Denmark: Action Plans for the Aquatic Environment and Green Growth Agreement

Fact sheet

for:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

European Climate Initiative EUKI

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This study is based on a policy paper with an overview of greenhouse gas emission reductions and policy instruments in non-ETS sectors across Europe (hereafter referred to as 'Policy Paper'). The Policy Paper can be downloaded from the EUKI website.

ABBREVIATIONS

APAE	Action Plan for the Aquatic Environment
CAP	Common Agricultural Policy
CH4	Methane
COP	Conference of Parties
DCE	Danish Centre for Environment and Energy
DKK	Danish krone
DüV	Fertiliser Application Regulation (‚Düngeverordnung')
EU	European Union
EUR	Euro
ETS	Emissions Trading System
GAK	Joint Task for the Improvement of Agricultural Structures and Coastal Protection (‚Gemeinschaftsaufgabe Verbesserung der Agrarstruktur und des Küstenschutzes')
GDP	Gross domestic product
GGA	Green Growth Agreement
GHG	Greenhouse gas
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogramme
km^2	Square kilometre
$MtCO_2e$	Million tonnes of carbon dioxide equivalent
N	Nitrogen
N2O	Nitrous oxide
UAA	Utilised Agricultural Area

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1. SUMMARY

Denmark has been a forerunner in climate policy for several decades. Exceeding international targets (such as the targets imposed by the European Union (EU)), it aims to be a fossil fuel independent society by 2050.

Denmark has significantly decreased its overall greenhouse gas (GHG) emissions by 27% from 75 million tonnes CO_2e ($MtCO_2e$) in 1990 to 55 $MtCO_2e$ in 2015. Current GHG emissions from the agricultural sector are responsible for over 21% of the country's overall emissions. This share of emissions has fallen by 16.9% over the period from 1990 to 2015, reflecting major improvements in the agricultural sector. The main policies that Denmark has been relying on over the last decades are the Action Plans for the Aquatic Environment (APAEs) and later in 2009 the Agreement on Green Growth (GGA), tackling mainly high nitrous oxide (N_2O) emissions and implementing the EU Nitrates Directive and the EU Water Framework Directive. The APAEs strongly regulate agricultural production by setting strict standards for the management and application of slurry and manure, the use of nitrogen fertiliser and requiring the planting of catch crops.

APAE I and APAE II collectively helped to decrease nitrogen discharge by 49%. While the effects on N_2O emissions were powerful (reduction of 2.2 $MtCO_2e$ per year), only minor reductions in methane (CH_4) emissions could be seen. As the APAE III seemed to have no measurable impact on emission reduction, the GGA was launched. The GGAs tackle some of the problems encountered in the APAEs and aim to bring together environmental and economic considerations of the agricultural sector. Their main focus is on nitrogen and phosphorous discharges into aquatic environments, renewable energy generation and biogas plants, the organic sector and the reduced use of pesticides. However, the incumbent government reveals a turn from previous climate commitments. Following this trend, the recent policies for the agricultural sector include more lenient regulation of fertiliser use. The agricultural sectors in Denmark and Germany exhibit strong similarities, especially considering economic, structural and political indicators. Comparable measures have been undertaken to decrease nitrogen and phosphorous leaching while maintaining or even increasing agricultural productivity. In Germany, the main tool is the Fertiliser Application Regulation ('Düngeverordnung'), amended in 2017.

2. INTRODUCTION TO THE INSTRUMENT

A series of action plans and political agreements, each comprising a list of measures, have allowed the Danish agricultural sector to have one of the lowest CO_2 footprints per unit of production. The action plans analysed in this study are the following:

- Action Plan for the Aquatic Environment (APAE) I (1987–1998),
- Action Plan for the Aquatic Environment II (1998–2004),
- Action Plan for the Aquatic Environment III (2004–2009),
- Agreement on Green Growth (GGA) (2009–2010).

Among the series of action plans implemented in the sector, these above-mentioned plans have the most measurable effects regarding greenhouse gas (GHG) emission reductions and display a high degree of transferability to the German context. Other action plans, such as the Plan for Sustainable Agriculture, the Ammonia Action Plan or Political Agreement on Food and Agricultural Package, have had limited impact on emission reductions. Therefore, the focus of this analysis is on the APAEs and the GGA.

The APAEs mainly focused on reducing nutrient loss to the environment, specifically nitrogen. As nitrogen discharge causes emissions of nitrous oxide (N_2O), a highly potent GHG, this regulation had a significant impact on the sector's GHG emissions.

The most relevant components of these policy action plans target the use of inorganic fertiliser, manure management and the planting of catch crops, all of which reduce the consumption and the nitrogen run off into the aquatic environment. Measures mainly comprise mandatory standards for fertiliser application, maximum limits for nitrogen use, and percentage of area covered by catch crops. The analysed action plans also include financial support for organic farming and investments at farm level, tradable nitrogen quotas and, more recently, support for bio-methane production. The mandatory standards introduced for these aspects of agricultural production had a significant effect on the reduction of nitrogen levels and thereby on N_2O emissions caused by the agricultural sector. The main purpose of these instruments was to reduce environmental pollution, especially nitrate levels, in the aquatic environment. GHG emission reductions were not the specific goal of these instruments.
The initial action plans mainly targeted pollution to the aquatic environment. The aquatic environment comprises all bodies of water, including wetlands, oceans, lakes, rivers and groundwater. The high levels of pollution in these water bodies in the 1980s led to measures being introduced to reduce nitrogen consumption and ultimate runoff into the environment.

3. NATIONAL CONTEXT

3.1 National climate policy

Denmark has been at the forefront of ambitious climate policy since the early 1990s, directed by national ambitions and in line with international climate policies. The Brundtland report of 1988 firmly put environmental issues on the political agenda. Since then, sustainability policies have been integrated into other sectoral policies via action plans. Sectoral action plans were implemented for the forestry and agriculture sector, transport, energy, the aquatic environment, development assistance and waste (Danish Ministry of Energy, Utilities and Climate, 2017). Many of the domestic policies are closely linked to the European Union (EU) climate policies and transpose EU environmental legislation. However, already in the early 1990s, Denmark imposed a CO_2 tax on certain energy products and an energy tax on mineral oil products, more than a decade before the EU Emissions Trading System (ETS) was launched. In 2009, the United Nations Framework Convention on Climate Change conference (15th Conference of the Parties, COP15) took place in Copenhagen with the aim of establishing a joint framework for climate change mitigation. Even though this event did not achieve the desired outcomes, it raised awareness for climate change and further increased public support for climate policies. It also encouraged some municipalities to set their own, more stringent climate targets.

Three years after the summit, the Danish government committed to the goal of a fossil fuel independent society, which is anchored in the 2012 Energy Agreement. The target is to achieve 35% of renewable energy in final energy consumption by 2020 and to be a low-carbon society by 2050. Further targets of the Energy Agreement are 10% of renewable energy sources in the transport sector by 2020; improvement of energy efficiency standards in buildings; and the expansion of wind power from 25% in 2012 to 50% in 2020 (Grantham Research Institute, 2015). The initiatives of the Energy Agreement are estimated to achieve a reduction of GHG emissions of 34% by 2020 (compared to 1990). Current estimates predict a 40% share of renewable energy by 2020 and will thus exceed the commitment. However, due to the discontinuation of EU subsidies for renewables and the expiry of the Danish Energy Agreement in 2020, the consumption of energy from renewable energy sources is likely to stagnate, and the use of fossil fuels is expected to increase in 2020 (Danish Energy Agency, 2017). In the Climate Policy Plan of 2013, a 40% reduction of GHG emissions by 2020 compared to 1990 was postulated. Electricity and heating are to be covered exclusively by renewable energy sources in 2035 and coal and oil for heating purposes are to be phased out by 2030 (Danish Government, 2013).

The Energy Agreement and Climate Policy Plan are supported by the Climate Change Act passed by parliament in 2014. The aim of this legally binding act is to build up an overall strategic framework to become a low-carbon society by 2050. However, specific reduction targets are not mentioned. One focus was to establish a Climate Council of independent and distinguished academics, which are experts in the fields of agriculture, energy, environmental protection, transport, nature and economics. Besides contributing to the public discussion on climate change, they are to advise the government on climate policy. Furthermore, the Climate Change Act obliges the Minister for Energy, Utilities and Climate to publish a report on proposed climate policies at least every five years containing a 10-year outlook. The Minister also has to submit an annual energy policy report to parliament, including on the status of current GHG emissions (Grantham Research Institute, 2015).

Between 1990 and 2015, total GHG emissions had fallen by 27% from approximately 75 million tonnes CO_2e ($MtCO_2e$) to 55 $MtCO_2e$ per year (Nielsen et al, 2018). However, in 2015 the Minister for Energy, Utilities and Climate backtracked on the commitment of a 40% reduction of GHG emissions by 2020 and stated to the national newspaper Altinget that current policies would lead to a sufficiently large decrease of 37% and that further efforts would be too expensive for Danish businesses (The Local, 2015). Nevertheless, in June 2018 an energy agreement was signed by the Danish government that aimed to reaffirm Denmark's climate policy to become a low-carbon society by 2050. The agreement includes several initiatives, such as the establishment of additional offshore wind farms; the allocation of financial support for green electricity; organic biogas production, and green mobility; as well as a plan for a coal phase-out in electricity production by 2030 (Ministry of Foreign Affairs of Denmark, 2018).

3.2 Sector context

Traditionally, agriculture in Denmark has played a major role in the country's economic and cultural landscape. However, mirroring the trend in most industrialised countries, the role of the agricultural sector has been declining continuously. While in 1990 it still accounted for 3.3% of Denmark's gross domestic product (GDP), it had dropped to 0.8% in 2016 (World Bank, 2018a). In 2017, 80,000 people were working in the agricultural sector, amounting to 2.6% of all people employed. This number has stayed relatively stable over the last ten years. By contrast, in 1991, 6% of the Danish people were employed in this sector, indicating a significant decline over the longer term (World Bank, 2018b) (Figure 1).

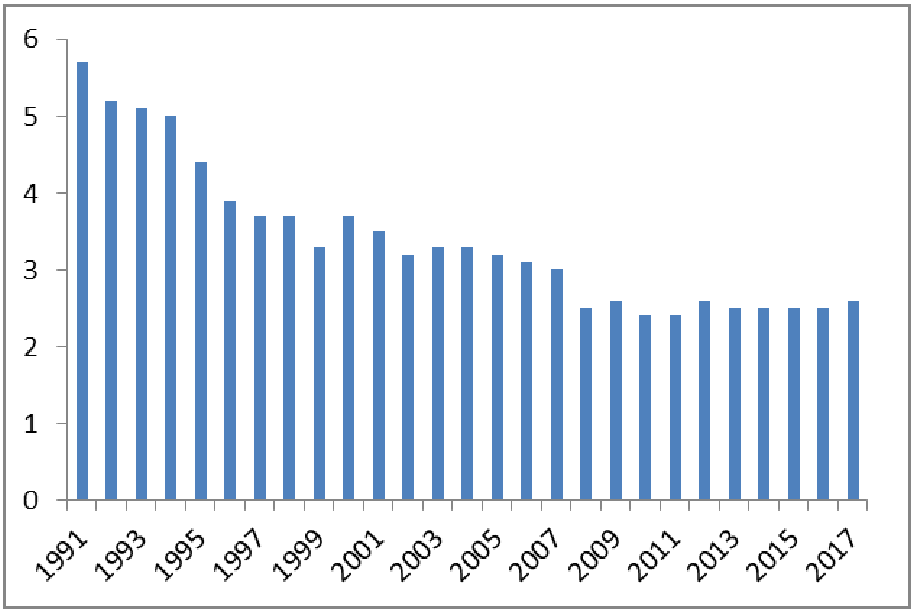

Figure 1: Employment in the Danish agricultural sector (% of total employment) 1991–2017 (World Bank, 2018b)

The number and size of agricultural holdings in Denmark has seen opposing trends over the last decades, resulting in fewer and larger farms. The Utilised Agricultural Area (UAA) amounted to 26,226 km^2 in 2016, covering 61% of the total land in Denmark. This amount constitutes a decrease in UAA by 11% since 1960. The number of farms has equally been decreasing, falling from 119,155 in 1980 to 36,637 in 2015 (-69%). Over the same timeframe, the average farm size almost tripled from 24 hectares (ha) to 72 ha. In general, the Danish agricultural sector is characterised by predominantly large holdings, with 20.3% of holdings having more than 100 ha compared to an average of 3.1% in EU-28 (European Commission, 2016). Interest in organic farming has risen considerably, and around 7% of land under cultivation was organically farmed in 2015.

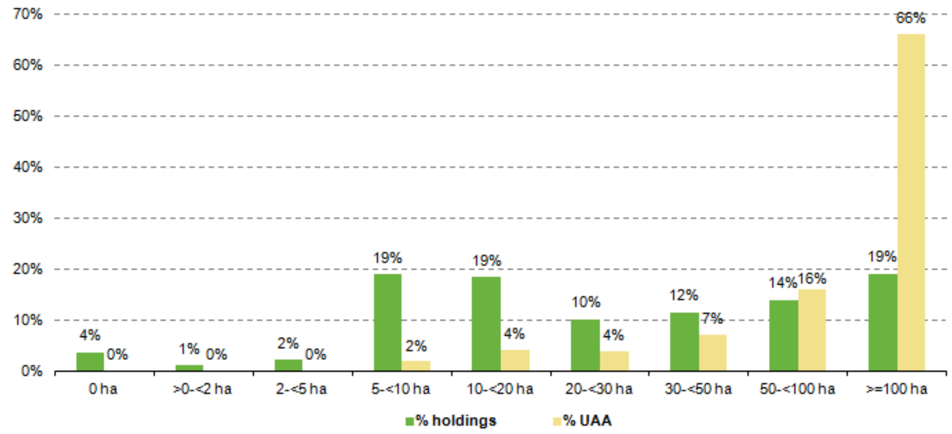

Figure 2: Number of holdings and UAA by UAA size classes (Eurostat, 2018a)

The numbers of livestock have remained relatively stable since 2000, with around 18 million poultry, 144,000 sheep and 13 million pigs. The cattle population decreased to 1.6 million (-15.6%), most of which are dairy cows. However, the fall in cattle population is due to higher productivity per animal since milk production remained nearly unchanged throughout the period.

The agricultural land use has undergone some changes from 1990 to 2015. While the percentage of land used for grain production stayed very stable in that period (56% in 1990 and 55% in 2015, root crops dropped from 8% to 3%, and grass and greenfeed in rotation increased from 12% to 19%. Agricultural products still account for a large proportion of Denmark's total export (10%), a fifth of which are dairy products (Danish Ministry of Energy, Utilities and Climate, 2017). The agricultural production value (gross production value) has seen a substantial increase from around EUR 7.1 billion in 1991 to EUR 9.4 billion in 2014. Of this production, livestock accounted for the majority of EUR 6.6 billion, while EUR 2.8 billion originated from crop cultivation (Eurostat, 2018a).

The agricultural sector is comprised of several organisations and cooperatives. In 2014, 28 agri-cooperatives existed in Denmark, with a total number of 45,710 members and a yearly turnover of EUR 25 billion. Interestingly, the largest food companies in Denmark are predominantly cooperatives such as Arla Foods A.m.b.a and Danish Crown A.m.b.a (cogeca, 2015).

Current GHG emissions from the agricultural sector make up 21% of the country's overall emissions, with a majority stemming from livestock production. Emissions from Denmark's agricultural sector have fallen by 16.9% over the period from 1990 to 2015, while overall emissions of all sectors dropped by 27% in the same period. The most important GHGs emitted by the agricultural sector in Denmark are methane (CH_4) and N_2O, both of which account for similar shares of the sector's GHG emissions (53% and 45% of CO_2e, respectively). The main sources of CH_4 emissions were enteric fermentation and manure management. N_2O emissions are driven by agricultural soils and manure management (Nielsen et al, 2018). While emissions derived from enteric fermentation have decreased by 8.1% since 1990, CH_4 emissions from manure management have increased by 19.6% in the same period, mainly due to a change from traditional animal housing systems (using solid manure) towards slurry-based housing systems[1]. The total decrease of CH_4 emissions from the agricultural sector was therefore at 0.4% from 1990 to 2016 (Nielsen et al, 2018) (Figure 3). Since 1990, a strong decrease in N_2O emissions of 26.5%

[1] Animal housing systems vary strongly and produce different levels of ammonia, CH_4 and N_2O emissions. Generally, animal housing systems can be divided into slurry- and straw-based (deep litter or solid manure) systems or a combination of both.

could be achieved, mainly due to management plans to lower the use of synthetic fertilisers, changes in manure use and a decrease in animal nitrogen excretion.

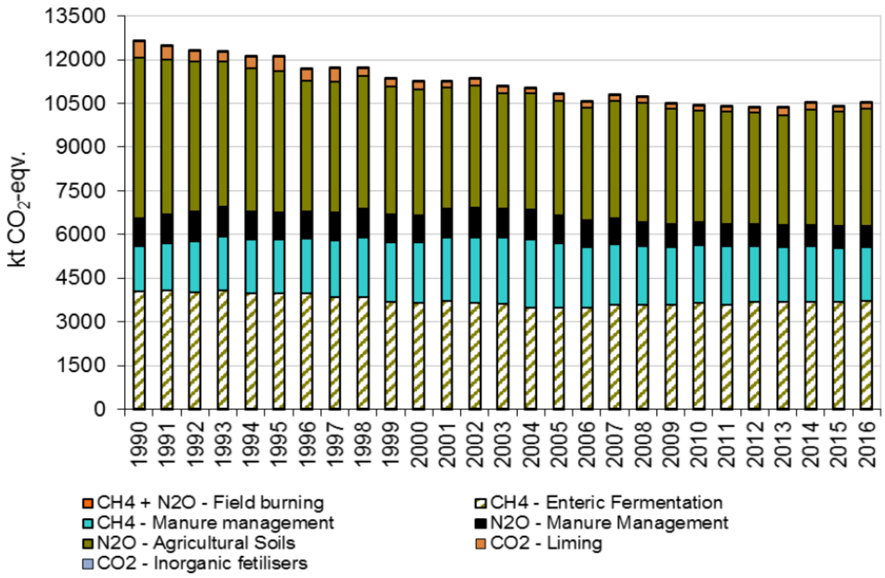

Figure 3: Danish GHG emissions in the agricultural sector from 1990–2016 (Nielsen et al, 2018)

4. GENERAL DESCRIPTION OF THE POLICY INSTRUMENT

4.1 History

Denmark has been an early adopter of environmental and climate policy for several decades and has a very comprehensive and well-developed environmental regulation system (van Grinsven et al, 2012). The first APAE, implemented in 1987, was a result of increased attention to the pollution of marine environments. Measures included in the first two action plans to address this problem were all based on binding regulation, whereas later action plans (APAE III and the GGA) also included government financing instruments and informational measures (Dalgaard et al, 2014). After the implementation of the first APAE, regulation was continuously tightened and made more comprehensive. After the evaluation of each action plan, the results were incorporated into the subsequent policy package. The measures therefore have to be considered as a continuous development rather than individual policy instruments.

The very active national environmental policy, beginning in the late 1980s, has built the foundation for the current status of Danish agriculture which has one of the lowest CO_2e footprints per unit of production globally. A large number of measures have been implemented in various actions plans, especially targeting the loss of nitrogen from agriculture to the environment. Initially, a primary focus was given to the protection of the aquatic environment (Albrektsen et al, 2017). At the time the first APAE was adopted, new technologies for nitrogen-efficient farming practices were already available at relatively low cost, meaning the measures could be implemented by farmers without excessive financial burden.

The series of action plans implemented to address nitrogen pollution contain a wide range of measures. These are mainly command-and-control regulation, setting the same standards and norms for all actors and all parts of the country (Dalgaard et al, 2014). The more recent GGA includes some more market-based measures, with tradable nitrogen quotas and support schemes for organic farming.

4.2 Legal basis

The APAEs and GGA are based on parliamentary approval and constitute binding regulation. From the APAE II onward, they have functioned as the national implementation of the EU Nitrates Directive and the EU Water Framework Directive. EU directives are binding to national authorities and are transposed into national law through legislative procedure. In its transposition mechanisms, Denmark relies on two different procedures: the interdepartmental coordination system and the parliamentary oversight procedure. Interdepartmental coordination is implemented through committees that each mirror one political area of responsibility, such as the Finance or Defence Committees. Those committees are closely linked to their respective ministry and the ministry responsible for the policy area usually chairs the committee (Gronnegard Christensen, 2010). Environmental EU directives are typically handed over to the Environment and Food Committee, proposing adequate bills for parliamentary resolution and translation into a national legislative context. Interestingly, Denmark has two ministries responsible for environmental issues: the Ministry of Energy, Utilities and Climate and the Ministry of Environment and Food. Usually, sector action plans are then compiled outlining specific objectives and measures. These action plans are, after parliamentary discussions, approved by parliament. In case of the APAEs and GGA, all major political parties represented in parliament agreed on the action plans.

4.3 Functioning

The primary focus of environmental regulation in the agricultural sector in Denmark has been on nutrient losses to the environment, specifically the aquatic environment. Reducing the amount of nitrogen discharged into the environment reduces emissions of N_2O, a GHG that has a 100-year global warming potential 298 times that of CO_2 (Umweltbundesamt, 2017a). The emission of N_2O occurs during the chemical transformation of nitrogen. The largest sources of N_2O are inorganic fertilisers applied to the soil and animal manure, along with nitrogen leaching and runoff (Albrektsen et al, 2017). The reduction of these sources therefore has a direct effect on GHG emissions from the agricultural sector. In addition, a quota system for nitrogen fertilisation was implemented from 1991 onwards, which established statutory norms for nitrogen applied to different crops and which were not to be exceeded for the farm as a whole. Initially, this quota was set at the economic optimum for fertilisation rates, based on a large number of experiments. This quota was reduced to below the economically optimum level in 1998 in order to achieve further reductions in nitrogen use.

The most GHG-relevant measures in these action plans have targeted fertiliser use, manure management and the planting of catch crops[2] (primarily grass planted in the autumn after harvest of the main crop in order to reduce nitrogen leaching). The GGA also focuses on efficiency in resource use and recovery of valuable by-products. A new goal is the target of using half of all manure for biogas generation by 2020. This will reduce emissions of CH_4 from manure. In general, the GGA was intended to address problems encountered in the implementation of the APAE III. The targets of the APAE III were included in the GGA but with an altered approach and a more targeted and output-based focus.

Please see Table 1 for a list of the most important provisions included in each policy package.

Table 1: Overview of relevant measures (based on Dalgaard et al (2014) and Danish Ministry of Energy, Utilities and Climate (2017))

Policy package	GHG-relevant measure
APAE I	Minimum slurry storage capacity of nine months
APAE I	Ban on slurry spreading from harvest to beginning of November on soil designated for spring crops
APAE I	Incorporation of manure within 12 hours of application
APAE I	Percentage of 65% of winter-green fields
APAE I	Mandatory fertiliser and crop rotation plans
APAE II	Mandatory requirement for the planting of catch crops, 6 to 10% of the total area of the farm, depending on the amount of manure used per ha
APAE II	Integration of catch crops in fertiliser plans
APAE II	Tightening of nitrogen standards. Maximum limit on the nitrogen applied to different crops lowered to 10% beneath the economic optimum level
APAE II	Increased utilisation rate for manure
APAE II	Standard for improved animal feeding practices to improve the utilisation of feed and reduce excretion of nitrogen
APAE II	Tax of DKK 5 (EUR 0.67) per kg of nitrogen in fertiliser

[2] Catch crops are fast-growing crops, often grass, which are grown in periods between the planting of main crops

Policy package	GHG-relevant measure
APAE II	Ban on the application of manure during autumn and winter
APAE II	Increasing the area of winter-green fields (fields planted with catch crops) to catch nitrogen
APAE II	Maximum rates of fertiliser application for different crops
APAE III	The percentage of mandatory catch crops increased to 10–14%
APAE III	Mandatory improvement of the utilisation of nitrogen in feed
APAE III	Tightening of requirements for utilisation of nitrogen in manure
GGA	Permanent 10 metre spraying-free, fertiliser-free and cultivation-free buffer zones
GGA	Ban on ploughing of grass fields during certain period of the year
GGA	Tightened regulation on existing requirements for catch crops
GGA	Ban on certain forms of soil cultivation in the autumn

All measures included in the APAEs, and partially those in the GGA, have contributed to manure and fertiliser becoming a valuable resource and encouraging their efficient use. As a result of stringent environmental regulation, the utilisation of nitrogen in manure is improved, leading to lower N_2O emissions.

4.4 Interlinkages with other policy instruments

Policies incentivising GHG emission reductions in the Danish agricultural sector are made up of a string of action plans, agreements and policy packages. The measures included in these are complementary and build upon each other. Other policies include the Action Plan for Sustainable Agriculture, the Ammonia Action Plan, and the Livestock Approval Act. All of these add to the regulatory framework in which the Danish agricultural sector operates. Their impact on GHG emissions is much less significant, which is why they are not analysed in more detail.

In general, the agriculture sector and its impacts are comprehensively regulated at EU level, based on the Common Agricultural Policy (CAP), the Nitrate Directive, the Water Framework Directive and the Habitat Directive. The CAP is the main instrument for financial support in this sector, providing income support for farmers and supporting sustainable rural development across the Member States. Subsidies for farmers are based on production, environmental considerations, animal welfare and food safety. After its reform in 2013, 30% of direct payments to farmers must be ‘Direct Green Payments’ which are linked to certain environmental public goods. These are based on three environmentally friendly farming methods, namely crop diversification, the maintenance of permanent grassland, and dedicating 5% of arable land to environmentally friendly measures (European Commission, 2016). While these provisions have numerous environmental benefits, including biodiversity protection and water quality, climate change mitigation is only one of several effects. Due to the CAP’s regulation, GHG emissions play only a very minor role in the allocation of subsidies and other funding mechanisms. Given that the CAP regulates the criteria based on which payments are made to farmers, it limits the scope of national policy measures such as subsidies to specifically address GHG emissions.

As mentioned in section 4.1, APAE II and APAE III are also recognised as implementation of the EU Nitrates Directive. The measures implemented in the APAEs and GGA were almost exclusively input-based and regulated at national level. The more recent EU Water Framework Directive requires additional approaches, which are output based and locally targeted. This shift in regulatory approaches was attempted with the successor action plans, namely the GGA 2.0 (2010) and the most recent Food and Agricultural Package (2015).

5. IMPACTS OF THE POLICY INSTRUMENT

5.1 Effectiveness

In general, available evaluations attribute most of the change in the level of N_2O emission to the three APAE. While some reduction in emissions would have occurred in the business-as-usual scenario due to higher efficiency, optimisation of production methods and the introduction of new technologies, these reductions would have been much smaller than the ones achieved through the measures included in the action plans (Dalgaard et al, 2014). Yet, the mitigation effect of the action plans has decreased over time, presumably also due to 'low-hanging fruits' having been captured in the earlier stages: According to the Danish Ministry of Energy, Utilities and Climate (2017), the effect of the APAEs I and II has been estimated to amount to a reduction of 2.2 MtCO2e per year. In contrast, the mid-term evaluation of APAE III concluded that no significant reductions in the key parameters that provide GHG emission reductions had been achieved, and found no decrease in the use of mineral fertiliser or nitrogen leaching. As a consequence, the GGA was introduced to address these shortcomings. The GGA includes the reduction target of APAE III and implements additional measures, mainly focused on increased efficiency in farming and financial support for production of bio-methane. In general, the approach of the GGA focused less on regulatory standards and more on financial incentives and support for the sector. An assessment of the combined effects of APAE III and the GGA in 2014 estimated a reduction of 0.19 MtCO2e per year from 2007–2011, with an approximate annual reduction of 0.337 MtCO2e for the period from 2012–2015 (Schelde and Olesen, 2016). As will be discussed in the following sections, the easier, initial reduction options are mainly used up and any further reductions are much more difficult to achieve.

Over the same period that regulatory requirements became gradually more stringent, efficiency increases and higher fertiliser value of manure could be observed. The GHG emission reductions in the Danish agricultural sector have mainly been achieved by a reduction in N_2O emissions, while emissions of CH_4 have remained largely unchanged. The main measures leading to reduced N_2O emissions from this sector have been the improvement of feed efficiency and improved utilisation of nitrogen in manure, which has led to a decreasing consumption of norganic nitrogen fertiliser (Nielsen et al, 2017). According to the Danish Centre for the Environment (DCE), a 23% reduction in N_2O emissions from manure management from 1985–2015 has been driven by stringent environmental requirements for the handling, storage and application of manure (Albrektsen et al, 2017). Another significant effect driven by the APAEs' requirements for reducing nitrogen loss to the environment has been a decrease in the consumption of nitrogen in inorganic fertilisers. Over the period from 1990 to 2010, the input of nitrogen in the agricultural sector decreased by 34%. This development is mainly attributed to the reduced application rates of synthetic fertiliser included in the action plans (Dalgaard et al, 2014). The level of nitrogen leached to the environment almost halved by 2015 compared to 1985 as a result of this decrease in consumption (Albrektsen et al, 2017).

The mid-term evaluation of APAE II in 2002 identified increased utilisation rates for manure, improving from 60 to 75% for pig slurry and 55 to 70% for cattle slurry (Danish Ministry of Energy, Utilities and Climate, 2017). According to Jacobsen (2004) (in Dalgaard et al, 2014), the key measures in APAE II were a higher required fertiliser equivalency of animal manure, and more stringent statutory fertilisation norms.

Figure 4 shows the distribution and development of different N_2O sources for the period 1990 to 2015[3].

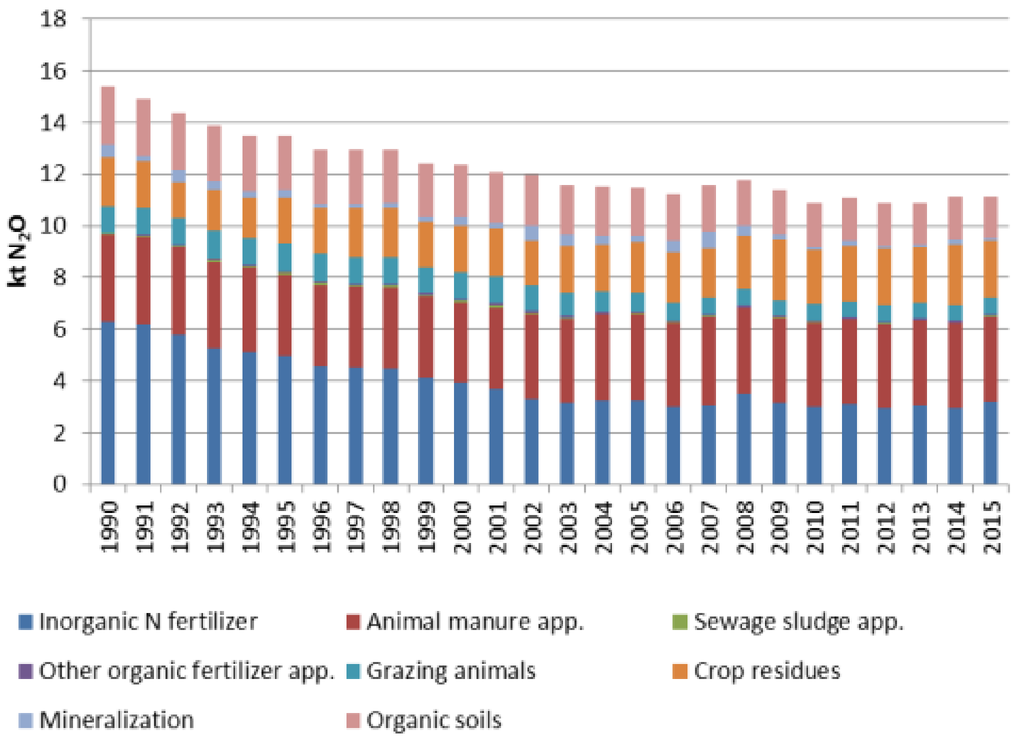

Figure 4: Development of N2O emissions from agricultural soils, 1990-2015 (Nielsen et al, 2017)

A further development induced by regulatory requirements is the increased use of catch crops. These crops not only reduce the leaching of nitrate to the environment but also sequester CO_2. The area covered by catch crops amounts to more than 220,000 ha, which is the equivalent of 8% of the agricultural area (Danish Ministry of Energy, Utilities and Climate, 2017). The amount of CO_2 reductions achieved by this development has not been estimated.

The latest estimate of the GHG reduction effect of the GGA, published in 2014, projected that the GGA would achieve an annual reduction of 0.5 MtCO2e by 2021 (Danish Ministry of Energy, Utilities and Climate, 2017). However, as will be discussed in section 5.4, the GGA was replaced first by the GGA 2.0 in 2010 and later by the Food and Agricultural Package in 2015. The measures included in these policy packages will lead to an increase in GHG emissions instead of further reductions.

The estimation of GHG emissions is based on the methodology used in the annual emission inventories, as described in the Intergovernmental Panel on Climate Change (IPCC) guidelines from 2006. While much data on different inputs for agricultural processes is available in the case of Denmark, a number of assumptions have to be made for the estimates. These include, for example, the expected change in nitrogen excretion as a result of increased feed efficiency. While both government and independent evaluations agree that the main reason for the marked reduction in agricultural GHG emissions are increasingly ambitious environmental requirements, the exact impact and contribution of individual measures are hard to quantify.

[3] According to Nielsen et al (2017), the increase in N_2O emissions from 2007 to 2008 was caused by an increased use of inorganic fertiliser due to stockpiling caused by an expected increase in fertiliser prices.

5.2 Cost efficiency

Due to its top-down, regulatory nature, the Danish approach to reducing GHG emissions in agricultural production meant that much of the costs was incurred by farmers who had to comply with strict regulation, thereby increasing production costs. Initially, the costs of these measures were mainly carried by farmers. However, the rate of implementation of these measures took account of whether the necessary technologies were available to ensure the implementation would be cost-efficient[4]. New technology, especially for manure related measures, was already available at reasonable cost when these measures were first implemented, making it economically feasible for farmers to comply with the regulation (Dalgaard et al, 2014).

Cost estimates of the measures implemented through the action plans vary widely. From 2003 to 2014, some ex-post and ex-ante assessments have been conducted (see for example Jacobsen et al, 2004, Borgesen et al, 2009). Based on estimates by Jacobsen (2009, 2012a, 2012b), the total annual cost of Danish initiatives to reduce nitrogen approximately amount to EUR 600 million, with roughly EUR 340 million of these costs being attributed to measures in the agricultural sector. The remaining costs relate to measures in industry and sewage treatment plants. Given that the estimated effect of the measures included in the APAEs is an annual reduction of 2.2 $MtCO_2e$, the cost per tCO_2e amounts to EUR 154.55. Another estimation of the cost of measures to reduce GHG emissions trough measures targeting nitrate leaching, ammonia volatilisation and reduced fertiliser use arrived at an estimation of DK 400-600 (EUR 54) per tCO_2e (OECD, 2008). These diverging numbers make an assessment of the action plans' cost efficiency very difficult.

As can be expected, the costs of reducing GHG emissions have increased over time after relatively easy reductions were achieved in the beginning. Another cost-increasing factor is reduced crop yields due to nitrogen fertilisation below the economic optimum (Dalgaard et al, 2014). As mentioned in section 4.3, the nitrogen quota was reduced to a level 10% below the economic optimum. These factors have led to costs rising above the levels originally estimated. In general, the application rates of nitrogen are currently below the economically efficient level, making a further reduction very costly.

The GGA had a budget of DKK 13.5 billion (approximately EUR 1.81 billion) for the period from 2009–2015, provided by the government of Denmark. This constitutes a significant increase in funding compared to previous initiatives (Agreement on Green Growth, 2009). Considering the relatively low amount of emission reductions this agreement has achieved; its cost efficiency can be considered low. For comparison, the APAEs each had approximately half of these funds available and achieved much larger GHG mitigation. Since 2009, nearly no emission reductions have taken place. The GGA instead provides financial support for different forms of investment at a farm level. The fact that no more easy options for GHG emission reductions are available is an important factor contributing to the decreasing cost efficiency.

5.3 Co-benefits and side-effects

Since the APAEs mainly aimed to reduce the pollution of the aquatic environment caused by agriculture, an important effect has been improved water quality in Denmark. Implementation of the action plans not only resulted in a substantial reduction in nitrate concentration in groundwater (Dalgaard et al, 2014), but also in improvements in the quality of coastal water. Large public health benefits are also estimated based on improved quality of drinking water and related health impacts (Andersen et al, 2013

[4] Based on interview with academic expert.

in Dalgaard et al, 2014). An overall reduced environmental impact of the agricultural sector along with increased sustainability can also be attributed to the APAEs and GGA.

A negative side effect is the increased production cost for farmers. Regulatory requirements mean a financial and administrative burden for farmers. As a result, agricultural associations are exercising growing pressure on the government to relax regulation in order to secure employment and the continued contribution of the agricultural sector to Danish exports. Since European farmers operate in a highly competitive market, there is little opportunity to pass on costs.

5.4 Success factors and challenges

A long-term and consistent effort by the Danish government has led to a transition of the agricultural sector towards greater sustainability and lower environmental impacts. Over the same period, agricultural production has continued to increase and resulted in a highly efficient agricultural industry. Even before the implementation of APAE I, the benefits of better utilisation of manure were becoming apparent, which was an important reason why farmers' associations supported the implementation of low-emission technologies (Dalgaard et al, 2014). As mentioned earlier, some of the changes observed in the Danish agricultural sector would likely have occurred based on the new technology available, but a much larger effect was achieved through the action plans.

While the recent shift in approaches implemented by the GGA 2.0 and Food and Agricultural Package includes a more spatially targeted instead of nationally homogenous regulation, it also includes an increase in fertilisation standards to the economically optimal level (previously at 10–15% below this level). According to an academic expert interview, the very strict regulation over the last three decades has led to an increased lobbying effort and founding of a new agricultural association, which successfully argued that the economic cost of strict environmental regulation was becoming an unreasonable burden on the sector. According to the expert, more recent emission reductions, which have been much smaller compared to previous rates of reduction, have mainly been achieved through higher efficiency in the sector instead of resulting from political interventions.

As a result of the strict regulation in the Danish agricultural sector, the government has seen strong opposition from farming organisations and other industry bodies. A new organisation was founded, the 'Sustainable Farming Union', which primarily focuses on economic sustainability and has sued the government for over-implementation of the EU Nitrates Directive, claiming the measures had been too costly relative to their effects on reducing nitrogen loading of the environment[5]. This court case was unresolved at the time this study was written. A result of this growing pressure has been a relaxation of environmental standards and norms in more recent policy packages (GGA 2.0 and Food and Agricultural Package). Based on the argument that a continuation of the policy initiated in 1987 would not be economically sustainable and harm the agricultural sector, current efforts and measures for the near- to mid-term future are expected to slow down progress and even lead to an increase in GHG emissions from agriculture by 2020 (Danish Energy Agency, 2017). However, while costs for reducing nutrient pollution through APAE I and APAE II have been considerable, not all of these costs were carried by farmers. According to an OECD report, the overall costs of APAE II were estimated at approximately DKK 525 million (EUR 70.43 million) annually. Of these costs, farmers bore approximately 60% with the remaining costs being paid by tax payers and through a price increase of water for households (OECD, 2008). It is therefore unclear, whether the agricultural sector has experienced economic harm based on these policies.

[5] Based on interview with academic expert.

The GHG emissions from this sector, based on a 2017 estimate, are expected to see a slight increase from 10.3 $MtCO_2e$ in 2015 to 10.6 $MtCO_2e$ in 2020 (Danish Ministry of Energy, Utilities and Climate, 2017). This increase is caused by both an increase in CH_4 emissions and N_2O emissions. The increase in CH_4 emissions is expected as a result of a larger number of dairy cattle combined with a higher milk yield, which causes higher emissions from enteric fermentation. This development is independent of Danish policy, while the increase in N_2O emissions is driven by a relaxation of regulatory requirements. Due to a loosening of the requirements for the use of inorganic fertilisers, an increase in their application is expected, leading to higher N_2Oemissions.

There have been warnings that continued tightening of emission reduction targets could result in a reduction of Danish agricultural production, with production being relocated to countries where the agriculture sector has a much larger climate and environmental footprint (Danish Centre For Food and Agriculture, 2016). The measures first implemented to reduce the loss of nitrogen to the environment, such as a ban on slurry spreading during certain periods or the mandatory incorporation of manure within a short time after application, are now mostly exhausted in Denmark, meaning that different types of measures will be necessary to further reduce GHG emissions from the agricultural sector. One instrument to achieve this would be to support nitrogen removal through wetlands[6]. Re-wetted wetlands act as a filter for nutrients and also sequester carbon. However, currently, the main emphasis is on supporting biogas production based on manure.

[6] Based on interview with academic expert.

6. TRANSFERABILITY

6.1 General comparability of the context

Comparability of the German and Danish agricultural sectors is very high regarding economic, political and structural context. In both countries a continuously decreasing trend in the sector's economic significance over the past few decades can be observed. In Denmark, the agricultural sector contributed 0.8% to the GDP in 2016, whereas it accounted for a lower 0.6% in Germany (World Bank, 2018a). The UAA in Germany totals an area of 16.7 million ha, compared to Denmark's 2.6 million ha (Eurostat, 2018b). Thus, a larger share of the country's land is under agricultural cultivation in Denmark (60% in Denmark and 47% in Germany). Average farm size in both countries was very similar in 2016, with 60 ha in Germany and 70 ha in Denmark.

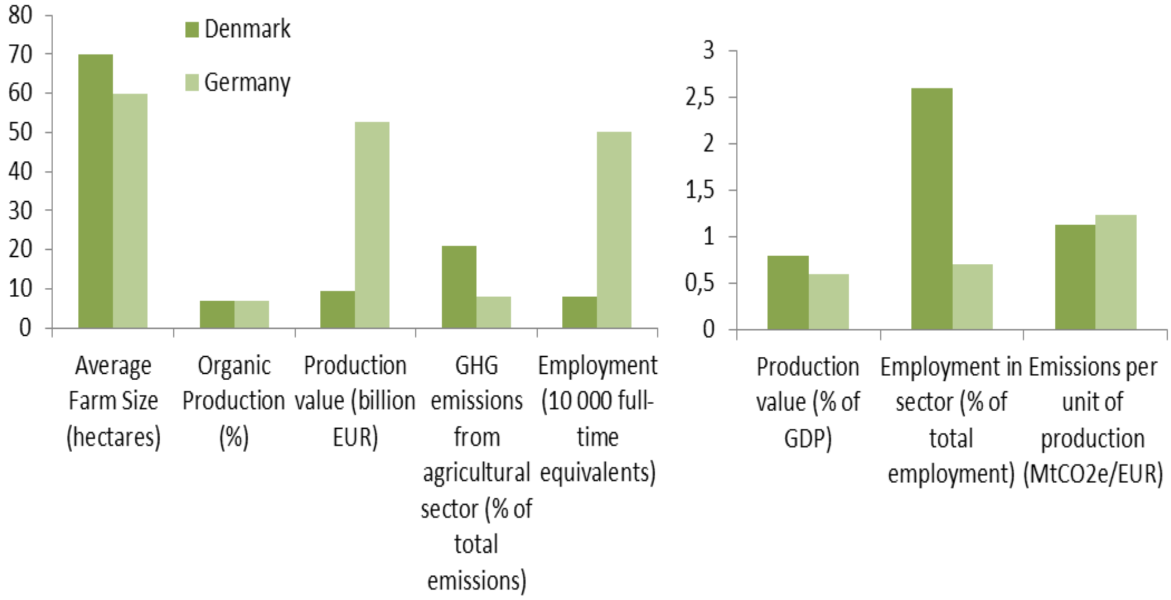

Figure 5: Comparability of the Danish and German agricultural sector (own figure)

Also, the share of farms using organic production methods is highly comparable (7% in both countries). The fact that almost half of all farms (46%) are run as a secondary occupation is a special feature of the German agricultural sector. Around 1 million people employed in the sector thus amount to 0.5 million full-time equivalents (0.7% of total employment). This is roughly six times more than the 80,000 workers (2.6% of total employment) in the Danish agricultural sector. In 2014 the production value of the German agricultural sector was estimated to be at EUR 52.5 billion, with almost half of this value coming from crop cultivation and livestock (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2017). At the same time the agricultural production value in Denmark amounted to around EUR 9.4 billion, with the vast majority of over EUR 6.6 billion derived from livestock (Knoema, 2018).

Latest estimates place the share of GHG emissions from the agricultural sector at 21% of overall emissions in Denmark. In Germany, approximately 8% of overall emissions are caused by this sector. However, Denmark has comparatively low emissions in other sectors, resulting in relative emissions being higher for agriculture. In contrast, the emissions caused per unit of production are lower in

Denmark than in Germany. Since 1990 significant emission reductions with simultaneous increases in productivity of the agricultural sector were achieved in both countries. In Germany, overall agricultural emissions have declined by 15.9% between 1990 and 2015, compared to the 16.9% reduction that the Danish sector has seen (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2017). Much of the reduction in Germany, however, has been due to a significant reduction of East German agricultural production in the aftermath of the German reunification.

In Germany, the main provisions of the EU Nitrates Directive have been put into effect by the Fertiliser Application Regulation (‘Düngeverordnung’, DüV), which was amended and implemented in May 2017. The most significant national funding instrument for farming and forestry, coastal protection and rural development with more than EUR 1 billion of total annual funding is the Joint Task for the Improvement of Agricultural Structures and Coastal Protection (‘Gemeinschaftsaufgabe Verbesserung der Agrarstruktur und des Küstenschutzes’, GAK). It entails a number of agricultural and infrastructure measures in its framework plan (Federal Ministry of Food and Agriculture, 2018). A distinctive feature of Germany’s political and administrative landscape is its federal structure in which the individual federal states (‘Länder’) in part implement their own regulatory measures or funding instruments.

However, in both countries (and all other EU Member States), the agricultural sector is additionally heavily regulated at EU level. Therefore, large amounts of the same regulations apply in Germany and Denmark, significantly reducing the flexibility in aligning the regulatory context and policy measures.

6.2 Properties of the instrument

The instrument has a high political threshold since it requires an agreement in parliament for its implementation and to make it legally binding. It also has to be in accordance with comprehensive regulation at EU level, making it an administratively, legally and politically challenging task to implement a similar instrument. While uniform standards for fertiliser application, manure management and planting of catch crops are technically easily transferable, differences in environmental circumstances can mean that a spatially targeted approach may seem more appropriate. If adjusting these standards to different circumstances, however, comprehensive information and wide-ranging data are required in order to set standards at the appropriate levels.

While a policy package containing a number of standards and provisions may be difficult to implement, putting into practice specific individual regulation may be easier to realise.

Given that it is legally binding, the provisions of the action plans are enforceable, and non-compliance can be sanctioned. As a result, actors affected are likely to comply with the new regulation and change their actions accordingly, as opposed to a scenario with no such binding regulation. Especially if changes need to be realised in a short period of time, a regulatory instrument provides an effective option by mandating a specific environmental outcome. However, it comes with a comparatively high cost of implementation as strict environmental requirements mean increasing production costs for farmers.

One of the disadvantages of a regulatory instrument with uniform standards and requirements is its lack of flexibility. All actors have to comply with the same regulation, independent of the cost incurred or local circumstances. The individual requirements included in the APAEs and the GGA can be adjusted to the German context if deemed necessary and effective.

6.3 Potential impacts

A number of comparable measures to those included in the APAEs I–III and the GGA have been implemented in Germany through the amendment of the DüV in 2017. However, the environmental requirements of this amendment are still not on par with the ones analysed in this study. Many of the standards included in the Danish policy packages are more stringent (see Table 2).

Table 2: Comparison of measures in Danish and German agricultural policy instruments with the more stringent measure in bold (own table)

Denmark		Germany	
Measure	**In**	**Measure**	**In**
10 metres mandatory permanent spraying-free, fertiliser-free and cultivation-free buffer zones along all watercourses and lakes, equivalent to approximately 50,000 ha	GGA	1 metre of mandatory manure/fertiliser-free buffer zone along watercourses. If slope >10% 5 m buffer zone and between 5 and 20 metres from watercourse manure has to be incorporated immediately	DüV §5
Planting additional catch crops on 140,000 ha agricultural land	GGA	Catch crops subsidised	GAK
10,000 ha of wetlands, that acts as biofilter removing nitrogen	GGA	Creation of mini-wetlands subsidised	GAK
Mandatory catch crops (6% and 10% of the total area of the farm property depending on the amount of manure used per ha). Catch crops included in fertiliser plan	APAE II	Catch crops subsidised	GAK
Nitrogen standard norms with maximum limit on the plant-available nitrogen applied to different crops lowered to 10% beneath economic optimal application rate	APAE II	Maximum limit on the plant-available nitrogen applied to different crops (e.g. winter rape 200 kgN/ha; potatoes 180 kgN/ha; cauliflower 300 kgN/ha)	DüV §4
Increased utilisation rates for manure through the period from APAE I to final rate in 2002 **(pig slurry: 60 to 75%, cattle slurry: 55 to 70%,** deep litter: 25 to 45%, other types 50 to 65%)	APAE II	Utilisation rates for nitrogen in manure (pig slurry: 60%, cattle slurry: 50%)	DüV §3 Absatz 5
Mandatory catch crops increased to 10 and 14%	APAE III	Catch crops subsidised	GAK
Improvement of utilisation of nitrogen and phosphor in feed	APAE III	No corresponding measure	
Minimum 9 months slurry storage capacity	APAE I	Minimum 6 months slurry storage capacity	DüV §12

Implementing requirements with a similar stringency and comprehensiveness is likely to lead to further reduction in GHG emissions than are already projected for the new DüV. In addition, the DüV and GAK as the other main policy instrument targeting the German agricultural sector contain several financial support instruments aiming at similar results as the Danish environmental regulation. Providing financial incentives for example for planting catch crops has less certain outcomes than setting a mandatory and enforceable standard. It is therefore yet unclear, which impacts the new DüV will have. A projection of the impact of the new DüV concludes that an emission reduction of 2.2 $MtCO_2e$ will be achieved in 2020 (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2017b). Mandating even lower levels of fertiliser use or higher nitrogen utilisation rates for manure would potentially result in an even larger reduction of GHG emissions.

While levels of N_2O emissions in Germany have decreased significantly between 1990 and 2015, this is mainly due to reductions in the industry sector, while emissions from agriculture have decreased by less than 10%. Since 2009, overall emissions of N_2O have stagnated (Umweltbundesamt, 2017b). While the measures included in the DüV are a significant improvement and a step towards reducing N_2O emissions from the agricultural sector, more could be achieved by requirements that are on par with those included in the APAEs and GGA.

Estimating the potential GHG impacts of measures included in the policy packages discussed here is plagued by difficulties of attributability of GHG emission reductions to individual measures. While evaluations were conducted of whole action plans, attributing amounts of decreased GHG emissions to a specific environmental standard is much more difficult, making an estimation of the impact of a similar measure in Germany very challenging. It can also be observed in the case of Denmark, that reducing N_2O emissions becomes increasingly difficult and expensive after the early, easier options for reductions are exhausted. Since Germany's regulation of the agricultural sector is less advanced in terms of regulating fertiliser use and other nitrogen-producing activities, it would be reasonable to assume that significant options for nitrogen reductions are still available.

6.4 Conclusion

Given the currently high levels of nitrate pollution and N_2O emissions caused by the agricultural sector, a comprehensive policy package addressing the different agricultural sources appears necessary. Whether the revised DüV will be sufficient in this regard will have to be evaluated in the near future. Should Germany continue to exceed both the nitrate levels allowed under the EU Nitrates Directive and levels of ammonia regulated by the EU Water Framework Directive, strict new measures will have to be adopted to quickly achieve significant reductions of these levels. A regulatory instrument addressing all agricultural sources of nitrogen and ammonia pollution would be the most effective option in this case.

If current standards and regulations are deemed insufficient by the EU in 2020, this would clearly call for the implementation of standards and environmental requirements similar to those in Denmark. A particular focus should be on those measures that have been most successful in decreasing nitrogen and N_2O levels, namely increased utilisation rates of nitrogen in manure, improved manure management, and reduced application rates for synthetic fertiliser.

If the implementation of a legally binding instrument is attempted in Germany, it would be important to consider and learn from the negative effects these measures have caused in Denmark, for example the political backlash in recent years. Given that the more recent Danish policy packages, namely the APAE III and GGA have had much less of an impact on nitrogen levels and N_2O emissions, it would be important to analyse exactly why this has been the case and how it would be possible to ensure that a similar instrument in Germany would actually achieve its intended objectives.

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