REDUCING AMMONIA EMISSIONS IN EUROPE: COSTS, REGULATION AND TARGETS WITH FOCUS ON DENMARK

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Abstract

The NEC directive has set targets for the 2010 ammonia emissions from a number of European countries. The target will be reached by most EU-countries and the total emission for EU-27 has been reduced by 22% from 1990 to 2007. Denmark is one of the countries with the largest reductions since 1990 and the article looks at the measures and costs involved. The conclusion is that the costs have been under 3 €/kg NH3-N. The findings suggest that the same measures might be cheaper in the Netherlands and Denmark than in the UK and the USA due to technology advances and stricter regulations in the past. The new Danish application procedure, when increasing the animal production, has tried to make the acceptance procedure quicker and dynamic ensuring that new technology is adopted quicker and that the farm is located in the right place. It is concluded that the new application process so far has not lived up to the high expectations at the outset. Despite this, the paper concludes that Denmark is likely to reduce emission by 50% from 1990 to 2020 and reach the likely 2020 NEC ceiling.

Keywords: Ammonia emission, costs, cost effective measures, NEC directive.

1. Introduction

The NEC Directive (2001/81/EC) (National Emission Ceiling) sets a ceiling for the national emissions for a number of atmospheric pollutants including ammonia (NH_3) from most European countries. The aim of reducing NH_3 emissions is to limit eutrophication of ecosystems in order to improve the protection of the environment and human health.

For the EU 27 countries, the emission ceiling was 4,292 kt NH3 in 2010 compared with the emission in 1990 of 5,090 kt NH3 (EAA, 2010). The largest emitters in 2007 were France, Spain and Italy. The current prognoses indicate that the total EU-27 emission will fall to 3,884 kt NH3 in 2010, which is 10% below the 2010 ceiling. This is a reduction of 24% from 1990 to 2010. Twenty-one of the EU-27 Member States have already in 2007 achieved their 2010 ceilings. The Baltic countries, Malta and Cyprus, will be more than 40% below the expected 2010 level, whereas Finland, Germany and Spain do not seem to be able to meet their respective 2010 ceilings (EAA, 2010).

Agriculture was responsible for 93% of NH_3 emissions in 2007 and the reduction in emissions within the agricultural sector is primarily due to a reduction in livestock numbers (especially cattle) since 1990, changes in the handling and management of organic manures, improved feeding and decreased use of nitrogenous fertilisers. The largest relative reductions in NH_3 emissions from 1990 to 2007 have happened in Belgium, The Baltic Countries, The Netherlands, Hungary and Denmark (EEA, 2009). For Denmark, the target for emissions is 69 kt NH_3 in 2010. The projected emission for 2010 is 65 kt NH_3, which is a reduction of 39% compared to the emissions of 106 kt NH3 in 1990.

The purpose of this paper is to give a short introduction to the Danish policy measures and the costs of reducing the large emissions. Secondly, the paper looks at current measures in Denmark and compares them to costs of measures in other EU countries and in the USA. The paper goes on to look at the new ammonia reducing policy, before it looks at whether Denmark will reach the preliminary 2020 NH_3 targets. The paper is unique in that it compares the costs across different

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countries. It also describes the complex regulation required to set up dynamic regulations which ensure that new technologies are implemented quickly, without imposing disproportional costs on farmers.

2. Measures and costs in Denmark

The largest part of the emission in Denmark comes from stables, storage and spreading of animal manure. (Jacobsen, 1999 and Gyldenkærne & Albrektsen, 2008) (See figure 1). The emissions from stables have been largely constant, whereas the emission from the other sources has been reduced. The share from buildings has increased from 33% in 1990 to over 50%. Approximately half of the emission comes from the pig production and this share has declined slightly from 2003 to 2007.

It should be noted that the standard Danish calculation includes emissions from crops and straw treated with ammonia for feeding, whereas they are not included in the European calculation approach used here. Most national analyses use NH_3 as their unit whereas calculations within agriculture are often focused on the nitrogen part (NH_3-N), where one tonne of NH_3 contains 0.8235 tonne NH_3-N.

The Danish measures aimed at reducing NH3-emissions has since the mid 1980'ties gone hand in hand with measures trying to improve water quality included in Action Plan I and II (Mikkelsen et al., 2010) (see appendix 1). The higher utilisation of animal manure has lead to lower use of mineral fertiliser and reduced the emissions by around 20 kt NH3-N in the 1990'ties (Jacobsen, 1999). The measures have included building a story tank for slurry of 6-9 months, cover on slurry storage and in-cooperation of slurry into the ground within 12 hrs. The reduced emissions have mainly been related to the spreading and storage, whereas the emission from stables has only been reduced slightly, although improvements related to feeding have helped to reduce emissions per animal.

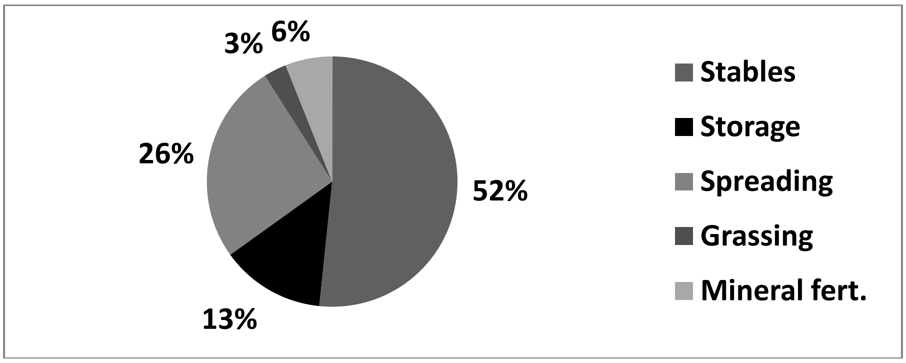

Figure 1. Ammonia emission from agriculture NH3-N/year average 2003-2007 from different sources (plants are excluded)
Source: Gyldenkærne and Albrektsen, 2008.

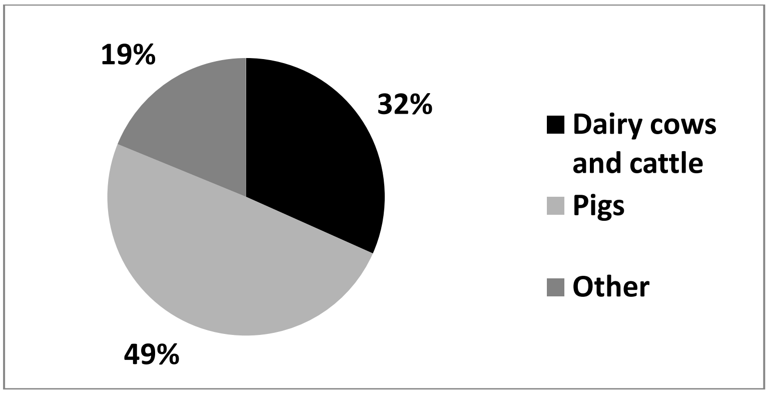

Figure 2. Ammonia emission from agriculture NH3-N/year average 2003-2007 from different types of animals
Source : Gyldenkærne and Albrektsen, 2008

Further measures suggested in Jacobsen (1999) include quick in-corporation of slurry in the soil (under 1 hour), a ban on broad spreading of slurry, cover on storage of solid manure, quick removal of slurry inside stables and the introduction of new types of stables. The cost of these measures where from 0 to 6.7 €/kg NH3-N. It was concluded that a further reduction of 10,000 tonnes would cost 17.4 million € a year. The average cost would be around 1.7 €/ kg NH3.

In 2001, The Danish Government decided on an ammonia action plan Skov and Naturstyrelsen (2001). The plan had four major measures (se appendix 1):

- A ban on broad spreading of animal manure
- A reduction in the time until slurry is incorporated into the soil (from 12 to 6 hrs.)
- Cover when storing solid manure is obligatory
- A ban on the use of ammonia in straw

The costs for the four major measures above were 7.1 million € and with a cost efficiency of around 1.1 € per kg NH_3. (Olesen et al., 2001 and Jacobsen, 2001).

The conclusion in 2007 was that the emissions in Denmark have been reduced quite substantially, given that the total number of animals is unchanged (fewer dairy cows and more pigs). Of the total emission of 65 kt NH3 in Denmark the non-agriculture part is 2,500 tonnes NH3 so 97% comes from Agriculture.

3. What is the current policy?

In 2007, a new legislation was introduced in Denmark for farmers who wanted to increase the animal production on their farm. The aim was to create a quicker and more user friendly electronic system than before, where some farmers experienced that getting an approval took 3-5 years for productions over 250 LU (or 8,750 finishing pigs). (Skov og Naturstyrelsen, 2009).

In the new regulation, it was included more directly than before that the local authorities need to look at the location of the farm and the emission of ammonia in order to live up to the requirements in the Habitat Directive (92/43/EEC). The aim of the law was to reduce emissions increasingly by 15% in 2007 and 20% in 2008 compared with the best technology in 2005/2006. It was later decided to increase the requirements to 25% in 2009 and 30% in 2010 based on the same starting point.

In the application for an increase in the animal production, the applicant has to show that the emission level lives up to the following three major requirements:

1. The requirements regarding emission of ammonia from stables and storage
   - The emission has in 2010 to be 30% under the reference system

2. Emission ceilings on ammonia from stables and storage for animal farms located near protected types of nature
   A) Further animal production is not allowed in a radius of 300 m from protected types of nature as the total emission may not be increased.
   B) From 300 to 1,000 m from protected types of nature certain deposition requirements may not be exceeded (the effect of the increased production may not exceed 0.3 to 0.7 kg N/ha depending on number of other animal farms).

Furthermore the aim of the new regulation method was to:

1. Provide an application procedure which would ease the administration required.
2. Improve the quality of the analyses made (all information and quality checked environmental calculations).
3. Ensure that all applicants are treated fairly and in the same manner across the country.

Source: www.Husdyrgodkendelse.dk

Figure 3 shows part of the approach adopted using finishing pigs as an example. The first step is to find a reference technology and an emission level based on the feeding practices in a given year. For finishing pigs, the year is 2005/2006 and the reference technology is slatted floor (25-49%), which gives a standard emission of 0.44 kg NH3-N per animal. The target for 2009 was a reduction of 25% which is equivalent to Level A in figure 3. As can be seen from figure 3, a change in norm year to 08/09 gives a lower reference emission due to changes in feeding (0.4 kg NH3-N per animal). A 30% standard reduction from baseline, which is required in 2010, will in this case give a lower emission level of 0.28 kg NH3-N (level C) and not the level B emission of 0,305 kg NH3-N per animal. But Level B can be achieved by changing to a new technology (50-75% fixed floor) which has an emission of 0.3 kg NH3-N per animal. But if the new technology becomes the new reference technology, the maximum emission requirements would give lower emission levels in the years to come. The key point is that the reference technology (stables) and the feeding practices change over time. The aim of the legislation is to encourage the use of new technologies (housing systems) for the benefit of the society, but at the same time not set standards which are too costly for the individual farmer.

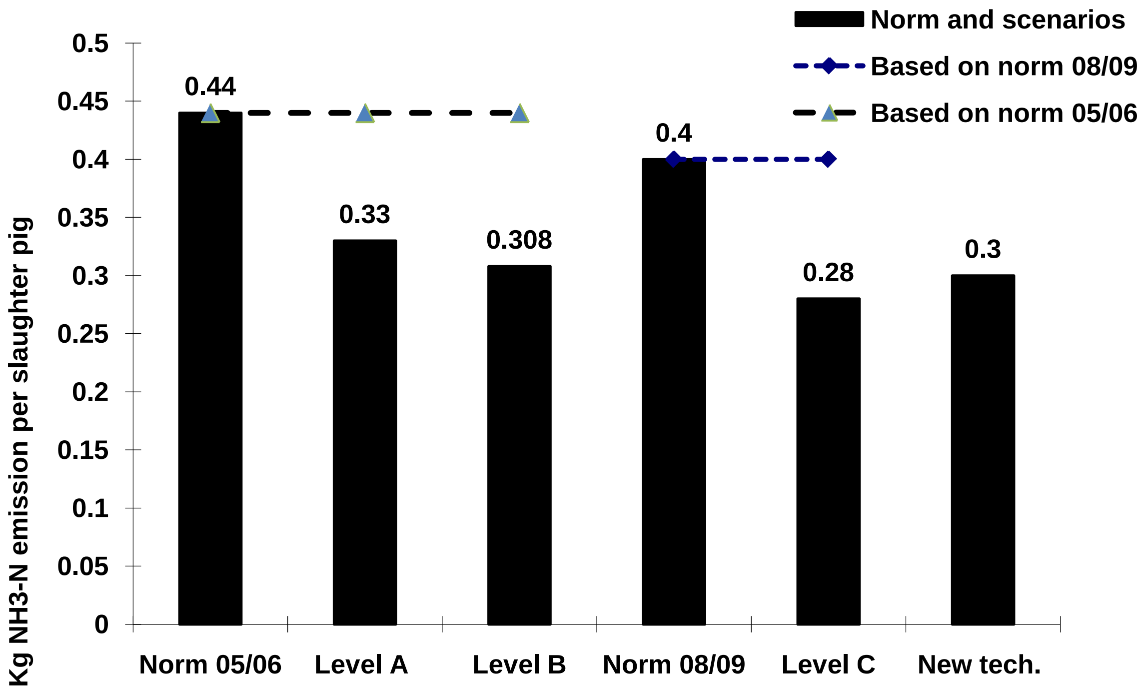

Figure 3. Emissions from partly slitted floor (25-49% fixed) in relation to the norms and new standards.
Note: New technology is slatted floor (50-75% fixed)
Source: Aaes et al., 2008 and own calculations.

The costs of new measures were first analysed by Schou and Martinsen (2006), Aaes et al., (2009) and by Niras (2009). The technologies which today are required when increasing the animal production can be found on a list of BAT technologies (Best Available Technology) (MST, 2010). This means that the municipality have to ensure that new technology gives a lower emission following a standard reduction, but the applicant should further describe how BAT technologies are implemented. In 2012, the BAT approach will alone set the standard and the general reduction level will probably no longer be needed.

The third element is then the location as described above. There is a lot of discussion about this and the allowed emission levels, but it will not be discussed in detail in this article. Note that on top of ammonia requirements, other requirements regarding e.g. odour from the farm have to be fulfilled depending on size of housing area and distance.

Table 1. Recommended NH_3-N emission requirements for conventional for farms with finishing pigs based on the BAT analysis.

	Average emission	Reduction from baseline	Cheapest technology	Cost per finishing pig	Cost of emission reduction
	Kg NH3-N per finishing pig	(%)		(€/finishing pig)	(€/NH3-N)
Baseline	0,44			0	0
75-210 LU	0,29	34	Solid floor (50-75%) + cooling of slurry	0 – 0.67	0 – 4.4
210-500 LU	0,26	41	Slatted floor + 20% air cleaning with acid	0.53 – 0.67	2.9 – 3.7
>500 LU	0,16	63	Drained floor and acidification of	0.8 – 1.07	2.9 – 3.8

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			slurry		

Source : Environmental Agency, 2010.
Note: 1 LU is 0,85 dairy cows until 2009. From 1.10.2009 it is 0,75 dairy cows. It is equivalent to 100 kg N ab storage.

Considerations regarding which BAT technologies should be on the list include an assessment of the effect it has on ammonia emission, the certainty and stability which the technology operates and the costs related to the specific technology. The costs are related to two areas, namely the cost for the farmer and the costs per kg NH3-N. Here a proportionality principle is adopted ensuring that the costs are not disproportionally high, both in terms of environmental costs and the farmers' costs (Niras, 2009; Jacobsen, 2010a and Jacobsen, 2010b). In the analysis the whole chain from feeding to field is analysed. Some of the likely measures are described in table 1, where the focus is on the stables.

Based on the proportionally analysis, the Ministry of Environment has decided the final BAT recommendations to the municipalities as shown in figure 4 and Table 1. The requirements are increasing with farm size which is a new step (see figure 4). This has been done to reduce the risk of increased local emission near very large farms. As technologies are often cheaper per livestock unit for larger farms the stricter rules for larger farms means that the costs for small and large farms per animal unit is almost the same. So the aim is to ensure that the farms are located at the right place and with costs of maximum 4-5 € per kg NH_3-N and up to 1 € per finishing pig.

The implementation of the electronic system has been more difficult than anticipated and so many fewer applications have been processed in 2008 and 2009 than expected. Furthermore, the decisions made, have in many cases, been taken to court by the local Nature Organisations and so there is still some uncertainty regarding the actual allowed emission levels. This has not been helped by the fact that the 98 municipalities have chosen different approval conditions although it was intended to be a uniform national regulation with similar targets across the country based on the same electronic calculation approach (See www.husdyrgodkendelse.dk).

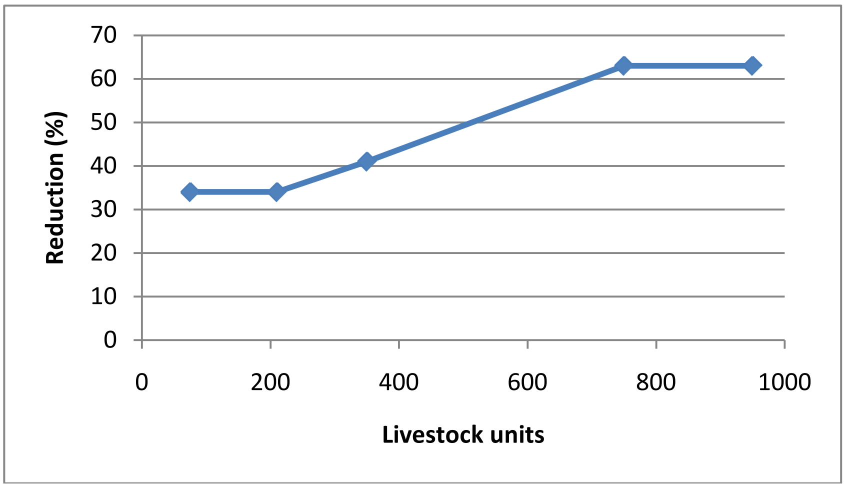

Figure 4. Reduction requirements (kg NH3-N per unit) for 2010 applications for finishing pigs compared to the 2005 norms and reference technology.
Source : Environmental Agency, 2010.

From an environmental economics point of view the measures should only be introduced until the marginal costs equal the marginal benefits. More research today is focusing on the issue of the benefits of reducing NH_3-emissions. These estimations will have large uncertainties, so they cannot

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yet give a clear answer to the likely marginal cost of NH3- emissions. However, they can be used as a first guideline.

The analysis is based on the health damage costs of NH_3 which has been calculated to 10 €/kg NH3-N for Denmark. The range is from 36 €/kg NH3-N in Belgium (high emission per ha) and to 3 €/kg NH3-N in Ireland based on the European Nitrogen Assessment (Brink et al., 2010). It is based on a value of life of 40,000 €/ life year. In the analysis only the health benefits are included. If the losses in terms of biodiversity is included the figure would be higher (perhaps another 2-10 € per kg NH_3-N). This implies that measures which are cheaper than 5 €/kg NH3-N should be implemented, but the upper range could be over 10 € per kg NH_3-N. There is a large variation between regions which is not included in this analysis. The benefit estimates has so far not been used in the Danish policy as the focus is on the NEC ceiling set by the European Commission.

4. What are the costs and measures in other EU countries?

Having looked at the costs of reducing NH3-emissions in Denmark it is relevant to compare the Danish costs with the costs of reducing ammonia emissions in other EU countries like The Netherlands and UK, but also in the USA.

4.1. The Netherlands

The costs for some measures in the Netherlands are presented in table 2. As for other countries, there are some cheap measures and some very expensive measures. Although much has been done on application of manure in The Netherlands, this still comes out as the cheapest measures. Manure processing and reducing pig numbers is the most expensive measures.

Table 2. Cost of reducing NH3-N emissions in 2020 (2005 prices).

	Potentieel	Cumul	Cost efficiency
	kton	kton	euro/kg NH3
Manure injection grassland	6	6	0,25
Ban on trailing shoe	4	10	0,25
Low protein feed for diary to reduce urea in manure	8	18	5,5
Air scrubbers pigs and poultry	19	37	6
Low protein food for pigs	1,5	38,5	9,5
Low emission dairy housing	2,5	41	11,5
Manure processing and balanced fertilization	12	53	22
Reduction of pig numbers by buy up pig quota	1,8	54,8	26

Source : De Haan et al., 2009.

Low-emission manure spreading is an effective and cheap method for reducing ammonia emissions; adverse effects on soil and meadow birds are limited. Low-emission manure spreading has reduced ammonia emissions from application by 60–70%. Although the original target set in 1990 (80% reduction in emissions during application) was not fully achieved, low-emission manure spreading does make a substantial contribution (80–90 ktonnes) towards meeting the national emission ceiling for 2010 (128 ktonnes for the Netherlands) (De Haan et al., 2009).

4.2. UK

In a recent analysis, the cost efficiency measures for the UK are presented based on the NARSES model (Webb et al, 2006). The focus in the UK analysis is more on dairy cows than pig production, where e.g. increased frequency of scraping in buildings is analysed. Cover over slurry tanks were analysed as well as application using injection as compared with using a splash plate (and not a trailing shoe as e.g. Danish analyses). In general, the application rates of 41 tonnes per ha for pig slurry is much higher than in Denmark were the application typically is 25 tonnes per ha. In the UK case, this leads to higher P application per ha, than what is removed with the crops. Storing farm yard manure also comes out as a recommendation. It is noted that the costs for a cover is probably lower as the reduction in volume is not included. Earlier (Webb et al., 2006) concluded that rapid incorporation of manures to arable land, covering manure stores and application of slurry by reduced emission machinery (e.g. injection using disc) is highly ranked in most European Countries and is already required in the Netherlands (Webb et al., 2006). Some of the UK measures are costly, but it should be noted that they are found to be much more expensive in the UK than in DK and The Netherlands. This would indicate that because the technologies are not as common in a given country the cost seems to be higher. Reduced slatted area and phase feeding is e.g. a relatively cheap measure in Denmark, where most of the other UK-measures are already implemented.

Table 3. English measures and costs to reduce NH_3-emission from pig production

	Effect (kt NH3-N)	Emission effect (%)	Marginal cost (€/kg NH3-N)	Implemente d in DK ?
Replace Urea with ammonium nitrate	11.118	100	0.25	
Immediate in-cooperation of slurry by injection (disk)	0.8	80	0.3	Partly
Flexible cover on slurry tanks	0,4	60	0.63	Yes
Apply pig slurry using a trailing shoe	1.0	30	1.61	Yes
Rigid tank cover for pig slurry	0,1	80	6.99	Partly
Phase feeding finishing pigs	1.6	12.5	12.59	(Yes)
Aerated flushing of pig slurry	2.1	60	17.19	No
Phase feeding weaners	0,1	10	116.44	(Yes)
Reduce slatted area		30	(13.10)	(Yes)

Source. Webb et al., 2006.
Note: Not all measures in the article are listed above.
Note: 1 € = 0,85 £

The costs here range from 0.3 to 116 € per kg NH_3-N. With a reduction requirement of 8,700 tonne NH_3-N, the largest marginal cost would be under 0,25 € per kg NH3-N if replacing urea with ammonium nitrate is used. The total UK NH3 emissions have been reduced from 1990 to 2007 by 21% and the emission will be close to the 2010 NEC ceiling. As the UK have not implemented as strict rules on manure handling as e.g. the Netherlands and Denmark, it is likely that many of the cost efficient measures are still unused e.g., applying dairy slurry to grassland using a trailing shoe (10.021 kt NH3-N). Several of the measures listed in the article are implemented in Denmark. Some of the costs for storing farm yard manure and using phase feeding seem to be much higher in the UK than in Denmark, perhaps as the technology is not as widely available.

4.3. USA

In the USA emission policies, reductions in ammonia emissions have been excluded from regulatory planning due to uncertainty in the level of emissions and feasibility of control strategies, which seems surprising in a European context. Recent advances have provided more reliable estimates Pinder and Adams (2007). The measures which are the cheapest are: chemical additives to housing floor, cover broiler manure, replace fertiliser with ammonium, allow crust on lagoon surface and imitate incorporation of applied manure as they have a cost under 0.8 € per kg NH3-N. Rigid cover on manure storage and applying manure with trailing shoe is considered expensive with a cost over

6.3 € per tonne NH_3-N. These cheap measures are cost effective compared to other measures towards SO2 and NOx in order to improve air quality (Pinder and Adams, 2007).

5. Conclusion

As shown in the article, large reductions in ammonia emissions have been achieved in the EU. The costs have been relatively limited, but some countries still have to reduce the emissions more as the emissions per ha are high and large areas have a high deposition. The choices of future political objectives have relied on the analyses conducted under the Clean Air For Europe (CAFE) programme, where costs and benefits of a wide range of control strategies were explored (Amann et al., 2008 and 2005). The environmental objectives with respect to NH_3 were to reduce the acid deposition in forest and eutrophication of eco systems by 40-50% in 2020 compared with year 2000. Denmark will in 2020 have reduced NH_3 emissions by 50% compared to 1990 and policies described in the article makes it likely that Denmark will reach or be close to the 2020 target despite the large reduction requirement. The EU 27 will have reduced the emissions by 27% from 1990 to 2020 (Sletø et al., 2009; Gyldenkærne and Mikkelsen, 2007), but it noted that the share of area which still in 2020 have to high deposition varies very much from country to country (EAA, 2005).

The Danish measures have mainly been focused on storage and application, but are not now focused on the stables. The Danish costs have so far been lower than 3 € per kg NH3-N, but future requirements could be more expensive. The new application systems have so far not lived up to the expectations with respect to quickness, uniform decisions and less administration.

The paper shows that the measures in several countries have costs which are lower than 5 € per kg NH3-N which in a European study is described as a possible minimum value of the benefits from reducing NH_3-N. The paper also shows large differences in costs for similar measures in different countries. It is noted that the USA have been slow on the uptake of measures to reduce ammonia emissions, perhaps because uncertainty regarding emissions levels have meant that no emissions targets have been set.

It seems as if countries which have a stricter regulation also have pushed the technologies the most and have lower costs for new technologies. Export of technologies is therefore a possibility for the agricultural sector in these countries.

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Appendix 1

Measures implemented to reduce ammonia emission from Danish Agriculture since 1985

Year	Measure	Expected effect (kt NH3-N)
1985	Minimum 6 month slurry storage capacity	
	Mandatory barrier on slurry tanks	
	Ban on slurry spreading between harvest and 15th October on arwa prior to spring crops	
1987	Minimum 9 month slurry storage capacity	
	Fertilizer plans	
	Mandatory incorporation of slurry within 12 hours after spreading.	
1991	Ban on slurry spreading between harvest and 1 February, except on grass areas and winter rape	
1998	Norms for utilisation of manure N (pig slurry = 60%)	
2001	Norms for utilisation of manure N (pig slurry = 70%)	
2002	Norms for utilisation of manure N (pig slurry = 75%)	
1998 – 2003	Improved feeding in Action Plan II	7,000
2001	**Ammonia action Plan :**	
2001	Solid cover on storage near protected areas	
2001	Further control with cover on slurry tanks (own control) or fixed cover	
2001	Improved stables	500
2001	Reducing the time until slurry is incorporated into the soil (from 12 to 6 hrs.)	
2004	Ban on broad spreading of animal manure	3,400
2002	Cover when storing solid manure	1,700
2004	Ban on the use of ammonia in straw	1,200 - 1,400
2004	Better handling and storage of manure from fur	2,600
	Total	**9,400 – 9,600**
2006	Injection of slurry required on grass land and black soil areas with less than 1,000 m to environmental sensitive areas	
2011	Injection of slurry required on all grass land and black soils	

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