Review of Legal Requirements on Ammonia and Greenhouse Gases Emissons from Animal Production Buildings in European countries

Conference Paper · June 2019

DOI: 10.13031/aim.201901070

CITATIONS
4

READS
1,824

27 authors, including:

Bjarne Bjerg
University of Copenhagen
90 PUBLICATIONS **1,741** CITATIONS
SEE PROFILE

Mislav Didara
Faculty of Agriculture in Osijek, University of Osijek, Croatia
35 PUBLICATIONS **221** CITATIONS
SEE PROFILE

Juha Grönroos
Finnish Environment Institute
57 PUBLICATIONS **1,026** CITATIONS
SEE PROFILE

Mélynda Hassouna
French National Institute for Agriculture, Food, and Environment (INRAE)
171 PUBLICATIONS **1,699** CITATIONS
SEE PROFILE

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Meeting Presentation
DOI: https://doi.org/10.13031/aim.201901070
Paper Number: 1901070

Review of Legal Requirements on Ammonia and Greenhouse Gases Emissions from Animal Production Buildings in European countries

Bjarne Bjerg[1], Peter Demeyer[2], Julien Hoyaux[3], Mislav Didara[4], Juha Grönroos[5], Mélynda Hassouna[6], Barbara Amon[7], Thomas Bartzanas[8], Renáta Sándor[9], Micheal Fogarty[10], Sivan Klas[11], Stefano Schiavon[12], Violeta Juskiene[13], Miroslav Radeski[14], George Attard[15], André Aarnink[16], Şeyda Özkan Gülzari[16, 17], Tadeusz Kuczyński[18], David Fangueiro[19], Monica Paula Marin[20], Stefan Mihina[21], Jože Verbič[22], Salvador Calvet[23], Knut-Håkan Jeppsson[24], Harald Menzi[25], Ozge Sizmaz[26], Tomas Norton[27]

[1]University of Copenhagen, Grønnegårsvej 2, 1870 Frederiksbeg C, Denmark.
[2]Institute for Agricultural and Fisheries Research, Van Gansberghelaan, 115, 9820 Merelbeke, Belgium.
[3]Walloon Air & Climate Agency, Avenue Prince de Liège, 7 à 5100 Jambes, Belgium.
[4]University of Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia.
[5]Finnish Environment Institute, Latokartanonkaari 11, 00790, Helsinki, Finland.
[6]INRA 65; route de Saint-Brieuc, CS 84215, F-35042 Rennes cedex, France.
[7]Leibniz Institute for Agricultural Engineering and Bioeconomy, Max-Eyth-Allee 100, D-14469 Potsdam, Germany.
[8]Agricultural University of Athens, Iera Odos 75, 11855, Athens, Greece.
[9]Hungarian Academy of Sciences, 2462 Martonvásár, Brunszvik u. 2., Hungary.
[10]Katestone Environmental, Portlaoise Enterprise Centre, Ireland.
[11]ORT Braude College of Engineering, Karmiel, 2161002, Israel.
[12]University of Padua, Viale dell'Università, 16 35020, Legnaro (PD), Italy
[13]Lithuanian University of Health Sciences, A. Mickeviciaus 9 LT-44307, Kaunas, Lithuania
[14]Faculty of Veterinary Medicine, St. "Lazar Pop-Trajkov" 5-7,1000 Skopje, Republic of North Macedonia.
[15]University of Malta, Msida MSD 2080, Malta.
[16]Wageningen Livestock Research, P.O. Box 338, 6700 AH Wageningen, The Netherlands
[17]Norwegian Institute of Bioeconomy Research, PO Box 115, 1431 Ås, Norway.
[18]University of Zielona Góra, Prof. Z. Szafrana 165-516 Zielona Góra, Poland.
[19]University of Lisbon, Tapada da Ajuda, 1349-0.17, Lisbon, Portugal
[20]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Bvd., Sector 1, 011464, Romania.
[21]Slovak University of Agriculture, Tr. A. Hlinku 2, 94976 Nitra, Slovakia.
[22]Agricultural Institute of Slovenia, Hacquetova ulica 17, SI-1000 Ljubljana, Slovenia.
[23]Universitat Politècnica de València, Edificio 7G - Camino de Vera s.n. 46022 Valencia,Spain.
[24]Swedish University of Agricultural Sciences, Box 103, 230 53 Alnarp, Sweden.
[25]Federal Office for the Environment, 3003 Bern, Switzerland.
[26]Ankara University, 06110 Diskapı, Ankara, Turkey.
[27]KU Leuven, Kasteelpark Arenberg 30, 3001 Heverlee/ Leuven, Belgium

Written for presentation at the
2019 ASABE Annual International Meeting
Sponsored by ASABE
Boston, Massachusetts

ABSTRACT. ***This review gathers information about the current legal requirements related to the emission of ammonia and greenhouse gases from animal housing in 21 out of the 28 EU countries and in 5 non-EU countries. Overall the review shows that most of the included countries have established substantial procedures to limit ammonia emission and practically no procedures to limit greenhouse gas emission. The review can also be seen as an introduction to the substantial initiatives and decisions taken by the EU in relation to ammonia emission from animal housing, and as a notification on the absence of corresponding initiatives and decisions in relation to greenhouse gases. An EU directive on industrial emissions from 2010 and an implementation decision from 2017 are the main general instruments to reduce ammonia emission from animal housing in the EU. These treaties put limits to ammonia emissions from installations with more than 2000 places for fattening pigs, with more than 750 places for sows and with more than 40,000 places for poultry. As an example, the upper general limit for fattening pigs is 2.6 kg ammonia per animal place per year.***

This review indicates that the important animal producing countries in the EU have implemented the EU requirements, and, that only a few countries with a large pig population, in relation to their geographical size, have implemented requirements that are stricter than what is required by the EU.

Keywords. Ammonia, Emission, EU, Europe, Greenhouse gas, Legal requirements, Legislation.

List of used abbreviations and definitions:

BAT (Best Available Technology): A technology approved for limiting the emission. Technologies are not supposed to be defined as BAT if they involve unreasonably high additional costs for the farmers.

BAT conclusions: Descriptions of the emission levels associated with the best available techniques.

BAT-AEL (BAT-associated emission levels): Binding emission levels determined from BAT (EU 2017).

Coll (Collection of laws): Term used in Slovak legislation where acts or decrees are parts of a Coll.

EPA (Environmental Protection Agency). When used, in this review, EPA refers to the Environmental Protection Agency in the particular country indicated by the context.

Fattening pigs: Term used for production pigs larger than 30 kg. The term is used even though some original documents use terms as finisher pigs or growing/finishing pigs for the same category.

GEREP tool: A tool available online (France, 2017b) from the French Ministry of Ecology, and used to estimate ammonia emissions.

IED (Industrial Emissions Directive): Main EU instrument regulating pollutant emissions from industrial installations (EU 2010).

IED farms: Farms covered by IED, which are installation for intensive raring

- with more than 40 000 places for poultry,
- with more than 2 000 places for production pigs (over 30 kg), or
- with more than 750 places for sows.

LAE-list: List of approved Low Ammonia Emission housing systems used in Flemish legislation (Flanders, 2004)

Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 28 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive (EU, 2009) and the Habitats Directive (EU, 1992).

NEC (National Emission Ceilings Directive): EU directive that state commitments for reduction of national emissions of certain atmospheric pollutants. The annex 2 in the directive includes a table B, which states reduction commitments for ammonia emission for each member country (EU 2016).

PAN-list: List of technologies in the Flemish Programmatic Approach on Nitrogen (Flanders, 2014) to protect nitrogen sensitive nature areas according to NATURA2000.

RAV-list: List of emission factors used in Dutch legislation (Netherlands, 2018b).

1. Introduction

Legal requirements are probably the most powerful tool to mitigate the negative consequences of emissions of substances as ammonia and greenhouse gases from livestock production activities. For the animal producers such requirements may increase costs or reduce production opportunities, and consequently reduce competitiveness compared to animal producers in countries with less strict legal requirements. Therefore farmers in some countries can have a justified expectation that legal requirement on emissions should be similar in different countries. In addition, knowledge about legal requirements in other countries may be helpful for the authorities in a specific country to define fair requirements.

Animal producers in EU countries are obliged to fulfil legal binding requirements expressed in BAT conclusions for intensive rearing of poultry or pigs provided in a commission implementation decision (EU, 2017). The decision defines intensive rearing as activities with more than 40,000 places for poultry, with more than 2,000 places for fattening pigs (over 30 kg), or with more than 750 places for sows. However, it does not define the size of the area associated with an animal place for the different categories of animals. This introduces room for national interpretation on the differences in production that trigger whether the activity should or not be treated as intensive rearing.

For ammonia emissions emerging from fattening pigs activities with more than 2 000 places the binding requirement (BAT-AEL) falls within the range from 0.1 to 2.6 kg NH_3 animal place^{-1} year^{-1} (EU 2017). Organic production is exempted from the requirement, and the upper end of the range is increased to 5.65 kg NH_3 animal place^{-1} year^{-1} for four defined housing systems:

- full litter system (in case of a solid concrete floor),
- kennel/hut housing (in case of a partly slatted floor),
- straw flow system (in case of a solid concrete floor), and
- littered external alley (in case of a solid concrete floor).

The mentioned implementation decision does not define emission factors for different housing systems or reduction performance of the defined BAT. Therefore, the implementation of the decision requires established procedures - by the member countries - to ensure that the farmer meets the requirement within the BAT-AEL range. Alternatively, the member countries can propose their own requirement, as long as it ensures that it retains the emissions within the BAT-AEL. Therefore, the wide range of requirements associated with the BAT-AEL enables significant difference in the requirements in the EU member countries.

Legal requirements on ammonia emissions from housing of other categories of animal production than those defined as intensive rearing are national affairs, though these usually are introduced to cope with other EU initiatives like the national emissions reduction directive NEC (EU, 2016) or the NATURA2000.

Operators of facilities in the EU that cause an ammonia release of more than 10 000 kg/year are (according to EU (2006)) obliged to declare the emission to the European Pollutant Release and Transfer Register. This obligation appears to be affordable for operators of the large animal productions facilities, that it concerns, and, therefore, this review will not investigate possible differences in how this obligation is implemented in the member states.

The aim of this study is to describe and compare the legal requirements on ammonia and greenhouse gas emissions that farmers have to meet in different countries when they are planning to establish or expand animal production buildings. The scope of the review is to include the 28 member countries of EU plus those non-EU countries which participate in the Cost Action 16106 on Ammonia and Greenhouse Gases Emissions from Animal Production Buildings (http://www.cost.eu/COST_Actions/ca/CA16106) project. For the sake of clarity and affordability, this review is targeted to fattening pigs and dairy cows, where fattening pigs represent the animal categories that are included by the IED and dairy cattle represents the animal categories that are not included by the IED.

2. Methods

Information about the legal requirements in this review is based on reports prepared by the co-authors in the participating countries.

3. Results

In this review, coauthors from 21 of the 28 EU-countries and from 5 non-EU countries provided information about the legal requirement on ammonia and greenhouse gas emissions from animal production buildings. The coauthors from the EU represents countries responsible for 94 % of the total pig population and 94 % of the total cattle population in the EU. The EU countries are responsible for 15 % of the pigs and 6 % percent of the cattle in the world. Information about population

sizes in individual countries and in different regions of the world are indicated in figure 1 (figures from FAOSTAT (2018)).

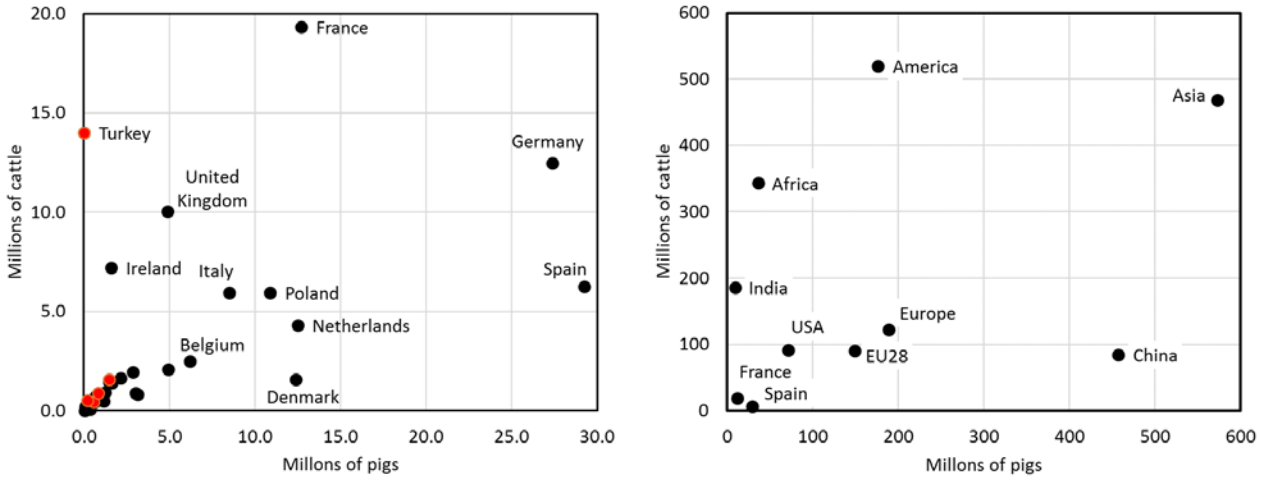

Figure 1. Cattle population plotted against pig population. Left hand graph includes the 28 EU countries (black bullets) and Israel, Norway, Republic of North Macedonia, Switzerland and Turkey (Red Bullets). The right hand graph includes global data. The graphs are based on animal population data from 2016 and extracted from FAOSTAT (2018).

3.1. Ammonia

The information gathered on legal requirement on ammonia emission from animal housing shows that the countries included in this study can be divided into four categories:

- EU Countries with stricter requirements than the upper end of the BAT-AEL
- Other EU Countries
- Non-EU countries with legal requirements.
- Non-EU countries with no legal requirements.

In Belgium, the legislation treated in this review is a regional competence and the differences is so significant that we have chosen to treat the regions Flanders and Wallonia in the same way as countries.

3.1.1. Countries with stricter requirements than the upper end of the BAT-AEL

3.1.1.1. Belgium (Flanders)

In Flanders, farmers are obliged to use low ammonia emission solutions when they build or renovate pig or poultry houses. The farmer must therefore select a housing system from a list officially approved Low Ammonia Emission housing systems – the LAE-list (Flanders, 2004). The expected ammonia emission from fattening pigs must not be higher than 1.4 kg per animal place per year, and the mentioned list contains eight housing systems that comply with that limit (see examples in Table 1). Next to those ‘stand-alone’ systems, the LAE-list also contains chemical and biological air cleaners and bio-filters for purification of ventilation exhaust air. These can subsequently be implemented to meet the requirements for e.g. traditional slurry based housing systems with fully slatted floors. Currently, the mentioned cleaning systems are expected to reduce the ammonia emission by 70%. New regulations are being prepared in order to provide in a new LAE-list with more diversification in air cleaning systems depending on their proven emission reduction levels.

Additionally, Flanders implemented in 2014 the Programmatic Approach on Nitrogen (Flanders, 2014) to protect its nature sensitive areas according to NATURA2000. Here all types of livestock buildings are affected, including naturally ventilated buildings e.g. for dairy cows and goats, if dispersion modelling indicates that their ammonia emissions could result in an exceedance of the maximum allowed ammonia deposition in a nearby nature sensitive area. Consequently, the farmer must apply ammonia emission reduction techniques in order to comply. Therefore, the farmers can select techniques as listed in the PAN-list (Flanders, 2014) containing both ‘hard’ construction techniques (e.g. floor systems) and ‘soft’ management techniques (e.g. feeding) starting from 10% ammonia emission reduction. The PAN-list also includes technique combinations.

Table 1. Examples of ammonia emission factors from the Flemish LAE-list with officially approved Low Ammonia Emission housing systems for fattening pigs (up to 110 kg) (Flanders, 2004).

Housing system	**Emission factor,** kg NH_3 animal place^{-1} year^{-1}
Aerated slurry system for manure collection and rinsing - pen area from 0.65 to 0.80 m²	1.4
Aerated manure system for manure collection equipped with a sewage system or other drainage system closed off from the air - pen area from 0.65 to 0.80 m²	1.4
Cooling deck system with 170% cooling surface using slatted floors with increased manure passage. Emission Surface max 0.8 m² per animal.	1.1
Manure pit with (water-) and manure channel, the last with slanted wall(s) and with slatted floors other than those with increased manure passage (Emission surface max 0.18 m² per animal)	1.2
Manure and urine gutter system equipped with a scraper system for separated removal of manure and urine	1.2

3.1.1.2. Denmark

A Danish farmer that wish to establish or expand animal production buildings must use housing systems and environmental technologies that ensures the ammonia emission is held below certain thresholds stated in a ministerial order (Denmark, 2018a). The procedure includes three steps:

- estimation of the expected emissions from the whished housings system,
- estimation of the emission that can be allowed, and
- addition of approved technologies that can reduce the emission to the allowable level.

The expected ammonia emission is calculated as an emission factor (kg NH_3-N m^{-2} year^{-1}) multiplied by the production area. The latter is defined as the area in fixed livestock facilities where the animals can stay and deposit manure. The ministerial order (Denmark, 2018a) dictates the emission factors that must be used for different categories of animals in different housing systems. For fattening pigs housing with slatted floor three emission factors exist, depending on the percentage of floor covered with solid floor. For dairy cows in cubicle housing, four emission factors exist depending on the design of walking areas (Table 2).

Table 2. Examples of Danish emission factors and BAT levels expressed in kg NH_3 m^{-2} year^{-1} (Denmark, 2018a), (The values are converted from kg NH_3-N m^{-2} year^{-1}). PA1 indicate the maximum production area where BAT level 1 applies. PA2 indicates the lower limit for production area for when BAT level 2 must be used. In between PA 1 and PA 2, the requirement is linearly related to the production area.

Animal category - and housing system	**Emission factor**	**BAT level 1**	**PA1, m²**	**BAT level 2**	**PA2, m²**
Fattening pigs:					
- Partly slatted floor, 50 - 75 % solid floor	1.70	1.97	1300	1.29	4500
- Partly slatted floor, 25 - 49 % solid floor	2.31	1.97	1300	1.29	4500
- Drained floor+ slatted floor (33 %/67 %)	2.79	1.97	1300	1.29	4500
Dairy cows, heifers and steers.					
- Cubicles with solid floor	2.04	0.81			
- Cubicles with slatted floor (scrapers in channels)	1.21	0.81			
- Cubicles with slatted floor (channel, backwash or ring channel)	1.63	0.81			
- Solid Drained floor with scrapers and liquid manure drainage	0.81	0.81			
- Deep litter	1.07	1.07			

The allowable emission is depending on whether the housing system is planned to be located near defined ammonia sensitive natural areas, which includes some of the Natura 2000 areas and additional areas of national or local significance. In larger distances from these areas, BAT levels, dictates the maximum allowable emission. In determination of the BAT levels, it is taking into account how costly it is to reduce emissions from the different housing systems. Due to limited options to reduce emissions from housing systems with solid manure, the BAT level for these housings systems corresponds to the expected emission, as it appears for deep litter dairy housing in Table 2. For pig housing, it is assumed that it is cheaper to reduce emissions from larger facilities than from smaller. Thus, two BAT levels are defined for these housing systems. For fattening pigs housed in systems with liquid manure, the BAT level is 1.97 kg NH_3 m^{-2} year^{-1} up to a production area of 1300 m^2, and 1.29 kg NH_3 m^{-2} year^{-1} for facilities with production areas above 4500 m^2. For productions areas between 1300 and 4500 m^2, the BAT levels are estimated as a linear relation with the production area. A consequence is that a production area of 2557 m^2 results in a BAT level of 1.7 kg NH_3 m^{-2} year^{-1}, which is identical with the expected emission from housing system with 50-75 % solid floor. Therefore, this housing system can be used in facilities with productions areas up to 2557

m^2, however larger facilities and housing systems with less solid floor has to be equipped with an approved environmental technology to reduce the ammonia emission.

The mentioned BAT levels are not are applied on small facilities if the estimated ammonia emission from the animal production is less than 910 kg NH_3 $year^{-1}$.

Near ammonia sensitive natural areas an additional requirement exists, that limits the deposition within these areas. Estimations of expected deposition is an integrated part of a special homepage (husdyrgodkendelse.dk) which farmers has to use when they apply for permits to establish or expand animal production. The limits for deposition in the ammonia sensitive natural areas depends on the category of the ammonia sensitive natural area, the deposition from neighboring farms and the distance to neighboring farms. The limits are lowest for Natura 2000 areas and can be as low as 0.24 kg NH_3 ha^{-1} in total deposition from a single farm or 0 kg NH_3 ha^{-1} in additional deposition (at expansion of the housing system).

To reduce the emission below the threshold level, the farmers can add approved technologies that can reduce the ammonia emission. The approved technologies are available at a list of technology (Denmark, 2018b) maintained by the EPA. The list includes technologies as acidification of manure in slurry pits (64 % reduction in pig housing and 50 % reduction in cattle housing), cooling of the bottom of slurry pits in pig housing (up to 34 % reduction) and various systems for cleaning of ventilation exhaust air.

3.1.1.3. Netherlands

In the Netherlands, farmers have to fulfil the Regulation on ammonia and livestock production (Netherlands, 2018a). For each farm, ammonia emissions are calculated based on emissions factors (kg NH_3 animal $place^{-1}$ $year^{-1}$), and the number of animal places. The emission factors are given in the so-called RAV-list (Netherlands, 2018b).

For new fattening pigs facilities, the maximum ammonia emission level is 1.5 kg NH_3 animal $place^{-1}$ $year^{-1}$. For facilities larger than 2 000 places this level is reduced to 1.1 kg NH_3 animal $place^{-1}$ $year^{-1}$ for facilities to be built after 1 January 2020. The mentioned RAV list includes emission factors for 37 housing systems for fattening pigs (see examples in Table 3), whereof 27 fulfil the current requirement (1.5 kg NH_3 animal $place^{-1}$ $year^{-1}$) and 16 also fulfil the coming requirement (1.1 kg NH_3 animal $place^{-1}$ $year^{-1}$) for facilities larger than 2 000 places.

Table 3. Examples of ammonia emissions factors for fattening pigs and dairy cows mentioned in the Dutch Rav-list (The Netherlands, 2018b).

Animal category - and housing system	**Emission factor,** kg NH_3 animal $place^{-1}$ $year^{-1}$	**Maximum emission,** kg NH_3 animal $place^{-1}$ $year^{-1}$
Fattening pigs:		
- Fully slatted floor	4.5	1.5
Partly slatted floor:		
- Manure cellar under entire animal area (without air trap)	4.5	1.5
- Manure collection in, and rinsing with, NH_3-lean liquid (including acidification)	1.6	1.5
- Manure collection in formaldehyde treated manure in combination with a metal triangle slatted floor	1.0	1.5
- Manure collection in water in combination with a triangle metal slatted floor	1.3	1.5
- Manure channel with inclined pit walls with triangle metal slatted floor on the manure channel and emitting manure surface area maximum 0.18 m^2 per pig	1.0	1.5
- Biological or chemical air scrubbing system with 70% ammonia emission reduction	0.9	1.5
- Convex floor with concrete slats on water channel and triangle metal slatted floor on slurry channel: Emitting slurry surface maximum 0.22 m^2 per pig	1.4	1.5
- Other housing systems	3.0	1.5
Dairy cows, and heifers older than 2 years.		
- Cubicles with solid sloping floor with profiling, with quick urine discharge with manure scraper	11.0	8.6
- Cubicles with solid sloping floor with rubber top layer, with quick urine discharge with manure scraper	11.0	8.6
- Cubicles with slatted floor with a convex rubber top layer and sealing flaps in the slits of the slatted floor, with manure scraper	6.0	8.6
- Cubicles with slatted floor with a convex rubber top layer, with manure scraper	7.0	8.6
- Mechanically ventilated barn with an acid air scrubbing system	5.1	8.6
- Other housing systems	13,0	8.6

The mentioned requirements and emission factors are not affected by the pen area that the permits are associated with. The animal welfare legislation requires a pen area of at least 0.8 m^2 per fattening pig place, however, many farmers get permits issued in relation to different animal welfare certification schemes, e.g. the "one star pigs" which require a minimum pen area of 1.0 m^2 per fattening pig.

For new dairy cow facilities, the maximum ammonia emission level is 8.6 kg NH_3 animal $place^{-1}$ $year^{-1}$, and the RAV list includes emission factors for 33 housing system for dairy cows, whereof 12 of them fulfil the requirement of maximum 8.6 kg NH_3 animal $place^{-1}$ $year^{-1}$ (see examples in Table 3).

There are some exemptions from former distinguished situations, but the described situations are valid for most livestock houses. In some provinces in the Netherlands (Noord Brabant and Limburg) the ammonia emission for newly build pig houses should be reduced with 85% from the emission value of traditional housing systems (Other housing systems, see table 3). Organic housing systems are not falling under the ammonia regulations.

3.1.1.4. Slovakia

Ammonia emission from animal housing in Slovakia is covered by a comprehensive legal framework for control and regulation of air pollutants from a wide range of sources (Slovakia 2010, 2012 and 2008). The requirements depend on the size of the source of pollution (large, medium or small), and Table 4 defines these sizes for fattening pigs and for dairy cattle.

Table 4. Definition of the size of the source of annual pollution for fattening pigs and dairy cows.

Animal category	Planned number of animal places	
	Large source of pollution	Medium source of pollution
Fattening pigs (of more than 30 kg)	> 2,000	≥ 500
Dairy cattle	> 500	≥ 200

Ammonia emission factors for housing systems are defined for different categories of animals (Slovakia, 2008). For dairy cattle, it constitutes 8.7 kg NH_3 animal $place^{-1}$ $year^{-1}$ and the corresponding number for fattening pigs is 2.89 kg NH_3 animal $place^{-1}$ $year^{-1}$.

Operates of both medium and large sources of pollution has a yearly obligation to report the emissions during the year elapsed to the competent District Office. The obligation includes;

- complete and true data on quantities released into the atmosphere,
- data on compliance with emission limits,
- computation of a charge for each medium and large source of pollution, and
- computation of the total of the annual due charge.

For ammonia the basic charge is 65 € $tones^{-1}$, and for emissions beyond the allowed level, the charge is three times as high.

Operators of large source of air pollution is required to limit the emissions of ammonia from animal housing by introducing low-emission technologies to achieve a 20 % reduction in relation to the mentioned emission factors.

At the planning of housings system categorised as large sources of pollution, it is necessary to address the reduction of ammonia emissions in a comprehensive manner, so that ammonia captured at one stage of manure processing would not cause an increase in emissions in the next processing stage.

The overall reduction in ammonia emissions from animal production can be achieved by applying low emission technologies. The achieved reduction in ammonia emissions should be evaluated individually for each particular farm. Values that can be achieved by implementing specific low-emission technology are listed in Slovakia (2008), and the numbers relevant for dairy cows and fattening pigs are reproduced in Table 5.

Table 5. Maximum reduction effect of Low-emission technologies relevant for cattle and pig housing.

Low-emission technology	Reduction up to %
Related to feed composition:	
- Addition biotechnological products to feed (concrete biotechnological products are not mentioned in the legislation)	50
Related to ventilation:	
- Utilization of ventilation with energy recovery	25
Related to slurry based pig housing:	
- Utilization of partially slatted floor, up to 50% of the area,	20
- Manure removal/disposal several times a day	50

3.1.1.5. Owervieiw over the requirements in the countries with stricter requirements than the upper end of the BAT-AEL

Figure 2 compares the general upper limits for ammonia emission from new and expanded fattening pig housing in Flanders, Denmark, The Netherlands and Slovakia. In Flanders and Denmark, the requirements are stricter close to special

ammonia sensitive natural areas, and it is stricter in some provinces in the Netherlands. For Denmark, the requirements are estimated on the preconditions that each fattening pig place corresponds to a production area of 0.65 m^2.

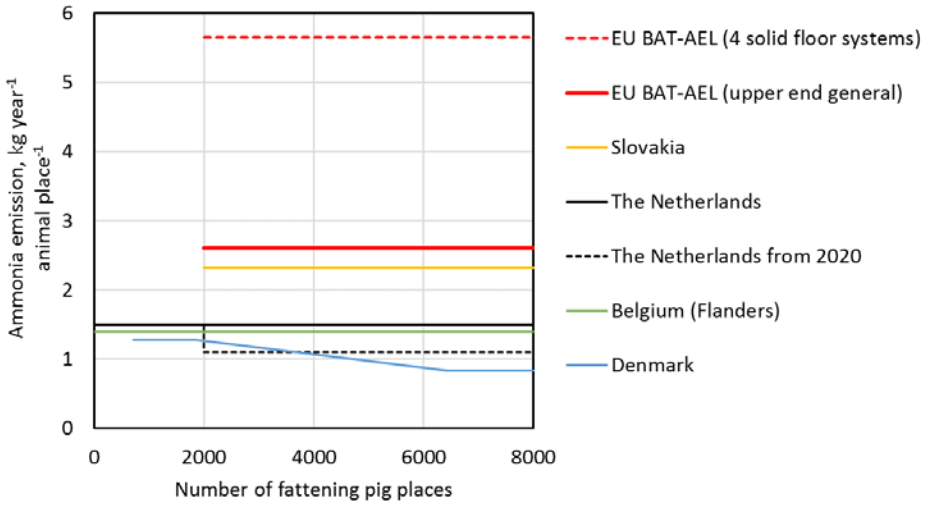

Figure 2. Upper end BAT-AEL and national legal requirements on ammonia emission from fattening pigs. In Flanders and Denmark, the requirements are stricter close to special ammonia sensitive natural areas, and it is stricter in some provinces in the Netherlands.

Denmark, The Netherlands and Slovakia are the only countries, in this review, that have introduced general restrictions on ammonia emissions from cattle housing, and the levels are indicated in Figure 3. However, the requirements are stricter in some provinces in the Netherlands, and close to special ammonia sensitive natural areas in Denmark. For Denmark, the level is calculated on the preconditions that the manure is handle as slurry, that the cows are heavier than 550 kg, and that each animal place corresponds to a production area of 8 m^2.

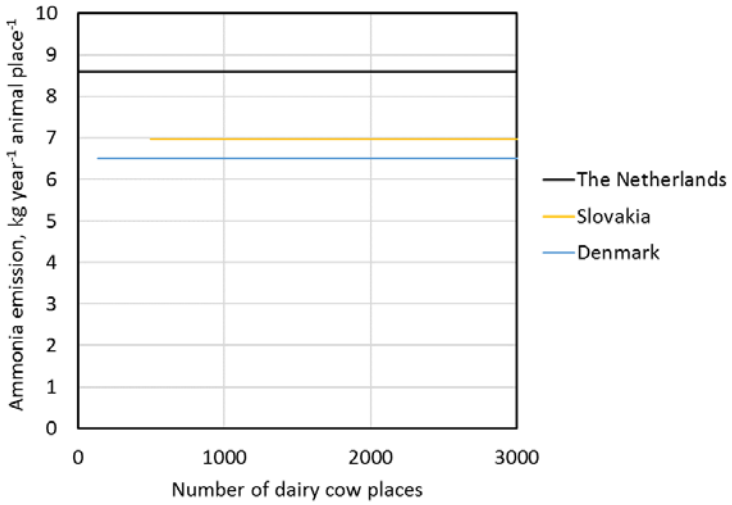

Figure 3. National legal requirements on ammonia emission from dairy cows. More restrict requirements might be stated in some regions or close to special ammonia sensitive natural areas.

3.1.2. Other EU Countries

3.1.2.1. Belgium (Wallonia)

In Wallonia, there is currently a process of determining a procedure for implementing the BAT in the framework of the IED Directive (EU, 2010), and it is anticipated that the procedure will be similar to the procedure in Flanders (see section 3.1.1.1).

3.1.2.2. Croatia

Croatian farmers that wish to establish new or expanding existing farms need to acquire an "Environmental impact study". For IED farms this impact study has to documents that the EU BAT-AELs are fulfiled.

3.1.2.3. Finland

For IED farms, Finnish farmers are obliged to use housing systems, feed compositions and abatement techniques that ensure that the ammonia emissions do not exceed the EU BAT-AELs. Ammonia emissions must be monitored using one of the techniques listed in BAT 25 (mass balance calculation, measurements or emission factors (EU, 2017)) and the monitoring results must be provided to the supervising authority annually.

3.1.2.4. France

The regulation of ammonia emission from IED farms are incorporated in the French Environmental Code (France 2013, 2017a).

There is currently a process, where 3300 IED farms (17 % of French poultry farms and 3 % of pig farms, 72 % located in West of France) will be re-examined. From 21 February 2017, they have two years to demonstrate whether they conform to the EU BAT-AEL (EU, 2017), and if not, four years to do it. The re-examination consists of a declaration with supporting documentation of estimated N and P excretion, and ammonia emissions. The excretions must be estimated using either

1. "simplified true balance" tools ("bilan réel simplifié" in Frence), or
2. default excretion included in the GEREP tool, or
3. manure chemical analyses.

The mentioned GEREP tool is available online (France, 2017b) from the French Ministry of Ecology, and is also used to estimate ammonia emissions, both at the re-examination process and when livestock IED farms fulfil their annual obligation to online declare emissions (e.g. of ammonia) (France, 2018).

To estimate ammonia emissions from each building, the farmer can include abatement factor associated with each BAT in the GEREP tool or use the results of measurement made on farm. BAT chosen by the farmers can be BAT listed in (EU, 2017) or in future other BAT when French Ministry of Ecology will have approved them. Table 6 shows examples of abatement factors obtained by combining techniques in France (2017b) to estimate ammonia emissions from a pig building.

In 2021, French authorities will begin to control livestock farms to verify conformity to BAT, in addition to these declarations of emissions.

Table 6. Example of abatement factors for ammonia emissions from a pig building with fully slatted floors, obtained by combining different manure management techniques in the French GEREP tool.

Technique	No slurry cooling	With slurry cooling
Storage in a pit during the entire duration of animal presence	1.00	0.60
Storage in a pit with slurry removed at least every 15 days	0.85	0.51
Storage in a pit with slurry removed at least twice a week	0.75	0.45
Mechanical removal with V-shaped scrapers	0.55	0.33
Removal by flushing with the liquid fraction of slurry	0.75	0.45
Floating slurry	0.80	0.48
Slurry acidification	0.40	0.24
Floating balls in the manure channel	0.75	0.45

3.1.2.5. Germany

The Federal Immission Control Act (Germany, 2010) and a technical instruction for keeping the air clean - TA Luft (Germany, 2002) integrate the requirements as written in the EU BAT-AEL and transfer them into German national legislation. The authorities control if regulations are met when farmers want to establish or expand their production. The farmer must proof that he fulfils the requirements. The TA Luft (Germany, 2002) gives very clear guidance on how this proof has to be performed. The proof is an essential part of the permission.

3.1.2.6. Greece

The Greek authorities have not yet established procedures to control that IED farms complies with the EU BAT-AELs, however it is expected that it will happen soon.

3.1.2.7. Hungary

According national decisions, Hungarian IED farms is obliged to fulfil the EU BAT-AELs from 15th February 2021, and from that date they need to have an authorization which satisfy the environmental requirements including the EU BAT-AELs.

3.1.2.8. Ireland

A significant number of Ireland's Natura 2000 sites are subject to nitrogen deposition levels that result in unfavourable conservation status. The EPA has responded to this by implementing an interim response and is also developing further

guidance for assessment. The current situation is detailed below.

IED farms must adhere to the BAT-AELs, and to obtain an IED licence for such farms the proponent must demonstrate that the farm will cause no significant adverse effects on protected flora and fauna in Natura 2000 sites.

The Environmental Impact Assessment Directive (EU, 2014) requires that proposals for pig farms with more than 900 sows or 3,000 places for fattening pigs complete an Environmental Impact Assessment Report that demonstrates that the farm will not cause air pollution.

The Air Pollution Act (Ireland, 2011) includes in its definition of air pollution "a condition of the atmosphere in which a pollutant is present in such a quantity as to be liable to have a deleterious effect on flora or fauna".

An Environmental Impact Assessment for pig houses must demonstrate that the facility will cause no significant adverse effects on protected flora and fauna in Natura 2000 sites. This indicates that the conservation status of the Natura 2000 sites must be maintained at favourable once the facility is operational. Ammonia deposition and the deposition of other nitrogen compounds are liable to have a deleterious effect of flora and fauna in Natura 2000 sites, resulting in unfavourable conservation status.

Historically and until the new guidance is published, the EPA has adopted guidance published by the United Kingdom's Environment Agency for England for the Environmental Impact Assessment Reports. Consequently, the EPA requires that all proposed developments within 20 km of a Natura 2000 site are screened using the Simple Calculation of Atmospheric Impact Limit (SCAIL) model (Ireland, 2014). The SCAIL model was developed by the Centre for Ecology and Hydrology in Scotland with funding from regulators in Ireland and the UK.

In Ireland, if SCAIL predicts impacts from a proposed development in isolation that are greater than 4 % of the critical level for ammonia or nitrogen deposition, one of the following is required:

- A cumulative assessment with other farms in the area using the SCAIL model.
- A detailed modelling assessment to consider cumulative impacts.

If the outcome from an Environmental Impact Assessment indicates that the BAT-AEL results in unfavourable conservation status at a Natura 2000 site, the development must be refused unless the farmer implements emission abatement to reduce emissions to levels that do not result in unfavourable conservation status.

Recent licenses issued in Ireland for new fattening pig farms have limited ammonia emissions to the BAT-AEL of 2.6 kg NH_3 animal $place^{-1}$ $year^{-1}$.

Recently the EPA has requested that BAT 23 of the BATs mentioned in EU (2017) is implemented at IED farms. This is achieved in new licences that state that licencees must estimate ammonia emissions and its reduction "by estimation or calculation of the reduction of ammonia emissions from the whole production process using the BAT implemented at the installation". The estimate or calculated reductions shall be submitted to the Agency as part of an Annual Environmental Report. Such a report must be submitted on an annual basis by all licencees to the EPA.

The EPA is in the final stages of developing new guidance for ammonia assessment for pig farms that includes:

- Definition of a threshold quantity of ammonia emissions that could cause a significant effect.
- A methodology for completing an ammonia impact assessment.

The EPA intends to adopt its new guidance for ammonia assessments in 2019.

There is no legal requirement to assess ammonia from new or expanding dairy cow production facilities in Ireland. Bovine livestock in Ireland is predominantly reared on permanent pasture, with grass or silage making up to 83.6 % of a typical dairy cow diet. Dairy cows in Ireland are at grass for up to 300 days and nights per year.

3.1.2.9. Italy

Italian farmers that operate animal production facilities are obliged to achieve an authorization for the emissions from the public authority. Within a general national frame, each region has developed a regulation body to comply these obligations. However, the four regions most important for animal farming (Piemonte, Lombardia, Veneto and Emilia Romagna) have signed an agreement (Italy, 2017) to make consistent all the actions aimed to improve the quality of the air in the Po basin among the four regions.

IEA farms are subjected to an *"Integrated authorization for the emission"*. The emission of these farms is evaluated on the basis of a monitoring and control plan. This plan is compiled by the farmers itself on the basis of regional guidelines, and subjected to an evaluation by the public control authority which release the authorization. A farmer that wish to establish or expand animal production activity must adopt the BAT to reduce the emissions. Within the monitoring and control plan the farmer must compile a check list of the best available techniques applied or not. Because of revised version of the BAT (EU, 2017) the farmers have time till the year 2021 to revise their techniques according to the new BAT conclusions. In Veneto, a web platform is available to compile the monitoring and control plan of each farm (Italy, 2018). With this applicative the emissions of each farm are quantified according to the structural and technical characteristics and the BAT applied. Maximum animal density is computed considering the area available for rearing and the minimum rearing area admitted by the current animal welfare regulations. When a feeding technique is applied the N excretion is accessed using a

mass balance method. The estimation of the ammonia emissions can be estimated by the farmer according to

- a mass balance approach,
- use of emission factors, or
- computations based on ammonia measurements and ventilation parameters within the housing rooms.

Examples of derived Emission factors for fattening pigs are given in Table 7.

Table 7. Example of emissions factors for different housing of fattening pigs (Italy, 2009).

BAT code	Housing	BAT	Emission factor, kg NH_3 /place/year
3.3.1	Slatted floor, storage pit underneath	no	3.0
3.1.2	Fully slatted floor, vacuum system for slurry removal	yes	2.2
3.1.12	Partial slatted floor, bedding in defecation area	yes	2.1

Farms not included by the IED are obliged to achieve a “general authorization for the emissions”, however those do not include specific limits for ammonia emission from animal housing.

3.1.2.10. Lithuania

Ammonia emissions from animal production buildings in Lithuania are covered by the Permission system for integrated prevention and control of pollution (Lithuania, 2013). Farmers who wish to build or renovate and expand pig or poultry houses must try to apply the best available technology and to use housing systems and environmental technologies that fulfil the requirements and ensure ammonia emission not exceed the EU BAT-AEL EU (2017). For IED farms an environmental impact assessment study must be submitted together with the permit application. The study must describe the negative impacts on the environment and the mitigating measures that guarantee the protection of the environment. Among other environmental issues, ammonia emissions from the buildings shall be estimated. The conditions under which the production must be carried out are described in the permit and evaluated individually for each particular farm. The permit also includes a future monitoring program of the farm environment including the frequency of monitoring studies. Monitoring program is prepared and implemented by the farm itself in compliance with the Regulation Order for farm environment monitoring (Lithuania 2009). Farms are recommended to carry out the monitoring of soil and ground water. If the concentration of air pollutants, estimated by simulation method according to national criteria does not exceed the limit values of pollution, the monitoring of air quality is not compulsory.

In addition, such farms are regularly inspected. Authorities that carry out the inspection function develop inspection plans and check if the farm fulfils the requirements.

3.1.2.11. Malta

The Maltese pig production is relatively small and there are hardly any pig facilities that are big enough to be covered by the EU BAT-AELs. Nevertheless, subsidiary legislation on emission control (Malta 2013) has a provision that any Commission Decision on BAT on installations for the intensive animal rearing (EU, 2017) are automatically transposed into Maltese law. Hence if there is an application for a farm with more than 2000 places for fattening pigs, the officer in charge of reviewing the application from a veterinary aspect will inform the Environment and Resource Authority. This authority will direct the applicant to an integrated pollution prevention and control procedure including adaptation of the EU BAT-AEL.

3.1.2.12. Poland

The Polish Ministry of Environment has disseminated guidelines for the practical application of the EU BAT conclusions for IED farms (Poland, 2017). According to national regulations all farms included by the IED is obliged to adapt their activities to the BAT requirement before February 2021.

3.1.2.13. Portugal

In Portugal, it is controlled that the EU BAT-AELs are met at national level. The procedure includes that operators of IED farms have to report emissions annually. In this report, they have to describe the solutions/BAT used in the current year to minimize emissions and they have to propose some actions for the next year (actions might be BAT implementation or staff training for example). So, the national procedure to control that EU BAT-AELs are fulfilled is based on the annual environmental reports from the operators of facilities covered by the IED.

3.1.2.14. Romania

In Romania, it is envisaged that the EU BAT-AELs requirements can be met by a nutritional strategy that includes

reduction of the protein content in the feed by using a balanced diet in relation to essential amino acids and to apply multi-stage feeding technologies, respecting the specific requirements of the production period. The strategy is implemented by assuming that farmers applies recommendations about nutrition techniques, including a careful alignment of the feed composition for each category of animals.

3.1.2.15. Slovenia

For IED farms, Slovenia farmers are obliged to obtain environmental permits that ensure the fulfilment of the EU BAT-AEL (Slovenia, 2015). Farmers that wish to establish or expand large animal production, including cattle production, are subject to an environmental impact assessment and have to obtain an environmental approval (Slovenia, 2014). It is not considered likely that this approval will impose requirements for ammonia emissions beyond the EU BAT-AEL.

3.1.2.16. Spain

Spanish farmers that establish or substantially modify IED farms are requested to document the technology and other techniques used to reduce emissions (BAT). In the next years farmers will have to adapt to the new BAT conclusions (EU, 2017).

3.1.2.17. Sweden

Swedes farmers that wish to establish or expand IED farms or facilities to above 400 animal units of cattle, have to apply for a permit according to the Environmental Regulation (Sweden 2013a) under the Environmental Code (Sweden 1998). One animal unit of cattle equals one cow or six calves between 1-6 months or three other cattle older than 6 months. An environmental impact assessment must be submitted together with the permit application. Among other environmental issues, ammonia emissions from the buildings shall be estimated; existing and best available abatement measures and the impact on the environment shall be described. The permit states the conditions under which the production must be carried out. Close to sensitive natural areas, e.g. Natura 2000 areas, the deposition of nitrogen due to the local animal production is accessed during the permit processing. The licensing authority is the County Administrative Boards.

In addition, the requirements for IED farms are incorporated in Swedish Environmental Code by the Industrial Emissions Regulation (Sweden 2013b), and the BAT conclusions according EU (2017) define the legal ammonia emission.

Ammonia emission is estimated from a mass balance at house level describing the nutrient flow according to the Swedish computer program VERA (Swedish Board of Agriculture, 2018). Using with standard assumption (e.g. on feed composition) for fattening pigs kept in slurry based systems the program results in figures that can be recalculated to an emission factor of 1,83 kg NH_3 animal $place^{-1}$ $year^{-1}$, which is significantly below the threshold of 2,6 kg NH_3 animal $place^{-1}$ $year^{-1}$ dictated by the upper end of EU BAT-AELs.

Farmers that wish to include the effects of available abatement measures to meet the requirement must refer to national or international results about the technology via advisors, firms, other farmers, authorities, SLU (Swedish University of Agricultural Sciences) etc.

3.1.2.18. United Kingdom

In the United Kingdom IED farms must comply with Environmental Permit Regulations (UK, 2010). These regulations implement the Integrated Pollution Prevention and Control Directive in England and Wales (UK, 2010), which demands the application of BAT technology for housing designs, with a preference of those systems stated as BAT-AEL in EU (2017). The requirement applies to farmers who plan to establish new or expand current housing systems. For existing facilities the EPA advise that only systems requiring an overall emission reduction of 20 % need to comply (UK, 2010).

For farmers that are undergoing regulatory control there is an expectation from the EPA that appropriate measures will be implemented to upgrade the housing systems to meet equivalent standards to BAT-AEL (2017) within an agreed timescale. Farmers who need to implement emission reduction must produce an “Emission Reduction Plan” for approval by the EPA, which then must be carried out within the timescale set out in the permit. Farmers can decide to use emission reduction techniques that are not directly supported by the EPA or mentioned in the implementing decision (EU, 2017). However, this option requires motivation on the effectiveness of the technique using thorough evidence from scientific peer-reviewed publications.

3.1.2.19. Overview over the requirements in EU countries with requirements at the upper end of the BAT-AEL

The review includes 18 EU countries where the upper end of the BAT-AEL constitutes the general maximum limit for ammonia emission from animal housing. Among these countries, Sweden and Ireland have introduced special requirements on deposition of nitrogen in special ammonia sensitive natural areas that locally may limit the emissions to a lower level than the BAT-AEL, or, in Sweden, constitute requirements for non-IED farms. Described ongoing implementation activates in Wallonia, France, Greece, Hungary, Poland and Romania indicates that the BAT-AELs is not yet fully implemented in all

EU countries. Among the 18 countries, Portugal is the only one that interpret the IED as it is sufficient to comply with the BAT-AELs at a national level.

3.1.3. Non-EU countries with legal requirements

3.1.3.1. Israel

Israeli animal producers are according to the Environmental Protection Law (Israel, 2012) obligated to report ammonia emission above 200 kg per year, however they are not subjected to emission limits.

3.1.3.2 Republic of North Macedonia

In Macedonian legislation, there is stated an emission limit for ammonia from poultry and pig production of 50 ppm v/v (Macedonia, 2010), however, it actually is a concentration limit as the mentioned unit indicates. Beyond that, there is no general limitation on ammonia emission from animal housing in Macedonia.

3.1.3.3. Switzerland

In Switzerland, there is no specific national legislation on ammonia emissions, however, the Ordinance on Air Pollution Control (Switzerland, 2018) requires that emissions shall be limited preventively by the authorities as far as it is technically and operationally feasible and economically acceptable. Policy implementation is under the responsibility of the 26 individual Cantons, and 3-5 of them have some specific limitations for large new animal houses close to vulnerable ecosystems.

3.1.3.4. Norway

According to Norway (2003), Norway's agreements with the EU would imply an obligation to comply with the IED, and new IED farms with liquid slurry storage must be designed in a way the ammonia emission is reduced by 20% or more compared to the reference. For pig farms, the reference is slatted floor on the entire floor area. The Norwegian Food Safety Authority published recommended concentrations of ammonia, carbon dioxide and hydrogen sulphide for pig (Norway, 2013) and cattle (Norway, 2018) systems in Norway. Cattle producers should keep and follow a written document describing how animals are protected from harmful gasses of liquid manure in the manure cellar when fertiliser is stirred or pumped (Norway, 2004 and 2017).

3.1.4. Non-EU countries without legal requirements

No legal requirement exists to reduce ammonia emission from animal housing in Turkey.

3.2. Greenhouse gases

None of co-author from the 26 countries that is included in this review have indicated that animal producers in their countries are subjected to legal requirement that limits Greenhouse Gases Emissions from animal housing. Though large animal producers in EU are obliged to report CO_2 emission above 100 000 000 kg $year^{-1}$, CH_4 emission above 100 000 kg $year^{-1}$ and N_2O emission above 10 000 kg per $year^{-1}$ (EU 2006). Similarly, Israeli animal producers are obliged to report CO_2 emission above 1 000 000 kg $year^{-1}$, CH_4 emission above 10 000 kg $year^{-1}$and N_2O emission above 10 000 kg $year^{-1}$ (Israel, 2012).

4. Discussion

The conducted review of legal requirements on ammonia and greenhouse gas emission from animal housing covers dairy cows and fattening pigs in 21 EU countries and 5 countries outside the EU. The delimitation to the mentioned animal categories was done for the sake of clarity and affordability, and it is assumed that the results for fattening pigs, would largely, also apply to the other animal categories covered by the IED. Likewise, it is assumed that the results for dairy cows, largely, also apply to other categories of animals not covered by the IED. Within the 26 investigated countries, pig farmers from Denmark, The Netherlands, Slovakia and the Flemish part of Belgium are subjected to stricter general limitation on ammonia emission from pig housing than their colleagues in the other countries (see Figure 2). Consequently, pig farmers in these countries may look at these requirements as a constraint that limits their potentials to compete with the pig farmers in other countries having less stringent requirements. An inventory of the animal populations in relation to the geographical size of the countries, presented in Figure 4, shows that, precisely, Denmark, The Netherlands and Belgium are the countries with the densest pig population, and this may explain why pig farmers in these countries are subjected to the strictest regulations amongst the countries involved in this study.

In the case dairy cattle housing the strictest requirements on ammonia emission applies for farmers in Denmark,

Slovakia and the Netherlands (see Figure 3). According to Figure 4, a high cattle density in the Netherlands can be used as argument for the relatively strict Dutch requirements for dairy farmers, whereas the even stricter requirement for Danish dairy farmers may be explained by a high total ammonia emission especially caused by the pig industry in Denmark. For Slovakia the strict requirement can neither be explained by high cattle density nor by large ammonia emissions from other categories of animals.

Figure 4 indicates a high cattle density in Ireland, where a mild climate and large areas with permanent pasture facilitate a large cattle population. These conditions allow e.g. that dairy cows are at grass for up to 300 days and nights per year, which naturally reduces the incitement to implement restriction on ammonia emission related to housing of these animals in Ireland.

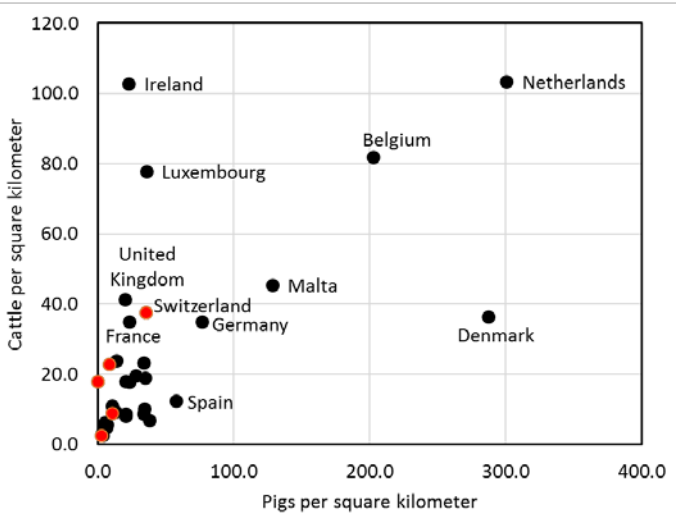

Figure 4. Cattle density plotted against pig density in the 28 EU countries (black bullets), and in Israel, Norway, Republic of North Macedonia, Switzerland and Turkey (Red Bullets). The graphs are based on animal population data from 2016 and extracted from FAOSTAT (2018) and on area data extracted from UNECE (2018). Exact figures for each country are reproduced in annex 1.

The review indicates that the majority of EU countries, and especially the countries with large pig production have implemented the IED in their national legislation. However, it also indicates that some EU countries use divergent interpretation of the IED, for instance:

- In Portugal it is assumed that it is sufficient to comply with EU BAT-AELs at a national level,
- In Romania it is assumed that the EU BAT-AELs requirements can be met by a nutritional strategy that includes reduction of the protein content in the feed by using a balanced diet in relation to essential amino acids and to apply multi-stage feeding technologies,
- In the United Kingdom it is assumed that it is acceptable to allow existing IED farms to exceed the BAT-AELs by up to 25 %, and
- In Greece it is assumed that it is acceptable that the authorities have not yet established procedures to ensure that IED farms comply with the EU BAT-AELs.

Differences also exist in how different countries use the term “fattening pig place” or in general “animal place”. In The Netherlands, these terms are connected to the animal welfare requirements in legislation or in animal welfare certification schemes. Due to a larger potential ammonia evaporation area, this connection might have the consequence, that the ammonia emission becomes larger in more animal friendly housing system, than in housing system that just comply with minimum pen area required by the legislation. Opposite to that, Danish legislation avoids the term “Animal place” and assumes that the ammonia emission is proportional related to area that the animals have access to. This approach has the consequence that it might be more difficult to comply with the ammonia emission requirement for an animal friendly than for a conventional housing system. The general strict Danish requirements will undoubtedly comply with the BAT-AELs even though the term “animal place” is avoided in Danish legislation.

The review is focused on the legal requirements as a tool to create a desired development by defining what is legal and what is not. The review of the Slovak conditions draws the attention to the fact that other tools as taxes on emission or subsidies to low emission solutions could be alternative options to obtain emission reductions.

The review of the conditions in the included countries indicates that large efforts have been taken to reduce ammonia emission and nearly no efforts have been taken to reduce greenhouse gas emissions from animal housing. In some extend this might be explained by the fact that the negative consequences of ammonia emission has been more important, on the public agenda, for a longer period of time, and is of more local character than the greenhouse gas emission. However, the fact that EU has taken substantial initiatives in relation to ammonia emission and has taken practically no initiatives in relations to greenhouse gasses from animal housing, is probably more decisive. It is obvious to assume that EU in the future

could become a powerful engine to initiate and draw a development towards reduced greenhouse gas emissions from livestock housing.

Conclusions

This review have gathered information about the legal requirement of ammonia and greenhouse gas emissions from animal housing in 21 of the 28 EU countries and from 5 non-EU countries. Overall the review shows that most of the included countries have established substantial procedures to limit ammonia emission and nearly no procedures to limit greenhouse gas emissions. The implementation of the IED has been a cornerstone for the administration of the limitation of the ammonia emission from animal housing in the EU countries, and most of the countries have implemented national procedures that establish the upper values of the EU BAT-AELs as general national thresholds. Four countries, including Denmark, The Netherlands, The Flemish part of Belgium and Slovakia have implemented stricter general limitation than dictated by the upper values of the EU BAT-AELs, and also for some of the farms that are not covered by the IED. The three first mentioned countries are characterized with a large pig population in relation to the geographical sizes of the country, however this is not the case for Slovakia. Slovakia also stands out as being the only country that has implemented tax on ammonia emission to protect the environment. Five countries including Denmark, The Flemish part of Belgium, Ireland, Sweden and Switzerland have implemented stricter requirement for farms that plans to expand or establish animal housing buildings close to ammonia sensitive natural areas as e.g. some of the Natura 2000 areas.

Literature:

Denmark (2018a) Ministerial order on permission and approval of livestock farming" (Bekendtgørelse om tilladelse og godkendelse m.v. af husdyrbrug- BEK nr 1467 af 06/12/2018). https://www.retsinformation.dk/Forms/R0710.aspx?id=205574. Accessed February 21 2019.

Denmark (2018b) List of Environmental Technologies. The Environmental Protection Agency. http://eng.mst.dk/trade/agriculture/environmental-technologies-for-livestock-holdings/list-of-environmental-technologies/ Accessed March 6 2018.

EU (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01992L0043-20070101. Accessed February 21 2019.

EU (2006) Regulation No 166/2006 the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R0166&from=EN. Accessed January 4 2019.

EU (2009) Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0147. Accessed February 21 2019.

EU (2010). Directive 2010/75/ of the European Parliament and of the Council of 24 November 2010 on industrial emissions. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32010L0075. Accessed April 26 2018.

EU(2014). Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0052. Accessed March 3 2019.

EU(2016). Directive 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016L2284&from=EN, Accessed November 15 2018.

EU(2017). COMMISSION IMPLEMENTING DECISION (EU) 2017/302 of 15 February 2017 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for the intensive rearing of poultry or pigs. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017D0302&from=EN Accessed March 15 2018.

FAOSTAT (2018). FAO Statistical Database. http://www.fao.org/faostat/en/#home. Accessed November 16 2018.

Flanders (2004) List of ammonia-low-emission house systems (AEA list): https://www.vlm.be/nl/themas/Mestbank/mest/emissiearme%20stallen/Paginas/default.aspx. Accessed November 15 2018.

Flanders (2014) PAS list and combinations of measures and techniques https://www.ilvo.vlaanderen.be/language/nl-BE/NL/Onderzoek/Ammoniak-emissiereducerende-maatregelen-en-technieken/PAS-lijst.aspx#.W-1M5uSWyUk. Accessed November 15 2018.

France (2013). Order of 27 December 2013 on general requirements applicable to installations covered by the authorization scheme under headings 2101, 2102, 2111 and 3660 of the nomenclature of classified installations for the protection of the environment. https://www.legifrance.gouv.fr/eli/arrete/2013/12/27/DEVP1329742A/jo/texte. Accessed December 3 2018.

France (2017a). Order of 23 March 2017 amending the general requirements applicable to installations covered by the authorization scheme under headings 2101, 2102, 2111 and 3660 of the nomenclature of classified installations for the protection of the environment. https://www.legifrance.gouv.fr/eli/arrete/2017/3/23/DEVP1703560A/jo/texte. Accessed December 3 2018.

France (2017b). Best Available Techniques Reference Document (BREF): Intensive Farming of Poultry or Pigs. http://www.installationsclassees.developpement-durable.gouv.fr/27-Document-de-reference-sur-les.html. Accessed December 3 2018.

France (2018). Annual reporting of emissions and transfers of pollutants and waste. https://www.declarationpollution.developpement-durable.gouv.fr/gerep/. Accessed December 3 2018.

Germany (2010) Federal Immission Control Act https://www.gesetze-im-internet.de/bimschv_39/index.html, Accessed November 15 2018.

Germany (2002) Technical instructions for keeping the air clean - TA Luft. https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Luft/taluft.pdf. Accessed November 15 2018.

Ireland (1987) S.I. No. 6/1987 - The Air Pollution Act. http://www.irishstatutebook.ie/eli/1987/act/6/enacted/en/index.html. Accessed March 3 2019.

Ireland (2011) S.I. No. 270/2011 - Air Pollution Act, 1987 (Marketing, Sale and Distribution of Fuels) (Amendment) Regulations 2011. http://www.irishstatutebook.ie/eli/2011/si/270/made/en/print. Accessed March 3 2019.

Ireland (2014) SNIFFER (2014) SCAIL-Agriculture update. Scotland & Northern Ireland Forum for Environmental Research (SNIFFER). Edinburgh Centre for Carbon Innovation, High School Yards, Infirmary Street, Edinburgh, EH1 1LZ. http://www.scail.ceh.ac.uk/agriculture/Sniffer%20ER26_SCAIL-Agriculture%20Final%20report_Issue_11032014.pdf. Accessed March 3 2019.

Israel (2012). Environmental Protection Law (emissions and transfers to the environment - reporting obligations and registration) http://www.sviva.gov.il/InfoServices/ReservoirInfo/DocLib/%D7%9B%D7%9C%D7%9C%D7%99/klali69.pdf. Accessed November 15 2018.

Italy (2009). Environmental authorization for the prevention and reduction of pollution. Approval Guidelines for the evaluation of the Integrated Environmental Authorization Application for livestock farms and the Monitoring and Control Plan. https://bur.regione.veneto.it/BurvServices/pubblica/DettaglioDgr.aspx?id=215143. Accessed January 3 2019.

Italy (2017). The agreement of the Po Basin https://bur.regione.veneto.it/BurvServices/pubblica/DettaglioDgr.aspx?id=347278. Accessed January 3 2019.

Italy (2018). Approval of the Guidelines for the review of Integrated Environmental Authorizations. https://bur.regione.veneto.it/BurvServices/pubblica/DettaglioDgr.aspx?id=375588. Accessed January 3 2019.

Lithuania (2009). Monitoring programme of the farm environment - September 16, 2009, No D1-546 https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.353115/xmDtUkzQNO. Accessed April 2 2019.

Lithuania, (2013). Permission system for intergrated prevention and control of pollution - July 15, 2013, No D1-528. https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.453692. Accessed April 2 2019.

Macedonia (2017) Rulebook for limit values for the permited levels of emissions. http://air.moepp.gov.mk/wp-content/uploads/2017/10/Pravilnik-za-granicnite-vrednosti-za-dozvolenite-nivoa-na-emisii-od-stacionarni-izvori.pdf Accessed January 2 2019.

Malta 2013. Subsidiary legislation 549.77. Industrial Emissions (Integrated Pollution Prevention and Control) http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=11531&l=1. Accessed January 2 2019.

Netherlands (2018a). Regeling ammoniak en veehouderij, https://wetten.overheid.nl/BWBR0013629/2018-07-20. Accessed November 12 2018.

Norway (2003). Forskrift om gjødselvarer mv. av organisk opphav (in Norwegian). Regulations on fertiliser products of organic origin. https://lovdata.no/dokument/SF/forskrift/2003-07-04-951#KAPITTEL_6 Accessed 3 May 2019.

Norway (2004). Forskrift om hold av storfe (in Norwegian). Regulations on keeping cattle. https://lovdata.no/dokument/SF/forskrift/2004-04-22-665 Accessed 3 May 2019.

Norway (2013). Retningslinjer for hold av svin (in Norwegian). Guidelines to keep pigs. https://www.mattilsynet.no/dyr_og_dyrehold/produksjonsdyr/svin/retningslinjer_for_hold_av_svin.5700 Accessed 3 May 2019.

Norway (2017). Forskrift om endring i forskrift om hold av storfe (in Norwegian). Regulations on changes in regulations on keeping cattle. 2019. https://lovdata.no/dokument/LTI/forskrift/2017-05-24-643 Accessed 3 May.

Norway (2018). Veileder til forskrift om hold av storfe (in Norwegian). Guidelines on regulations to keep cattle. 2010, last changed in 15.01.2018. https://www.mattilsynet.no/om_mattilsynet/gjeldende_regelverk/veiledere/veileder_om_hold_av_storfe.1853/binary/Veileder%20om%20hold%20av%20storfe. Accessed April 16 2019.

Netherlands (2018b) RAV-list. https://www.infomil.nl/onderwerpen/landbouw/ammoniak/rav-0/bijlage-1/emissiefactoren-per. Accessed November 12 2018.

Poland (2017). Guidelines for the practical application of the BAT Conclusions in the intensive breeding of poultry and pigs: Part 2 Installations for the breeding of pigs. http://www.ekoportal.gov.pl/fileadmin/user_upload/Wytyczne_dotyczace_praktycznego_zastosowania_Konkluzji_BAT_w_zakresie_intesywnego_chowu_drobiu_i_swin_-_Czesc_II_Instalacje_do_chowu_swin.pdf. Accessed January 4 2019.

Slovakia (2010). Act no. 137/2010 Coll on Air;

Slovakia (2012). Decree of Ministry of Environment of the Slovak republic no. 410/2012 Coll. executing certain provisions of the Act no. 137/2010 Coll on Air;

Slovakia (2008). Official Journal of the Ministry of Environment of the Slovak Republic no. 8/2008, part General Emission Dependencies and General Emission Factors for Selected Technologies and Devices (currently under novelization).

Slovakia (2005). Regulation No. 389/2005 Coll.

Slovakia (1998). Act no. 401/1998 ACT on air pollution charges.

Slovenia (2014). Decree on activities which are subject to an environmental impact assessment. Official Gazette of the Republic of Slovenia, no. 51/2014, 57/2015, 26/2017.

Slovenia (2015). Decree on activities and installations causing large-scale environmental pollution. Official Gazette of the Republic of Slovenia, no. 57/2015.

Sweden (1998). Environmental Code (Miljöbalken). https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808. Accessed April 26 2018.

Sweden (2013a). Environmental Regulation (Miljöförordningen). http://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljoprovningsforordning-2013251_sfs-2013-251. Accessed April 26 2018

Sweden (2013b). Industrial Emissions Regulation. http://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/industriutslappsforordning-2013250_sfs-2013-250. Accessed April 26 2018.

Switzerland, (2018). Ordinance on Air Pollution Control. https://www.admin.ch/opc/en/classified-compilation/19850321/index.html. Accessed January 2 2019.

UK (2010). EPR 6.09 sector guidance note. How to comply with your environmental permit for intensive farming. https://www.gov.uk/government/publications/intensive-farming-introduction-and-chapters. Accessed March 28 2019.

UNECE (2018). UNECE Statistical Database. https://w3.unece.org/PXWeb2015/pxweb/en/STAT/. Accessed November 16 2018.

Annex 1: Animal population and animal density for cattle and pigs in EU28m and in Israel, Norway, Republic of North Macedonia, Switzerland and Turkey. The animal population data is 2016 figures extracted from FAOSTAT (2018) and used area data is extracted from UNECE (2018).

Country	Animals, millions		Density, Animals km^{-2}	
	Cattle	Pigs	Cattle	Pigs
Austria	2.0	2.8	23	34
Belgium	2.5	6.2	82	202
Bosnia and Herzegovina	0.5	0.5	9	11
Bulgaria	0.6	0.6	5	5
Croatia	0.5	1.2	8	21
Cyprus	0.1	0.4	7	38
Czechia	1.4	1.6	18	20
Denmark	1.6	12.4	36	287
Estonia	0.3	0.3	6	7
Finland	0.9	1.2	3	4
Republic of North Macedonia	Not availably	Not availably	Not availably	Not availably
France	19.3	12.7	35	23
Germany	12.5	27.4	35	77
Greece	0.6	0.8	5	6
Hungary	0.8	3.1	9	34
Ireland	7.2	1.6	103	23
Israel	0.5	0.2	23	9
Italy	5.9	8.5	20	28
Latvia	0.4	0.3	6	5
Lithuania	0.7	0.7	11	11
Luxembourg	0.2	0.1	78	36
Malta	0.0	0.0	45	128
Netherlands	4.3	12.5	103	301
Norway	0.9	0.8	3	3
Poland	5.9	10.9	19	35
Portugal	1.6	2.2	18	23
Romania	2.1	4.9	9	21
Slovakia	0.5	0.6	9	13
Slovenia	0.5	0.3	24	13
Spain	6.3	29.2	12	58
Sweden	1.4	1.5	3	3
Switzerland	1.6	1.5	38	35
Turkey	14.0	0.002	18	0.002
United Kingdom	10.0	4.9	41	20