Economic analysis of the ammonia regulation with respect to Natura 2000 sites

Germany, the Netherlands, and Denmark

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Economic analysis of the ammonia regulation with respect to Natura 2000 sites:

Germany, the Netherlands, and Denmark

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Economic analysis of the ammonia regulation with respect to Natura 2000 sites: Germany, the Netherlands, and Denmark

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The analyses in this report have been carried out in relation to the project on ammonia regulation with a focus on Nature 2000 sites, initiated by the Danish Environmental Agency. The analyses in the project include a comparison between the ammonia regulation and associated costs in three countries. The project as a whole consists of three parts analysing the situation in Denmark, Germany – with a particular focus on Schleswig-Holstein – and the Netherlands from a legal perspective, an economic perspective and a natural science perspective. All reports from the project can be found on http://ifro.ku.dk/ammonia

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Summary

This report is part of the analyses in the Natura and Ammonia project initiated by the Environmental Agency under the Danish Ministry of Food and Agriculture. The purpose of the overall project is to look at the regulation with respect to ammonia emissions from livestock farms near Nature 2000 sites in Germany, the Netherlands and Denmark. The analyses include nature, legal and economic perspectives. The purpose of this report is to compare the costs of reaching the emission targets for different farms near Natura 2000 sites based on reports from the Netherlands, Schleswig-Holstein and Denmark.

The analyses are based on three different case farms in each country located 400 and 2,000 m from Nature 2000 areas. The costs of implementing BAT emission requirements were calculated, and so were the additional costs of further reduction requirements related to nature sites based on the chosen abatement technology. Based on this, the additional annual costs were calculated of meeting the Natura 2000 specific requirements compared to the general BAT requirements.

The three regions chosen (the Netherlands, Schleswig-Holstein and Denmark) all have a large agricultural production. The full time farms are largest in Denmark, whereas the Netherlands have the highest livestock density. With respect to technologies, acidification is used today on some dairy and pig farms in Denmark, but not on farms in the Netherlands or in Schleswig-Holstein. Air scrubbers have already been implemented on half of the pig farms in the Netherlands, but are seldom used in Denmark.

Natura 2000 protected areas make up 9-10 per cent of the land area in the three regions. The Netherlands and Denmark have limited agricultural livestock production near (<400 m) Natura 2000 sites, while 20-30 per cent of the livestock production is more than 2,000 m from Natura 2000 in both countries. In Denmark, most livestock is within 2,000 m from other nature types outside Natura 2000 (category 2 and 3). In the Netherlands, finisher farms and poultry farms near Natura 2000 are only half the size of the average farm, but this is not the case for dairy farms. In Denmark, livestock farms near Natura 2000 are only 10 per cent smaller than the average farm. It seems as if the restrictions regarding Natura 2000 have had little impact on the livestock farm size in Denmark, and findings suggest that most production increases are on livestock farms without restrictions regarding ammonia emissions.

The ammonia emissions show a decreasing trend for Denmark and the Netherlands, but this is yet not the case for Germany. The conclusion is that it might be difficult for Denmark to reach the 2020 target, but Germany will have greater challenges in reaching the 2030 targets. Looking at the Danish and Dutch BAT combined with the German TA air requirements indicate that the allowed emissions for finishers and dairy cows are higher in Schleswig-Holstein than in Denmark and the Netherlands.

The regulation approaches applied in the three countries are different. The Danish approach is based on levels of total NH_3-N load from the farm in relation to set standards based on the number of nearby livestock farms. The German approach is to compare initial load and critical load in order to decide whether a production can be established. Generally, the approach is to look at the additional load from new projects, but in some cases the total load from the case farm is used in the assessment. The Dutch PAS system is based on the fact that some of future gains from tightening the general ammonia regulation and other measures will create a room for development, which now can be used for new projects.

Three case farms are analysed to illustrate regulatory concepts used under different conditions. For the analysis, the case farms are assumed to expand by 100 per cent, resulting in (1) a total production of 14,400 finishers, (2) a dairy farm of 240 cows and (3) a slaughter chicken farm of 600,000 broilers. The required emission levels are analysed under different proximities to Natura 2000 (400 and 2,000 m) and for various other conditions. In Denmark, additional conditions include 0-2 neighbouring livestock farms. In Schleswig-Holstein, the additional condition is a case where the initial load is above or below the critical load. In the Netherlands, the case farms are analysed with or without room for development.

The Filter Decree, used in Schleswig-Holstein, only applies to larger pig farms (10 per cent of all finisher farms) and it requires ammonia reductions by 80 per cent at a cost of around 4.5 euro per finisher per year. This makes the BAT related requirements more costly in Schleswig-Holstein than in Denmark.

The analyses show that the allowed emissions for farms 400 m from Natura 2000 require large reductions. Therefore, in all three countries, the implications in most cases would be that the expansion would not take place at this location. The strictest requirement is found in Schleswig-Holstein when the initial load is larger than the critical load. The analysis on the case farm in Schleswig-Holstein is based on the total load from the farm, but in some cases it will be based on the additional load as is the Dutch case. In Schleswig-Holstein, the emission does not need to be lower after expansion than before, as might be the case in Denmark and the Netherlands.

When the distance to a Natura 2000 site is 2,000 m, the strictest requirements are found in the Netherlands, as the PAS system requires a similar NH_3 emission level as with a 400 m distance where very low additional deposition is allowed. For farms in Denmark and Schleswig-Holstein, the BAT level reductions are sufficient to fulfil the requirements when the farm is 2,000 m away from Natura 2000 sites.

The technologies used on the farms include different floor types as well as different types of air cleaning and capacities (20-100 per cent capacity). In Schleswig-Holstein, the installation of air cleaners or air scrubbers is part of the Filter Decree, but only for larger pig farms. Further reduction requires slurry acidification not only in the field but also in the stable, and perhaps it requires phase feeding. In the Netherlands, most farms have air scrubbers in the base situation and so the expanded part of the farm also needs air scrubbers.

For the different farms the costs vary from 0 to 30,000 euro per year. In general, the costs are zero when the distance is 2,000 m to Natura 2000, but in the Netherlands the costs might be up to 20,000 euro. The costs are limited when the most favourable conditions are used with a distance of 400 m to Nature 2000, and the costs are high (> 20,000 euro per farm) when the strictest requirements are applied. The costs are in the order of 0.5-2 euro per finisher, 35-65 euro per dairy cow, and 0-11 euro per 1,000 broilers. The total costs are highest for the finisher farms, followed by the dairy farms and the broiler farms respectively.

Looking at the costs compared to ammonia reductions, the costs to obtain the BAT requirements in Denmark are around 5-8 euro per kg NH_3. For finishers on larger pig farms in Schleswig-Holstein, the cost is around 4.5 euro per kg NH_3 in relation to the Filter Decree. Looking at requirements on top of the BAT requirements, the highest costs are found for farms near Natura 2000 and with strict conditions. Here, the costs are another 5-21 euro per kg NH_3 for finishers and dairy farms. The results indicate that the costs per kg NH_3 are lower at farms with broilers than for dairy farms.

It should be emphasised that estimates of requirements, technology selection and cost calculation are subject to a large uncertainty as it is difficult to compare regulations across countries. In addition, there will be future changes, why this analysis should be regarded as a snapshot.

1. Introduction

1.1. Purpose and content

The analyses in this report have been carried out in relation to the project on ammonia regulation with a focus on Nature 2000 sites, initiated by the Danish Environmental Agency. The analyses in the project include a comparison between the ammonia regulation and associated costs in three countries, namely the Netherlands, Germany (Schleswig-Holstein) and Denmark.

Natura 2000 sites are protected nature areas in the EU. The purpose is to protect different habitat types and wild animals as well as rare plants. Analyses have shown that ammonia emissions have an impact on both nature and the wellbeing of people, and so, regulation has been implemented to reduce ammonia emissions. As a majority of the ammonia emissions comes from other countries, regulation is required both at the national level and at the EU level. At the EU level, the NEC directive sets targets for the maximum ammonia emissions from each country.

The purpose of this report is to compare the economic analyses made regarding the regulation approach and the costs for the selected case farms in the Netherlands, Schleswig-Holstein (SH) in Germany and Denmark. This analysis is based mainly on country reports from the three countries, carried out by Harry Luesink and Rolf Michels from Wageningen Economic Research in the Netherlands, Uwe Latacz-Lohmann from the University of Kiel in Germany, and Brian H. Jacobsen and Lisa Ståhl from the University of Copenhagen in Denmark. Brian H. Jacobsen and Lisa Ståhl have written this report, but the content has been discussed with the above-mentioned authors, as their contributions are a large part of this report. For more details regarding the calculations, reference can be made to the country reports (Jacobsen & Ståhl, 2018; Latacz-Lohmann, 2017; Luesink & Michels, 2018a+b). Professor Mette Termansen, IFRO, University of Copenhagen, has conducted an internal peer review of the report.

At the outset, it should be noted that comparisons between countries are not easy as they often will be based on different starting points, regulatory approaches, definitions etc. One should, therefore, not expect to be able to compare all the economic results one-to-one, but rather use this as an insight to different approaches. The comparison might give inspiration regarding changes in future regulation in the different countries in order to achieve their targets.

This report starts by an overall comparison of agricultural production in the three countries/regions and of the location of livestock production in relation to, primarily, the Natura 2000 sites.

The report goes on to compare the baseline situation and the requirement in the three countries related to the general ammonia emission requirements for all livestock farms. The analysis considers three case farms: a finisher production, a dairy farm and a farm with broilers.

The report then goes on to look at the emission requirements for farms near Natura 2000 sites and other nature sites. As the regulation is different in the three countries, the analysis will look at different requirements in each country in order to compare them. In this analysis, the technologies used will be discussed and compared. For the case farms, the total costs and the production unit costs will be compared for the different emission levels, just as the unit cost (cost in euro per kg NH_3 reduced) will be compared. The report concludes with a discussion of the findings, focusing on similarities and differences regarding regulation and costs in the three countries.

For a more detailed comparison of the regulation and the background for the Natura 2000 regulation approach used, reference can be made to the two other summary reports on nature and legal aspects (Anker et al., 2018; Fredshavn & Bak, 2018). An overall project report has also been prepared (Jacobsen et al., 2018).

1.2. Method

The approach used here is to base the analyses on selected case farms from the three countries. The cases cover the same farm size and productions in the three countries, namely a finisher farm, a farm with dairy cows and a farm with broilers. The case farms are expected to expand by 100 per cent.

For the selected case farms, we have looked at the additional annual costs of implementing the required technologies. The costs include:

- Additional capital outlay may be necessary (e.g. for installing an exhaust air cleaning system), resulting in higher capital costs (depreciation and interest) of the investment
- Operating costs of ammonia reduction techniques (e.g. electricity for exhaust air cleaning, sulfuric acid for manure acidification)
- Opportunity costs of forgone investment opportunities – for example, when animal housing facilities must be smaller than initially planned in order to ensure that sensitive vegetation in the vicinity is not harmed. This approach is only used in the German analysis.

In some analyses (Germany), the overall profit has been calculated, and so, it is possible to consider whether an expansion of the production is profitable under average farming conditions and whether a smaller expansion (given the implementation of an environmental regulation) is profitable. In other cases (Denmark and the Netherlands), the additional costs have been calculated, but a profit has not been calculated. The income from the rest of the farm is not included in the calculations and a return on equity is not included either.

The baseline is the case where the requirements for all livestock farms, irrespective of location, are fulfilled. This includes the BAT requirements. The additional costs are the costs associated with requirements due to proximity to nature sites. In the Danish case, the costs are calculated as the yearly costs using the lifetime of the asset (often around 10 years) and an interest rate of 4 per cent. In the Netherlands, the lifespan of the buildings are 25 years, 10 years for the air scrubber and 12 years for the heat exchanger (pers. comm. Izak Vermeij, Wageningen University).

The interest rate used in the German case is 2 per cent and in the Dutch case 3.5 per cent. The lifespan for the analyses in the German calculations are 30 years including reinvestments in inventory in year 10, 15 and 20. For an investment of 100 DKK, the yearly cost with the same life span (10 years) would be 12.33 DKK in Denmark and 11.13 DKK in Germany. So, the difference in costs due to differences in interest rate is limited (maximum 10 per cent).

The analysis covers three types of case farms located 400 and 2,000 m from nature sites. In the analyses from the different countries, variations of important parameters are used to incorporate variation due to specific regulation: In Denmark, this is the number of livestock neighbours; in Germany, it is the difference in initial load vs. critical load; and in the Netherlands, it is the allowed room for development. The German cases are situated in Schleswig-Holstein, and the Dutch cases are based on a location in Overijssel, whereas the Danish cases are based on a national approach.

An alternative to an expansion on the present location is to move the production to another location. It should be noted that the option of moving the farm or the expansion to another location has not been included in the analysis. Furthermore, the cost for existing farms if they have to go through a re-evaluation and comply with new requirements has not been analysed. The analysis does not cover the potential loss of value if the farm cannot expand on the current location.

The case farms have been chosen to illustrate the situation for different types of farms at different locations, but it does not aim to cover all likely outcomes of reduction requirements and costs.

2. Agriculture and Natura 2000

2.1. Agricultural production

Table 1 shows the key numbers regarding agricultural production. Denmark has the largest agricultural area with more than 2.6 million ha and the largest full-time farms. In the Netherlands, the number of holdings is the largest, and the average size of the farm is the lowest.

Most of the permanent pasture is found in the Dutch farms, whereas the Danish agricultural production is more focused on cereals, and the area per farm is much larger in Denmark than in the Netherlands. The most intensive livestock production is in the Netherlands, where livestock units per ha are twice the Danish level and three times higher than in Schleswig-Holstein. The high livestock intensity also raises the ammonia deposition and the costs related to transport of manure (Jacobsen, 2017b). The highest livestock density in the Netherlands is in the southeast (pig farms). The most livestock intensive part of Denmark is Jutland where the high-intensive areas include both dairy and pig farms. In Schleswig-Holstein, the largest intensity is in the north (county Schleswig-Flensburg, pig production) and in the south (county Steinburg, dairy farms).

Denmark and the Netherlands have roughly the same amount of pigs and sows, but Denmark has relatively few finishers compared to the Netherlands due to the export of around 13 million piglets to Germany in 2016, which also increases the number of finishers in Schleswig-Holstein.

The Netherlands has far more dairy cows, egg-laying hens and chickens as well as broilers than Denmark and Schleswig-Holstein. In recent years, there has been an increase in the number of dairy cows in the Netherlands, and so, measures have been introduced to reduce the amount of dairy cows back to 2016 levels. This is done because the current derogation from the EU Nitrate Directive for dairy farms requires that the total Dutch manure production is below a certain limit (Jacobsen, 2017b). The derogation allows dairy farms in the Netherlands to apply 230/250 kg N per ha where the standard limit in the Nitrate Directive is 170 kg N per ha.

The livestock farms in the Netherlands own a relatively small area compared to farms in Denmark. Schleswig-Holstein has mainly dairy cows and cattle, whereas the number of sows is relatively low. In later years, there has been an increase in poultry and dairy cows and a reduction in sows and finishers, but not in piglets.

Table 1. *Agricultural production in Denmark (DK), Schleswig-Holstein (SH) and the Netherlands (NL) in 2016*

	DK 2016	**SH 2016**	**NL 2016**
Number of farm holdings (total)	35,674	12,716	55,681
of which part-time farms	25,000	4,270	8,352
Area per farm (UAA ha/farm)	74	78	32
	1,000 ha		
Utilisable agricultural area (UAA) (total)	2,630	990	1,796
Arable land	1,470	655	504
Permanent pasture	230	314	975
Green feed	510	212	216
	1,000 animals		
Livestock (total) in LSU	4,100	1,015	6,600
Livestock units per ha (LSU/ha)	1.5	1.0	3.7
Cattle (number of animals)	1,568	1,095	4,251
Dairy cows (number of animals)	572	397	1,745
Pigs (total) (number of animals)	12,383	1,462	12,479
Finishers (number of animals)	2,969	934	5,726
Sows (number of animals)	999	94	931
Sheep (number of animals)	147	206	784
Chicken (total) (number of animals)	17,898	3,759	105,620
Laying hens (number of animals)	4,644	1,438	46,212
Broilers (number of animals)	11,745	2,247	49,188

LSU is based on the EU definition of an animal unit, which is different from the Danish definition where 1 AU is 100 kg N from storage (Jacobsen & Ståhl, 2018).
Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2018a).

Table 2 shows the different housing systems and their use. The systems used for dairy cows in the three countries are very similar, but there seems to be a higher use of 100 per cent slatted flooring for finishers in Germany than in Denmark.

Table 2. *The housing systems used in Denmark, Schleswig-Holstein and the Netherlands (per cent)*

Livestock category and production system	Denmark 2012/13	Schleswig-Holstein 2010	The Netherlands 2015
Dairy cows (large breed)			
- Tie-stalls	7	11	2[a)]
- Cubicle housing	86	84	81
- Deep bedding	7	5	17[a)]
Total	100	100	100
Pigs finishers			
- 100 % slatted	0	59	0
- Partly slatted / partly solid (25-75 %)	37	38	(90)[c)]
- Drained and slatted (33/67)	60		(8)[c)]
- Others (including deep bedding)	3	3	(2)[c)]
Total	100	100	100
Sows			
- 100 % slatted	8	21	??
- Partly slatted	80	69	25 [b)]
- Deep bedding	11	10	
Total	100	100	100
Broilers			
- Regular housing (39 days)	--		
- Mixed air ventilation			
- Regular housing (32 days)	17		
- Regular housing (35 days) *	79		
- Regular housing (40 days)	3		
- Organic and free range (“skrabekyllinger”)	1		
Total	100	100	100

[a)] Low emission stables
[b)] Regular housing 25 % and air scrubber 47 %.
[c)] Estimations based on comments from Harry Luesink, Wageningen, 2017.
Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2018a).

Table 3 shows the use of different emission technologies in the stables in Denmark and the Netherlands. There is no data available for Germany. The overview provides an indication of which technologies are used to reduce ammonia emissions to adhere to both general and Natura 2000 specific regulation. For dairy farming in Denmark, low emission flooring is used, but whether it is the same as the low emission stables in the Netherlands is not certain. Acidification is used in Denmark on both dairy farms and pig farms, whereas the technology is not approved in the Netherlands and only at test level in Germany, although the technology (acidification used in the field) now has been approved to some extent. The use of acidification in stables in Denmark is almost constant. However, the use of acidification in the field in Denmark has decreased in 2016-17 as the economic gain has been reduced following the possibility to apply the economic optimal level of nitrogen. This could make it more difficult to reach the implementation levels previously expected in the ammonia forecasts for 2020 and 2030 (Mikkelsen & Albrektsen, 2017).

Table 3. *Adaptation of technologies in stables in Denmark, Schleswig-Holstein and the Netherlands (per cent)*

Technology used	Denmark 2020	The Netherlands 2015
Dairy farms		
- Low emission floor		17
- Slurry acidification	7	
- Other technologies		2
Finishers		
- Partly solid floor / Drained floor	47	
- Acidification	2	
- Air scrubbers	3	46
- Cooling	5	27
- Other technologies		
Sows		
- Air scrubbers	7	47
- Cooling	20	
- Acidification	1	
- Floor		29
Broilers		
- Heat exchange	50	
- Mixed air ventilation		79
- Multilevel system and slatted floor + band aeration		3
- Floor heating and cooling		3
- Low emission housing		3

Sources: Jacobsen and Ståhl (2018); Luesink and Michels (2018a).

2.2. Location of Natura 2000 areas in relation to agricultural production

Denmark has the lowest share of Natura 2000 sites in the three countries or regions, while Germany (Schleswig-Holstein) has the largest share, but all three are within 8-10 per cent of the total area. Denmark, Germany, and the Netherlands have regulation in place regarding nature outside Natura 2000, but that is not the focus of this report. In Denmark, ammonia sensitive nature outside Natura 2000 is included in category 2 and 3 nature (see table 11). In the Netherlands, nature outside Natura 2000 sites can be divided into two categories: sites within the Nature Network and area outside the Nature Network (other nature). There are more rules and regulations for farms near the Nature Network than other nature sites. However, regulations on nitrogen emissions and deposition only apply on Natura 2000 sites. In Germany, there is a large number of nature reserves (Naturschutzgebiete), designated under national legislation (Bundesnaturschutzgesetz).

The base deposition in Denmark has been reduced from 17 kg N per ha in 2006 to 13 kg N per ha in 2015 (Institut for Miljøvidenskab (n/d). The largest Danish deposition values are found near the German border where the deposition is 19 kg N per ha in 2015 as a large share of the deposition in Denmark comes from abroad. The average for Schleswig-Holstein is around 20 kg N/ha in 2015 (Umweltbundesamt, 2018), and for the Netherlands, the average deposition is around 25 kg N per ha or 1,767 mol N per ha (see http://www.clo.nl/indicatoren/nl018914-vermestende-depositie). Mol N is used as a unit in the Netherlands as also emissions from other sectors are included in the calculations. There are a number of areas in the Netherlands where the deposition is higher than 40 kg N per ha. Overall, the deposition is the highest in the Netherlands and the lowest in Denmark.

The share of nature receiving a deposition above the critical load is relatively high in most of the Netherlands, Germany and in the western part of Denmark (especially near the border to Germany). The deposition in Germany has been reduced, but it still exceeds the critical load in many regions as the deposition in some areas of Schleswig-Holstein (northwest) is above 20 kg N per ha (see Latacz-Lohmann, 2017)

Table 4. *Natura 2000 sites in Denmark, Germany, and the Netherlands*

	Denmark	Schleswig-Holstein	The Netherlands
Natura 2000 sites	• 261 sites • 8.5 % of land area	• 271 sites • 9.9 % of land area	• 138 sites • 10.0 % of land area
Intensive agriculture in Natura 2000	• 14.4 % (before suggested change)	• 10.5 %	• 8 % (16 %) *

* Note: When extensive grassland is included the share is 16 per cent.
Sources: Anker et al. (2018); Fredshavn and Bak (2018).

2.3. Agriculture near nature

Only a small amount of the Dutch utilized agricultural area lies within 400 m of one or more Natura 2000 areas. The same accounts for the number of animals that is kept within the proximity of Natura 2000. Almost 30 per cent of the agricultural area, 28 per cent of the dairy cows, 18 per cent of the finishers and 17 per cent of the broilers in the Netherlands are located within 2,000 m of Natura 2000 areas (see table 5). About 45 per cent of the Dutch agriculture farms are located within 2,000 m of other nature sites; this is the case for 53 per cent of the dairy cows, 51 per cent of the finishers and 42 per cent of the broilers (see also figure 1).

Table 5. *Location of agricultural production and livestock near Natura 2000 and other nature sites in Denmark and the Netherlands (per cent of given production or area)*

	< 400 m to Natura 2000	400-2,000 m to Natura 2000	> 2,000 m Natura 2000	< 2,000 m to other nature sites
Denmark				
- Livestock	5	19*	76	98
The Netherlands				
- area	7	23	77	45
- dairy cows	4	24	76	53
- finishers	2	16	84	51
- broilers	1	16	84	42

* Category 1 (nature not forest) and other nature sites in Denmark include §3 areas.
Note: There are no data from Schleswig-Holstein on the proximity to Natura 2000
Sources: Jacobsen and Ståhl (2018); Luesink and Michels (2018a).

This means that only 20 per cent of the dairy cows, 30 per cent of the finishers, and 40 per cent of the broilers are kept in farms that are located more than 2,000 m from nature (Natura 2000 and other nature sites). In other words, a large share of the livestock production in the Netherlands is between 400 and 2,000 m away from nature areas when other nature areas are included. Many of the intensive livestock farms (pigs) are located in the southeast part of the country.

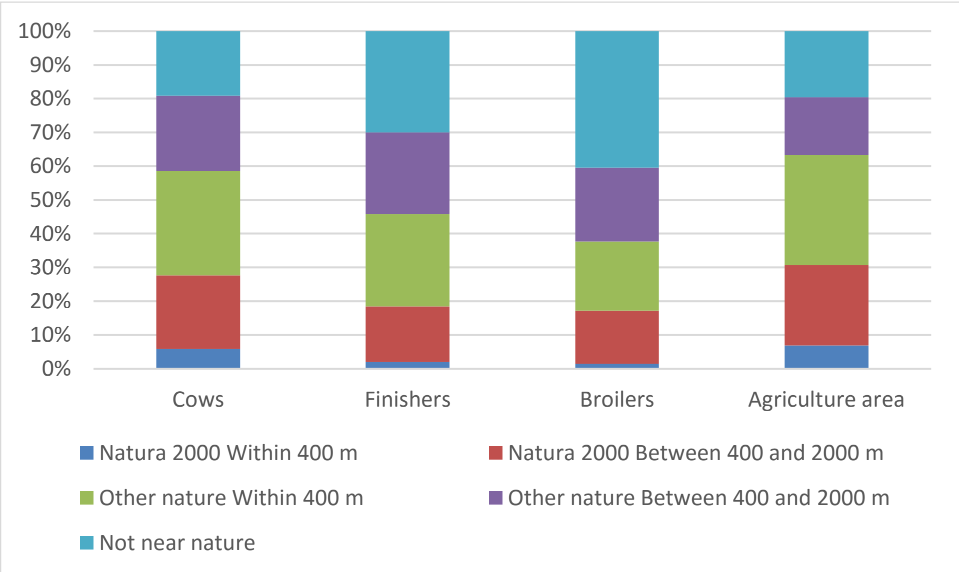

Figure 1. *Agriculture area (per cent) and amount of animals (per cent) kept near nature areas in the Netherlands in 2016*

Source: Luesink and Michels (2018a)

Looking at the size of the farms, figure 2 shows the average size within 400 m from Natura 2000 and other sites compared with a distance of 400-2,000 m from Natura 2000 and other nature sites. The Dutch average is index = 100 and so it is clear that pig farms and broiler farms within

400 m from Natura 2000 are around half the size of the average farm. For dairy farms, the size does not change with the distance to nature sites. Finisher farms between 400 and 2,000 m from other nature sites are larger than the average finisher farm.

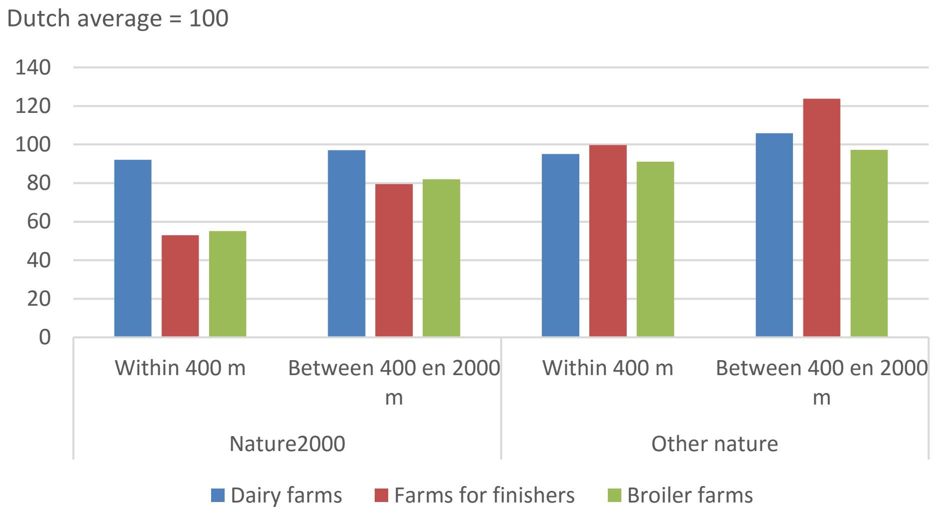

Figure 2. *Farm size of farms for dairy, finishers and broilers near nature areas*

Source: Luesink and Michels (2018a)

In Denmark, the nature sites are divided into categories (see table 6). Category 1 is Nature 2000, whereas category 2 and 3 are outside Nature 2000 areas. For Denmark, a relatively small share (4 per cent) of the livestock is within 400 m from Natura 2000 sites (category 1), but around 50 per cent of the livestock production is within 400 m from other nature sites (see table 5). Looking at category 1 and 2 together, 27 per cent of the livestock production is closer than 1,000 m from nature sites, but when category 3 is included this share increases to 86 per cent. In other words, much of the livestock production is less than 1,000 m from category 1-3 nature.

Table 6. *Nature categories used in Denmark*

Category 1 habitats	Category 2 habitats	Category 3 habitats
The following habitats if located within a Natura 2000 site: 1. Areas with one of the 43 Annex I habitats considered sensitive to ammonia deposition – no size threshold applied 2. Heaths and dry grasslands protected by the Nature Protection Act § 3.	The following habitats located outside Natura 2000 sites: 1. Raised bogs 2. Lobelia-lakes 3. Heaths above 10 ha 4. Dry grasslands 2.5 ha.	The following habitats located outside Natura 2000 sites: 1. Other areas with heath, bog/moor or dry grassland protected by the Nature Protection Act § 3. 2. Old grown forests fulfilling the criteria for being sensitive for ammonia deposition

Source: Anker et al. (2018)

Livestock farms located closer than 1,000 m to category 1 and 2 are found to be 20 animal units (AU) (10-14 per cent) smaller than the average for farms farther than 1,000 m away (Jacobsen & Ståhl, 2018). In Denmark, 1 AU is equal to 100 kg N in manure from storage. There is no clear difference with respect to size of livestock farms in relation to category 3 nature. The analysis shows that mink farms are located with the same average distance from Natura 2000 sites as the average livestock farm. There are no data from Schleswig-Holstein on the proximity of the livestock production to Natura 2000 sites.

The Environmental Agency in Denmark have not collected all data regarding the category 3 requirements issued by the municipalities, and so, it is uncertain to which extent proximity to category 3 nature requires further reduction requirements. A recent analysis indicate that many municipalities use the minimum deposition requirement of 1 kg N per ha, but not all category 3 areas will require protection (Jacobsen & Ståhl, 2018). It is assumed, based on discussions with the Environmental Agency, that less than half of the farms near category 3 will be given further emission reduction requirements.

In a similar analysis, DCE has found that 8 per cent of all the livestock farms are situated near category 1 nature (size and distance together) (Levin & Nygaard, 2017). The number of large fulltime farms (>150 AU) near category 1 is around 1,200. Looking at applications for livestock permits in Denmark, the analysis shows that 11 per cent of the applications were close to category 1 nature, which is not too far from the assumptions made in this report. The distance to other farms included in the analysis increases with farm size. The expansions in 2007-2015 are mainly (70 per cent) on larger farms with more than 75 AU. With 11 per cent applying for a permit and 8 per cent of the farms situated near Natura 2000, there is no indication that farms near Natura 2000 do not apply for permits due to high costs etc.

Other analyses show that the ammonia regulation has affected around 500-1,000 farms during the period 2005-2015 (Bak & Damgaard, in prep.). The share of farms that expand is clearly larger for farms not affected by the regulation in relation to ammonia emission. However, the analysis shows that these farms are affected by the regulations after the expansion. The findings show that if farms near nature sites had developed like other farms have done, the total Danish emission would have been 4.1 kt N higher, and the area where total load is higher than the critical load would have been 14 per cent higher. So, the conclusion is that the regulation has decreased the likely emissions over time (Bak & Damgaard, in prep.).

As shown in table 5, the regulation may have implications on livestock production both in Denmark and in the Netherlands. A small share of the livestock production is close to Natura 2000 sites in both countries, but a somewhat larger share in Denmark is less than 2,000 m away from other nature sites.

2.4. National ammonia emission targets

Ammonia emissions in all three countries originate mainly from agriculture. It is estimated that 96 (DK), 95 (DE) and 85-90 per cent (NL) respectively are related to agriculture. Thus, there is a focus on ammonia emissions from agriculture in particular in relation to the achievement of the emission ceilings established under the Gothenburg Protocol and the NEC and NERC Directives.[1]

Table 7. *National NH_3 emissions in relation to NEC emission ceilings (kt NH_3)*

	Denmark		Germany		Netherlands	
	%	Total kt	%	Total kt	%	Total kt
1990 Actual emission		125		793		369
2005 Actual adjusted emission		84		678		156
2010 Actual adjusted emission		76		641		135
2020 Expected adjusted emission		67		(683)		100
NEC 2010		69		550		128
NEC 2020 (% of 2005)	76	64	95	644	87	118
NEC 2030 (% of 2005)	76	64	71	481	79	107

Notes: The unadjusted values are 7-8 kt NH_3 higher in Denmark (2010-2015) in the LRTAP report. The unadjusted values are 2-3 kt NH_3 higher in Denmark compared to the DCE projection (2005-2035). The unadjusted values for Germany are 40-65 kt NH_3 higher in 2015-2035 in LRTAP report.
There is some uncertainty with respect to the likely 2020 level for Germany, but it is set at 683 kt NH_3 based on a previous estimation using the old emission factors and then added 100 kt NH_3 to compensate for change in emission factors since the UBA report.
Sources: EEA (2017); Haenel et al. (2016); Mikkelsen and Albrektsen (2017); and own calculations.

The ammonia emissions show a decreasing trend for Denmark and the Netherlands, but this is not yet the case for Germany. The conclusion is that Denmark might find it somewhat difficult to reach the 2020 target of 64 kt NH_3. The Danish forecast for 2030 is 66 kt NH_3 due to much lower uptake of new technology compared to previous expectations. Then, only limited reductions from 2020 to 2030 are forecasted (Mikkelsen & Albrektsen, 2017).

The Netherlands have achieved their target for 2010 and are expected to be on their way to the 2020 target, although the higher number of cows in 2015-2017 could increase the emissions. The 2030 target could easily be reached. Germany has found it very difficult to reduce ammonia emissions, and so, the expected levels in 2020 are even higher than the 2010 target. It seems to be really a challenge to reach the 2030 target, which is 30 per cent below the current emission levels. The possible measures consist of immediate incorporation of manure, change in pig slurry storage, N-adapted feeding and exhaust air purification (Jörss et al., 2014). With the so-called APS+ -scenario, it might be possible to reduce emissions to under 500 kt per year in the future.

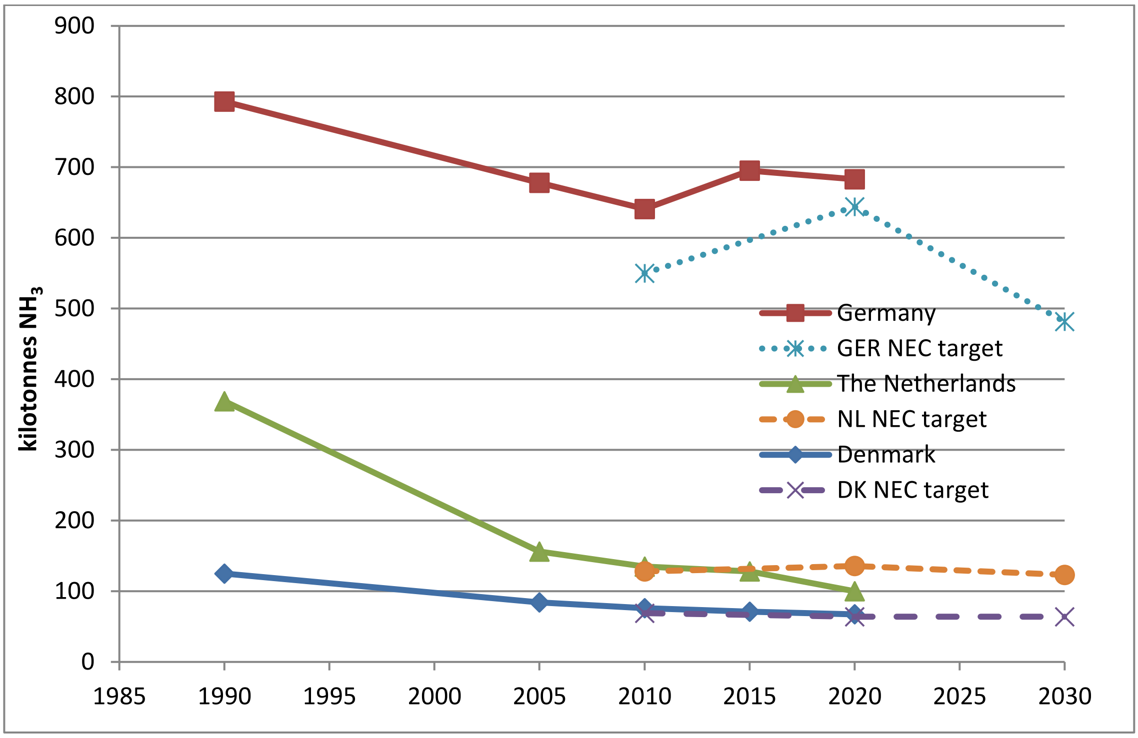

Figure 3. *Ammonia emissions from 1990 to 2020 compared to the NEC directive requirements (kilotonnes NH_3)*

Sources: EEA (2017); Mikkelsen and Albrektsen (2017); and own calculations.

3. The regulation approach and reduction requirements on case farms

This section will provide a short overview of the regulations set up and the relation to the actual requirements at the farm level (see also Anker et al., 2018). The overall regulatory approach is described in table 11. The focus here is on the requirements of the general ammonia regulation and the regulation near Natura 2000 under different conditions.

3.1. General regulation on emission for livestock

In Denmark, an official technology list is available, covering the Best Available Technology (BAT). This list includes technologies which have been approved and that have a certified effect on ammonia emissions and, at the same time, a reasonable cost for farmers. Denmark and the Netherlands have converted the BAT requirements into emission requirements, whereas in Germany emission requirements seem linked to the technology.

BAT in Germany is currently defined by the "Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs", published in 2003[2]. This document is available on the website of the Umweltbundesamt and is intended to provide state authorities with guidance in the approval procedure of new animal housing facilities.

The document lists some **general principles** for pig housing facilities. These include:

- Reduction of emitting manure surfaces
- Removing slurry from the pit to external slurry storage
- Applying an additional treatment, such as aeration, to obtain flushing liquid
- Using surfaces that are smooth and easy to clean.

The document explicitly excludes the following techniques from the list of BAT for new pig housing facilities:

- Manure cooling (too expensive)
- Partly slatted flooring with manure scrapers underneath (operational difficulties)
- Fully or partly slatted floor systems with flushing gutters or tubes underneath when operated with aerated liquid (odour peaks, operational problems).

Regarding **storage of manure** from pigs and poultry, BAT is to design storage facilities with sufficient capacity until further treatment or application to land. German national legislation (in the form of the Düngeverordnung 2017) stipulates storage capacities for at least six months (nine months when a farm keeps more than 3 LU/ha UAA).

It is BAT to cover slurry tanks using one of the following options:

- A rigid lid, roof or tent structure, or

[2] https://www.umweltbundesamt.de/sites/default/files/medien/419/dokumente/bvt_intensivtierhaltung_zf_1.pdf

- A floating cover such as chopped straw, natural crust, canvas, foil, peat, light expanded clay aggregate (LECA), or expanded polystyrene (EPS).

Further BAT requirements apply to spreading of manure (not listed in this report).

It is to be expected that BAT requirements will be tightened with the implementation of the new Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs published by the EU Commission in 2015.[3] It remains to be seen how this document will be implemented in national law. The fact that Germany has fallen short of its ammonia reduction commitments under the NEC Directive may cause the federal government to impose strict BAT requirements for livestock farmers.

The German approach includes several regulations which include both the air quality control (TA air) and regulation related to Natura 2000. The TA air requirements focus on larger installations with more than 1,500 places for finishers or 560 places for sows. Installations below this level require permission under the building law and not by the emission law (TA air). In some cases, an Environmental Impact Assessment (EIA) has to be made. The full EIA report is required when the building has more than 60-80,000 places (poultry) and 3,000 places for finishers. As the procedure is very time consuming and expensive, farmers try to keep the livestock enterprise below the threshold sizes.

In the Netherlands, the regulation regarding application of slurry states that it is only allowed on grassland with shallow injection, sod injection or narrow band application. Application of slurry on arable land is only allowed with injection, shallow injection, sod injection, narrow band application or with incorporation in one track.

More recently, low emission housing for animals has been introduced. Since 2013, all farms with shed animals must reduce the ammonia emission from stables. The emission factors for housing systems that farmers have to use have been published in the RAV-list (Regeling Ammoniak en Veehouderij – the Ammonia and Husbandry Regulation). Internal compensation is possible, meaning that a part of a farmer's existing housing systems does not have to apply the best available techniques (BAT), provided the farmer compensates for the missed ammonia reduction by applying techniques further than BAT in other housing systems. Internal compensation is only applicable for housing systems in stables established before 1 January 2007. Moreover, farmers that quit farming by 1 January 2020 at the latest may in the meantime still keep animals in regular housing systems.

In Denmark, the BAT emission requirements were given as 'per animal' until 1 August 2017, but they have now been changed to emission 'per square meter', which can be converted into emission 'per animal place', as is used in the Netherlands and Germany.

[3] http://eippcb.jrc.ec.europa.eu/reference/BREF/IRPP_Final_Draft_082015_bw.pdf

When comparing ammonia requirements between countries, it is a problem that the production cycles of finishers are different, and so, the number of animals per place is not the same. In Denmark, the piglets are moved from the sow to the next section at the weight of 7 kg and stay in this section until they weigh 32 kg. In Germany and the Netherlands, the piglets are 25 kg before being moved. The finishers therefore weigh from 25 to 102 kg in the Netherlands, 28-115 kg in Germany and 32-110 kg (live weight) in Denmark. In other words, the finishers stay a shorter time in the same building in Denmark than in Germany, and so, one has to be careful when comparing the emissions per finisher.

Based on tables 8 and 9 there seems to be a tendency for the Danish BAT requirements to be lower than the ones used in the Netherlands, when the emissions are converted to 'per kg NH_3-N' as is used in Denmark. It should be noted that in Denmark the allowed emission level per animal for finishers is smaller the larger the farm, whereas this is not the case in the Netherlands. As shown in table 9, the allowed emissions in the Netherlands have been reduced further after 1 January 2018 and then the difference is limited. The emission factors used in the German TA air system (table 10) seems to be higher for finishers, dairy cows and broilers than the BAT requirements used in the Netherlands and Denmark.

Table 8. *Reference and BAT standard emission requirements for stables in Denmark (new regulation from 1.8.2017 (kg NH_3-N/animal place)*

	Area per animal (m^2)	Reference NH_3-N/place	75-250 AU NH_3-N/place	250-750 AU* NH_3-N/place	> 750 AU NH_3-N/place
Finishers	0.65	1.50	1.05	1.05-0.69	0.69
Dairy cows	7.99	10.71	5.35	5.35	5.35
Broilers (35 days) (per 1,000)	0.054	0.04	0.03	0.03	0.03

Notes: Emission per place = emission per animal.
* Prod. per year.
Emissions in Denmark are in NH_3-N. To convert from NH_3-N to NH_3 the values have to be divided by 0.8235.
Source: Jacobsen and Ståhl (2018).

Table 9. *BAT standard emission requirements for stables in the Netherlands (kg NH_3 and NH_3-N/animal place)*

	Prod. per place per year	1.7.15 - 31.12.17 NH_3/place	1.7.15 - 31.12.17 NH_3-N/place	After 1.1.2018 NH_3/place	After 1.1.2018 NH_3-N/place
Finishers	2.88	1.5	1.2	1.1	0.9
Dairy cows	1	11.0	9.1	8.6	7.1
Broilers	7.5	0.035	0.029	0.024	0.020

Note: Production of finishers per place is 3.71 in Denmark and 2.6 in Germany. The production space for broiler is calculated as an increase of 300,000 broilers produced requires 40,000 new places.
Source: Luesink and Michels (2018a)

Table 10. *TA Luft emission factors in Germany (kg NH_3/animal place)*

	System	Emission Kg NH_3/place	Emission Kg NH_3-N/place
Finishers	Forced or free ventilation, different floors	2.43-4.86	2.0-4.0
Dairy cows	Loose housing	14.57-15.79	12.0-13.0
Broilers	Deep litter	0.0486	0.04

Source: Latacz-Lohmann (2017)

3.2. Regulation on emission for livestock near Natura 2000 and other nature sites

Table 11 provides an overview of the regulation of livestock production near nature areas. As noted, there are clear differences between the systems and the values used. The Dutch approach includes emissions from other sectors, which is why the allowed emissions are in mol per ha. The limit of 1 mol per ha is the same as 14 gram or 0.014 kg per ha, which is very low, and so, the requirement has an impact on farm expansions in a large area. The PAS system furthermore relies on an agricultural package with measures that will reduce emissions by 10 kt NH_3 by 2030.

Table 11. *Overview of criteria used in an assessment regarding allowed deposition near Natura 2000 areas*

Denmark	Germany	Netherlands
"Ammonia-sensitive" habitats (category 1) Permit thresholds: • Total load below 0.2-0.7 kg N/ha/year (cumulation model) (Livestock Installations Act – category 1)	Critical Loads (CL) for "nitrogen-sensitive" habitats (not binding) Assessment thresholds (cut-off/de minimis – no further assessment needed): • Additional load below 0.3 kg N/ha/year (cut-off), or • Additional load below 3 % of CL (de minimis)	PAS ("nitrogen sensitive" habitats): Cut-off assessment threshold (no permit requirement): • Additional load below 1 mol N/ha/year (or 0.05 mol N/ha/year if there is no or little "room for development" left) Permit threshold: • within "room for development"

Source: Anker et al. (2018)

The German approach is to look at the initial load plus the additional load due to the project and compare this to the critical load on the location in an FFH assessment (Flora Fauna Habitat). For newer buildings (after 2004) the total emission from the farm after the expansion are included in the project calculations, but for older buildings or buildings where an acceptance has been granted since 2004, only the additional emissions from the project are included in the calculations. If the initial load is higher than the critical load the project can only be approved if the additional project-related nitrogen deposition at the FFH site remains below 0.3 kg N per ha and below 3 per cent of CL (for more detail, see Anker et al., 2018). The approval will also take into account the deposition from other projects for which planning permissions have been applied.

In the Netherlands, only nitrogen-sensitive Natura 2000 sites are included in the PAS evaluation. The PAS evaluation is an integrated approach looking at the nitrogen deposition. It aims to achieve the objectives of European nature policy, while creating the necessary room for development and livestock production (Anker et al., 2018). The system focuses on ecological restoration of 118 Natura 2000 sites where the critical load is under 34 kg N per ha. The room for development, which is given back to the livestock sector, comes from an expected reduction of more than 10 kt NH_3 from today until 2030. Part of the reduction is allocated back to the sector as room for development in the provincial rules. The reduction of 10 kt NH_3 comes from the stringent rules on the use of fertiliser and animal housing, implemented from 1 January 2018.

The ammonia deposition was expected to decrease by up to 18 per cent (alternative 3), but with the PAS system the deposition will still be reduced by 10 per cent by 2030 compared to 2014 (Luesink & Michels, 2018a). Using the critical load, as in Germany, was not considered as realistic, while around 60-65 per cent of the area will always be above that level in 2030 no matter which approach is used. The PAS system may be seen as trying to strike a balance between achieving nature benefits and economic growth in the agricultural sector.

3.3 Case farms

Table 12 describes the case farms used in the analysis. We assume the expansion to be 100 per cent compared to the present farm. In some cases, the ammonia-reducing measures will only be necessary to implement in the new part of the buildings, while in other cases that goes for the full production.

Table 12. *Livestock production and technologies on the case farms analysed before and after expansion*

	Before expansion	After expansion
Finishers	Annual production of 7,215 finishers of 32-107 kg. 33 % drained floor and 66 % slatted floor. Slurry tanks with a required cover.	Annual production of 14,430 finishers of 32-107 kg. New building and technology has to be decided.
Dairy cows	120 dairy cows. Cubicles with slatted flooring and a recirculation manure pit. Slurry tanks with a required cover.	240 dairy cows. New building and technology has to be decided.
Boilers	A production of 300.000 slaughter chickens annually. A loose housing system. Solid manure.	A production of 600,000 slaughter chickens annually. New building and technology has to be decided.

Notes: For the Dairy farm calculations have been made with and without heifers and calves as heifers and calves are not included in the Dutch case, but they are included in the German case.
The finishers in Denmark, Germany and the Netherlands have different weight intervals. The interval shown is the Danish one.

3.4. The reduction requirements for the case farms in Denmark

Table 13 describes the reduction requirements for the three Danish case farms in the case where they lie 400 m from nature areas. The first emission level is the base emission level based on the emissions when using the reference technology. The next step is the BAT emission requirements which have to be reached by all livestock farms. The second level is the emissions related to proximity to nature sites and the number of livestock farms near category 1 and Natura 2000 sites. For finishers the required reductions for category 2 to 3 outside Natura 2000 are also included. The allowed emission levels were calculated by the Danish Environmental Protection Agency using the online electronic application system based on the regulation before 1.8.2017 (see more in Jacobsen & Ståhl, 2018).

The table 13 shows that the reduction for finishers compared to the baseline situation is 47-85 per cent, or, compared to the BAT level, it is 41-83 per cent when the expanding farm is near 1-

2 livestock farms. The reduction required for nature category 2 and 3 is lower than for category 1 nature. There are no additional reduction requirements for the farms when located 2,000 m away from Natura 2000 sites compared to the BAT requirements.

Table 13. *Allowed ammonia emissions and reduction requirement for the case farms situated 400 m from nature areas in Denmark (kg NH_3-N)* [a)]

Farm type	Baseline emission, before/ after BAT [b)]	No. of neigh-bours / Nature type	0	1	>1
7,215+ 7,215 finishers (5,000 places)	Baseline = 5,682 kg BAT = 5,040 kg -11 %[c)]	Category 1	2,989 kg -47 %	1,642 kg -71 %	835 kg -85 %
		Category 2	4,066 kg -28 %	-	-
		Category 3	6,907 kg [d)] 0 %	-	-
120+120 dairy cows with heifers	Baseline = 3,283 kg BAT = 2,585 kg -21 %	Category 1	2,809 kg [d)] 0 %	1,592 kg -51 %	1,052 kg -68 %
120+120 dairy cows without heifers	Baseline = 2,690 kg BAT = 2,053 kg -24 %	Category 1	2,809 kg N [d)] 0 %	1,592 kg N -41 %	1,052 kg N -61 %
300,000+ 300,000 broilers	Baseline = 3,838 kg BAT = 3,325 kg -13 %	Category 1	2,903 kg -24 %	1,967 kg -49 %	983 kg -74 %

[a)] Note that the emissions in the Danish cases here are in kg NH_3-N and not NH_3.
[b)] BAT is here based on the allowed BAT emissions set by the Environmental Protection Agency.
[c)] Compared to baseline before BAT and all kg are kg NH_3-N
[d)] In these cases, the allowed emission is higher than the BAT requirement, and so, the BAT requirement is the allowed level.
Note: The calculations are carried out with and without heifers and calves to be able to compare with conditions in Germany and the Netherlands
Sources: Environmental Protection Agency (2017); Jacobsen and Ståhl (2018).

Table 13 and figure 4 show that the requirement for category 1-1 and 1-2 (category 1 location with 1 or 2 livestock neighbours) is lower than the emissions from the stable before the expansion (old stable). These large reduction requirements are often hard to fulfil with the present technologies as will be discussed later. On the other hand, it is not uncommon that the reduction requirements related to category 3 nature sites are limited. In relation to category 3 nature, it is found that many farms have a requirement of a maximum additional deposition of 1 kg N per ha.

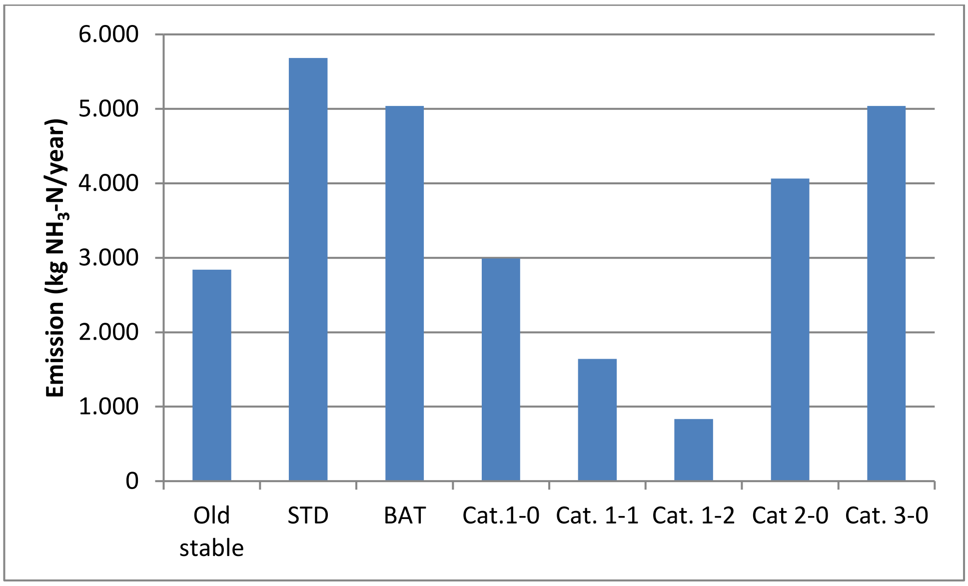

Figure 4. *Required emission for case farm in Denmark with finishers with a distance of 400 m from nature sites (kg NH_3-N/year).*

Note: STD is the standard reference technology, category 1-0 is category 1 nature with no livestock neighbours, and so on. The allowed emission for category 3-0 is the BAT requirement of 5,040 kg NH_3-N and not the calculated allowed emission of 6,907 kg NH_3-N as the requirement is the lower of the two.
Source: Jacobsen and Ståhl (2018).

3.5. The reduction requirements for the case farms in Schleswig-Holstein

The approving authority must check whether the cut-off criterion or the *de minimis* criterion applies. As explained in section 3.2., the project's additional load (Zusatzbelastung) has to be below 0.3 kg N per ha per year in the reception area (cut-off criterion) or below 3 per cent of the Critical Load (*de minimis* criterion). In the screening process, this check requires the agency to estimate the additional load based on a transformation of an extended version of the minimum distance function (see also Latacz-Lohmann, 2017).

Therefore, more measures have to be implemented when the distance is only 400 m. As seen before, the emission levels based on the technologies in Germany are somewhat higher than in Denmark, even though the type of stables is similar.

Furthermore, Schleswig-Holstein has had the Filter Decree in place from 2014 which covers pig installations with more than 2,000 fattening places or with more than 750 sows. These farms must install an air filter or air scrubber. An increase of the housing capacity requires air filters or scrubbers, but that is not obliged for existing farms which do not increase their production. The Filter Decree is managed by the regional government in Schleswig-Holstein and in four other German federal states with high livestock density. The decree also requires cover over slurry storages above a certain size (6,500 m^3). It is estimated that in Schleswig-Holstein only 40 farms or 10 per cent of all pig farms are larger than 2,000 fattening places, and so, the Filter Decree currently applies to only a small share of the pig farms (Latacz-Lohmann, 2017). There is no general refitting obligation for existing pig farming installations that exceed the above threshold size.

The next step is to determine whether the deposition from an expansion exceeds the limit of 0.3 kg N per ha, as described above. If the additional deposition is below 0.3 kg N per ha (cut-off criterion) the expansion can be approved without further examination.

If the initial load is higher than the critical load of around 5-20 kg N per ha, depending on the area and nature type, the expansion may only increase N deposition by 3 per cent of the critical load (*de minimis* criterion). In other words, the project has to be adjusted so that the additional emission is below 3 per cent of the critical load either by using ammonia-reducing technologies or through a smaller expansion of the project[4]. Relocating the project is also an option, but this is not assumed to be the case in this analysis.

In the case where the initial deposition (e.g. 15 kg N per ha) is lower than the critical load (e.g. 20 kg N per ha), the project can only have an additional deposition of 5 kg N per ha. If the additional deposition is higher than the gap between the original deposition and the critical load, an adjustment has to be made. This adjustment will often be smaller than the adjustment needed in the case above where the initial deposition is larger than the critical load. If the projected total load (after realization of the project) remains below the critical load of the nitrogen-sensitive site, the project can be approved without specific emission reduction requirements.

If the initial load is higher than the critical load technical measures have to be adopted, but it can often be difficult to reach the allowed emission levels. On the other hand, if the initial load is lower than the critical load this will allow for an expansion of the farms.

In Germany, areas with nitrogen-sensitive vegetation are designated as so-called FFH (Flora Fauna Habitat) areas in which certain constraints are imposed on farming activities. These constraints are laid down in the management plans for individual FFH areas and can vary with the type of habitat concerned. Not all protected FFH habitats have nitrogen-sensitive vegetation.

In the case where the total load is lower than the critical load, the project needs to ensure that the maximum deposition from the project is 5 kg N per ha (the difference between initial load and critical load). The calculations for the pig farm extension show that the initial deposition is 7.39 kg N per ha (see table 14). In order to reach the accepted level, the emissions have to be reduced from 3,640 to 2,463 kg NH_3 (-32 per cent).

In the case where total load is higher than the critical load, the project needs to ensure that the maximum additional deposition is less than 0.3 kg N per ha, as shown in table 14. It is assumed that a combination of phase feeding and slurry acidification in the extension can bring ammonia

[4] If the critical load is e.g. 10 kg N per ha, the project must be adjusted so that its additional load does not exceed 0.3 kg N per ha (i.e. 3 per cent of 10 kg N per ha).

emissions down by 60 per cent from 3,640 to 1,456 kg NH_3 per year[5]. To ensure that the additional emission stays below 0.3 kg N per ha, the permitted emission from the case farm is only 147 kg NH_3 per year (-96 per cent). The current technologies cannot provide this level. The permitted emission would only allow for 500 fattening places, and the project is therefore not profitable.

With a distance of 2,000 m to Natura 2000, the emission of 3,640 kg NH_3 gives a deposition of 0.3 kg N per ha, and so, no additional investment is required when the farm is more than 2,000 m away.

For the dairy farm, the base emission is 3,983 kg NH_3 per year including the emission from the heifers. The allowed minimum distance to Natura 2000 based on the TA Luft regulation is in this case 407 m. The other emission levels are similar to the levels found for the finishers. In the German system, there is no requirement related to existing buildings as long as they do not apply for a permit to extend the operations.

For the broilers with 80,000 places, the total emission is 3,888 kg NH_3. Just as for the dairy cows, this is allowed under the emission law (TA Luft) with a distance of around 400 m (402 m).

When the current deposition is below the critical load, we need to look at the additional deposition. This is 7.9 kg N per ha, and so, it has to be reduced to 5 kg N per ha, which is the difference between the initial load and the critical load.

Observe that a calculation as the above is based on the total emission from the farm. Assuming that the pre-existing animal house was erected **after** registration of the FFH site in 2004, the emission from the entire facility (old building and extension) is taken into account. If the initial facility was erected **before** registration of the FFH site, only the emission from the extension is counted. In the analysis it is assumed that the initial facility was built after registration of the FFH site. This is probably a quite realistic assumption since most Natura 2000 sites in Schleswig-Holstein were registered before 2004. The legal base of this administrative practice is the so-called "Verschlechterungsverbot" (requirement to prevent deterioration) which was established in case law (a ruling of the Bundesverwaltungsgericht) in 2012.

If the house was erected before the registration of the FFH site in 2004, only the additional emission from the expansion is included in the calculation.

[5] Note that slurry acidification is presently only used at project scale in Germany. Given its proven reduction potential, it is realistic to assume that the technology will spread in the future.

Table 14. *Allowed ammonia emissions and reductions for case farms 400 m from nature areas in Schleswig-Holstein(Kg Nh_3 per year)*

Farm type	Baseline emission, before BAT	Filter Decree	TL<CL	TL>CL
7,215+7,215 finishers (5,000 places) (TA > 870 m)	18,200 kg NH_3 Load = 37 kg N/ha	3,640 kg NH_3 -80 % Load = 7.4 kg N/ha	2,462 kg NH_3 -86 % Load1 < 5 kg N/ha Target = 5.0 kg N/ha	147 kg NH_3 -99 % Load1 = 3.0 kg N/ha Target < 0.3 kg N/ha
120+120 dairy cows with 160 heifers (240 places) (TA > 407 m)	3,983 kg NH_3	3,983 kg NH_3 0 %	2,462 kg NH_3 -38 % Load1 = 8.1 kg N/ha Target = 5.0 kg N/ha	147 kg NH_3 **-96 %** Load1 = 8.1 kg N/ha Target < 0.3 kg N/ha
300,000+ 300,000 broilers (80,000 places) (TA > 402 m)	3,880 kg NH_3	3,880 kg NH_3 0 %	2,462 kg NH_3 **-37 %** Load1 = 7.9 kg N/ha Target = 5.0 kg N/ha	147 kg NH_3 -96 % Load1 = 1.5 kg NH_3 Target < 0.3 kg N/ha

Notes: TL and CL are Total load and Critical load. Total load is initial load + additional load. If the TL > CL the cut-off level of 0.3 kg N per ha. The 0.3 kg N per ha is the allowed change in total load due to expansion.
Load1 is the additional load before new technology. After new technology the target level has to be reached
Source: Latacz-Lohmann (2017)

3.6. The reduction requirements for the case farms in the Netherlands

The finisher farm needs to respect the BAT requirement of 1.5 kg NH_3 per place. The starting point is a farm with 1.4 kg NH_3 per place, which is the national average (3,500 kg NH_3) (see table 15). Around one third of the floor is drained and two thirds are slatted, and all the slurry is stored under the stable floor. With 100 per cent room for development, the maximum emission is 7,225 kg NH_3 per year. The approach used is similar for the dairy and the broiler farm and the calculations are easier than in Germany and Denmark.

In the current situation, the farms will have an added emission that will increase the deposition level with more than 5 mol NH_3 per ha or 0.07 kg NH_3 per ha. In that case, an analysis has to be made whether there is room for additional deposition according to the PAS system. As described in Anker et al. (2018) and in Luesink and Michels (2018a+b), the PAS system has an evaluation of the emission locally including an option to apply for “room for development”. In the subsequent analyses, there is either 0 or 100 per cent room for development available as a permit is either given or not given. However, even with room for development, a typical permit will allow only 3 mol N per ha and only rarely around 4 mol per ha. With 100 per cent room for development, the expected increase in production adhering to the BAT requirement is possible. On the other hand, a farm with 0 per cent room for development cannot increase the emission compared to the baseline emission before the expansion.

Table 15. *Allowed ammonia emissions and reductions for case farms 400 m from nature areas in the Netherlands (kg NH_3 per year)*

Farm type	Baseline not near Nature 2000 / PAS area	Near Nature 2000 but with room for development	Near Nature 2000 but no room for development
7,215+7,215 finishers (5,000 places)	7,225 kg NH_3	7,225 kg NH_3 0 %	3,500 kg NH_3 -50 %
120+120 dairy cows without heifers (240 places)	2,064 kg NH_3	2,064 kg NH_3 0 %	1,320 kg NH_3 -36 %
300,000+ 300,000 broilers (80,000 places)	2,880 kg NH_3	2,880 NH_3 0 %	1,480 NH_3/year -50 %

Notes: Emissions are here NH_3 and not NH_3-N as in Denmark
Emission before expansion is 3,475 kg NH_3 for the finishers.
Emission before expansion is 1,320 kg NH_3 for the dairy cows.
Emission before expansion is 1,480 kg NH_3 for the broilers.
Source: Luesink and Michels (2018a).

3.7. Comparison of reduction requirements across the countries

The overall conclusion is that, often, it will be technically difficult to find solutions that can reduce emissions to an extent that meet the strict requirements. In Denmark, this will be the case when the project is in category 1 with two livestock neighbours; in Schleswig-Holstein, when the initial emissions exceed the critical load; or in the Netherlands, when a project is located near Natura 2000 and there is no room for development.

Table 16. *Allowed emissions in kg NH_3 per year and with 400 m from nature sites*

Country and nature type	Name Neighbouring TL/CL levels development room	Baseline before BAT	BAT	Light 0 neigh TL<CL 100 %	Medium 1 neigh	Strict 2 neigh TL>CL 0 %
Natura 2000						
Denmark, cat. 1	Finishers	6,900	6,120	3,630	1,994	1,014
	Dairy farm	3,987	3,139	3,411	1,933	1,277
	Broilers	4,661	4,038	3,525	2,389	1,194
Netherlands	Finishers		7,225	7,225	---	3,500
	Dairy farm		2,064	2,064	---	1,320
	Broilers		2,880	2,880	---	1,480
Schleswig-Holstein	Finishers	18,200	3,640	2,462	---	147
	Dairy farm	3,983	3,983	2,462	---	147
	Broilers	3,880	3,880	2,462	---	147
Other nature						
Denmark, cat. 2/3	Finishers	6,900	6,120	---------- 4,937- 6.120 ----------------		

Notes: The Danish dairy case is without heifers and calves. The Danish emission has been converted from NH_3-N to NH_3 (divided by 0.8235). For Nature category 3, the BAT requirement has been used.
Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2018a).

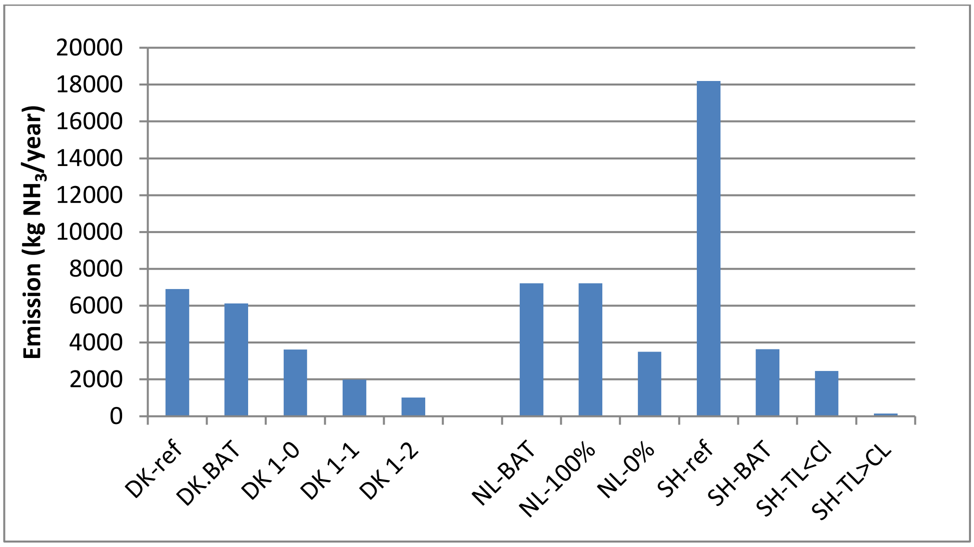

Figure 5. *Emissions and emission requirements for finishers near Natura 2000 in Denmark (DK), Schleswig-Holstein (SH) and the Netherlands (NL) in 400 m distance from Natura 2000 sites.*

Note: Weights for finishers are 25 to 102 kg in the Netherlands, 28 to 115 kg in Schleswig Holstein and 32 to 110 kg in Denmark. DK 1-0 refer to nature category 1, with no livestock neighbours.
Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2018a).

Table 17. *Actual emissions in kg NH_3 per year and with 400 m from nature sites*

Country and nature type	Name Neighbouring TL/CL levels development room	Baseline before BAT	BAT	Light 0 neigh TL<CL 100 %	Medium 1 neigh	Strict 2 neigh TL>CL 0 % [a)]
Natura 2000						
Denmark, cat. 1	Finishers	6,900	5,727	3,174	1,518	759
	Dairy farm	3,267	2,451	2,451	1,633	1,225
	Broilers	4,661	3,961	3,263	---	---
Netherlands	Finishers		7,225	7,225	---	2,688
	Dairy farm		2,064	2,064	---	1,164
	Broilers		2,880	2,880	---	1,320
Schleswig-Holstein	Finishers	18,200	3,640	2,462	---	---
	Dairy farm	3,983	3,983	2,462	---	---
	Broilers	3,880	3,880	2,462	---	---
Other nature						
Denmark, cat. 2/3	Finishers	6,900	5,727	---- 5,037 / 5,727 ----		

Notes: The Danish dairy case is without heifers and calves. The Danish emission has been converted from NH_3-N to NH_3 (divided by 0.8235).)

[a)] In some cases it has not been possible to reach the allowed emission level (---)

Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2018a).

Comparing the emissions in the regions shows that the initial emission in Germany for finishers is much higher than in Denmark and the Netherlands. However, the Filter Decree reduces the emissions for large pig farms to a level, which is lower than the BAT levels in Denmark and the Netherlands.

The allowed emission in Denmark for farms near Natura 2000 under strict conditions (two neighbours) has a lower level than in the Netherlands, but higher than in Schleswig-Holstein where almost no emission is allowed when the initial load is higher than the critical load.

The allowed emission in Denmark for farms near Natura 2000 under light conditions (no neighbours) is also lower than in the Netherlands for finishers, but similar for dairy cows and broilers and a little higher than the level in Schleswig-Holstein.

With 2,000 m to Natura 2000 sites, the allowed emission in the Netherlands is lower than in Denmark where the BAT level is sufficient. In the Schleswig-Holstein case, the BAT requirements are acceptable for finishers and dairy cows, but a small reduction of production is required for the broilers.

4. Cost of measures on case farms

This section describes the costs of the technologies in the three countries before moving on to the calculation of the costs of fulfilling the requirements for the case farms. The chapter finish with a comparison of the cost in the three countries.

4.1. Cost of technologies in the three countries

Similar technologies are available to reduce ammonia emissions in Denmark, Schleswig-Holstein and the Netherlands. One main difference, with regard to the technology applied at different regulation levels, is that air filters/scrubbers are now required on larger pig farms in Germany, whereas it seems to be a reference technology in the Netherlands. It is not necessarily required to reach BAT emission levels in Denmark. Therefore, the costs of air scrubbers are embedded in the Schleswig-Holstein baseline case calculation at 4.5 euro per finisher.

In Denmark, air scrubbers are used in the finisher case farm as a means to attain the stricter ammonia levels when the farm is close to nature. The costs depend on the cleaning capacity and on the farm size and range from 0.7 to 3.9 euro per finisher. Air scrubbers are also used in the Dutch case on finisher farms when there is no room for development. The costs there range from 5.1 to 10.1 euro per pig space per year, depending on comparing with a normal stable or one with cooling. For the Dutch dairy case farm, air cleaners have an additional cost of 63.30 euro per cow place per year, although the norm is naturally ventilated stables. The measure is used neither in the Schleswig-Holstein, nor in the Danish dairy case farm. In the Schleswig-Holstein broiler case farm, air cleaners are considered at a cost of 0.022 euro per broiler, whereas in the Danish case it is not considered because of dust issues.

Another main difference is that stable acidification is approved in Denmark, but not yet a fully approved technology in Germany. However, is has been used for the case farms in Schleswig-Holstein. In the Netherlands, acidification is not an approved technology for several reasons such as compliance and risk of phosphor loss, and so, it is used on neither of the case farms (Jacobsen, 2017a). For the Danish dairy case farm, stable acidification is the chosen technology either alone (50 euro per cow) or combined with dredgers in the new stable (60 euro per cow per year in total). The cost of stable acidification used on the Danish pig farm is around 3.3 euro per finisher. As investment costs are only partly related to the stable size, stable acidification entails economies of scale. However, acidification cannot replace solid cover over the manure tank when the farm is closer than 300 m to Natura 2000 sites or category 2 nature sites.

Although not yet an approved measure, cost estimates of stable acidification in the Schleswig-Holstein report imply a similar cost level as in Denmark if implemented. In-field acidification is used on the Schleswig-Holstein finisher case farm at a cost of 1.15 euro per finisher or 1.5 euro per m^3 of slurry. Field acidification in Germany is more expensive than in Denmark according to the Danish calculations where the cost is only 0.4-0.7 euro per m^3 (Hansen et al., 2013;

Jacobsen, 2017a). As the costs of this technology are dependent on the amount of slurry to be applied, economies of scale cannot be expected to a large degree.

Stable design is considered in all three reports. Dredgers in dairy barns have smaller unit costs the larger the farm and the cost is around 15 euro per cow when installed on the entire dairy case farm. The flooring costs depend largely on the number of animals/floor space. Economies of scale are therefore not as relevant for flooring. In the Dutch dairy case farm, a low emission stable "cassettes en mestschuif" costs 25.6 euro per cow space per year more than the reference stable "langsleuven". In Schleswig-Holstein, a low emission floor and slide will cost less than the reference stable. Low emission stables for finisher farms entail more solid floor, and the costs increase with size, as there are no economies of scale. More solid floors are used in the Danish case for achieving the general (BAT) requirements and to adhere to the least restrictive nature type requirement and are thus without additional costs. Low emission stables are not used in the Schleswig-Holstein case. In the Dutch case, a stable with separated removal of dung and urine does not carry additional costs for the case farm. Cooling is an option for the Dutch finisher case farm at a cost of 5 euro per finisher place per year, but not in the Schleswig-Holstein case, since cooling is considered too expensive a technology in Germany. Assuming total re-use of heat and 20W per m^2, cooling in Denmark would entail savings of around 0.8-1.3 euro per finisher with larger unit benefits the larger the farm. As cooling on its own is not an effective enough technology with regards to the Danish reduction requirements, it is not used on the case farm, although it could be combined with e.g. a lower effect air washer and then achieve some of the reduction targets at a lower combined cost. The re-use of heat is not likely for all finisher farms, as it often requires a production of piglets that can use the heat. With no heat re-use, cooling will typically be too costly.

For the Dutch broiler case farm with no room for development, tube heating is assumed installed in the old barn while heat exchangers are installed in the new barn. Because of energy savings, these do not entail additional costs compared to the reference system. Heat exchangers are also used for the Danish broiler case farm with additional costs of 7 euro per 1,000 chickens. These costs do not entail economies of scale, as the number of heat exchangers is considered with regard to standard farm sizes for slaughter chicken farms of 300,000-600,000 chickens. In the Netherlands, the reuse of heat means that the technology can provide an economic gain just as in Denmark. No technology is available which can provide the required reductions, when other livestock farms are located near the broiler farm in Denmark.

4.2. Cost for case farms in Denmark

For the finishers, the additional costs of complying with nature specific ammonia requirements are calculated as the costs of the specific technology necessary in each case minus the costs of the baseline technology. In this case, the baseline technology to achieve BAT is 50-75 per cent solid floors. Another option would have been to combine changes in feeding and storage in order to reduce the emissions by 11 per cent and then use this as the baseline.

The required emission reductions in relation to ammonia sensitive nature are achieved by installing chemical air cleaning in the stable (sometimes both the old and new stable). This will entail a yearly net cost of 6,000-32,000 euro per year or 0.5-2.2 euro per finisher depending on the number of livestock farms nearby.

For the dairy farm to adhere to the BAT requirements when expanding from 120 to 240 dairy cows (without heifers), the dairy farm needs to achieve ammonia reductions of 24 per cent compared to the baseline/reference stable of 2,690 kg NH_3-N. This is done by installing wire drawn dredgers in both the old and the new stable. Another option is to install low emission flooring with dredgers in the new stable that reduces the emission by 50 per cent, thus achieving a total reduction of 25 per cent for the entire farm.

If the dairy case farm is situated close to Natura 2000 areas (category 1) and has no livestock neighbours in the proximity, the allowed emission is higher than BAT. The explanation is that the allowed emission is based on a detailed calculation in the program, which in this case allows a larger emission than in the BAT standards, and so, the required emission level is the BAT emission level.

Being in proximity of category 1 nature and having 1-2 neighbours nearby, the farm has to install acidification in both the new and existing stable. The costs are 12-14,000 euro per year or 50-60 euro per dairy cow.

For broilers, the technology used is heat exchangers at the cost of around 4,300 euro per year or 7 euro per 1,000 broilers. No technology for further reduction is available.

The costs for finishers near category 2 nature are 3,300 euro as the requirement is less strict than in the other cases. There are no reduction requirements with respect to category 3 in this case.

Table 18. *Additional costs for case farms related to ammonia requirements for case farms 400 m from category 1-3 nature compared to BAT emission requirements in Denmark (euro per year)*

Regulation	Natura 2000			Category 2 nature	Category 3 nature
No. of neighbours	0	1	>1		
Cost per farm (euro)					
Finishers	6,479	18,463	31,767	3,268	0
Dairy cows	0	12,096	14,278		
Broilers	4,317	Not possible	Not possible		
Cost per unit (euro/unit)					
Finishers	0.4	1,3	2.2	0.2	0
Dairy cows	0	50	60		
Broilers (1,000)	7.2	Not possible	Not possible		
Cost per kg NH_3 (euro/kg NH_3)					
Finishers	3.7	6.5	9.5	7.0	0
Dairy cows	0	21.8	17.1		
Broilers	9.1	Not possible	Not possible		

Note: Costs per kg NH_3-N are calculated as the additional costs in relation to the additional reduction in ammonia emission (marginal cost approach). Conversion is 7.45 DKK = 1 EUR and emissions have been converted from NH_3-N to NH_3. There are no calculated values for dairy cows and broilers for category 2 and 3.

Source: Jacobsen and Ståhl (2018).

4.3. Cost for case farms in Schleswig-Holstein

The assumption for the case farms in Germany is that it is an extension of an existing farm. In addition, the analysis considers the situation where the critical load of nitrogen deposition has already been exceeded and another situation where the current deposition is below the critical load.

As mentioned before, the general requirement for all pig farms above a certain size is that they need to install an air filter that can be either a chemical or a biological washer on pig farms over a given size. As shown in table 19, the costs of the Filter Decree are quite large. The ammonia reduction is estimated to be around 80 per cent and the costs for different options are 13.9-15.4 euro per place or 5.6 euro per pig. In the case of farm calculation, the cost used is 4.5 euro per finisher (see table 19).

For further reductions on the finisher farm, field acidification has been used as a measure to reduce the emissions by 32 per cent compared to the Filter Decree requirements. The cost related to the acidification is 1.5 euro per m^3 slurry, which results in a yearly cost of 16,500 euro per year. This is 3.3 euro per place, 1.15 euro per finisher, or 14 euro per kg NH_3 in the case where the total load is less than the critical load.

Table 19. *Additional costs for case farms related to ammonia requirements for case farms 400 m from Natura 2000 areas in Schleswig-Holstein (cost per year; cost per livestock; and cost per kg NH_3)*

Regulation	BAT (Filter Decree) [1)]	TL<CL	TL>CL No investments (loss of income)	TL<CL	TL>CL
Distance		400	400	2000	2000
Cost per farm (euro per year)					
Finishers	32,462	16,500	(27,418)	0	0
Dairy cows	0	8,250	(57,039)	0	(solid floor) 0
Broilers	0	6,679	(14,607)	0	1,460
Cost (euro) per unit of animal					
Finishers	4.51	1.15	(3.81)	0	0
Dairy cows	0	34.40	(475)	0	0
Broilers (1,000)	0	22	(49)	0	5.4
Cost (euro) per kg NH_3					
Finishers	4.46	14 [2)]	(15.06)	0	0
Dairy cows	0	5.2	(29)	0	0
Broilers	0	4.9	(7.5)	0	7.5

Notes: Costs per kg NH_3-N are calculated as the additional costs in relation to the additional reduction in ammonia emission (marginal cost approach).
[1)] BAT cost for finishers is 4.5 euro per finisher or 32,462.
[2)] Cost are calculated as (16,500 / (3,640 – 2,462) = 14.0 euro per kg NH_3
Source: Latacz-Lohmann (2017).

For the broilers, an air filter with 100 per cent capacity is installed, and so, the emission is reduced to 2,527 kg NH_3 (-35 per cent) or 5.13 kg N per ha or around 5 kg N per ha. The total cost is 6,679 euro per year or 0.022 euro per broiler or 4.91 euro per kg NH_3 when the total load is less than the critical load.

In the case of 2,000 m, the additional load is 0.316 kg N per ha, and so, the production increase is reduced from 40,000 places to 35,967 places. In the case that the total load is lower than the critical load, there are no additional costs.

For Schleswig-Holstein, it is assumed that loss of income will mean that the expansion is not possible as it is not possible to reduce the emissions to 147 kg NH_3 but only to e.g. 778 kg NH_3 in the case of the broiler farm.

The overall conclusion of the cost calculations is that if the distance is 2,000 m there are generally no additional costs, but for the broilers the size is reduced a little when the initial load is higher than the critical load. For the dairy farm, low emission flooring with no additional cost is selected.

With a distance of 400 m, the expansion can be made when the initial load is lower than the critical load. The costs vary between 0 and 16,500 euro per farm. The highest additional costs are for the finisher farms, which also have the highest costs in baseline due to the Filter Decree. Hence, the total cost (including baseline) for the finisher farm is close to 100,000 euro per year or 6.8 euro per finisher produced. However, the farm is still profitable.

In the case of a distance of 400 m where the initial load is higher than the critical load, the reduction requirements are large and no technologies can provide this reduction. A reduction in the size of the expansion will make the expansion unprofitable, and so, the farm will not be expanded (see table 19).

4.4. Cost for case farms in the Netherlands

The Dutch farms start with a stable that have emissions like the average Dutch farm, and so, some have larger emissions (3.0 kg NH_3 per place) than the allowed limit of 1.5 kg NH_3 per place for finishers and some have less. The costs for expansion with no impact on nature or a long distance from nature sites are 27,500 euro per year (or 1.9 euro per finisher) in order to pay for air washers in the existing building and cooling in the new building (see table 20). The BAT technologies are also the requirement with room for development. With no room for development, the costs of additional air washers etc. are 20,325 euro, which is equal to 2.8 euro per extra finisher produced.

For the dairy farm, the costs for measures to fulfil the BAT requirement are limited, and so, the additional costs compared to the basic investment is around 2,000 euro per year (8 euro per cow) (see table 21). With no room for development, the costs will increase to 17,200 euro as air washers are introduced. The additional cost is 15,192 euro per year or 126 euro per new cow. For both finishers and dairy cows, the costs in the case of no room for development are so high that an expansion is probably not realised.

Table 20. *Emissions and costs in the Netherlands for the pig farm extension (from 2,500 to 5,000 finisher places)*

Scenario	Baseline not near Natura 2000 / PAS area	Near Natura 2000 but with room for development	Near Natura 2000 but no room for development
Additional emission Additional emission Total emission Actual emission Total per place	1.5 kg NH_3/place (3,750 kg NH_3/year) 7,225 1.45 NH_3	1.5 kg NH_3/place (3,750 kg NH_3/year) 7,225 1.45 NH_3	0 kg NH_3/place (0 kg NH_3/year) 3,475 (2,688) 0.7 NH_3
Measures	1/3 drained and 2/3 slatted floor	1/3 drained and 2/3 slatted floor	air scrubber also in old building
Increased costs (euro per year) Euro per extra finisher produced	0 0	0 0	20,325 2.8
Abatement costs (euro per kg NH_3)	0	0	4.5
Extension project realised	yes	yes	perhaps not

Note: Emission from the base 2,500 places is 3,475 kg NH_3 (1.39 * 2,500).
Production is 14,400 finishers and 2.88 pigs per place per year.
Source: Luesink and Michels (2018a).

Table 21. *Emissions and costs in the Netherlands for the dairy farm (from 120 to 240 dairy cows)*

Scenario	Baseline for old housing system (120 cows)	Baseline not near Natura 2000 / PAS area	Near Natura 2000 but with room for development	Near Natura 2000 but no room for development
New requirement (kg NH_3 per year) Additional emission Total allowed	11.0 kg NH_3/place (1,320 kg NH_3)	8.6 kg NH_3/place +744 kg NH_3 2,064 kg NH_3	8.6 kg NH_3/place +744 kg NH_3 2,064 kg NH_3	5.5 kg NH_3/place 0 kg of NH_3 1,320 kg of NH_3
Measures	replaced	none	none	new low-emission stable + air washer
Costs (euro per year) Additional costs Euro per cow		2,016	2,016 0 0	17,208 15,192 126
Abatement costs (euro per kg NH_3)	---	0	0	17
Extension project realised		yes	yes	probably not

Note: 720 grazing hours per year.
Source: Luesink and Michels (2017).

For the broilers, the production increases from 300,000 to 600,000, requiring an increase of 40,000 places (table 22). The requirements to reach the BAT level indicate that the farmer might gain from including heaters on the farm. In the case of no room for development, the inclusion of heat exchangers might also be a benefit (negative costs). In the further calculations, the costs are set to 0, as not all farms will be able to gain from heat exchangers.

Table 22. *Emissions and costs in the Netherlands for the broiler case farm (40,000-80,000 places)*

Scenario	Baseline not near Natura 2000 / PAS area	Near Natura 2000 but with room for development	Near Natura 2000 but no room for development
New requirement Additional emission Total emission	0.035 kg NH_3/place +1,400 (1,480+1,400) 2,880	0.035 kg NH_3/place +1,400 2,880	0 kg NH_3/place 0 1,320
Additional measures	none	none	tube heating in the old stable + heat exchanger in the new stable
Increased costs (euro per year) Euro per 1,000 broilers	0	0	- 800 (0) 0
Abatement costs (euro per kg NH_3)			0
Extension project realised	yes	yes	perhaps

Note: Emission from the base 2,500 places is 3,475 kg NH_3.
Source: Luesink and Michels (2018a).

4.5. Comparison of costs across countries

Costs mainly depend on the reduction requirements. In Denmark, the rules for farms located close to Natura 2000 areas are stricter than in the Netherlands, and so, the costs are higher. For a finisher case farm in Denmark with more than one neighbouring livestock farm, the extra cost is almost 32,000 euro. In the Netherlands, a finisher farm with room for developments have no additional costs and for farms with no room for development, the cost is almost 20,500 euro. In Schleswig-Holstein, an expansion when a farm exceeds the critical load is also expensive, and so, evaluated not to be profitable. The same might be the case in Denmark and in the Netherlands.

When a farm lies further away from a Natura 2000 area (2,000 m), the rules in the Netherlands are stricter and the extra costs are higher than in Denmark and Schleswig-Holstein. In the case where the initial load is higher than the critical load in Schleswig-Holstein, it is impossible to reach the target, but if this is not the case the costs for finishers is at the same level as the middle scenarios for Denmark. In the case of a distance of 2,000 m from Natura 2000, the Schleswig-Holstein farms have relatively low additional costs.

Table 23. *Extra yearly costs (euro per farm) for the case farms near nature areas in Denmark, the Netherlands and Schleswig-Holstein. The costs are compared to BAT requirements or similar.*

Country and nature type	Neighbouring farms/development room	Finisher 400 m	Finisher 2,000 m	Dairy 400 m	Dairy 2,000 m	Broiler 400 m	Broiler 2,000 m
Natura 2000							
Denmark, cat. 1	no neighbour	6,479	0	0	0	4,323	0
	1 neighbour	18,463	0	12,096	0	not possible	0
	>1 neighbour	31,767	0	14,278	0	not possible	0
Netherlands	100 % room	0	0	0	0	0	0
	no room	20,325	20,325	15,825	15,825	0	0
Schleswig-Holstein	TL < CL	16,500	0	8,250	0	6,679	0
	TL > CL	not possible	0	not possible	0	not possible	1,460
Other nature							
Denmark, cat. 2		3,268	0	not calculated	not calculated	not calculated	not calculated
Netherlands	.	0	0	0	0	0	0

Note: The costs for broilers can be negative as the heat exchangers can save money and therefore are cheaper than traditional housing.
In the case of Schleswig Holstein, TL and CL are Total load and Critical Load.
No additional costs as other Nature sites are not included in the PAS regime.
Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2018a).

In table 24, the same calculations are shown as cost per animal unit (finisher, dairy cow or 1,000 broilers) and the overall picture is the same. The production after the expansion is 14,000 finishers, 240 dairy cows and 600,000 broilers respectively. The costs for farms near Natura 2000, where the reduction requirements are high, seems to be around 1.3-2.2 euro per finisher, 50-66 euro per dairy cow and not possible for broilers. As before, the costs are often limited for farms 2,000 m away except in the Netherlands where the costs are the same for farms 400 and 2,000 m away.

Table 24. *Costs in euro per unit of livestock (finisher/dairy cow/1,000 broilers) compared to farms with BAT requirement or similar. The farms have expanded by 100 per cent and have a distance of 400 and 2,000 m to nature sites.*

Country and nature type	Neighbouring farms/development room	Finisher 400 m	Finisher 2,000 m	Dairy 400 m	Dairy 2,000 m	Broiler 400 m	Broiler 2,000 m
Natura 2000							
Denmark, cat. 1	no neighbour	0.4	0	0	0	7	0
	1 neighbour	1.3	0	50	0	not possible	0
	>1 neighbour	2.2	0	60	0	not possible	0
Netherlands	100 % room	0	0	0	0	0	0
	no room	1.4	1.4	66	66	0	0
Germany	TL < CL	1.1	0	34	0	11	0
	TL > CL	not possible	0	not possible	0	not possible	5
Other nature							
Denmark, cat. 2		0.23	0	not calculated	not calculated	not calculated	not calculated
Netherlands		0	0	0	0	0	0

Note: The costs related to the full production, not just the expansion.
Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2017).

The costs of reaching the BAT requirements have been calculated to 5-8 euro per kg NH_3-N (4-7 euro per kg NH_3) in Denmark and 4.5 euro per kg NH_3 per finisher in Schleswig-Holstein. In table 25, the costs per kg NH_3 have been calculated in order to see if the costs for additional measures on top of the BAT requirements are similar across the different case farms and countries. In general, the costs are higher for dairy farms with 0-22 euro per kg NH_3, whereas the costs for broiler farms are below 6 euro per kg NH_3 if the technology is available. Finisher farms are in the middle with costs of 4-14 euro per kg NH_3. This indicates that the reductions are cheaper for broilers when the technology is available. In table 25, the costs are calculated based on the annual costs compared to the actual reduction in NH_3 compared to the emission they have when they use the BAT required technology.

Table 25. *Costs in euro per kg NH_3 for farms 400 and 2,000 m from Natura 2000 sites for additional measures on top of the BAT requirements*

Country and nature type	Neighbouring farms/development room	Finisher 400 m	Finisher 2,000 m	Dairy 400 m	Dairy 2,000 m	Broiler 400 m	Broiler 2,000 m
Natura 2000							
Denmark, cat. 1	no neighbour	4	0	0	0	9	0
	1 neighbour	7	0	22	0	not possible	0
	>1 neighbour	10	0	17	0	not possible	0
Netherlands	100 % room	0	0	0	0	0	0
	no room	5	5	21	21	1	1
Germany	TL < CL	14	0	5	0	5	0
	TL > CL	not possible	0	not possble	0	not possble	8

Note: The Danish emissions have been converted to NH3 (NH_3 = NH_3-N/0.8235).
Sources: Jacobsen and Ståhl (2018); Latacz-Lohmann (2017); Luesink and Michels (2017).

5. Concluding remarks

The purpose of this report is to compare the costs of reaching the emission targets for different farms near Natura 2000 sites based on reports from the Netherlands, Schleswig-Holstein and Denmark.

The analyses focus on three different case farms (finisher, dairy and broiler farm) in each country located 400 m and 2,000 m from Natura 2000 areas. The additional costs of implementing BAT emission requirements were calculated and so were the costs of further reduction requirements related to nature sites based on the chosen abatement technology. Based on this, the additional annual costs of meeting the Natura 2000 specific requirements were calculated by comparing them to the costs of meeting the general BAT requirements.

The three regions chosen (the Netherlands, Schleswig-Holstein and Denmark) all have a large agricultural production. The full-time farms are largest in Denmark, whereas the Netherlands have the highest livestock density.

With respect to technologies, acidification is used on some dairy and pig farms in Denmark, but not in the Netherlands nor in Schleswig-Holstein. Air scrubbers are already implemented on half the pig farms in the Netherlands due to previous emission requirements. No data on stable technologies presently used is available from Schleswig-Holstein.

The area protected as Natura 2000 sites make up 9-10 per cent of the land area in the Netherlands, Schleswig-Holstein and Denmark. Both the Netherlands and Denmark have limited agricultural production near (<400 m) Natura 2000 sites while 20-30 per cent of the livestock production lies within 2,000 m of Natura 2000 sites in both countries. In Denmark, most livestock (98 per cent) is within 2,000 m from some nature types (category 1, 2 and 3), whereas this is only the case for around 50 per cent of livestock farms in the Netherlands. However, the definitions of "other nature sites" might vary between the countries.

In the Netherlands, finisher farms and poultry farms near Natura 2000 are only half the size of the average farm. In Denmark, livestock farms near Natura 2000 are only 10 per cent smaller than the average farm. It seems as if the restrictions regarding Natura 2000 have influenced neither the livestock farm size in Denmark nor the size of the dairy farms in the Netherlands.

The ammonia emissions show a decreasing trend for Denmark and the Netherlands, but this is not yet the case for Germany. The conclusion is that Denmark probably will find it difficult to reach the 2020 target of 64 kt NH_3. Germany has found it very difficult to reduce ammonia emissions, and so, the expected levels in 2020 are higher than the 2020 target and higher than the 2010 target. It therefore seems to be a challenge to reach the 2030 targets and in order to reach them it is likely that a number of further measures to reduce ammonia emissions will have to be implemented in Germany. This will also have a positive influence on the deposition in Denmark.

The general livestock regulation in the countries apply to all livestock farms independently of their location. The emissions from these farms follow requirements regarding BAT technologies and/or BAT emission levels. Only in Denmark, the allowed BAT emission levels for finishers are smaller per animal the larger the production. With economies of scale the implication is that the costs per finisher is the same across farm sizes. In the Netherlands, BAT emission levels have been reduced from 1 January 2018 for dairy cows and they will also be reduced for pigs and poultry from 1 January 2020. The Danish and Dutch BAT and the German TA air requirements indicate that the allowed emissions for finishers and dairy cows are higher in Schleswig-Holstein than in Denmark and the Netherlands. Observe however, that finishers do not have the same weight intervals in the three countries as production cycles differ.

For farms near nature sites (Natura 2000 or other nature sites), there are often more restrictions on the allowed ammonia emissions. The regulation approaches applied in the three countries are very different. The Danish approach is based on levels of total NH_3 load from the farm in relation to set standards based on the number of nearby livestock farms. The German approach is to compare initial load and critical load in order to decide whether a production can be established. The cut-off value regarding the additional emission of 0.3 kg N per ha is used. In the case that the initial load is higher than the critical load, 3 per cent of the critical load is the maximum additional impact allowed, and so, if the critical load is 10 kg N per ha the maximum is 0.3 kg N per ha. It is indicated that most farms in Schleswig-Holstein are located so that the initial load (often 15-20 kg N per ha) is above the critical load (5-20 kg N per ha). In the Dutch system, a PAS assessment has to be made if the load is over 1 mol (0.0014 kg per ha). The system is set up so that the projected national reduction of ammonia emissions of 10 kt NH_3 in 2030 is partly used to increase the production already today. At the national scale, animal production rights will ensure that there will be no increase in the livestock production. The challenge seems to be to ensure that the increases in emission rights would still ensure an overall reduction to reach the 2030 target. The room for development allows some farms to expand, but without this allowance the farms can only expand if they keep the same emissions as before the expansion (lower emission per animal) and the emission is lower than 3 mol per ha.

The average deposition is the lower in Denmark where it has been reduced from 17 to 13 kg N per ha over the last 10 years. The levels are highest (around 19 kg N per ha) near the German border. The deposition in Germany is around 15-25 kg N per ha and 25 kg N per ha in the Netherlands, but in some areas in the Netherlands the deposition is more than 100 kg N per ha.

Three case farms are analysed to illustrate regulatory concepts used under different conditions. For the analysis, the case farms are assumed to expand by 100 per cent, resulting in a total production of 14,400 finishers, 240 dairy cows 600,000 broilers, respectively. The sizes should reflect a typical livestock expansion in the three countries.

The analysis shows that the German Filter Decree, which only applies to larger pig farms (10 per cent of all finisher farms), reduces emissions by 80 per cent at a cost of around 4.5 euro per finisher per year. This makes the BAT related requirements more costly in Schleswig-Holstein than in Denmark. The BAT levels in Denmark and the Netherlands are not very different, but the costs are only calculated for the Danish case. The general BAT emission levels are highest in Germany.

The overview indicates that the general requirements regarding storage and application are somewhat stricter in the Netherlands than in Denmark, which again seems to be stricter than in Germany.

The analyses show that the allowed emissions for farms 400 m from Natura 2000 require large reductions, and so, in most situations this will implicate that an expansion will not take place at this location in either of the countries. The strictest requirement is found in Schleswig-Holstein when the initial load (from farms and other sources) is larger than the critical load (additional emission below 0.3 kg N per ha). In the Netherlands, the emission does not need to be lower than the emission before the expansion, as the focus in the assessment is on the additional amount and not the total deposition. The total deposition is in many cases in the Netherlands higher than the critical load. For farms in Schleswig-Holstein that were established before 2004, the requirements are linked only to the expansion and not to the total deposition of the farm as is the case in the case farm calculation. Overall, it is the cheapest to expand the case farms in the Netherlands both in the case of strict and light requirements when the farm is 400 m from Natura 2000 sites.

When the distance to the Natura 2000 site is 2,000 m, the strictest requirements are found in the Netherlands, as the PAS system requires a similar NH_3 emission level as with a 400 m distance. Additional measures are required if the deposition increases by more than 0.014 kg N per ha. Here, the permit is linked to the possibility of getting an additional emission allowance through the “room for development” permit given by the local government. Even with the room for development, the emission is not allowed to be over 3 mol per ha, but this restriction has not been included as it is very case dependent. For Denmark and Schleswig-Holstein, in some cases the BAT level reductions are sufficient to fulfil the requirements when the farm is 2,000 m away from Natura 2000 sites.

It seems as if most livestock farms in the Netherlands and Schleswig-Holstein will be in a position where the strict requirements apply, as the room for development is limited in the Netherlands (perhaps especially in the livestock intensive areas) and the average initial load in Schleswig-Holstein is above the critical load. In Denmark, most livestock farms near Natura 2000 will not have 1-2 neighbouring livestock farms. In the Danish case, it seems as if the regulation encourages farms to expand where there are no livestock farms nearby or where the distance to Natura 2000 is more than 2,000 m. The German regulation will also encourage farms to choose locations with a low initial load and a high critical load.

The regulations in relation to other nature sites than Natura 2000 differ. In Germany and the Netherlands, the analyses do not include additional requirements in relation to other nature sites, whereas additional requirements may be in place in Denmark. It is somewhat unclear to what extent there might be requirements related to other nature sites in Germany and the Netherlands, as that has not been the focus point for this analysis.

For existing farms that do not expand, there are no requirements in Denmark, but a re-evaluation of the emission permit after 8 years might mean that new technologies are required. In the Netherlands, ammonia reductions are required if a farm wishes to continue production after 2020. In that case, ammonia-reducing measures have to be implemented even if the farm does not expand, but it is not clear how strict the requirements will be.

Technologies have to be used to ensure that ammonia reductions follow the requirements above. However, in some cases no technology is available unless a new building is constructed for the whole production.

For the different farms, the additional costs on top of the BAT requirement vary from 0 to 30,000 euro per year. In general, the costs are 0 when the distance is 2,000 m to Natura 2000, but in the Netherlands the costs might be up to 20,000 euro. The costs are limited for the implementation of the lowest requirements with a distance of 400 m, and the costs are high and sometimes too high with the strictest requirements. In Denmark, there is a tendency for the costs to be the highest 400 m from Natura 2000, and in the Netherlands the highest 2,000 m from Natura 2000. The costs are in the order of 0.5-2 euro per finisher, 35-65 euro per dairy cow and 0-11 euro per 1,000 broilers. The total costs are highest for the finisher farms, followed by the dairy farms and the broiler farms respectively. In Denmark, there are costs linked to requirements related to nature sites outside Natura 2000. However, a full analysis regarding category 2 and 3 was not undertaken for Denmark. There might be large local differences in the reduction requirements and costs for these other nature areas depending on the distance to sensitive nature sites.

Looking at the costs compared to ammonia reductions, the costs to obtain the BAT requirements in Denmark are around 5-8 euro per kg NH_3. For finishers on larger pig farms in Schleswig-Holstein, the cost is around 4.5 euro per kg NH_3 in relation to the Filter Decree. Looking at requirements on top of the BAT requirements, the highest costs are found for farms near Natura 2000 and with strict conditions. Here, the costs are 5-21 euro per kg NH_3 for finishers and dairy farms. The results indicate that the costs per kg NH_3 are lower at farms with broilers than for dairy farms.

It has not been possible to make a total analysis at the national level for all three countries of the additional overall costs of the technologies for farms near Natura 2000, as the data for proximity and the uptake of technologies does not provide enough foundation for such a comparison. However, the analysis has shown how the costs for the farms vary with the type of farm, available technologies, local conditions, and the regulation implemented in the three countries.

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