production and processing sectors: final report*. Prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for Meat and Livestock Australia (MLA), Meat and Livestock Australia Limited, Sydney.

Meat & Livestock Australia (2017), *Red meat industry can be carbon neutral by 2030*, <https://www.mla.com.au/news-and-events/industry-news/red-meat-industry-can-be-carbon-neutral-by-2030>.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (n.d), *Réseau Mixte Technologique Fertilisation & Environnement*, http://www.rmt-fertilisationenvironnement.org/moodle/pluginfile.php/2774/mod_resource/content/1/RMT_FE_4pages_FRA.pdf.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2019), *La Haute Valeur Environnementale : une reconnaissance officielle de la performance environnementale des viticulteurs et des agriculteurs*, <https://agriculture.gouv.fr/la-haute-valeur-environnementale-une-reconnaissance-officielle-de-la-performance-environnementale>.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2018a), *Le Programme Ambition Bio 2022 présenté à l'issue du Grand Conseil d'Orientation de l'Agence Bio*, <https://agriculture.gouv.fr/le-programme-ambition-bio-2022-presente-lissue-du-grand-conseil-dorientation-de-lagence-bio>.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2018b), *RAPPORT D'ACTIVITE 2017 - Programme National pour le Développement Agricole et Rural (PNDAR)*, <https://agriculture.gouv.fr/developpement-agricole-et-rural-casdar>.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2017), *Certification environnementale des exploitations agricoles*, <https://agriculture.gouv.fr/certification-environnementale-des-exploitations-agricoles-0>.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2016), *The Ministry of Agriculture, Agrifood and Forestry in Action*, https://agriculture.gouv.fr/sites/minagri/files/plaqqingb72_0.pdf.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2015), *Plan de développement de l'agroforesterie - Pour le développement et la gestion durable de tous les systèmes agroforestiers*, https://agriculture.gouv.fr/sites/minagri/files/151215-ae-agrofesterie-v2_plan.pdf.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2014a), *Plan Protéines Végétales*, <https://agriculture.gouv.fr/le-plan-proteines-vegetales-pour-la-france-2014-2020>.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2014b), *Enseigner à produire autrement*, https://agriculture.gouv.fr/sites/minagri/files/enseigner_a_produire_autrement.pdf.

Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt (MAAF) (2013), *Programme Ambition Bio 2017*, https://agriculture.gouv.fr/sites/minagri/files/documents/pdf/Programme_Ambition_bio_2017_cle09281b.pdf.

Ministère de l'Agriculture et de l'Alimentation (MAA) (2017), *The agroecology project in France*, https://www.moag.gov.il/yhidotmisrad/research_economy_strategy/publication/2018/Documents/3_Schwartz_20170620_projet_agro_%C3%A9cologique_Isra%C3%ABlv3.pdf.

Ministère de l'Écologie, du Développement Durable et de l'Énergie (MEDDE) (2013), *Le Plan Énergie Méthanisation Autonomie Azote*, <https://agriculture.gouv.fr/file/le-plan-energie-methanisation-autonomie-azote-ema>.

Ministère de l'Écologie, du Développement Durable et de l'Énergie (MEDDE) (2015), *Stratégie Nationale Bas-Carbone, Summary for decision-makers*, https://unfccc.int/files/focus/long-term_strategies/application/pdf/national_low_carbon_strategy_en.pdf.

Ministère de l'Écologie, du Développement Durable et de l'Énergie (MEDDE) (2018), *Projet de Stratégie Nationale Bas-Carbone - La transition écologique et solidaire vers la neutralité carbone*, <https://www.ecologique-solidaire.gouv.fr/sites/default/files/Projet%20strategie%20nationale%20bas%20carbone.pdf>.

Ministère de l'Écologie, du Développement Durable et de l'Énergie (MEDDE) (2017a), *Plan Climat*, https://www.ecologique-solidaire.gouv.fr/sites/default/files/2017.07.06%20-%20Plan%20Climat_0.pdf.

Ministère de l'Écologie, du Développement Durable et de l'Énergie (MEDDE) (2017b), *The Seventh National Communication of France – United Nations Framework Convention on Climate Change*, https://unfccc.int/sites/default/files/resource/901835_France-NC7-2-NC%20-%20FRANCE%20%20-%20EN%20-VF15022018.pdf.

Ministère de la Transition écologique et solidaire (MTES) (2016), *Loi de transition énergétique pour la croissance verte*, <https://www.ecologique-solidaire.gouv.fr/loi-transition-energetique-croissance-verte>.

Ministère de la Transition écologique et solidaire (MTES) (2018), *Suivi de la Stratégie Nationale Bas-Carbone*, <https://www.ecologique-solidaire.gouv.fr/suivi-strategie-nationale-bas-carbone>.

Ministério do Meio Ambiente (2011), *Strategies to Reduce Deforestation in Brazil: From controlling illegal deforestation to the challenge of sustainable production in the country's forests and savannas*, <http://www.stapgef.org/sites/default/files/stap/wp-content/uploads/2013/09/Strategies-to-Reduce-Deforestation-in-Brazil.pdf>.

Ministério do Meio Ambiente (2018a), *Plano de Ação para Prevenção e Controle do Desmatamento e das Queimadas no Cerrado (PPCerrado) e Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal (PPCDam) Fase 2016-2020, Volume I, II e III*, http://combateadodesmatamento.mma.gov.br/images/Doc_ComissaoExecutiva/Livro-PPCDam-e-PPCerrado_20JUN2018.pdf.

Ministério do Meio Ambiente (2018b), *Taxa de desmatamento na Amazônia Legal*, <http://www.mma.gov.br/informma/item/15259-governo-federal-divulga-taxa-de-desmatamento-na-amaz%C3%B4nia.html>.

Ministry of Ecology and Environment (2018), *China's Policies and Actions for Addressing Climate Change 2018*, http://english.mee.gov.cn/News_service/news_release/201812/P020181203536441502157.pdf.

Ministry of Economic Affairs and Climate Policy (EZK) (2017), *Seventh Netherlands National Communication under the United Nations Framework Convention on Climate Change*.

National Development and Reform Commission (NDRC) (2017), *China's Policies and Actions for Addressing Climate Change 2017*, <https://reliefweb.int/sites/reliefweb.int/files/resources/P020171122611767066567.pdf>.

Netherlands Enterprise Agency (2018), *Methodology for estimating emissions from agriculture in the Netherlands – update 2018*, <https://english.rvo.nl/sites/default/files/2018/04/Vonk-et-al-2018-Methodology-report-agriculture-2018.pdf>.

Newton et al (2016), *Overcoming barriers to low carbon agriculture and forest restoration in Brazil: the Rural Sustentável project*, World Development Perspectives, 4, 5-7, <https://doi.org/10.1016/j.wdp.2016.11.011>.

Nico Polman and Rolf Michels (2017), *Agricultural policy objectives on productivity, climate change adaptation and mitigation; Policy assessment for the Netherlands*. Wageningen, Wageningen Economic Research, Memorandum 2017-045.

Observatório ABC (2017), *Análise dos Recursos do Programa ABC Safra 2016/17*, http://observatorioabc.com.br/wp-content/uploads/2017/09/Sumario_ABC_Relatorio4_GRAFICA.pdf.

OECD (2001), *Impacts of environmental regulations on intensive livestock production in the Netherlands*.

OECD (2015), *OECD Environmental Performance Reviews: Brazil 2015*, OECD Publishing, Paris, <http://dx.doi.org/10.1787/9789264240094-en>.

OECD (2019), *A Global Economic Evaluation of GHG Mitigation Policies for Agriculture*, [COM/TAD/CA/ENV/EPOC(2018)7/FINAL].

OECD (2018), *Agricultural Policy Monitoring and Evaluation 2018*, Paris, https://doi.org/10.1787/agr_pol-2018-en.

OECD (2019b), *Agricultural Policy Monitoring and Evaluation 2019*, unpublished.

Origin Green IRELAND (n.d), *What is Origin Green?*, <https://www.origingreen.ie/what-is-origin-green/about-origin-green/>

Poloncarz and Levine (2018), *Governor Jerry Brown signs SB 100 and Executive Order to achieve carbon neutrality by 2045*, Inside Energy & Environment, <https://www.insideenergyandenvironment.com/2018/09/governor-jerry-brown-signs-sb-100-and-executive-order-to-achieve-carbon-neutrality-by-2045/>.

Presidency of the Republic of Brazil (2017), *Government launches 2017/2018 Agricultural and Livestock Plan*, <http://www.brazil.gov.br/about-brazil/news/2017/06/government-launches-2017-2018-agricultural-and-livestock-plan-1>.

Presidency of the Republic of Brazil (2018a), *Brazil hits climate change target three years early*, <http://www.brazil.gov.br/about-brazil/news/2018/08/brazil-hits-climate-change-target-three-years-early>.

Presidency of the Republic of Brazil (2018b), *Cerrado deforestation went down in 2018*, <http://www.brazil.gov.br/about-brazil/news/2018/12/cerrado-deforestation-went-down-in-2018>.

Presidency of the Republic of Brazil (2018c), *INPE divulga dados sobre o desmatamento do bioma Cerrado*, <http://www.obt.inpe.br/OBT/noticias/inpe-divulga-dados-sobre-o-desmatamento-do-bioma-cerrado>.

7th International Greenhouse Gas and Animal Agriculture (2019), *Greenhouse Gas and Animal Agriculture Conference 2019*, <http://www.ggaa2019.org/?q=pt-br/node/67>.

Teagasc (2018), *An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030*, <https://www.teagasc.ie/media/website/publications/2018/An-Analysis-of-Abatement-Potential-of-Greenhouse-Gas-Emissions-in-Irish-Agriculture-2021-2030.pdf>.

Teagasc (n.d), *The Dairy Carbon Navigator – Improving Carbon Efficiency on Irish Dairy Farms*, <https://www.teagasc.ie/media/website/publications/2019/Bord-Bia-Dairy-Carbon-Navigator-LR5.pdf>.

The Greenhouse Gas Emissions and Removals Estimates (SEEG) (2019), *Emissions by sector – Agropecuária*, <http://plataforma.seeg.eco.br/sectors/agropecuaria>.

The Irish Farmers' Association (2018), *Initial Public Consultation – National Energy & Climate Plan 2021-2030 Ireland IFA submission to public consultation*, <https://www.ifa.ie/wp-content/uploads/2018/11/181112-Consultation-on-National-Energy-Climate-Plan.pdf>.

The Irish Farmers' Association (2017), *Smart Farming progress report 2017*, <http://smartfarming.ie/wp-content/uploads/2017/10/SFRF.pdf>.

The London School of Economics and Political Science (LSE) (2016), *13th Five-Year Plan*, <http://www.lse.ac.uk/GranthamInstitute/law/13th-five-year-plan/>.

The People's Republic of China (2014), *Second National Communication on Climate Change of The People's Republic of China*, <https://unfccc.int/resource/docs/natc/chnnc2e.pdf>.

The World Bank (2016), *Development of Systems to Prevent Forest Fires and Monitor Vegetation Cover in the Brazilian Cerrado Project*, <http://documents.worldbank.org/curated/en/405861468000593624/pdf/PAD1234-PAD-P143185-R2016-0041-1-Box394870B-OUO-9.pdf>.

The World Bank (2018), *State and Trends of Carbon Pricing 2018*, <https://openknowledge.worldbank.org/bitstream/handle/10986/29687/9781464812927.pdf?sequence=5&isAllowed=y>.

UNFCCC (United Nations Framework Convention on Climate Change) (2015), *INDCs as communicated by Parties: China*, <http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx>.

UNFCCC (United Nations Framework Convention on Climate Change) (n.d), *Emissions Summary for China*, https://unfccc.int/files/ghg_data/ghg_data_unfccc/ghg_profiles/application/pdf/chn_ghg_profile.pdf.

U.S. Department of Agriculture (USDA) (2014), *Biogas Opportunities Roadmap*, https://www.usda.gov/oce/reports/energy/Biogas_Opportunities_Roadmap_8-1-14.pdf.

United States Environmental Protection Agency (US EPA) (2018), *Inventory of US Greenhouse Gas Emissions and Sinks 1990-2017*, <https://www.epa.gov/sites/production/files/2019-02/documents/us-ghg-inventory-2019-main-text.pdf>.

Vandaele (2012), INTÉGRER L'AGRICULTURE dans les politiques d'atténuation des changements climatiques - RECUEIL D'EXPÉRIENCES INTERNATIONALES, ADEME, <https://www.ademe.fr/sites/default/files/assets/documents/integrer-agriculture-dans-politiques-attenuation-changements-climatiques-2012.pdf>.

Van Grinsven H.J.M. and A. Bleeker (2017), *Evaluation of the Manure and Fertilisers Act 2016: Synthesis Report*. PBL Netherlands Environmental Assessment Agency, The Hague, <https://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2017-evaluation-of-the-manure-and-fertilisers-act-2016-2779.pdf>.

Vreugdenhil Dairy Foods (n.d), *Sustainable dairy farming*, <https://www.vreugdenhildairyfoods.com/sustainability/Sustainable-dairy-farming/>.

Wageningen University & Research (WUR) (2015), *Agricultural Economic Report 2015 – Summary*, https://www.wur.nl/upload_mm/6/5/1/57e0a915-70f3-49d0-adb2-5b24d17e112b_Summary_AgriculturalEconomicReport2015.pdf.

Wageningen University & Research (WUR) (2018), *WUR is making use of smart solutions to limit greenhouse gas emissions*, <https://www.wur.nl/en/newsarticle/WUR-is-making-use-of-smart-solutions-to-limit-greenhouse-gas-emissions.htm>.

Wang, Huang, and Rozelle (2010), *Climate Change and China's Agricultural Sector: An Overview of Impacts, Adaptation and Mitigation*, ICTSD–IPC Platform on Climate Change, Agriculture and Trade, Issue Brief No.5, International Centre for Trade and Sustainable Development, Geneva, Switzerland and International Food & Agricultural Trade Policy Council, Washington DC, USA, http://www.agritrade.org/events/documents/ClimateChangeChina_final_web.pdf.

White (2018), *China takes action on climate change in agriculture*, Climate Change, Agriculture and Food Security, <https://ccafs.cgiar.org/news/china-takes-action-climate-change-agriculture-0#.XJjLEM9Kj S>.

Zhang (2017), *The pollution regulations affecting China's pork producers*, The Pig Site, <https://thepigsite.com/news/2017/12/the-pollution-regulations-affecting-chinas-pork-producers-1>.

ANNEXES

Table A.1. Agriculture, Forest and Land Use – Overview of Costs and Emissions Reduction Potential

Name of the measure	Objective of the measure	Direct spend	Marginal cost per tonne of carbon abated (€) (as per MACC)	Cumulative GHG emissions reduction 2017-2020 (ktCO ₂ e)	Cumulative GHG emissions reduction 2017-2030 (ktCO ₂ e)
Rural Development Programme	Overarching benefits for rural environment, including climate change mitigation, preservation of habitats and species, and maintaining good water quality	€1,865.15 million	Approx 550	1 454	10 054
Forestry Programme	Increase level of forest cover; Increase supply of FBB to bridge expected supply gap by 2020 and beyond; Increase timber mobilisation by supporting private forest holders in actively managing their forests; Enhance the environmental and social benefits of new and existing forests.	€132.5 million	Approx 20	120	2 440

Source : DAFM, 2017

Table A.2. Projects funded under the Research Stimulus Fund (RSF), 2010-17

Project title	Research call	Lead institution	DAFM award
Novel Technologies, Solutions and Systems to Reduce Greenhouse Gas Emissions in Animal Production Systems	2018 Joint Call		€ 575,000
AGRI-SOC: Evaluating Land-Use and Land Management Impacts on Soil organic Carbon in Irish Agricultural Systems.	DAFM National Call 2017	Teagasc	€ 598,052 (co-funded by EPA)
Mitigating Agricultural impacts through Research and Knowledge Exchange	EPA CO-FUND 2017	Teagasc	€ 249,877
Managing and Reporting of Greenhouse Gas Emissions and Carbon Sequestration in different landscape mosaics	ERAGAS-ERANET Call 2016	Teagasc	€ 236,134
Refining direct fed microbials (DFM) and silage inoculants for reduction of methane emissions from ruminants	ERAGAS - ERANET Call 2016	University College Cork	€ 218,920

Mitigating Agricultural Greenhouse Gas Emissions by improved pH management of soils	ERAGAS ERANET 2016	- Call	National University of Galway	€ 244,999
Predicting appropriate GHG mitigation strategies based on modelling variables that contribute to ruminant environmental impact	ERAGAS ERANET 2016	- Call		€ 244,418
Manipulation and Integration of Nitrogen Emissions	DAFM National Call 2015		Teagasc	€ 1,143,119
Enhancement of the CAPRI modelling with specific focus on its environmental and economic analytical capacity for Ireland	DAFM National Call 2015		University College Dublin	€ 499,479
Measurement and abatement of NH ₃ emissions from agriculture	DAFM National Call 2013		Teagasc	€ 1,246,289
Gaseous Emissions - Agriculture and Land Use Network	DAFM National Call 2010		Teagasc	€ 1,698,135

Source: <https://www.agriculture.gov.ie/research/competitivenationalprogrammes/researchstimulusfunds/>

Table A.3. The environmental component of French regional RDPs

	Total RDP funding (in million)	Measure 10: AECMs	Measure 11: Organic agriculture	Priority 4	Priority 5	of which 5D	of which 5E
Alsace	183,9	22,5%	9,3%	52,7%	3,6%	0,51%	-
Aquitaine	1044	6,1%	5,8%	49%	16%	-	14,9%
Auvergne	1780	5,3%	2,5%	71,8%	2%	-	0,66%
Basse-Normandie	474	13,2%	7,2%	40,5%	5,3%	-	-
Bretagne	672,3	25,6%	8,7%	39,1%	3,7%	-	0,59%
Bourgogne	849,9	12,6%	8,6%	65,5%	2,9%	0,89%	-
Centre-Val de Loire	525,9	24%	9%	60,8%	1,8%	-	1,79%
Champagne- Ardenne	326,67	18,3%	7,1%	40,3%	9,7%	-	4,27%
Corsica	262	6%	2,3%	56,0%	3,2%	-	2,79%
Franche-Comté	646	6%	6,5%	68,2%	3,2%	-	0,12%
Haute-Normandie	181,8	15,2%	8,3%	26,9%	8,3%	4,40%	3,3%
Île-de-France	114	21,2%	14,9%	49,4%	2,9%	-	-
Languedoc- Roussillon	981	11,9%	8,5%	66,6%	7,8%	-	2,21%
Limousin	860	6,8%	3,1%	70,5%	3,6%	-	3,55%
Lorraine	533	15,8%	7,6%	54,1%	-	-	-
Midi-Pyrénées	2100	4,5%	6,9%	70,5%	2,8%	-	1,2%
Nord-Pas de Calais	186	29%	8,5%	30,3%	8,5%	4,38%	0,85%
Pays de la Loire	775	23,2%	15,5%	42%	15,1%	-	0,35%
Picardie	218	27,3%	6,2%	43,8%	2,4%	-	0,97%

Poitou-Charentes	653,6	26,2%	9,7%	62,2%	9,6%	-	0,15%
Provence-Alpes-Côte	815	14,1%	3,6%	75,3%	4%	-	0,02%
Rhône-Alpes	1629	5,3%	4,8%	65,3%	1,9%	-	0,09%

Source: EU, 1995-2019g