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Integrated Ammonia Abatement - Modelling of Emission Control Potentials and Costs in GAINS

Klimont, Z. and Winiwarter, W.

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International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236 807 342
Fax: +43 2236 71313
E-mail: publications@iiasa.ac.at
Web: www.iiasa.ac.at

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Integrated ammonia abatement – Modelling of emission control potentials and costs in GAINS

Zbigniew Klimont

Wilfried Winiwarter

Approved by

Markus Amann
Programme Leader, MAG

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Abstract

With progressing reduction of the emissions of other air pollutants, control of ammonia emissions, particularly from agricultural sources, moves into the centre stage of air pollution control in Europe. Over the recent years, more countries have implemented practical emission control measures, so that practical experience with such measures has substantially grown compared to a decade ago.

This report describes how the new information on potentials and costs for the reduction of ammonia emissions that has been presented by national experts at a recent workshop has been incorporated into the GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model developed by the International Institute for Applied Systems Analysis (IIASA). The former GAINS methodology has been modified to align better with the new focus of the UNECE Task Force on Reactive Nitrogen on large installations and to avoid calling for emission reductions on small (hobby) farms. As such a distinction will exclude measures with excessive costs (at small farms), the new cost estimates that address large farms only are lower than earlier calculations that applied to all sources.

A comparison of unit cost estimates (costs per amount of ammonia reduced) reveals significant variations across countries, explained by local circumstances that have impacts on costs. Still, the most important patterns remain constant between countries. Animal feeding with low nitrogen diets and manure application techniques that minimize ammonia release are most cost effective, along with efficient application and/or substitution of urea fertilizer.

Finally, the report provides also updates to the cost method used to estimate ammonia control costs in GAINS.

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About the Authors

Zbigniew Klimont and Wilfried Winiwarter work as Senior Research Scholars at the Mitigation of Air Pollution and Greenhouse Gases (MAG) programme of the International Institute for Applied Systems Analysis (Laxenburg, Austria).

Zbigniew Klimont graduated from Warsaw Technical University (Poland) in environmental engineering. His work focuses on the sources and mitigation potentials of ammonia and black carbon.

Wilfried Winiwarter earned a doctoral degree in analytical chemistry from Vienna University of Technology. During his employment with Austria's largest non-university research institution, AIT - Austrian Institute of Technology, he focused on the release of trace constituents into the atmosphere and their subsequent transformations. Dr. Winiwarter holds the title of a “Universitätsdozent” in environmental chemistry, awarded by Vienna University of Technology.

Integrated ammonia abatement – Modelling of emission control potentials and costs in GAINS

Zbigniew Klimont and Wilfried Winiwarter

1 Introduction

With progressing reduction of the emissions of other air pollutants, control of ammonia emissions, particularly from agricultural sources, moves into the centre stage of air pollution control in Europe. Over the recent years, more countries have implemented emission control measures, so that practical experience with such measures has substantially grown compared to a decade ago. New information has become available that indicates that in practice costs of several measures are lower than previously anticipated.

This report describes how the new information on potentials and costs for the reduction of ammonia emissions that has been presented by national experts at a recent workshop has been incorporated into the GAINS model developed by the International Institute for Applied Systems Analysis (IIASA).

The Greenhouse gas – Air pollution INteractions and Synergies (GAINS) model is a tool to estimate cost-effective strategies to reduce emissions of air pollutants and greenhouse gases (Amann et al., 2011). It allows assessing, for specific economic sectors and individual countries, the options to reduce emissions, their costs and their environmental effects

GAINS represents the multi-pollutant/multi-effect nature of atmospheric pollution. GAINS includes emissions of greenhouse gases (CO_2, CH_4, N_2O, F-gases) and air pollutants (SO_2, NO_x, NMVOC, NH_3 and several particulate matter species). GAINS considers the implications emission controls may have on other pollutants than those originally targeted, thereby capturing that some measures may cause intended or unintended side effects on emissions of one or more other components. GAINS defines unabated emission factors (representative of the ‘reference’ technology in a given sector without any emission controls) and considers the effects of emission control measures through ‘abated’ emission factors. The difference between these two factors divided by the unabated emission factor is defined as the reduction efficiency, and is associated with certain emission control costs.

The dispersion and transformation of trace constituents in the atmosphere is represented in GAINS via source-receptor relationships, which are derived from model runs of complex atmospheric chemistry-transport models. Likewise, environmental impacts are quantified in GAINS by parameterized ecosystems or human health response functions derived from complex disciplinary models. Using external information on the drivers of emissions, i.e., energy consumption and other activities, GAINS estimates emissions and environmental impacts of emission control scenarios for every five years over the period 1990 to 2030. GAINS covers now the whole world at regionally different spatial resolutions. In principle, GAINS distinguishes individual countries to reflect common legislative and market situations. For some large countries, e.g., India, China or Russia, GAINS considers sub-national regions, while some other countries with lower emissions have been lumped into groups like Northern Africa or Central America. GAINS has been used in a number of policy related exercises, and detailed technical documentations of the model have been produced for these applications. (e.g., Amann et al., 2007; Höglund-Isaksson et al., 2009). Further documentation as well as the model itself can be accessed at http://gains.iiasa.ac.at.

This document presents the updated methodology and data used for calculating costs of controlling ammonia emissions in the GAINS model. The principle elements of cost calculations with a focus on other components have been described, e.g., by Klimont et al. (2002). Some specific effects on policy applications of the new ammonia control costs described here in detail have been assessed by Klimont and Winiwarter (2011).

2 The agricultural module of the GAINS model

2.1 Emission calculation

Agricultural ammonia emissions, constituting typically ~90% of the total ammonia emissions in a country, emerge from animal husbandry and application of mineral nitrogen fertilizers. Animal manure contains nitrogen mostly in the form of urea (for birds, uric acid), which will hydrolyze to ammonia under microbial influence. Ammonia formation – precondition for the use of manure as fertilizer – may give rise to ammonia emissions into the atmosphere.

The initial version of the GAINS ammonia module has been developed by Klaassen (1991a, 1991b). Updates have been documented by Brink et al. (2001a, 2001b), Klimont and Brink (2004), Klimont (2005), Kuczynski et al. (2005) and Klimont et al. (2005). These reports and papers describe the detailed structure and the underlying data sources. For activity data, GAINS contains a number of future scenarios based on sources such as national projections and work of international organizations like FAO, EFMA, IFA, and OECD. Historical data rely on statistical information validated by national experts during several consultation processes in the context of the preparations of CLRTAP Protocols, the National Emission Ceilings (NEC) Directive of the European Union, and the Clean Air For Europe (CAFE) program.

While emissions from mineral fertilizer application can adequately be assessed by multiplying the applied fertilizer amounts with region/fertilizer specific emission factors, a more complex approach has been developed for manure. Following insights from recent international activities to characterize ammonia emissions from animal husbandry, GAINS differentiates four stages of manure treatment where ammonia emissions may take place. In a mass-conservation approach, any measure that keeps ammonia from evaporating will keep it available for the next stage, such that an emission reduction in one stage may lead to an increase in the following stage. These stages are “housing”, “storage”, “application”, and “grazing”. Emission factors and abatement technologies are available for each of the stages. This approach has been extended to treat even more stages consistently and to cover all compounds of interest in agriculture (Asman et al., 2011, and the Tier 2 approach in Klimont and Brink, 2004); however, this extension has not been implemented yet in GAINS.

The current approach to assess emissions in such a four-stage concept thus can be described as presented by Klimont and Brink (2004):

$$EL_{j,l} = \sum_i L_{i,j} \sum_k \sum_{s=1}^{4} \left[ef_{i,j,l,s} \left(1 - \eta_{i,k,l,s}\right) X_{i,j,k,l} \right] \quad (1)$$

where:

EL ammonia emissions from livestock farming [kt NH_3/year];
i,j,k,l livestock category, year, abatement technique, country;
s emission stage (four stages)
L animal population [thousand heads];
ef emission factor [kg NH_3 / animal per year];
η reduction efficiency of abatement technique;
X implementation rate of the abatement technique

In the above equation, emission factors of each stage are influenced by the nitrogen losses at previous stages. This influence can be expressed as:

$$ef_1 = Nx_1 \, v_1 \quad (2a)$$

$$ef_2 = Nx_1 \, (1 - v_1) \, v_2 \quad (2b)$$

$$ef_3 = Nx_1 \, (1 - v_1 - (1 - v_1) \, v_2) \, v_3 \quad (2c)$$

$$ef_4 = Nx_4 \, v_4 \quad (2d)$$

where:

$ef_{1,2,3,4}$ NH_3-nitrogen loss at the different emission stages, i.e., housing (1), storage (2), application (3), and grazing (4),
$Nx_{1,4}$ N excretion during housing (1) and grazing (4),
$v_{1,2,3,4}$ N volatilization rates at distinguished emission stages

Key country- and activity type-specific parameters for assessing emissions can be retrieved from the on-line version of the GAINS model (http://gains.iiasa.ac.at). They include volatilization rates, excretion rates, days spent in housing, reduction efficiency, application level of control measure, animal population and use of mineral fertilizer.

2.2 Activity categories and emission control options in GAINS

In order to reflect the significant differences in national practices of animal husbandry, GAINS not only differentiates livestock into major categories, but also distinguishes between animals kept on liquid (slurry) and solid manure systems (often referred to as farmyard manure or FYM). For mineral fertilizer, urea (and ammonium carbonate) is differentiated from other nitrogen fertilizer types:

- Livestock categories
  - Dairy cows (distinguishing liquid and solid manure systems)
  - Other cattle (distinguishing liquid and solid manure systems)
  - Pigs (distinguishing liquid and solid manure systems)
  - Sheep and goats
  - Horses, donkeys and mules
  - Laying hens
  - Other poultry
  - Fur animals
  - Camels
  - Buffaloes
- Mineral N-fertilizers
  - Urea
  - Other

These distinctions allow consideration of a variety of important aspects. Differentiation of nitrogen excretion during grazing and housing, for example, reflects the time per year (in days) animals stay outdoors. For dairy cows, allowance is made for time spent indoors for milking during periods they mostly spend outdoors, which will also lead to manure accumulating in animal housing. While, in general, GAINS assumes N excretion to be constant over time, for dairy cows a relation with milk yields has been introduced (see Klimont and Brink, 2004; however, the actual coefficients provided in that paper have changed owing to new information).

The differentiation between liquid manure and solid manure (manure collected on layers of straw or other bedding material) allows distinguishing between processes that are chemically and biologically quite different, and thus associated with different emission factors. Storage of manure in liquid form will foster anaerobic reactions to take place (excluding oxygen and oxidation), while aerobic conditions will prevail for solid manure.

A number of measures to reduce ammonia emissions have been developed and successfully applied in several countries. GAINS distinguishes key sets of such abatement measures and applies them to different categories of farm animals. Not all measures may be available or practical for specific animal categories (a listing of feasible combinations is shown in Table 1.1). Klimont and Brink (2004) provide a detailed description of these options. The different abatement technologies address specific stages of the process chain.

Low nitrogen feed describes a method of dietary changes, where a lower protein (nitrogen) content of animal feed leads to reduced nitrogen excretion. This will basically affect all stages in a similar way (although the effect on stage 4, grazing, may be different).

Low emission housing covers a number of options that prevent ammonia emissions from animal housing, basically reducing the surface area and exposure time of manure in the animal house. This includes flushing systems or other means of immediate transport of manure into storage. While it principally targets stage 1, GAINS assumes that covered stores will be built along the new low emission houses affecting stage 2 emissions.

Air purification includes options that treat the air ventilated from animal housing. As an add-on technology, they change the emission factor of stage 1 (housing). As discussed in the guidance document to the Annex IX of the Gothenburg Protocol, the treatment of exhaust air by acid scrubbers or biotrickling filters has proven to be practical and effective for large scale operations in the Netherlands, Germany and Denmark. Thus, the GAINS database has been updated to consider the recent shift away from biofilters (for which the previous cost data had been developed) to acid scrubber systems.

Covered storage refers to the reduction of exposure of stored manure to air. GAINS distinguishes between low efficiency systems (e.g., floating foils or polysterene) and high efficiency systems that allow more efficient separation from the atmosphere (using concrete, corrugated iron or polyester caps). These measures reduce the emission factor for storage (stage 2), but due to increased availability of nitrogen will lead to an increase in emissions from application (stage 3).

Low ammonia application describes the distribution of manure to agricultural fields in a way to minimize surface exposure, by placing it under a cover of soil or vegetation. This is sufficient to reduce emissions compared to the reference technology (broadcasting). Low efficiency methods include slit injection, trailing shoe, slurry dilution, band spreading for liquid slurry, and incorporation of solid manure by ploughing into the soil the day after application. High efficiency methods involve the immediate incorporation by ploughing within four hours after application, deep and shallow injection of liquid manure and immediate incorporation by ploughing (within 12 hours after application) of solid manure. Only emission factors for manure application are affected.

As the GAINS approach is formulated for mutually exclusive emission control options, combinations of the above options need to be explicitly defined, both in terms of emission factors and costs. Combinations considered in GAINS reflect the most important combinations of options applied at different stages (see Table 1).

Improved application or substitution of urea is an abatement option for the application of mineral fertilizers only. It refers to the substitution of urea (and ammonium carbonate) as fertilizers by other chemical forms of fertilizers that are less easily releasing ammonia, e.g., ammonium nitrate.

Table 1. Emission control options for ammonia in animal husbandry, as currently implemented in GAINS

	FEED	HOUSING		STORAGE	APPLICATION	TOTAL NUMBER OF OPTIONS
Animal category	Low nitrogen feed (LNF)	Low emission housing (SA)	Air purification (BF)	Covered storage (CS)	Low ammonia application (LNA)	(including combinations)
dairy cows	x	x		x	x	18
other cattle		x		x	x	9
pigs	x	x	x	x	x	31
laying hens	x	x	x	x	x	20
other poultry*)	x	x	x	x	x	21
sheep					x	2
						101
Total measures including given option	45	18	30	32	58	

*) Includes also poultry manure incineration

3 Emissions control costs

3.1 Concept

The basic intention of a cost evaluation in the GAINS model is to identify the value to society of the resources diverted in order to reduce emissions of a specific compound. In practice, these values are approximated by estimating costs at the production level rather than prices to the consumers. Therefore, any mark-ups charged over production costs by, e.g., food industry or retail markets, do not represent actual resource use and are ignored. Certainly, there will be transfers of money with impacts on the distribution of income or on the competitiveness of the market, but these should be removed from a consideration of the efficiency of a resource. Any taxes added to production costs are similarly ignored as transfers.

As in the cost modules for other pollutants, a central assumption in the GAINS ammonia module is the existence of a free market for abatement equipment across Europe that is accessible to all countries at the same conditions. Thus, the capital investments for a certain technology can be specified as being independent of the country. Likewise, certain elements of operating costs are assumed to be identical for all countries. The calculation method takes into account several country-specific parameters that characterize the situation in a given country or region in order to assess the variable operating costs', for instance, labour, energy, water, disposal costs, etc.

Thus, expenditures for emission controls are differentiated into three categories, although for some technologies not all categories are relevant:

- investments,
- fixed operating costs (costs of maintenance, insurance, administrative overhead), and
- variable operating costs (e.g., energy, water, labour costs, feed and fertilizer price, costs of waste disposal, etc.).

Considering the above, costs per unit of activity, i.e., number of life animals, or tons of fertilizer use, are calculated. Furthermore, taking into account the abatement efficiency of a specific measure, unit costs per unit of removed pollutant (NH_3) can be estimated.

The following sections introduce the cost calculation principles used in GAINS and explain the construction of the cost curves that can be further used in the optimization module of the GAINS model. To illustrate the methodology, examples of cost calculations are given. Values of all parameters used to calculate country-specific costs and the national cost curves are provided in the Annex of this report, and they are also available from the on-line implementation of the GAINS model (http://gains.iiasa.ac.at).

3.2 Investments

Investments cover the expenditure accumulated until the start-up of an abatement technology. These costs include, e.g., delivery of the installation, construction, civil works, ducting, engineering and consulting, license fees, land requirement (purchase) and capital. The GAINS model uses investment functions where these cost components are aggregated into one term.

Investments for individual control measures are calculated as a function of the size of an installation. In its generic form, total investments *T* contain a constant and a size-dependent part, the latter typically characterized by the average farm size *ss* expressed as the average number of animal places on a farm for a specific livestock category. This linear approach may be transformed to express specific investments *I* per animal place. The form of either of these functions is described by its fixed and variable coefficients, ci^f and ci^v.

$$T_{i,j,k} = ss_{i,l} \cdot ci^f_{\ i,k} + ci^v_{\ i,k} \qquad (3a)$$

$$I_{i,k,l} = ci^f_{\ i,k} + \frac{ci^v_{\ i,k}}{ss_{i,l}} \qquad (3b)$$

where

ci^f, ci^v	investment function coefficients (Annex: Table A1)
ss	average farm size (Annex: Table A2)
i,k,l	livestock category, abatement technique, country

Note that the "average farm size" relates only to the larger farms in a country and excludes very small (subsistence or hobby) farms from the analysis, for which measures are not considered as practical. Section 3.6 of this report describes in detail how the "applicability" factors of measures were derived.

A slightly different function has been developed to estimate investments for storage options, as typically costs depend on the volume of manure to be stored (*ManVol)* rather than on the number of animal places. Conversion between these parameters can be performed using country specific data on agricultural practice. GAINS considers typical storage time, annual manure production and the number of production cycles to assess the volume of manure to be stored.

$$T_{i,k,l} = ManVol_{i,l} \cdot ci^f_{\ i,k} * + ci^v_{\ i,k} \qquad (4a)$$

Conversion of this equation may be performed via

$$ManVol = ss \cdot \frac{st}{12} \cdot mp \cdot ar \tag{4b}$$

With parameter "12" (number of months per year) factored into the coefficient ci^f, this conversion yields the investments per animal place:

$$I_{i,k,l} = ci^f{}_{i,k} \cdot st_{i,l} \cdot mp_{i,l} \cdot ar_{i,l} + \frac{ci^v{}_{i,k}}{ss_{i,l}} \tag{4c}$$

where

st	storage time (Annex: Table A4)
mp	manure 'production' of a single animal per year (Annex: Table A3)
ar	production cycles per year (Annex: Table A5).

Costs calculated this way refer to the total manure produced, both inside housing and during grazing. While manure excreted during grazing would not need to be collected in stores (which would reduce the requirements for retrofitting capacity and costs), dimensioning of such installations has to be done for the period it is used full time. Thus GAINS cost calculations assume capacities for full-time use of storage.

The number of production cycles per year *ar* allows conversion between the number of animals produced (as typically presented in production statistics), and the number of animal places, which strongly determine costs of measures. Manure production *mp* is given for a single animal, e.g., for the lifetime of a pig that is fattened typically over a four to six month period, but yearly for longer-living animals like dairy cows.

Coefficients ci^f, ci^v are derived from actual cost data (see Klaassen, 1991b[1]) as a result of a regression calculation performed on the linearized expression (Equations 3a and 4a, respectively). For manure storage, they represent costs for a cover (lid) assuming an existing manure tank. Fig. 1 presents this regression calculation for high efficiency measures (referenced by Klimont and Winiwarter, 2011). The inversion into size-specific costs (here by manure storage capacity) is shown in Fig. 2, both for the sample points and the regression. Both figures indicate a considerable scatter of available cost data and their representation in the cost function.

[1] Further updated with information received during bilateral meetings with national experts, specifically from UK, Denmark, Switzerland, Netherlands.

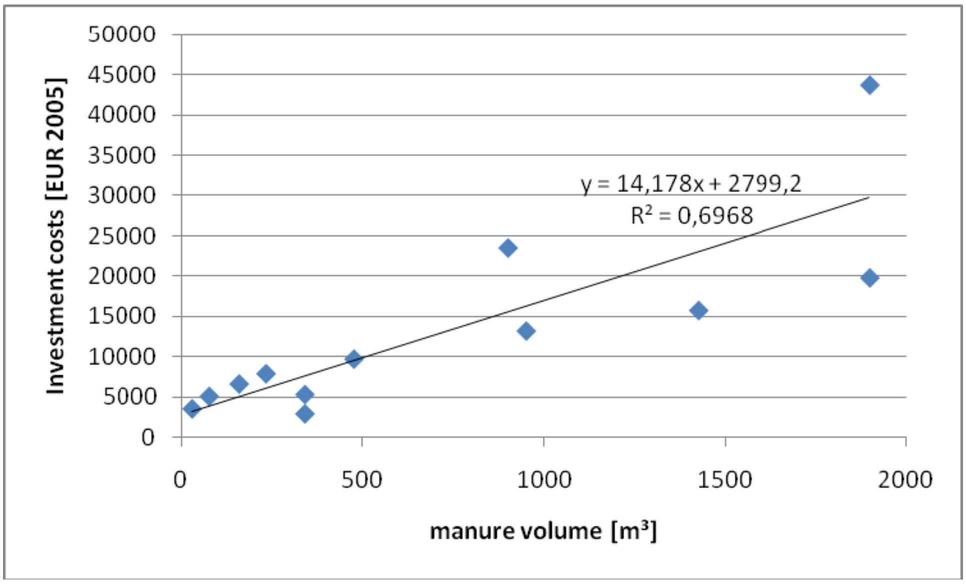

Fig. 1. Regression function to derive cost coefficients (costs expressed as EUR of the year 2005) for high efficiency measures in manure storage

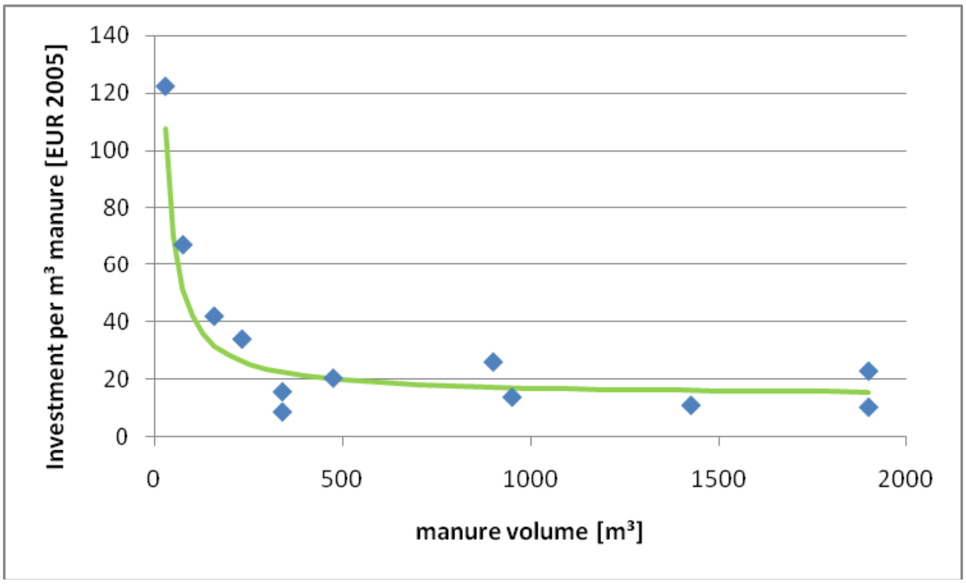

Fig. 2. Size-dependent investment costs for high efficiency measures to abate ammonia from manure storage. The inverted regression function (line) indicates high costs for small units (costs expressed in EURO of the year 2005)

Costs per amount of manure produced can be translated into an investment function with parameters for average farm size (expressed as number of animals per farm) and the typical storage time in a specific country. The example of pig manure (Fig. 3) applies the equations presented above to calculate costs vs. farm size, for two different values of storage time (all other parameters constant). The influence of storage time on the size of the storage tank needed can be visualized as a function of the tank-size dependent investment costs.

A comparison of the results derived from the GAINS calculation with cost data collected for the UK (Ryan, 2004) demonstrates that GAINS estimates are within the wide scatter of reported data (Fig. 4).

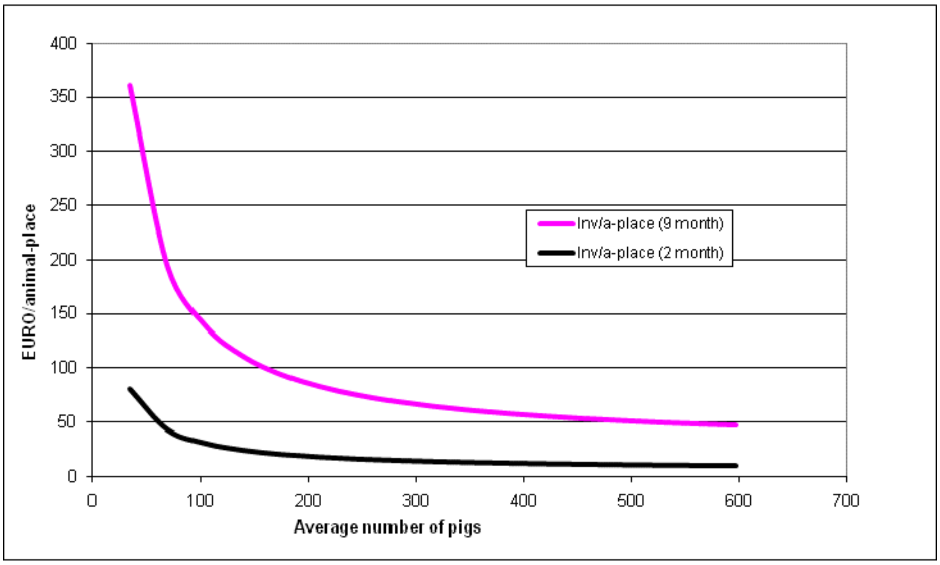

Fig. 3. GAINS investment functions for storage of pig manure (per animal place) for different storage capacity required (storage time)

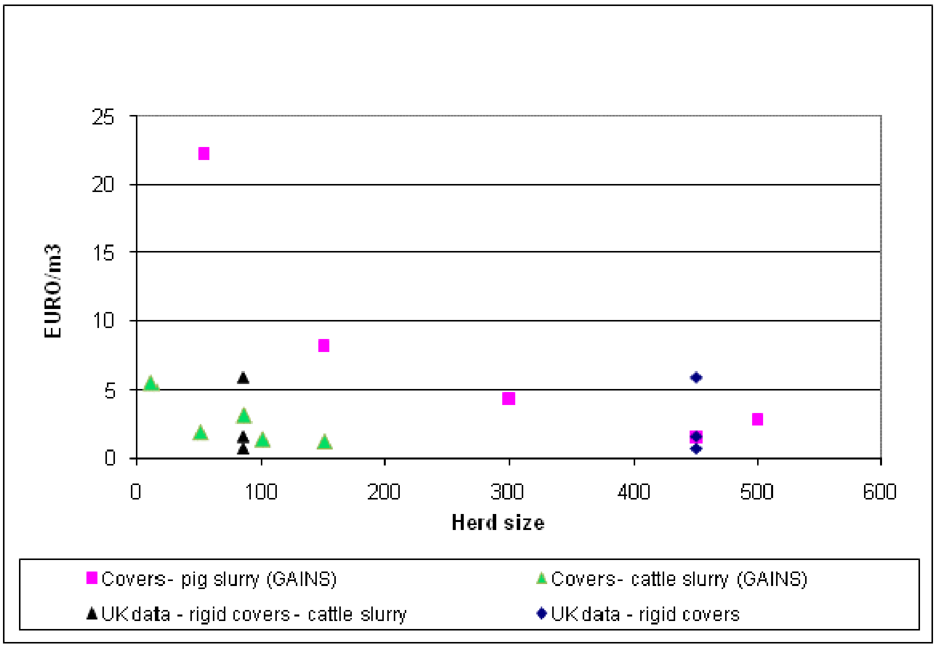

Fig. 4. Comparison of costs for storage covers between GAINS and UK data

Investments are annualized over the technical lifetime *lt* of the installation by using the interest rate *q* (as %/100). GAINS allows for using different interest rates to reflect different (social planners and private consumers) perspectives, although for all calculations performed within the Gothenburg Protocol, NEC, and CAFE related work an agreed social interest rate of 4% was used:

$$I_{i,k,l}^{an} = I_{i,k,l} \cdot \frac{(1+q)^{lt_k} \cdot q}{(1+q)^{lt_k} - 1} \tag{5}$$

where

i,k,l	livestock category, abatement technique, country
lt	lifetime of abatement technique (Annex: Table A1)
q	interest rate (e.g., 0.04 = 4%)

All parameters used to derive investments are listed in the Annex to this report, Table A1 – A5. They are also available from the on-line application of GAINS.

3.3 Operating costs

Annual fixed expenditures OM^{fix} cover costs of repairs, maintenance and administrative overhead per animal place. These cost items are not related to the actual use of the installation. As a rough estimate for annual fixed expenditures, a standard percentage *fk* of the total investments is used:

$$OM^{fix}{}_{i,k,l} = I_{i,k,l} \; x \; fk_{i,k} \tag{6}$$

where

i,k,l	livestock category, abatement technique, country
fk	percentage of investment costs (Annex: Table A7)

Variable operating costs OM^{var} are related to the actual operation of an installation and take into account additional costs incurred beyond the reference technology, the “no control” baseline situation, due to extra supplies needed. These supplies are given per animal produced and year:

- additional labour demand,
- increased energy demand for operating the device (e.g., for the fans and pumps), either as gas or electricity,
- animal feed,

- water, or
- waste disposal.

Variable operating costs are calculated using the quantity *Q* needed (demand) of a certain extra supply *p* for a given control technology *k*, and its (country-specific) price *c*.

$$OM^{\text{var}}_{i,k,l} = \sum_{p} Q_{i,k,p} c_{i,k,l,p} \quad (7)$$

where

p	parameter type (additional energy, labour, waste disposal, etc.)
i,k,l	livestock category, abatement technique, country
Q	quantity of *p* (Annex: Table A6)
c	unit price of a given *p* (Annex: Table A8)

While the equations above are used in GAINS in general, a somewhat adapted version is needed to estimate costs of low ammonia application. For this abatement option, costs (per cubic meter of manure) are calculated as a function of the manure application rate Q^{mh}. Cost parameters are specific for grassland and arable land, requiring separate treatment:

$$C^{mg}_{k',l} = ci^{fg}_{k'} - ci^{vg}_{k'} \cdot Q^{mh}_{k',l} \quad (8a)$$

$$C^{ma}_{k',l} = ci^{fa}_{k'} - ci^{va}_{k'} \cdot Q^{mh}_{k',l} \quad (8b)$$

where

k', l	abatement technique (low or high efficiency; applied to grassland or arable land), country
C^{mg}, C^{ma}	cost of option *k'* per m^3; grassland, arable land
ci^{fg}, ci^{vg}	cost coefficients for a specific option *k'* used on grassland (Annex: Table A9)
ci^{fa}, ci^{va}	cost coefficients for a specific option *k'* used on arable land (Annex: Table A9)
Q^{mh}	manure application rate per hectare for option *k'* (Annex: Table A8)

Total annual costs of the low ammonia application measures are calculated using a country-specific share of manure applied on grassland S^{mg}. At the same time, costs are also expressed per animal produced using country- and animal-specific manure production rates *mp*. Here only the indoor share needs to be considered, as low ammonia application only applies to manure collected during the housing period:

$$OM^{\mathrm{var}}_{i,k,l} = (S^{mg}{}_{i,l} \cdot C^{mg}{}_{i,k,l} + (1 - S^{mg}{}_{i,l}) \cdot C^{ma}{}_{i,k,l}) \cdot mp_{i,l} \cdot \frac{Nx_{1,i,l}}{Nx_{1,i,l} + Nx_{4,i,l}} \tag{9a}$$

where

i,k,l	livestock category, abatement technique (low or high efficiency), country
S^{mg}	share of manure applied to grassland (the rest of manure is considered to be applied on agricultural land) (Annex: Table A10)
mp	manure 'production' of a single animal per year (Annex: Table A3)
$Nx_{1,4}$	N excretion during housing (1) and grazing (4), considered proportional to the respective manure production shares

All individual parameters of the calculations are presented in the Annex, Tables A6 – A10. The fact that solid manure typically is not applied at grassland at all can be handled by setting the S^{mg} parameter to zero.

Low ammonia application (i.e., reducing loss of ammonia to the atmosphere) introduces additional nitrogen into soils. This ammonia nitrogen that is not emitted into the air may thus be considered as extra fertilizer that saves mineral fertilizer. Associated cost savings can be calculated with data on fertilizer costs:

$$Nsav_{i,k,l} = ef_{i,l,3} \cdot \eta_{i,k,l,3} \cdot c_{fert,l} \cdot {}^{14}\!/_{17} \tag{9b}$$

where

i,k,l	livestock category, abatement technique, country
$Nsav$	saved fertilizer costs (per live animal)
ef_3	unabated emission factor (as in equation (2))
η_3	removal efficiency (as in equation (1) for stage 3, application)
c_{fert}	fertilizer costs (as in equation (7); Annex: Table A8)
14/17	stoichiometric factor (N content in ammonia)

An example for operating costs is presented in Fig. 5. As expressed in Equation (8), a size dependency exists: costs for low ammonia manure application increase with decreased application rate. This is confirmed by UK data (Ryan, 2004), which are shown as squares in Fig. 5, and previously reflected in GAINS as shown by the crosses. New information on manure application costs, however, requires a new concept to be used (Webb et al., 2011), shown as lines in Fig. 5. Costs of spreading slurry are now considered as a function of the intensity of equipment use, while the density of application is not considered any longer. The economic optimum, i.e., high use of equipment, is a service-oriented approach where manure application is contracted out. For manure incorporation, the relationship to the density of application still exists but, with the now favoured contractor-concept, application rates are considered as constant (assumed at a 50 m³/ha application rate). Consequently, the "variable" cost coefficients in Equation (8) have now been set to zero in GAINS.

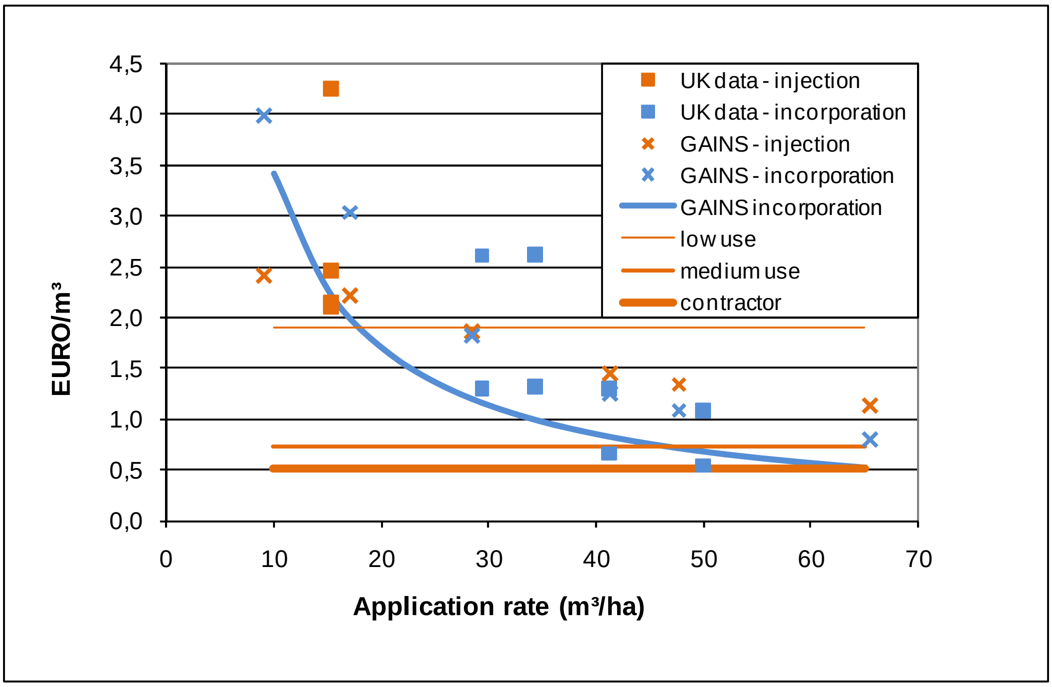

Fig. 5. Comparison of cost data for slurry injection (orange) and for incorporation of manure (blue). Current GAINS implementation uses application rate of 50 m³/ha only (bold lines, "incorporation" as well as the rate-independent "contractor" model)

3.4 Unit costs

Considering the above-mentioned cost elements, unit costs *ca* of specific measures to reduce ammonia emissions can be calculated. Unit costs in GAINS are expressed per activity unit, i.e., per annual average number of live animals, and the amount of nutrient N applied in mineral fertilizer.

Unit costs *ca* are derived by adding annualized investments, fixed operation costs and variable operation costs times the intensity of their application (number of production cycles), considering savings in mineral fertilizer due to ammonia buried in soil during application. A conversion from animal places to the average number of live animals at any given time (activity rate used in GAINS) is provided by the number of production cycles *ar* and capacity utilization factor *sb*:

$$ca_{i,k,l} = \frac{I^{an}{}_{i,k,l} + OM^{fix}{}_{i,k,l} + OM^{var}{}_{i,k,l} \cdot ar_{i,l}}{sb_{i,l}} - Nsav_{i,k,l} \qquad (10)$$

where

i,k,l	livestock category, abatement technique, country
ca	unit costs per live animal
ar	production cycles per year (Annex: Table A5)
sb	capacity utilization factor(Annex: Table A11)
Nsav	saved fertilizer costs (per live animal)

Costs can also be expressed per unit of abated emissions. In a multi-pollutant environment as in GAINS this notation is of limited value, but when comparing abatement costs of a specific compound it may become very useful.

$$cn_{i,k,l} = \frac{ca_{i,k,l}}{ef_{i,l} \cdot \eta_{i,k,l}} \qquad (11)$$

where

η_k	removal efficiency of option k
$ef_{i,l}$	emission factor for livestock category i and country l, assuming no abatement is in place (unabated emission factor per live animal)

Data on production cycles and capacity utilization are presented in the Annex (Tables A5 and A11); emission factors and removal efficiencies are essential parameters of emission calculation and are available in the GAINS on-line application (http://gains.iiasa.ac.at).

Fig. 6 shows unit costs for two storage control measures, illustrating their size dependence as discussed earlier. The figure compares UK numbers (values for a farm size of 85 animals) with current GAINS estimates, showing reasonable agreement.

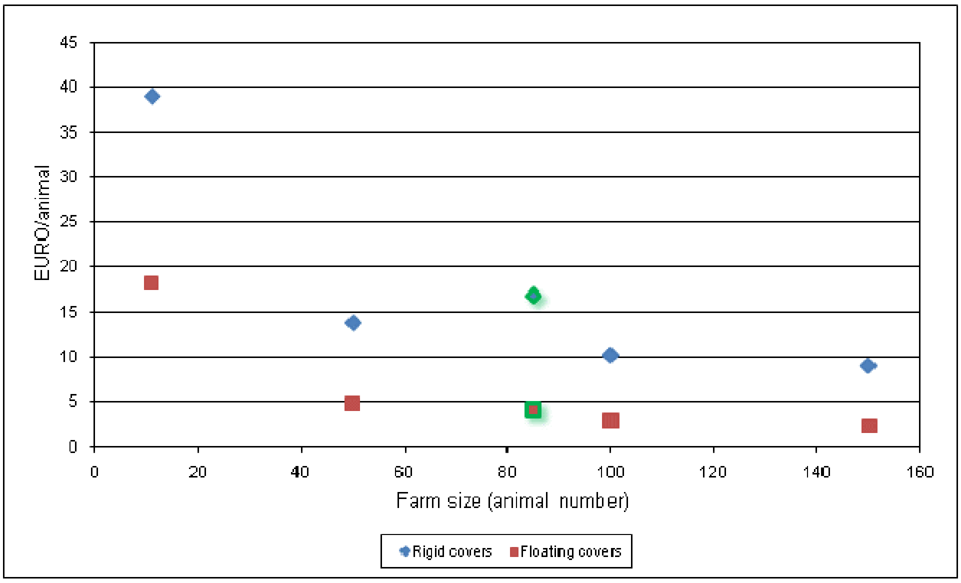

Fig. 6. Total annual costs per animal for storage of cattle manure, including elements of investments and operating costs; specific UK data are outlined in green with shading.

3.5 Marginal costs and emission control cost curves

Unit costs, as calculated in the previous section, do not necessarily provide information about the cost-effectiveness of a measure. However, information about the cost effectiveness is essential for the development of emission control strategies. Very often marginal cost curves are used to analyse cost effectiveness of different measures.

Costs as presented in the previous section refer to a change in abatement relative to a base case, i.e., the no-control situation that should be representative of the reference technology in a given country. Marginal costs relate the extra costs for an additional measure to the extra emission reduction achieved by that measure (compared to the abatement of the less effective option), allowing also to consider cases where some emission reduction measures have been taken already. GAINS uses the concept of marginal costs for ranking the available abatement options, according to their cost effectiveness, into so-called “national cost curves” (see the example of an idealized cost curve in Fig. 7).

If, for a given emission source (category), a number of control options are available, these options are sorted by their cost effectiveness. Marginal costs *mc* for control option *k* are calculated from a comparison with the next less cost-effective option *k-1*:

$$mc_k = \frac{cn_k \eta_k - cn_{k-1} \eta_{k-1}}{\eta_k - \eta_{k-1}} \qquad (12)$$

where

cn_k cost effectiveness for option k
η_k removal efficiency of option k

Marginal costs express the increment in costs for an increment in emission reduction. Sorting the available emission reduction options by increasing marginal costs delivers the cost-optimal combination of measures for a given emission reduction target. In a first step, all available capacity of the cheapest option (least marginal cost) is taken; the next step applies to the second cheapest option and so forth. Multiplying, for each step, the available capacity with the emission savings per unit (removal efficiency times emission factor) yields saved emissions, and total annual costs can be calculated as available capacity times the marginal costs. A cost curve (Fig. 7) can be constructed by stepwise subtracting the respective emission savings from the total emissions before abatement, and by adding the costs of each of the options taken. A more detailed discussion of cost curves is provided by Klimont et al. (2002).

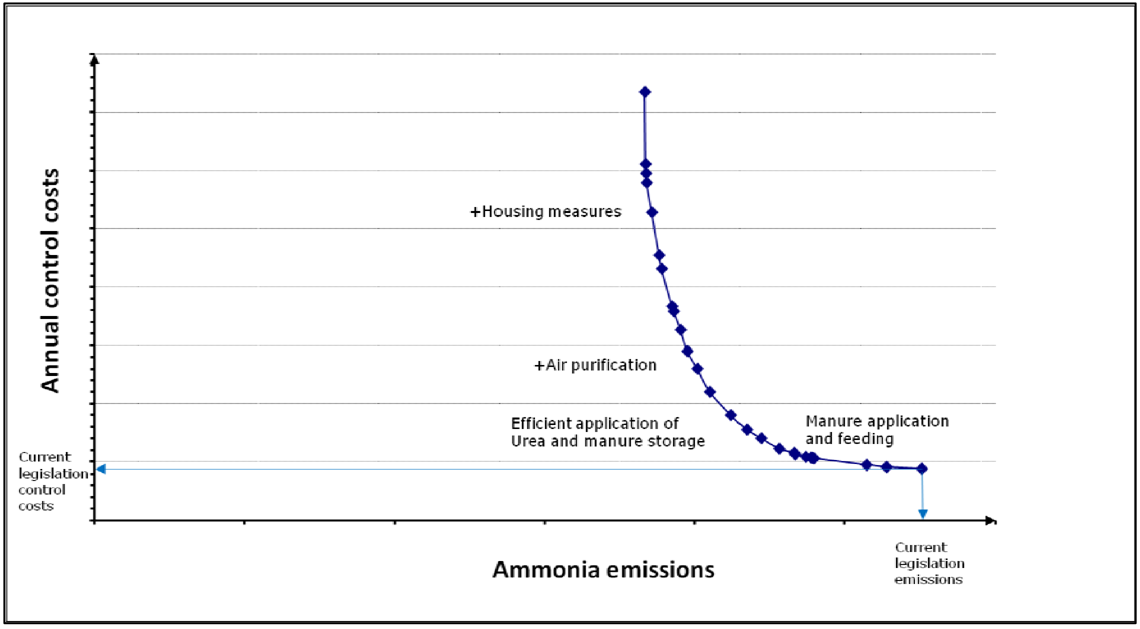

Fig. 7. Ammonia cost curve: typical example

A cost curve indicates the potential for further abatement, associated costs and the abatement measures that are necessary and cost-effective to achieve the required total emission reduction. In the example presented in Fig. 7 the starting point is reflected by the highest emissions on the right hand side, i.e., before any of the further measures are taken into account. The actual shape of the curve will depend on the respective situation in a given country, i.e., which measures are already implemented and how much potential is there for further abatement. For example, if all cheap measures have been implemented in the baseline, the curve would be typically much steeper than that shown in Fig 7.

3.6 Implementation limits (applicability) of measures

It is important to consider practical constraints for applying control measures. These constraints may be of very different nature, including soil conditions (stoniness, slope), farm practices and sizes, local regulations, and technical limitations. Such constraints are often referred to as applicability and are considered in GAINS for each country/region, animal category and abatement option. Thereby, GAINS considers that measures can only be applied to a certain extent (given as a percentage of the total activity), and no further implementation is deemed possible in the model (Annex: Table A12). A realistic assessment of these constraints is essential to provide accurate information about the total reduction potential.

In practice, the potential for implementing ammonia abatement measures in farms depends, inter alia, on the size of farms. In particular, some measures for housing and storage of manure are impractical and rather expensive for small (subsistence or "hobby") farms. Using average farm sizes in the calculations can inflate computed costs in countries with large shares of small farms, and divert attention from large farms that may still cover a sizable fraction of the animal population, where such measures would be possible at lower costs. To avoid such biases in the cost-effectiveness analysis, GAINS excludes farms smaller than 15 LSU[2], for which data are provided in the EUROSTAT statistics, from the mitigation potential. This distinction has only very little effect for countries where "industrial type" farms dominate (e.g., Netherlands, Denmark, Czech Republic), but reduces the potential (and abatement costs) for countries that have a sizeable share of "hobby" and subsistence farmers (e.g., Poland, Romania or Bulgaria).

Such an exclusion of small farms <15 LSU delivers a more realistic cost estimate of measures that actually can be introduced at larger farms, as suggested by the TFRN (document draft ECE/EB.AIR/WG.5/2011/xx dated Jan 11, 2011). However, it also implies that no measures would be possible for small farms.

For the GAINS calculations data on applicability limits have been compiled from questionnaires submitted by national experts and subsequent bilateral consultations with these experts, distinguishing between liquid and solid manure systems. The following procedure has been employed to account for exclusion of small farms:

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[2] Livestock units (LSU) intend to make animal categories comparable by defining equivalent numbers to cattle. Animal specific conversion rates used in GAINS are shown in the Annex, Table A0.

- The percentage of animals (by GAINS animal category) on farms larger than 15 LSU was extracted from the Eurostat statistics (see discussion below).
- This percentage was multiplied with the applicability rate that was determined in the previous assessment for all farms, reflecting climatic, topographical or geological conditions in a country.
- Specific consideration was given to animal categories for which liquid and solid systems are distinguished in GAINS. We assume a separation strictly by farm size, such that the largest farm on solid system is still a little bit smaller than the smallest farm on liquid system. As a consequence, applicability of measures was extended to solid systems only if they are already fully applied to liquid systems.

$$A*_{i,l} = A_{i,l} \cdot share_{i,l} \tag{13}$$

with

*A**	Applicability excluding small farms
A	Applicability (limitations according to other parameters than farm size)
i	GAINS animal category
l	country

$$share_{i,l} = nlarge_{i,l} / n_{i,l} \tag{14}$$

nlarge	number of animals on large farms
n	total number of animals

with an exemption for separation into solid and liquid systems

for liquid manure systems:

$$\left.\begin{array}{r} share_{i,l} = nlarge_{i*,l} / n_{i*,l} \\ share_{i,l} = 1 \end{array}\right\} \left\{\begin{array}{c} if \;\; share < Fl_{i*,l} \\ else \end{array}\right. \tag{14a}$$

for solid manure systems:

$$share_{i,l} = \left.\begin{array}{c} share_{i,l} = 0 \\ \dfrac{nlarge_{i*,l} / n_{i*,l} - Fl_{i*,l}}{1 - Fl_{i*,l}} \end{array}\right\} \left\{\begin{array}{c} if \;\; share \;\; for \;\; liquid \;\; system < 1 \\ else \end{array}\right. \tag{14b}$$

i^* GAINS animal category, but not differentiating manure systems ("dairy cattle", "other cattle", "pigs")

Fl GAINS fraction of animals on liquid systems

It may be argued that feeding measures (LNF) and manure application by contractors (LNA) may likewise be applied on small farms (and at costs comparable to those of large farms). As training and compliance checking might be difficult for small farms, and as the number of small farms will strongly decrease in the future, the 15 LSU threshold has been maintained as an applicability limit for LNF and LNA, unless specific information for a particular country was made available by the national experts.

Statistical data are available from EUROSTAT (http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database, table: *ef_ls_ovlsureg* – "Livestock: Number of farms and heads by livestock units (LSU) of farm and region". Note that farm sizes given in LSU comprise all animals on this farm, not only the respective GAINS animal type. We argue that, for the purpose of this exercise, costs for storage capacity should be estimated for the overall manure production, independent of how many animal categories there are in a farm.

Dividing animal numbers for each country/LSU-size class by the respective number of holdings allows deriving average animal numbers per holding for each class. Again dividing these average animal numbers by the respective utilization rate *sb* (Annex Table A11) yields the farm size *ss* in units of animal places. Calculating the weighted average (by animal number) of the classes larger than 15 LSU allows to assess the farm size an average animal is staying at, to be used as the "farm size" for the respective country. Resulting farm sizes (as animal places) are displayed in the Annex (Annex Table A2). The number of animals in all classes larger than 15 LSU divided by total number of animals provides the shares of animals on large and medium sized farms, which is needed to determine the applicability of measures.

4 Integration of TFRN cost data

The Task Force on Reactive Nitrogen (TFRN) of the UNECE Convention on Long Range Transboundary Air Pollution, in a workshop on "Costs of ammonia abatement and the climate co-benefits" (Paris, October 25-26, 2010), has provided new information on costs of ammonia control measures. The following section provides a summary of this information and describes how this new information has been considered in GAINS.

4.1 Costs of low nitrogen feed

Following van Vuuren and Oenema (2011), the variability of feed costs depends on market fluctuations rather than a change of local conditions. Prices of soybeans as alternative (low nitrogen) feed may be more expensive or cheaper than conventional feeding. Average costs, according to these authors, are estimated at 0.5 €/kg NH_3-N abated (for the most ambitious and thus most expensive reduction target of 15%, which is used in GAINS), excluding grazing animals. As phase feeding operations may be in place already for the farm sizes considered, GAINS does not include investments for this option; this results for most countries in additional feed costs of 2 (cattle and pigs), 5 (poultry) and 8 (laying hens) Euro-cents per 100 kg feed, which is much lower than what has been considered in GAINS before.

4.2 Costs for animal housing

New information on animal housing (Pineiro et al., 2011) supports the assumptions currently used in GAINS and therefore cost data in GAINS were left unchanged.

Relevant for housing emissions, however, are also chemical scrubbers for cleaning exhaust air as they are used for PM abatement as well. The GAINS “BF” (originally: biofiltration) option is now used to cover that abatement measure. Scrubbers will not produce waste (thus amount of waste to be disposed is set to zero), and fixed investment costs are lower than assumed for biofuels. With costs of 30, 3 and 1.5 € per animal place for pigs, layers and other poultry (about half the previous GAINS values, all other parameters unchanged), respectively, abatement costs emerge for most countries near 10 €/kg NH_3-N as suggested by Pineiro et al. (2011).

4.3 Costs for storage

Discussions at the TFRN workshop (see a comprehensive overview prepared by Bittman et al., 2011) seemed to confirm the cost data that are currently used in GAINS for manure storage. Per m³ storage capacity and year, costs range at <1 € / m³ for low efficiency measures, ~40% reduction; <5 € / m³ for high efficiency measures, ~80% reduction, which can be expressed as up to 2 €/kg NH_3-N (low efficiency) and up to 4 €/kg NH_3-N abated (high efficiency measures). Thus, the GAINS implementation of costs for storage was not altered. These cost data, that apply for the particular stage, could be even lower, although there is large variability between countries. As a conservative estimate, the lower end of the cost range of measures considered in GAINS tends to coincide with the upper end of data presented by Bittman et al. (2011). However, GAINS costs cover lid construction only (for high efficiency options), i.e., does not include costs of building the tank itself.

4.4 Costs for manure spreading

New evidence presented at the workshop (Webb et al., 2011) demonstrates differences in costs depending on the utilization of equipment. For large farms or for contractors performing the work, investments will decrease in importance as contractors would operate clearly cheaper. In a cost-optimized approach, small or medium sized farms would not choose the more costly option of buying own equipment, but rely on contractor work instead. Costs depend on labour costs and other country-specific parameters; GAINS assumes 0.52 €/m³ manure spread. Solid manure can be added to arable land only (immediate incorporation) at slightly higher costs (0.70 €/m³; see Webb et al. ,2011, for details). Notably, these cost estimates apply to manure spreading from housing only, i.e., for the time animals stay inside houses. This is different to storage/housing, as for these processes the size of installations might be adapted to seasons when animals are indoors over extended periods. Recent experience indicates costs of this measure below 1 €/kg NH_3-N, and even lower for the high efficiency options.

5 Results and discussion

To maintain a balance between more country-specific detail and a practical Europe-wide approach for the assessment of ammonia emissions control costs, GAINS uses a uniform methodology for all countries with country-specific input data that reflect structural differences across countries, which justify differences in emission control costs in an objective way. However, comparison of the outcomes of such an approach with country-specific studies are often difficult, as national studies report cost data in different formats and employ different definitions and assumptions.

A way to facilitate comparisons of cost data from different studies is to relate costs of measures to the amount of ammonia abated (*cn* as derived in Eq. (11)). The following figures (Fig. 8-16) provide abatement costs in €/kg NH_3-N abated. The acronyms of measures are those of Table 1, with "covered storage" CS and "low-ammonia application" divided into high-efficiency and low-efficiency measures each, as described above. Results are presented by animal category, and ranges display minimum and maximum values computed for the European countries (as the extremes of the lines) as well as 25-percentile and 75-percentile as the upper and lower end of the main bar for each of the elements in this bar chart. In a few cases, extreme outliers have been removed from the charts (but not from the GAINS model).

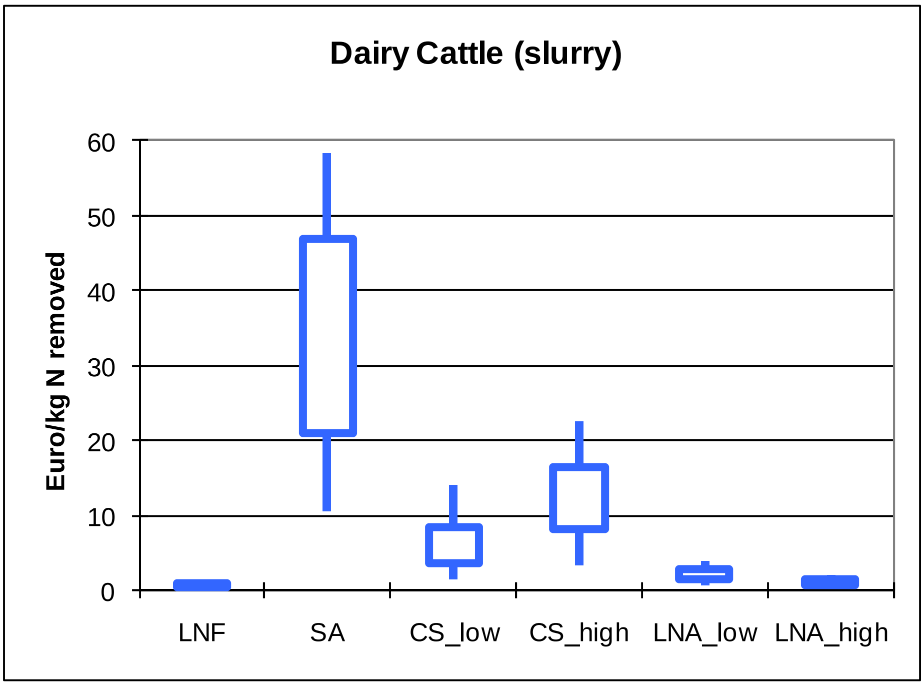

Fig. 8. Abatement costs per abated ammonia nitrogen for dairy cows (liquid manure systems)

As shown in Fig. 8, despite considerable variability between countries, the cost-effective ranking of measures remains consistent for dairy cows. Low nitrogen feed (LNF) as well as low ammonia application techniques (LNA) are clearly the most cost-effective measures. It is interesting to note that high efficiency methods in manure application come with lower costs per ammonia abatement. Thus the low efficiency methods, even as they seem to be cheaper at first sight, will not be chosen in a cost-effectiveness analysis. Results are similar for other cattle (Fig. 9), only that costs are somewhat higher. As other cattle usually spends less time indoors, all investments for indoor measures (animal houses of covered storage) will apply to part of emissions only, during time spent indoors, thus being less cost-effective.

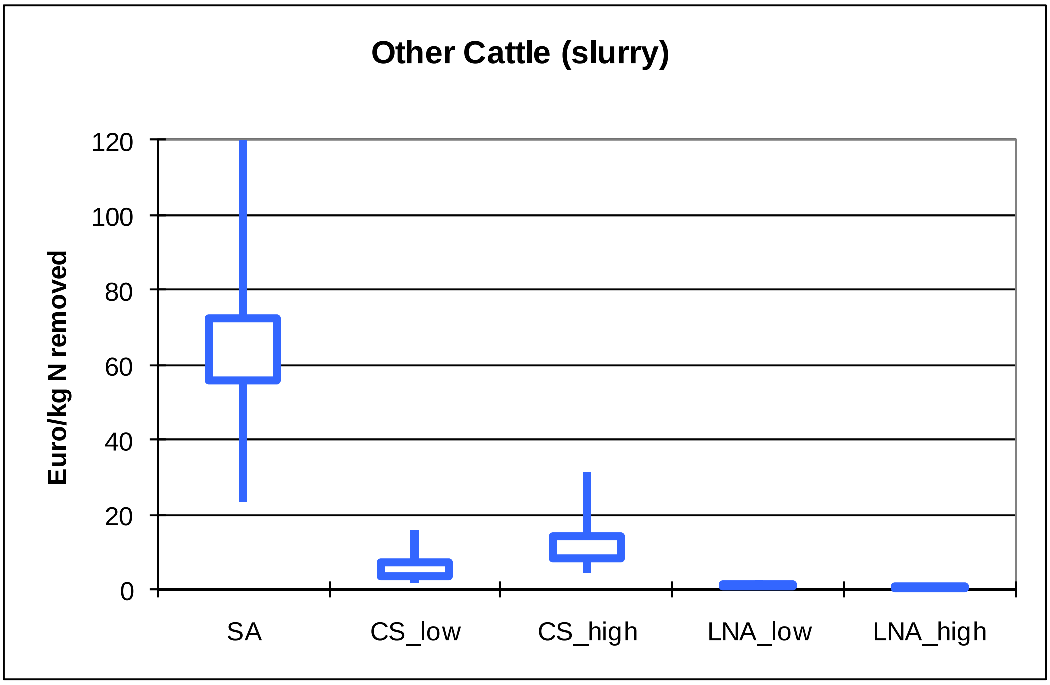

Fig. 9. Abatement costs per abated ammonia nitrogen for other cattle (liquid manure systems) Each bar ranges from the 25th to the 75th percentile of countries in GAINS, with minima and maxima represented by upper and lower end of vertical lines.

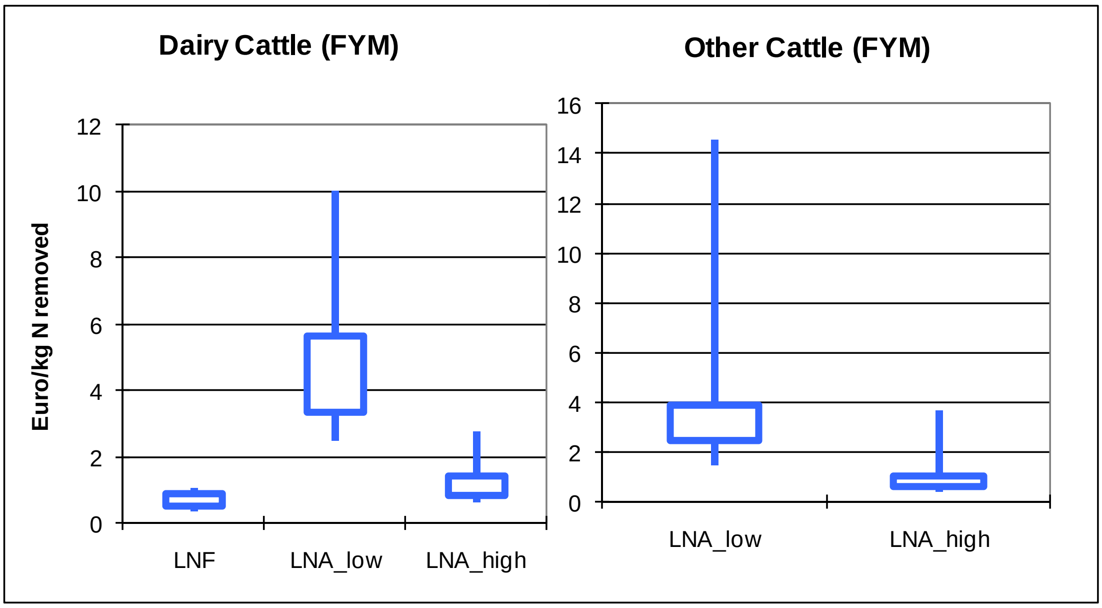

Fig. 10. Abatement costs per abated ammonia nitrogen for cattle (solid manure systems)

Solid manure systems for cattle (Fig. 10) show larger scatter between countries, which mostly results from larger extreme values. Again, high efficiency measures of manure application appear as cost-effective.

Costs of measures for ammonia abatement at pig farms are comparable to those at cattle farms. As pigs spend all of their time indoors in most countries, even covered manure storages become a cost effective option (Fig. 11 and Fig. 12).

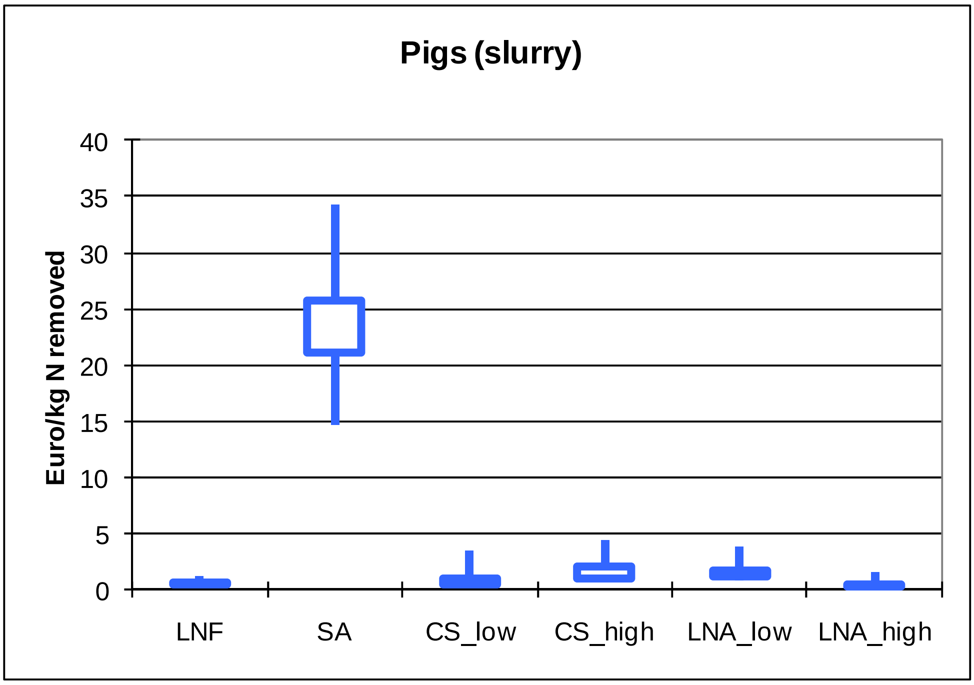

Fig. 11. Abatement costs per abated ammonia nitrogen for pigs (liquid manure systems)

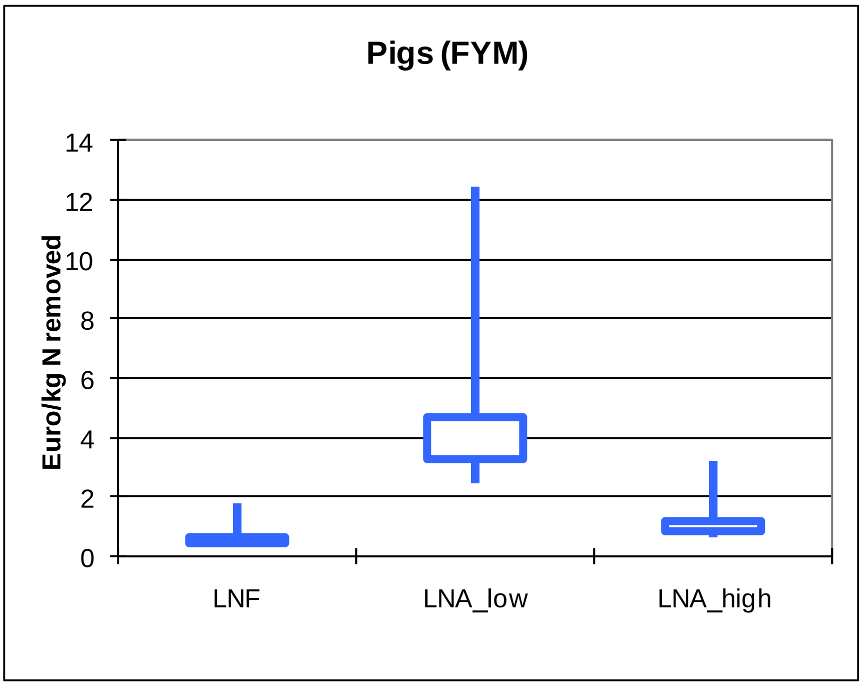

Fig. 12. Abatement costs per abated ammonia nitrogen for pigs (solid manure systems)

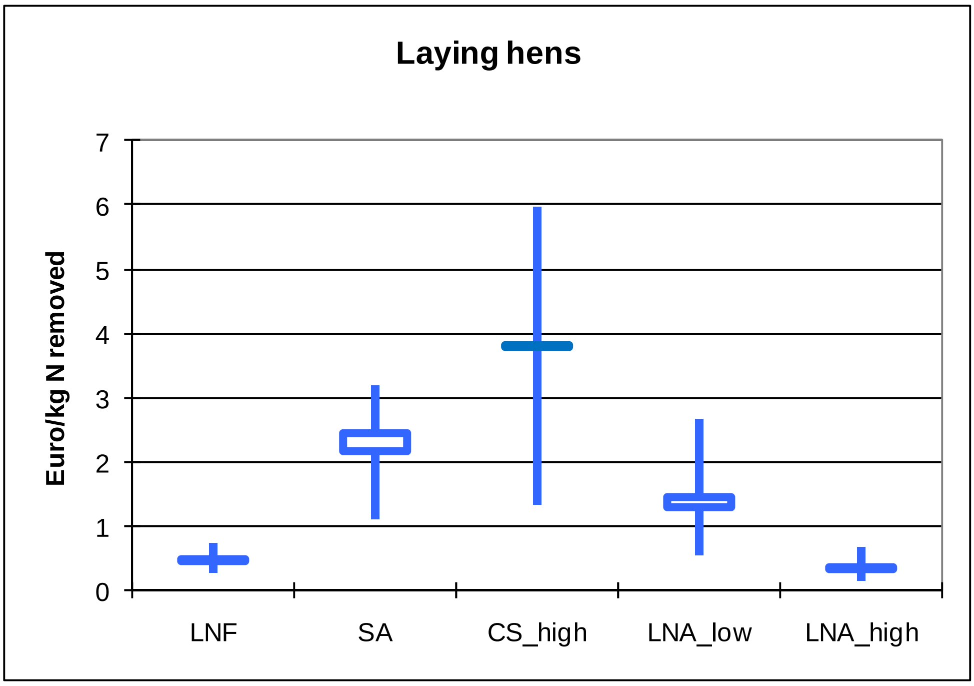

Fig. 13. Abatement costs per abated ammonia nitrogen for laying hens

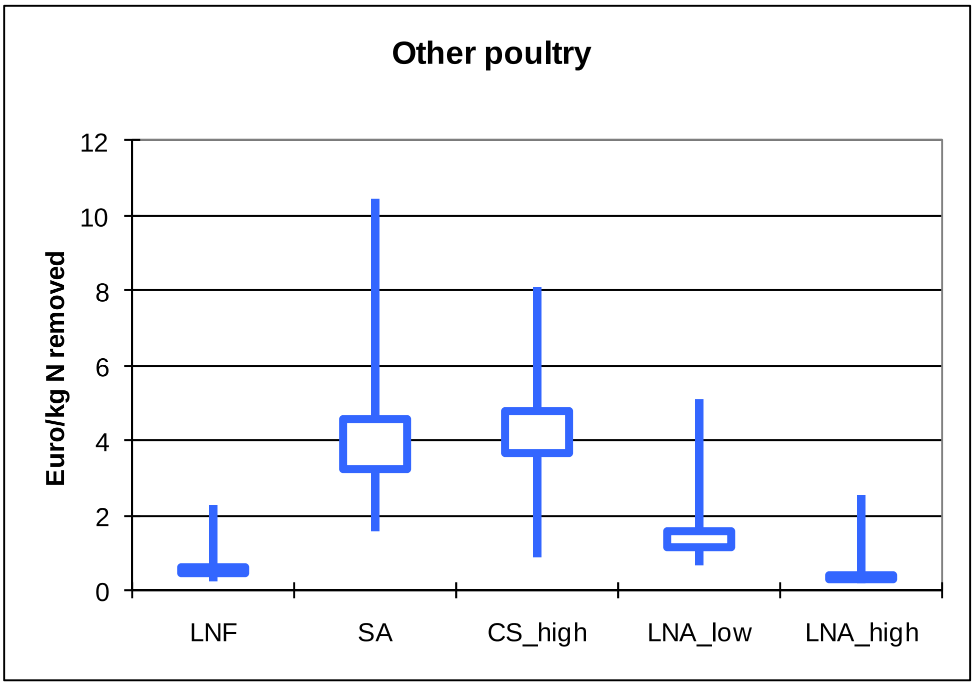

Fig. 14. Abatement costs per abated ammonia nitrogen for other poultry

Although for poultry cost estimates are somewhat different (Fig. 13 and Fig. 14), the main messages about efficiency of feeding and manure application hold. Relative to cattle and pigs, poultry offers more opportunities to reduce emissions from housing (SA), although costs are at the upper end of the range.

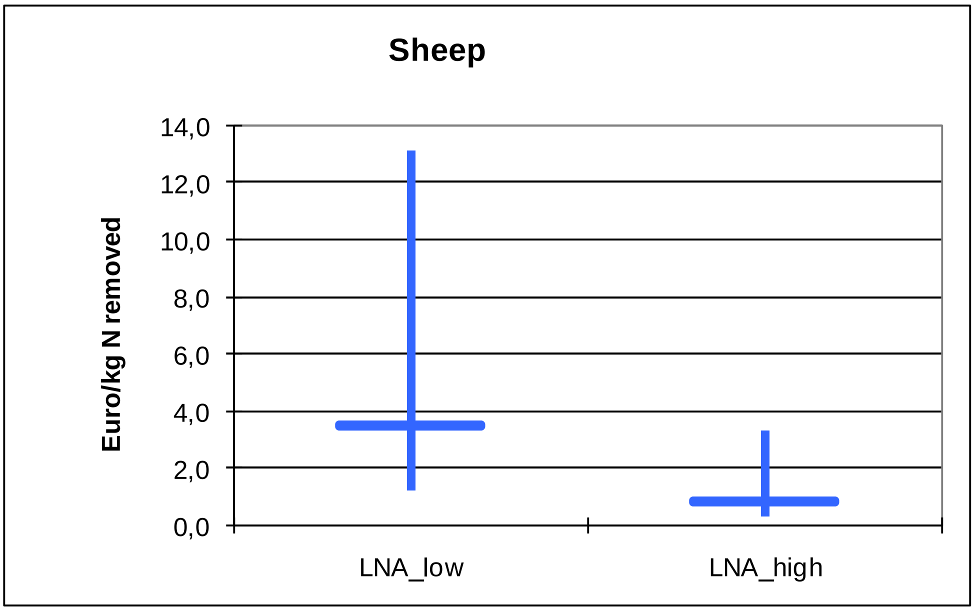

Fig. 15. Abatement costs per abated ammonia nitrogen for sheep

For sheep, there is clear indication for the cost-effectiveness of high-efficiency application measures (for the periods sheep are kept indoors). As most national estimates refer to the same source of information, the range from the 25th to the 75th percentile of countries is shown as a single horizontal line. However, this does rather indicate lack of data rather than reliability of results.

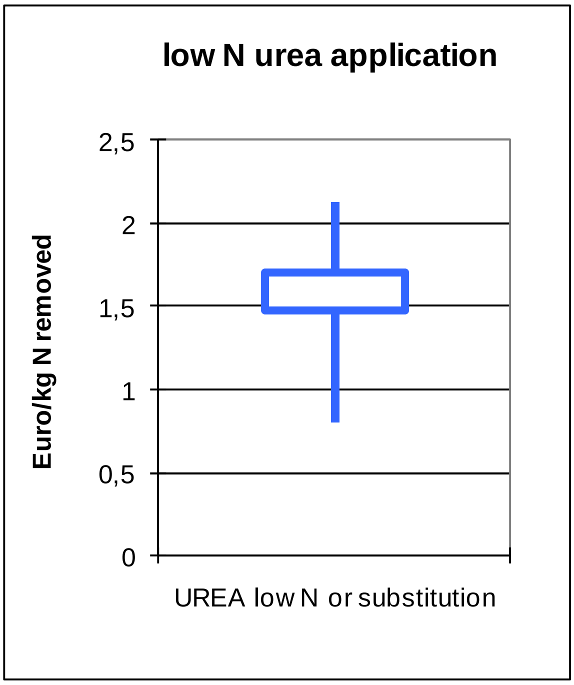

Fig. 16. Abatement costs per abated ammonia nitrogen for low ammonia emission urea application methods or substitution with ammonium nitrate

Using techniques to reduce ammonia from urea application, or substitution of urea are cost-effective abatement methods for most countries and are treated here as one option, although costs differ considerably across countries (Fig. 16).

In general, differences in emission control costs across countries are often caused by differences in emission factors that have been reported by countries in their national inventories. Low emission factors at a particular emission stage imply high control costs as, given a fixed removal efficiency, only a small amount of ammonia will be removed. Since abatement costs for a given measure are assumed independent of the emission factor, costs related to removed ammonia will be high. Although emission factors are influenced, inter alia, by agricultural practices in a country, in many cases low emission factors in national inventories seem to be motivated by different interpretations of the reference technology. This is especially the case for the stage of manure storage, where calculated abatement costs result in extreme values. Such extreme abatement costs were removed from the graphical display when it was clear that these factors would not play a role in any model calculations.

In general, if uncertainties prevail, GAINS attempts to arrive at a conservative estimate in terms of mitigation potentials (i.e., it does not include additional potential that is less certain). Also cost estimates are conservative, as they exclude potential cost decreases due to larger experience and wider penetration. Such cost decreases are realistic, as shown again by recent experience with low nitrogen application of manure techniques. So, in general, GAINS results in ammonia abatement measures should be expected to rather result in smaller reductions than eventually can be realized, and to be available at somewhat lower costs.

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ANNEX

Table A0: Livestock categories, GAINS codes (as used in further tables of this Annex), and LSU's per head

Livestock	Comments	GAINS code	LSU
Dairy cows	Excluding suckling cows; distinguishing between liquid and solid manure systems	DL, DS	0.90
Other cattle	All other cattle incl. bulls, beef cattle, suckling cows, youngstock; distinguishing between liquid and solid manure systems	OL, OS	0.90
Pigs	Including fattening pigs and sows; distinguishing between liquid and solid manure systems	PL, PS	0.25
Laying hens		LH	0.01
Other poultry	All poultry except laying hens, including broilers, turkeys, ducks, geese, etc	OP	0.03
Sheep and goats		SH	0.10
Fur animals	In some countries this category might be used for other animals, e.g., rabbits	FU	0.02
Horses	Including mules and asses	HO	0.80

Table A1: Ammonia abatement technology-specific parameters used in the GAINS model

Abatement technique	Livestock category	Investment function coefficients [EUR2005] ci^f	ci^v	Equip-ment lifetime [years] lt
Low nitrogen feed	DL	0	0	10
Low nitrogen feed	DS	0	0	10
Low nitrogen feed	PL	0	0	10
Low nitrogen feed	PS	0	0	10
Low nitrogen feed	LH	0	0	10
Low nitrogen feed	OP	0	0	10
Low emission housing	DL	459.	2631	10
Low emission housing	OL	459.	2631	10
Low emission housing	PL	117.	116	10
Low emission housing	LH	1.08	0	10
Low emission housing	OP	2.34	0	10
Covered storage of manure - high efficiency	DL	1.18	2799	15
Covered storage of manure - low efficiency	DL	0.176	1445	10
Covered storage of manure - high efficiency	OL	1.18	2799	15
Covered storage of manure - low efficiency	OL	0.176	1445	10
Covered storage of manure - high efficiency	PL	1.18	2799	15
Covered storage of manure - low efficiency	PL	0.176	1445	10
Covered storage of manure - high efficiency	LH	1.18	0	15
Covered storage of manure - low efficiency	LH	0.176	0	10
Covered storage of manure - high efficiency	OP	1.18	0	15
Covered storage of manure - low efficiency	OP	0.176	0	10
Covered storage of manure - high efficiency	SH	1.18	0	15
Covered storage of manure - low efficiency	SH	0.176	0	10
Air purification	PL	30	3291	10
Air purification	PS	30	3291	10
Air purification	LH	3	0	10
Air purification	OP	1.5	0	10

Table A2: Country-specific parameters: farm size (number of animal places per farm by livestock category)

	Country	ISSDL	ISSDS	ISSOL	ISSOS	ISSPL	ISSPS	ISSLH	ISSOP	ISSSH
		Dairy cows liquid - solid		Other cattle liquid - solid		Pigs liquid - solid		Laying hens	Other poultry	sheep
ALBA	Albania	72	3	134	5	5710	3	69092	175361	197
AUST	Austria	18	6	49	16	369	8	11019	20166	21
BELA	Belarus	125	3	295	7	9495	3	163197	328287	125
BELG	Belgium	45	6	149	16	1417	30	31656	31553	53
BOHE	Bosnia-Herc.	72	3	134	5	5710	3	69092	175361	197
BULG	Bulgaria	72	3	134	5	5710	3	69092	175361	197
CROA	Croatia	72	3	134	5	5710	3	69092	175361	197
CYPR	Cyprus	106	1	255	9	6474	9	8702	122557	377
CZRE	Czech Rep	355	4	807	12	3383	12	127457	112234	93
DENM	Denmark	132	6	208	17	3429	28	16508	91024	98
ESTO	Estonia	311	4	611	10	5092	5	6156	5059	287
FINL	Finland	29	9	90	19	1105	66	16595	39626	107
FRAN	France	48	9	143	15	1577	9	51202	15913	227
GERM	Germany	105	8	206	16	1284	24	65335	83393	258
GREE	Greece	62	6	105	11	2063	9	25940	76048	218
HUNG	Hungary	411	5	789	9	7444	7	59687	131427	419
IREL	Ireland	60	7	116	16	6234	6	15135	50072	203
ITAL	Italy	108	7	275	13	3870	5	92783	109846	224
LATV	Latvia	115	3	212	8	4442	6	220040	3638	63
LITH	Lithuania	125	3	295	7	9495	3	163197	328287	125

	Country	ISSDL	ISSDS	ISSOL	ISSOS	ISSPL	ISSPS	ISSLH	ISSOP	ISSSH
LUXE	Luxembourg	43	4	181	18	1020	1	337	292	48
MALT	Malta	69	2	157	11	504	1	10273	10591	26
MACE	Macedonia	72	3	134	5	5710	3	69092	175361	197
MOLD	Moldova	125	3	295	7	9495	3	163197	328287	125
NETH	Netherlands	75	7	178	15	2473	31	50458	79651	129
NORW	Norway	23	9	68	18	409	41	20586	56190	198
POLA	Poland	39	4	94	7	1458	21	59940	50395	86
PORT	Portugal	79	6	210	10	2434	5	62992	21887	231
ROMA	Romania	36	2	94	3	12364	2	98311	249095	320
RUSS	Russia (Eur.)	125	3	295	7	9495	3	163197	328287	125
SKRE	Slovakia	317	2	726	4	2596	5	116725	184750	492
SLOV	Slovenia	19	5	43	11	8911	7	792	13271	57
SPAI	Spain	75	8	173	14	2524	8	51262	26994	530
SWED	Sweden	80	9	152	17	1748	45	46639	96121	132
SWIT	Switzerland	18	6	49	16	369	8	11019	20166	21
UKRA	Ukraine	125	3	295	7	9495	3	163197	328287	125
UNKI	United Kingd.	112	3	218	15	2131	17	44505	137491	952
SEMO	Serbia Mont.	72	3	134	5	5710	3	69092	175361	197

Table A3: Country-specific parameters: Manure production per animal per year (m^3 per individ. animal and year)

	Country	PMDL	PMDS	PMOL	PMOS	PMPL	PMPS	PMLH	PMOP	PMSH
		Dairy cows liquid - solid		Other cattle liquid - solid		Pigs liquid - solid		Laying hens	Other poultry	sheep
ALBA	Albania	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
AUST	Austria	22	16	9.58	7.2	0.9	0.9	0.061	0.0049	1.2
BELA	Belarus	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
BELG	Belgium	22	16	11.28	8.5	0.9	0.9	0.061	0.0035	1.2
BOHE	Bosnia-Herc.	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
BULG	Bulgaria	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
CROA	Croatia	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
CYPR	Cyprus	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
CZRE	Czech Rep	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
DENM	Denmark	21	20.3	10.08	7.55	0.95	0.95	0.061	0.0038	1.2
ESTO	Estonia	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
FINL	Finland	24	18	15	11.25	1.14	1.14	0.05	0.0025	1.5
FRAN	France	22	16	12.1	9.1	1.02	1.02	0.061	0.0066	1.2
GERM	Germany	20	16	11.6	9	1.04	1.04	0.09	0.005	1.2
GREE	Greece	22	16	11.97	9	1.09	1.09	0.061	0.0049	1.2
HUNG	Hungary	22	16	8.34	6.3	0.97	0.97	0.061	0.005	1.2
IREL	Ireland	22	16	14.22	10.7	1.01	1.01	0.061	0.0049	1.2
ITAL	Italy	26	19.5	13.6	10.2	1	1	0.061	0.0049	1.2
LATV	Latvia	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
LITH	Lithuania	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2

	Country	PMDL	PMDS	PMOL	PMOS	PMPL	PMPS	PMLH	PMOP	PMSH
LUXE	Luxembourg	22	16	13.31	10	1.06	1.06	0.061	0.0049	1.2
MALT	Malta	22	16	8.34	6.3	1.06	1.06	0.061	0.0049	1.2
MACE	Macedonia	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
MOLD	Moldova	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
NETH	Netherlands	22.8	17.1	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
NORW	Norway	18	14	10.57	7.9	0.8	0.8	0.061	0.0049	1.2
POLA	Poland	18	14.6	8	6	0.8	0.63	0.048	0.0049	1.2
PORT	Portugal	19	14.3	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
ROMA	Romania	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
RUSS	Russia (Eur.)	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
SKRE	Slovakia	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
SLOV	Slovenia	22	16	8.34	6.3	0.97	0.97	0.061	0.0037	1.2
SPAI	Spain	22	16	12.62	9.5	1.02	1.02	0.061	0.0049	1.2
SWED	Sweden	22	16	8	6	0.8	0.8	0.05	0.0043	1.2
SWIT	Switzerland	20	16	10.46	7.85	0.85	0.85	0.061	0.004	1.2
UKRA	Ukraine	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2
UNKI	United Kingd.	20.8	15.6	8.2	6.15	1.4	1.05	0.043	0.0073	2.1
SEMO	Serbia Mont.	22	16	8.34	6.3	0.97	0.97	0.061	0.0049	1.2

Table A4: Country-specific parameters: storage time by livestock category (months)

	Country	STDL	STDS	STOL	STOS	STPL	STPS	STLH	STOP	STSH
		Dairy cows liquid - solid		Other cattle liquid - solid		Pigs liquid - solid		Laying hens	Other poultry	sheep
ALBA	Albania	4	4	4	4	4	4	4	4	4
AUST	Austria	5	5	5	5	5	5	5	5	5
BELA	Belarus	4	4	4	4	4	4	4	4	4
BELG	Belgium	4	4	4	4	4	4	4	4	4
BOHE	Bosnia-Herc.	4	4	4	4	4	4	4	4	4
BULG	Bulgaria	4	4	4	4	4	4	4	4	4
CROA	Croatia	4	4	4	4	4	4	4	4	4
CYPR	Cyprus	4	4	4	4	4	4	4	4	4
CZRE	Czech Rep	4	4	4	4	4	4	4	4	4
DENM	Denmark	8	8	8	8	9	9	7	7	7
ESTO	Estonia	5	5	5	5	5	5	5	5	5
FINL	Finland	12	12	12	12	12	12	12	12	12
FRAN	France	4	4	4	4	4	4	4	4	4
GERM	Germany	7	7	7	7	8	8	4	4	4
GREE	Greece	4	4	4	4	4	4	4	4	4
HUNG	Hungary	4	4	4	4	4	4	4	4	4
IREL	Ireland	9	9	9	9	5	5	15	15	10
ITAL	Italy	5	4	5	4	4	3	2	2	9
LATV	Latvia	9	9	9	9	9	9	12	12	12
LITH	Lithuania	4	4	4	4	4	4	4	4	4

	Country	STDL	STDS	STOL	STOS	STPL	STPS	STLH	STOP	STSH
LUXE	Luxembourg	4	4	4	4	4	4	4	4	4
MALT	Malta	4	4	4	4	4	4	4	4	4
MACE	Macedonia	4	4	4	4	4	4	4	4	4
MOLD	Moldova	4	4	4	4	4	4	4	4	4
NETH	Netherlands	6	4	6	4	8	8	6	6	2
NORW	Norway	8	12	8	12	8	8	8	8	6
POLA	Poland	3	3	3	3	3	3	3	3	3
PORT	Portugal	6	6	6	6	5	5	5	5	12
ROMA	Romania	4	4	4	4	4	4	4	4	4
RUSS	Russia (Eur.)	6	6	6	6	6	6	6	6	6
SKRE	Slovakia	4	4	4	4	4	4	4	4	4
SLOV	Slovenia	4	4	4	4	4	4	4	4	4
SPAI	Spain	4	4	4	4	4	4	4	4	4
SWED	Sweden	9	7	9	7	9	7	7	7	7
SWIT	Switzerland	5	5	5	5	5	5	5	5	3
UKRA	Ukraine	4	4	4	4	4	4	4	4	4
UNKI	United Kingd.	4	4	3	3	6	6	6	6	6
SEMO	Serbia Mont.	4	4	4	4	4	4	4	4	4

Table A5: Country-specific parameters: animal production cycles per year by livestock category)

	Country	ARDL	ARDS	AROL	AROS	ARPL	ARPS	ARLH	AROP	ARSH
		Dairy cows liquid - solid		Other cattle liquid - solid		Pigs liquid - solid		Laying hens	Other poultry	sheep
ALBA	Albania	1	1	0.9	0.9	2	2	0.8	6.08	1
AUST	Austria	1	1	0.9	0.9	2.5	2.5	0.8	6.08	1
BELA	Belarus	1	1	0.9	0.9	2	2	0.8	6.08	1
BELG	Belgium	1	1	0.5	0.5	2.5	2.5	1.08	8.6	1
BOHE	Bosnia-Herc.	1	1	0.9	0.9	2	2	0.8	6.08	1
BULG	Bulgaria	1	1	0.9	0.9	2	2	0.8	6.08	1
CROA	Croatia	1	1	0.9	0.9	2	2	0.8	6.08	1
CYPR	Cyprus	1	1	0.9	0.9	2	2	0.8	6.08	1
CZRE	Czech Rep	1	1	0.9	0.9	2	2	0.8	6.08	1
DENM	Denmark	1	1	0.9	0.9	2	2	0.82	8	1
ESTO	Estonia	1	1	0.9	0.9	2	2	0.8	6.08	1
FINL	Finland	1	1	0.9	0.9	3	3	1	6.08	1
FRAN	France	1	1	0.9	0.9	2	2	0.8	6.08	1
GERM	Germany	1	1	0.9	0.9	2.4	2.4	1	8	1
GREE	Greece	1	1	0.9	0.9	2	2	0.8	6.08	1
HUNG	Hungary	1	1	0.9	0.9	2.2	2.2	0.86	7	1
IREL	Ireland	1	1	0.9	0.9	2	2	0.8	6.08	1
ITAL	Italy	1	1	0.9	0.9	2	2	0.8	6.08	1
LATV	Latvia	1	1	0.9	0.9	2	2	0.8	6.08	1
LITH	Lithuania	1	1	0.9	0.9	2	2	0.8	6.08	1

	Country	ARDL	ARDS	AROL	AROS	ARPL	ARPS	ARLH	AROP	ARSH
LUXE	Luxembourg	1	1	0.9	0.9	2	2	0.8	6.08	1
MALT	Malta	1	1	0.9	0.9	2	2	0.8	6.08	1
MACE	Macedonia	1	1	0.9	0.9	2	2	0.8	6.08	1
MOLD	Moldova	1	1	0.9	0.9	2	2	0.8	6.08	1
NETH	Netherlands	1	1	0.9	0.9	2	2	0.8	6.08	1
NORW	Norway	1	1	0.9	0.9	2	2	0.8	6.08	1
POLA	Poland	1	1	0.9	0.9	2	2	0.8	6.1	1
PORT	Portugal	1	1	0.9	0.9	2	2	0.8	6.08	1
ROMA	Romania	1	1	0.9	0.9	2	2	0.8	6.08	1
RUSS	Russia (Eur.)	1	1	0.9	0.9	2	2	0.8	6.08	1
SKRE	Slovakia	1	1	0.9	0.9	2	2	0.8	6.08	1
SLOV	Slovenia	1	1	0.55	0.55	1.74	1.74	1	8.1	1
SPAI	Spain	1	1	0.9	0.9	2	2	0.8	6.08	1
SWED	Sweden	1	1	1.5	1.5	3	3	0.83	7	1
SWIT	Switzerland	1	1	0.9	0.9	3.2	3.2	0.77	7.5	1
UKRA	Ukraine	1	1	0.9	0.9	2	2	0.8	6.08	1
UNKI	United Kingd.	1	1	1	1	2.3	2.3	0.8	6.6	1
SEMO	Serbia Mont.	1	1	0.9	0.9	2	2	0.8	6.08	1

Table A6: Additional demand (quantity Q) for commodities to operate specific abatement (per individual animal and year)

Abatement technique	Livestock Cat.	QFI Feed (100 kg / animal)	QG Gas (m^3 / animal)	QE Electricity (kWh / animal)	QL Labour (hr / animal)	QW Water (m^3 / animal)	QD Waste disposed
Low nitrogen feed	DL	65	0	0	0.01	0	0
Low nitrogen feed	DS	65	0	0	0.01	0	0
Low nitrogen feed	PL	7	0	0	0	0	0
Low nitrogen feed	PS	7	0	0	0	0	0
Low nitrogen feed	LH	0.462	0	0	0	0	0
Low nitrogen feed	OP	0.0332	0	0	0	0	0
Low emission housing	DL	0	0	0	0	0	0
Low emission housing	OL	0	0	0	0	0	0
Low emission housing	PL	0	0	0	0	0	0
Low emission housing	LH	0	0.25	1	0	0	0
Low emission housing	OP	0	0	0	0	0	0
Covered storage of manure - high efficiency	DL	0	0	0	0	0	0
Covered storage of manure - low efficiency	DL	0	0	0	0	0	0
Covered storage of manure - high efficiency	OL	0	0	0	0	0	0
Covered storage of manure - low efficiency	OL	0	0	0	0	0	0
Covered storage of manure - high efficiency	PL	0	0	0	0	0	0
Covered storage of manure - low efficiency	PL	0	0	0	0	0	0
Covered storage of manure - high efficiency	LH	0	0	0	0	0	0
Covered storage of manure - low efficiency	LH	0	0	0	0	0	0

Abatement technique	Livestock Cat.	QFI	QG	QE	QL	QW	QD
Covered storage of manure - high efficiency	OP	0	0	0	0	0	0
Covered storage of manure - low efficiency	OP	0	0	0	0	0	0
Covered storage of manure - high efficiency	SH	0	0	0	0	0	0
Covered storage of manure - low efficiency	SH	0	0	0	0	0	0
Air purification	PL	0	0	16	0.089	0.57	0
Air purification	PS	0	0	16	0.089	0.57	0
Air purification	LH	0	0	10.2	0	0.0915	0
Air purification	OP	0	0	1.34	0	0.0121	0

Table A7: Generic parameters to calculate operating costs

Abatement technique	Livestock Cat.	FK fixed operation costs (%)	CF additional feed costs (EUR2005 / 100 kg)
Low nitrogen feed	DL	0	0.03
Low nitrogen feed	DS	0	0.03
Low nitrogen feed	PL	0	0.03
Low nitrogen feed	PS	0	0.03
Low nitrogen feed	LH	0	0.08
Low nitrogen feed	OP	0	0.05
Low emission housing	DL	0.08	0
Low emission housing	OL	0.08	0
Low emission housing	PL	0.08	0
Low emission housing	LH	0	0
Low emission housing	OP	0	0
Covered storage of manure - high efficiency	DL	0.05	0
Covered storage of manure - low efficiency	DL	0.02	0
Covered storage of manure - high efficiency	OL	0.05	0
Covered storage of manure - low efficiency	OL	0.02	0
Covered storage of manure - high efficiency	PL	0.05	0
Covered storage of manure - low efficiency	PL	0.02	0
Covered storage of manure - high efficiency	LH	0.05	0
Covered storage of manure - low efficiency	LH	0.02	0.00
Covered storage of manure - high efficiency	OP	0.05	0.00
Covered storage of manure - low efficiency	OP	0.02	0.00
Covered storage of manure - high efficiency	SH	0.05	0.00
Covered storage of manure - low efficiency	SH	0.02	0.00
Air purification	PL	0.03	0.00
Air purification	PS	0.03	0.00
Air purification	LH	0.04	0.00
Air purification	OP	0.04	0.00

Table A8: Country-specific parameters: manure application rate and commodity costs

	Country	QMH manure appl.rate [m³ per ha]	CE electricity costs [EUR2005/ kWh]	CK fertilizer costs [EUR2005/ kg N]	CG gas costs [EUR2005/ m³]	CL Labour costs [EUR2005/ hr]	CW Water costs [EUR2005/ m³]	CD Disposal costs [EUR2005/ m³]
ALBA	Albania	18	0.083372	0.7679	0.28522	1.3164	0.59238	30.2772
AUST	Austria	13	0.060335	0.84469	0.28522	20.2945	0.59238	30.2772
BELA	Belarus	16	0.048268	0.39492	0.28522	4.0589	0.59238	30.2772
BELG	Belgium	39	0.06582	0.84469	0.28522	23.2564	0.59238	30.2772
BOHE	Bosnia-Herc.	9	0.083372	0.7679	0.28522	3.4007	0.59238	30.2772
BULG	Bulgaria	11	0.06582	0.84469	0.28522	1.8649	0.59238	30.2772
CROA	Croatia	9	0.06582	0.7679	0.28522	7.0208	0.59238	30.2772
CYPR	Cyprus	9	0.06582	0.84469	0.28522	9.7633	0.59238	30.2772
CZRE	Czech Rep	13	0.06582	0.84469	0.12067	5.9238	0.59238	30.2772
DENM	Denmark	22	0.06582	0.84469	0.57044	22.0497	0.59238	30.2772
ESTO	Estonia	16	0.06582	0.7679	0.28522	3.8395	0.59238	30.2772
FINL	Finland	10	0.06582	0.84469	0.12067	26.1086	0.59238	30.2772
FRAN	France	13	0.06582	0.84469	0.28522	22.3788	0.59238	30.2772
GERM	Germany	22	0.06582	0.7679	0.28522	22.5982	0.59238	30.2772
GREE	Greece	8	0.06582	0.84469	0.28522	10.97	0.59238	30.2772
HUNG	Hungary	8	0.06582	0.84469	0.14261	6.1432	0.59238	30.2772
IREL	Ireland	17	0.06582	0.84469	0.28522	17.7714	0.59238	30.2772
ITAL	Italy	12	0.06582	0.7679	0.28522	21.8303	0.59238	30.2772

	Country	QMH	CE	CK	CG	CL	CW	CD
LATV	Latvia	16	0.06582	0.84469	0.28522	6.0335	0.59238	30.2772
LITH	Lithuania	16	0.06582	0.84469	0.28522	3.5104	0.59238	30.2772
LUXE	Luxembourg	39	0.06582	0.84469	0.28522	24.3534	0.59238	30.2772
MALT	Malta	39	0.06582	0.84469	0.28522	9.7633	0.59238	30.2772
MACE	Macedonia	9	0.06582	0.84469	0.28522	1.8649	0.59238	30.2772
MOLD	Moldova	16	0.048268	0.84469	0.28522	2.8522	0.59238	30.2772
NETH	Netherlands	40	0.06582	0.84469	0.28522	22.7079	0.59238	30.2772
NORW	Norway	24	0.06582	0.84469	0.28522	22.2691	0.59238	30.2772
POLA	Poland	12	0.06582	0.78984	0.28522	3.291	0.59238	30.2772
PORT	Portugal	13	0.06582	0.84469	0.28522	6.582	0.59238	30.2772
ROMA	Romania	13	0.06582	0.84469	0.28522	2.3037	0.59238	30.2772
RUSS	Russia (Eur.)	16	0.026328	0.39492	0.28522	6.0335	0.59238	30.2772
SKRE	Slovakia	13	0.06582	0.78984	0.28522	3.9492	0.59238	30.2772
SLOV	Slovenia	9	0.06582	0.78984	0.28522	11.9573	0.59238	30.2772
SPAI	Spain	6	0.06582	0.78984	0.28522	17.2229	0.59238	30.2772
SWED	Sweden	8	0.06582	0.84469	0.28522	24.0243	0.59238	30.2772
SWIT	Switzerland	17	0.06582	0.84469	0.28522	28.7414	0.59238	30.2772
UKRA	Ukraine	16	0.048268	0.42783	0.28522	3.9492	0.59238	30.2772
UNKI	United Kingd.	15	0.06582	0.84469	0.28522	17.1132	0.59238	30.2772
SEMO	Serbia Mont.	9	0.083372	0.78984	0.28522	3.9492	0.59238	30.2772

Table A9: Cost parameters for low ammonia application techniques [EUR2005]

Abatement technique	Livestock Cat.	CFMA	CVMA	CFMG	CVMG
		Arable land		Grassland	
Low ammonia application techniques - high efficiency	DL	0.52	0	0.52	0
Low ammonia application techniques - low efficiency	DL	0.52	0	0.52	0
Low ammonia application techniques - high efficiency	DS	0.7	0	0.7	0
Low ammonia application techniques - low efficiency	DS	0.7	0	0.7	0
Low ammonia application techniques - high efficiency	OL	0.52	0	0.52	0
Low ammonia application techniques - low efficiency	OL	0.52	0	0.52	0
Low ammonia application techniques - high efficiency	OS	0.7	0	0.7	0
Low ammonia application techniques - low efficiency	OS	0.7	0	0.7	0
Low ammonia application techniques - high efficiency	PL	0.52	0	0.52	0
Low ammonia application techniques - low efficiency	PL	0.52	0	0.52	0
Low ammonia application techniques - high efficiency	PS	0.7	0	0.7	0
Low ammonia application techniques - low efficiency	PS	0.7	0	0.7	0
Low ammonia application techniques - high efficiency	LH	0.7	0	0.7	0
Low ammonia application techniques - low efficiency	LH	0.7	0	0.7	0
Low ammonia application techniques - high efficiency	OP	0.7	0	0.7	0
Low ammonia application techniques - low efficiency	OP	0.7	0	0.7	0
Low ammonia application techniques - high efficiency	SH	0.7	0	0.7	0
Low ammonia application techniques - low efficiency	SH	0.7	0	0.7	0

Table A10: Country-specific parameters: Share of manure applied on grassland

	Country	DL	DS	OL	OS	PL	PS	LH	OP	SH
		Dairy cows liquid - solid		Other cattle liquid - solid		Pigs liquid - solid		Laying hens	Other poultry	sheep
ALBA	Albania	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
AUST	Austria	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
BELA	Belarus	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
BELG	Belgium	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
BOHE	Bosnia-Herc.	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
BULG	Bulgaria	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
CROA	Croatia	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
CYPR	Cyprus	0.05	0	0.05	0	0.1	0	0	0	0.05
CZRE	Czech Rep	0.05	0	0.05	0	0.1	0	0	0	0.05
DENM	Denmark	0.57	0	0.57	0	0.14	0	0.24	0.24	0.25
ESTO	Estonia	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
FINL	Finland	0.1	0	0.1	0	0.05	0	0.05	0.05	0.02
FRAN	France	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
GERM	Germany	0.1	0	0.1	0	0.05	0	0.5	0.5	0.1
GREE	Greece	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
HUNG	Hungary	0.65	0	0.65	0	0	0	0.05	0.05	0.65
IREL	Ireland	0.98	0	0.98	0	0.9	0	1	1	1
ITAL	Italy	0.2	0	0.1	0	0.2	0	0	0	0
LATV	Latvia	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
LITH	Lithuania	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5

	Country	DL	DS	OL	OS	PL	PS	LH	OP	SH
LUXE	Luxembourg	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
MALT	Malta	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
MACE	Macedonia	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
MOLD	Moldova	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
NETH	Netherlands	0.8	0	0.6	0	0.2	0	0.1	0.1	0.8
NORW	Norway	0.15	0	0.15	0	0	0	0	0	0
POLA	Poland	0.4	0	0.4	0	0.4	0	0.1	0.1	0.1
PORT	Portugal	0.1	0	0.2	0	0	0	0	0	0
ROMA	Romania	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
RUSS	Russia (Eur.)	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
SKRE	Slovakia	0.05	0	0.05	0	0.1	0	0	0	0.05
SLOV	Slovenia	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
SPAI	Spain	0.8	0	0.8	0	0.2	0	0.1	0.1	0.8
SWED	Sweden	0.81	0	0.81	0	0	0	0	0	1
SWIT	Switzerland	0.9	0	0.9	0	0.9	0	0.4	0.4	0.5
UKRA	Ukraine	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5
UNKI	United Kingd.	0.78	0	0.78	0	0.46	0	0.47	0.47	1
SEMO	Serbia Mont.	0.5	0	0.5	0	0	0	0.5	0.5	0.5

Table A11: Country-specific parameters to convert into common units (capacity utilization rate as share)

	Country	SBDL	SBDS	SBOL	SBOS	SBPL	SBPS	SBLH	SBOP	SBSH
		Dairy cows liquid - solid		Other cattle liquid - solid		Pigs liquid - solid		Laying hens	Other poultry	sheep
ALBA	Albania	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
AUST	Austria	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
BELA	Belarus	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
BELG	Belgium	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
BOHE	Bosnia-Herc.	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
BULG	Bulgaria	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
CROA	Croatia	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
CYPR	Cyprus	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
CZRE	Czech Rep	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
DENM	Denmark	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
ESTO	Estonia	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
FINL	Finland	1	0.98	0.98	0.9	0.9	1	0.97	0.8	1
FRAN	France	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
GERM	Germany	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
GREE	Greece	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
HUNG	Hungary	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
IREL	Ireland	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
ITAL	Italy	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
LATV	Latvia	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
LITH	Lithuania	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1

	Country	SBDL	SBDS	SBOL	SBOS	SBPL	SBPS	SBLH	SBOP	SBSH
LUXE	Luxembourg	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
MALT	Malta	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
MACE	Macedonia	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
MOLD	Moldova	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
NETH	Netherlands	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
NORW	Norway	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
POLA	Poland	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
PORT	Portugal	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
ROMA	Romania	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
RUSS	Russia (Eur.)	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
SKRE	Slovakia	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
SLOV	Slovenia	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
SPAI	Spain	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
SWED	Sweden	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
SWIT	Switzerland	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
UKRA	Ukraine	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
UNKI	United Kingd.	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1
SEMO	Serbia Mont.	1	1	0.98	0.98	0.97	0.97	0.97	0.77	1

Table A12: Applicability rates of measures [%]

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
		Abatement technique – applicability [%]						
ALBA	DL	65.3	32.7	0.0	32.7	32.7	73.5	19.6
ALBA	DS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALBA	OL	0.0	0.0	0.0	36.3	36.3	81.8	21.8
ALBA	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALBA	PL	100.0	100.0	70.0	50.0	25.0	95.0	35.0
ALBA	PS	51.2	0.0	35.8	0.0	0.0	46.1	25.6
ALBA	LH	36.8	36.3	14.7	19.6	36.3	39.2	24.5
ALBA	OP	72.6	77.4	58.1	67.7	77.4	87.1	67.7
ALBA	SH	0.0	0.0	0.0	0.0	0.0	21.0	6.3
AUST	DL	80.0	60.0	0.0	68.0	68.0	93.0	60.0
AUST	DS	52.2	0.0	0.0	0.0	0.0	63.4	22.4
AUST	OL	0.0	0.0	0.0	68.0	68.0	93.0	60.0
AUST	OS	0.0	0.0	0.0	0.0	0.0	61.7	21.8
AUST	PL	100.0	100.0	80.0	82.0	82.0	94.0	88.0
AUST	PS	84.2	0.0	67.4	0.0	0.0	75.8	59.0
AUST	LH	66.9	66.0	44.6	35.7	66.0	56.2	56.2
AUST	OP	69.4	74.0	64.8	37.0	68.5	58.3	58.3
AUST	SH	0.0	0.0	0.0	0.0	0.0	34.4	20.6
BELA	DL	80.0	52.0	0.0	68.0	68.0	90.0	24.0
BELA	DS	30.8	0.0	0.0	0.0	0.0	37.3	11.0
BELA	OL	0.0	0.0	0.0	68.0	68.0	90.0	24.0
BELA	OS	0.0	0.0	0.0	0.0	0.0	35.5	10.4
BELA	PL	100.0	100.0	70.0	50.0	25.0	95.0	35.0
BELA	PS	64.9	0.0	45.4	0.0	0.0	58.4	32.4
BELA	LH	56.1	59.9	44.9	15.0	29.9	59.9	37.4
BELA	OP	67.4	80.9	71.9	18.0	35.9	80.9	62.9
BELA	SH	0.0	0.0	0.0	0.0	0.0	23.0	6.9
BELG	DL	80.0	50.0	0.0	83.0	66.0	83.0	18.0
BELG	DS	69.4	0.0	0.0	0.0	0.0	70.4	40.7
BELG	OL	0.0	0.0	0.0	80.0	66.0	80.0	14.0
BELG	OS	0.0	0.0	0.0	0.0	0.0	64.8	31.9
BELG	PL	95.0	95.0	30.0	95.0	95.0	80.0	45.0
BELG	PS	94.0	0.0	29.7	0.0	0.0	94.0	79.2
BELG	LH	93.8	94.8	54.9	39.9	94.8	37.9	69.8

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
BELG	OP	85.9	94.9	54.9	40.0	73.9	94.9	79.9
BELG	SH	0.0	0.0	0.0	0.0	0.0	69.5	36.9
BOHE	DL	80.0	40.0	0.0	40.0	40.0	90.0	24.0
BOHE	DS	18.2	0.0	0.0	0.0	0.0	22.1	6.5
BOHE	OL	0.0	0.0	0.0	38.4	38.4	86.5	23.1
BOHE	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOHE	PL	66.8	66.8	46.7	33.4	16.7	63.4	23.4
BOHE	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOHE	LH	36.8	36.3	14.7	19.6	36.3	39.2	24.5
BOHE	OP	72.6	77.4	58.1	67.7	77.4	87.1	67.7
BOHE	SH	0.0	0.0	0.0	0.0	0.0	21.0	6.3
BULG	DL	80.0	23.0	0.0	30.0	30.0	69.0	40.0
BULG	DS	18.2	0.0	0.0	0.0	0.0	22.1	7.8
BULG	OL	0.0	0.0	0.0	30.0	30.0	69.0	40.0
BULG	OS	0.0	0.0	0.0	0.0	0.0	25.5	9.0
BULG	PL	100.0	100.0	70.0	50.0	25.0	75.0	60.0
BULG	PS	33.6	0.0	23.5	0.0	0.0	30.2	16.8
BULG	LH	36.8	39.2	14.7	19.6	36.3	39.2	24.5
BULG	OP	72.6	87.1	58.1	67.7	77.4	87.1	67.7
BULG	SH	0.0	0.0	0.0	0.0	0.0	14.9	10.5
CROA	DL	80.0	40.0	0.0	40.0	40.0	90.0	24.0
CROA	DS	18.2	0.0	0.0	0.0	0.0	22.1	7.8
CROA	OL	0.0	0.0	0.0	38.4	38.4	86.5	23.1
CROA	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CROA	PL	66.8	66.8	46.7	33.4	16.7	63.4	23.4
CROA	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CROA	LH	36.8	36.3	14.7	19.6	36.3	39.2	24.5
CROA	OP	72.6	77.4	58.1	67.7	77.4	87.1	67.7
CROA	SH	0.0	0.0	0.0	0.0	0.0	21.0	6.3
CYPR	DL	80.0	40.0	0.0	40.0	40.0	90.0	24.0
CYPR	DS	58.9	0.0	0.0	0.0	0.0	71.5	25.2
CYPR	OL	0.0	0.0	0.0	40.0	40.0	90.0	24.0
CYPR	OS	0.0	0.0	0.0	0.0	0.0	72.6	25.6
CYPR	PL	100.0	100.0	70.0	50.0	25.0	95.0	35.0
CYPR	PS	98.4	0.0	68.9	0.0	0.0	88.6	49.2
CYPR	LH	54.2	53.4	21.7	28.9	53.4	57.8	36.1
CYPR	OP	73.3	78.2	58.6	68.4	78.2	88.0	68.4

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
CYPR	SH	0.0	0.0	0.0	0.0	0.0	67.2	20.2
CZRE	DL	80.0	70.0	0.0	80.0	70.0	90.0	50.0
CZRE	DS	68.9	0.0	0.0	0.0	0.0	93.4	73.8
CZRE	OL	0.0	0.0	0.0	70.0	60.0	90.0	50.0
CZRE	OS	0.0	0.0	0.0	0.0	0.0	90.8	71.7
CZRE	PL	98.6	98.6	69.0	88.7	78.9	93.6	78.9
CZRE	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CZRE	LH	73.2	87.9	29.3	0.0	9.8	97.6	48.8
CZRE	OP	75.0	94.9	70.0	0.0	40.0	99.9	90.0
CZRE	SH	0.0	0.0	0.0	0.0	0.0	44.5	27.8
DENM	DL	100.0	70.0	0.0	95.0	95.0	100.0	95.0
DENM	DS	99.1	0.0	0.0	0.0	0.0	99.1	99.1
DENM	OL	0.0	0.0	0.0	95.0	95.0	100.0	95.0
DENM	OS	0.0	0.0	0.0	0.0	0.0	95.2	95.2
DENM	PL	100.0	100.0	95.0	95.0	95.0	100.0	100.0
DENM	PS	99.6	0.0	94.6	0.0	0.0	99.6	99.6
DENM	LH	49.6	99.3	99.3	9.9	89.4	99.3	99.3
DENM	OP	50.0	99.9	99.9	10.0	89.9	99.9	99.9
DENM	SH	0.0	0.0	0.0	0.0	0.0	68.8	68.8
ESTO	DL	80.0	52.0	0.0	68.0	68.0	90.0	50.0
ESTO	DS	62.5	0.0	0.0	0.0	0.0	80.4	26.8
ESTO	OL	0.0	0.0	0.0	68.0	68.0	90.0	50.0
ESTO	OS	0.0	0.0	0.0	0.0	0.0	73.8	24.6
ESTO	PL	100.0	100.0	70.0	50.0	25.0	95.0	60.0
ESTO	PS	90.3	0.0	63.2	0.0	0.0	81.2	54.2
ESTO	LH	7.1	7.5	4.7	1.9	3.8	8.5	7.5
ESTO	OP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESTO	SH	0.0	0.0	0.0	0.0	0.0	31.9	20.0
FINL	DL	100.0	70.0	0.0	50.0	50.0	80.0	60.0
FINL	DS	79.7	0.0	0.0	0.0	0.0	75.7	39.8
FINL	OL	0.0	0.0	0.0	50.0	50.0	80.0	60.0
FINL	OS	0.0	0.0	0.0	0.0	0.0	87.5	46.1
FINL	PL	100.0	50.0	90.0	50.0	50.0	70.0	70.0
FINL	PS	98.8	0.0	88.9	0.0	0.0	98.8	49.4
FINL	LH	49.4	88.9	88.9	49.4	49.4	98.8	49.4
FINL	OP	49.4	98.8	88.9	49.4	49.4	98.8	49.4
FINL	SH	0.0	0.0	0.0	0.0	0.0	63.6	31.8

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
FRAN	DL	80.0	60.0	0.0	68.0	68.0	93.0	60.0
FRAN	DS	69.5	0.0	0.0	0.0	0.0	94.3	89.3
FRAN	OL	0.0	0.0	0.0	68.0	68.0	93.0	60.0
FRAN	OS	0.0	0.0	0.0	0.0	0.0	92.2	87.3
FRAN	PL	100.0	100.0	80.0	82.0	82.0	94.0	88.0
FRAN	PS	98.4	0.0	78.7	0.0	0.0	98.4	93.5
FRAN	LH	74.2	89.0	79.1	39.6	73.2	62.3	62.3
FRAN	OP	74.5	94.4	89.4	39.7	73.5	89.4	69.5
FRAN	SH	0.0	0.0	0.0	0.0	0.0	76.8	53.5
GERM	DL	50.0	70.0	0.0	80.0	74.0	93.0	63.0
GERM	DS	41.2	0.0	0.0	0.0	0.0	82.5	51.9
GERM	OL	0.0	20.0	0.0	80.0	74.0	93.0	63.0
GERM	OS	0.0	0.0	0.0	0.0	0.0	81.1	73.0
GERM	PL	100.0	100.0	86.0	86.0	80.0	95.0	86.0
GERM	PS	78.7	0.0	67.7	0.0	0.0	78.7	70.9
GERM	LH	48.9	78.3	78.3	68.5	78.3	96.8	84.1
GERM	OP	49.9	79.9	79.9	69.9	79.9	98.9	85.9
GERM	SH	0.0	0.0	0.0	0.0	0.0	81.1	73.0
GREE	DL	80.0	50.0	0.0	20.0	20.0	80.0	40.0
GREE	DS	60.1	0.0	0.0	0.0	0.0	77.3	25.8
GREE	OL	0.0	0.0	0.0	20.0	20.0	80.0	40.0
GREE	OS	0.0	0.0	0.0	0.0	0.0	73.7	24.6
GREE	PL	100.0	100.0	70.0	50.0	25.0	95.0	90.0
GREE	PS	19.1	0.0	13.4	0.0	0.0	18.1	11.5
GREE	LH	35.4	28.4	14.2	4.7	28.4	37.8	42.5
GREE	OP	65.3	69.7	43.5	8.7	52.3	69.7	78.4
GREE	SH	0.0	0.0	0.0	0.0	0.0	57.6	28.8
HUNG	DL	80.0	80.0	0.0	50.0	40.0	90.0	60.0
HUNG	DS	62.0	0.0	0.0	0.0	0.0	79.7	66.4
HUNG	OL	0.0	0.0	0.0	50.0	40.0	90.0	60.0
HUNG	OS	0.0	0.0	0.0	0.0	0.0	77.5	73.2
HUNG	PL	98.7	98.7	69.1	49.3	49.3	93.8	57.2
HUNG	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HUNG	LH	30.8	40.3	40.3	0.0	40.3	41.1	40.3
HUNG	OP	74.4	90.3	90.3	0.0	90.3	99.2	90.3
HUNG	SH	0.0	0.0	0.0	0.0	0.0	76.1	38.1
IREL	DL	80.0	30.0	0.0	80.0	50.0	60.0	10.0

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
IREL	DS	67.9	0.0	0.0	0.0	0.0	87.4	29.1
IREL	OL	0.0	0.0	0.0	80.0	50.0	60.0	10.0
IREL	OS	0.0	0.0	0.0	0.0	0.0	77.6	25.9
IREL	PL	99.9	80.0	80.0	80.0	80.0	60.0	10.0
IREL	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IREL	LH	74.4	89.2	89.2	89.2	89.2	89.2	79.3
IREL	OP	74,9	89.9	94.9	89.9	89.9	89.9	79.9
IREL	SH	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ITAL	DL	80.0	40.0	0.0	60.0	50.0	25.0	25.0
ITAL	DS	62.9	0.0	0.0	0.0	0.0	36.0	36.0
ITAL	OL	0.0	0.0	0.0	75.0	75.0	25.0	25.0
ITAL	OS	0.0	0.0	0.0	0.0	0.0	31.5	31.5
ITAL	PL	97.4	97.4	87.7	58.5	48.7	19.5	19.5
ITAL	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ITAL	LH	73.5	78.4	78.4	68.6	68.6	78.4	29.4
ITAL	OP	74.3	89.2	89.2	69.4	69.4	79.3	29.7
ITAL	SH	0.0	0.0	0.0	0.0	0.0	24.0	24.0
LATV	DL	80.0	52.0	0.0	68.0	68.0	90.0	50.0
LATV	DS	36.9	0.0	0.0	0.0	0.0	47.4	15.8
LATV	OL	0.0	0.0	0.0	68.0	68.0	90.0	50.0
LATV	OS	0.0	0.0	0.0	0.0	0.0	51.5	17.2
LATV	PL	100.0	100.0	70.0	50.0	25.0	95.0	60.0
LATV	PS	58.7	0.0	41.1	0.0	0.0	55.8	35.2
LATV	LH	59.5	63.4	39.6	15.9	31.7	71.4	63.4
LATV	OP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LATV	SH	0.0	0.0	0.0	0.0	0.0	24.2	12.1
LITH	DL	67.6	43.9	0.0	57.4	57.4	76.0	42.2
LITH	DS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITH	OL	0.0	0.0	0.0	63.3	63.3	83.7	46.5
LITH	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LITH	PL	100.0	100.0	70.0	50.0	25.0	95.0	60.0
LITH	PS	12.2	0.0	8.5	0.0	0.0	11.6	7.3
LITH	LH	56.1	59.9	37.4	15.0	29.9	67.4	59.9
LITH	OP	67.4	80.9	62.9	18.0	35.9	85.4	80.9
LITH	SH	0.0	0.0	0.0	0.0	0.0	23.0	11.5
LUXE	DL	80.0	60.0	0.0	68.0	68.0	93.0	60.0
LUXE	DS	68.0	0.0	0.0	0.0	0.0	69.0	39.8

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
LUXE	OL	0.0	0.0	0.0	68.0	68.0	93.0	60.0
LUXE	OS	0.0	0.0	0.0	0.0	0.0	66.0	32.5
LUXE	PL	100.0	100.0	30.0	95.0	95.0	94.0	88.0
LUXE	PS	91.0	0.0	27.3	0.0	0.0	86.4	72.8
LUXE	LH	94.0	95.0	55.0	40.0	95.0	38.0	70.0
LUXE	OP	86.0	95.0	55.0	40.0	74.0	95.0	80.0
LUXE	SH	0.0	0.0	0.0	0.0	0.0	64.2	41.4
MACE	DL	75.2	37.6	0.0	37.6	37.6	84.6	22.6
MACE	DS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MACE	OL	0.0	0.0	0.0	40.0	40.0	90.0	24.0
MACE	OS	0.0	0.0	0.0	0.0	0.0	0.1	0.0
MACE	PL	100.0	100.0	70.0	50.0	25.0	95.0	35.0
MACE	PS	33.6	0.0	23.5	0.0	0.0	31.9	16.8
MACE	LH	36.8	36.3	14.7	19.6	36.3	39.2	24.5
MACE	OP	72.6	77.4	58.1	67.7	77.4	87.1	67.7
MACE	SH	0.0	0.0	0.0	0.0	0.0	21.0	6.3
MALT	DL	80.0	40.0	0.0	40.0	40.0	90.0	50.0
MALT	DS	68.4	0.0	0.0	0.0	0.0	87.9	29.3
MALT	OL	0.0	0.0	0.0	40.0	40.0	90.0	50.0
MALT	OS	0.0	0.0	0.0	0.0	0.0	86.5	28.8
MALT	PL	76.1	76.1	53.2	38.0	19.0	72.3	45.6
MALT	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MALT	LH	58.9	58.1	23.6	31.4	58.1	62.9	39.3
MALT	OP	70.5	75.2	56.4	65.8	75.2	84.5	65.8
MALT	SH	0.0	0.0	0.0	0.0	0.0	17.4	8.7
MOLD	DL	80.0	52.0	0.0	68.0	68.0	90.0	24.0
MOLD	DS	30.8	0.0	0.0	0.0	0.0	37.3	11.0
MOLD	OL	0.0	0.0	0.0	68.0	68.0	90.0	24.0
MOLD	OS	0.0	0.0	0.0	0.0	0.0	41.1	12.1
MOLD	PL	100.0	100.0	70.0	50.0	25.0	95.0	35.0
MOLD	PS	71.5	0.0	50.0	0.0	0.0	67.9	35.7
MOLD	LH	56.1	55.4	22.5	15.0	29.9	59.9	37.4
MOLD	OP	67.4	71.9	53.9	18.0	35.9	80.9	62.9
MOLD	SH	0.0	0.0	0.0	0.0	0.0	23.0	6.9
NETH	DL	79.6	89.6	0.0	17.9	17.9	99.5	49.8
NETH	DS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NETH	OL	0.0	39.9	0.0	24.9	24.9	99.8	49.9

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
NETH	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NETH	PL	100.0	100.0	90.0	100.0	95.0	100.0	99.0
NETH	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NETH	LH	100.0	100.0	100.0	15.0	95.0	0.0	100.0
NETH	OP	100.0	100.0	100.0	15.0	95.0	0.0	100.0
NETH	SH	0.0	0.0	0.0	0.0	0.0	86.6	43.3
NORW	DL	80.0	60.0	0.0	15.0	15.0	80.0	50.0
NORW	DS	57.7	0.0	0.0	0.0	0.0	61.8	20.6
NORW	OL	0.0	0.0	0.0	15.0	15.0	80.0	50.0
NORW	OS	0.0	0.0	0.0	0.0	0.0	49.9	16.6
NORW	PL	97.8	48.9	88.1	0.0	14.7	48.9	0.0
NORW	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NORW	LH	74.5	79.5	89.5	0.0	94.4	74.5	74.5
NORW	OP	74.9	89.9	94.9	0.0	94.9	74.9	74.9
NORW	SH	0.0	0.0	0.0	0.0	0.0	38.4	38.4
POLA	DL	80.0	80.0	0.0	80.0	80.0	80.0	60.0
POLA	DS	27.4	0.0	0.0	0.0	0.0	37.2	37.2
POLA	OL	0.0	0.0	0.0	80.0	80.0	80.0	60.0
POLA	OS	0.0	0.0	0.0	0.0	0.0	36.6	36.6
POLA	PL	100.0	100.0	80.0	90.0	90.0	80.0	60.0
POLA	PS	47.0	0.0	37.6	0.0	0.0	44.7	37.6
POLA	LH	49.1	58.9	58.9	13.1	26.2	58.9	52.4
POLA	OP	67.3	80.8	80.8	18.0	35.9	85.3	71.8
POLA	SH	0.0	0.0	0.0	0.0	0.0	36.5	18.3
PORT	DL	80.0	20.0	0.0	20.0	20.0	80.0	60.0
PORT	DS	59.0	0.0	0.0	0.0	0.0	67.4	67.4
PORT	OL	0.0	0.0	0.0	20.0	20.0	80.0	60.0
PORT	OS	0.0	0.0	0.0	0.0	0.0	68.7	68.7
PORT	PL	94.7	94.7	66.3	66.3	66.3	75.7	66.3
PORT	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PORT	LH	66.0	70.4	44.0	8.8	52.8	44.0	17.6
PORT	OP	70.4	84.5	65.7	9.4	56.3	47.0	18.8
PORT	SH	0.0	0.0	0.0	0.0	0.0	52.4	45.9
ROMA	DL	50.2	14.4	0.0	18.8	18.8	43.3	25.1
ROMA	DS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROMA	OL	0.0	0.0	0.0	17.6	17.6	40.4	23.4
ROMA	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
ROMA	PL	30.9	30.9	21.6	15.4	7.7	23.2	18.5
ROMA	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROMA	LH	13.2	14.1	8.8	7.0	13.0	13.2	10.6
ROMA	OP	37.8	45.4	35.3	20.2	37.3	37.8	30.2
ROMA	SH	0.0	0.0	0.0	0.0	0.0	42.9	16.1
RUSS	DL	67.6	43.9	0.0	57.4	57.4	76.0	25.3
RUSS	DS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RUSS	OL	0.0	0.0	0.0	63.3	63.3	83.7	27.9
RUSS	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RUSS	PL	100.0	100.0	70.0	50.0	25.0	95.0	35.0
RUSS	PS	12.2	0.0	8.5	0.0	0.0	11.6	6.1
RUSS	LH	56.1	59.9	52.4	15.0	29.9	59.9	37.4
RUSS	OP	67.4	80.9	71.9	18.0	35.9	80.9	62.9
RUSS	SH	0.0	0.0	0.0	0.0	0.0	23.0	6.9
SKRE	DL	80.0	52.0	0.0	20.0	20.0	90.0	50.0
SKRE	DS	58.9	0.0	0.0	0.0	0.0	75.7	25.2
SKRE	OL	0.0	0.0	0.0	20.0	20.0	92.0	50.0
SKRE	OS	0.0	0.0	0.0	0.0	0.0	80.0	26.7
SKRE	PL	100.0	100.0	70.0	30.0	30.0	95.0	60.0
SKRE	PS	58.9	0.0	41.2	0.0	0.0	56.0	35.3
SKRE	LH	66.8	80.2	44.5	35.6	65.9	80.2	80.2
SKRE	OP	72.4	86.8	67.5	38.6	71.4	86.8	86.8
SKRE	SH	0.0	0.0	0.0	0.0	0.0	70.2	35.1
SLOV	DL	80.0	46.0	0.0	60.0	55.0	90.0	24.0
SLOV	DS	8.4	0.0	0.0	0.0	0.0	10.7	3.6
SLOV	OL	0.0	0.0	0.0	50.3	46.1	75.4	20.1
SLOV	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SLOV	PL	90.5	90.5	63.3	45.2	90.5	86.0	31.7
SLOV	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SLOV	LH	18.3	18.1	12.2	9.8	18.1	22.0	18.3
SLOV	OP	55.5	59.2	44.4	51.8	59.2	70.3	59.2
SLOV	SH	0.0	0.0	0.0	0.0	0.0	16.9	5.1
SPAI	DL	80.0	50.0	0.0	20.0	20.0	80.0	60.0
SPAI	DS	65.3	0.0	0.0	0.0	0.0	84.0	28.0
SPAI	OL	0.0	0.0	0.0	20.0	20.0	80.0	60.0
SPAI	OS	0.0	0.0	0.0	0.0	0.0	83.4	27.8
SPAI	PL	100.0	100.0	70.0	10.0	10.0	95.0	90.0

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
SPAI	PS	86.6	0.0	60.6	0.0	0.0	82.3	52.0
SPAI	LH	73.1	82.8	68.2	9.7	58.5	77.9	87.7
SPAI	OP	74.6	99.5	99.5	10.0	59.7	79.6	89.6
SPAI	SH	0.0	0.0	0.0	0.0	0.0	74.8	65.5
SWED	DL	100.0	70.0	0.0	100.0	92.0	93.0	50.0
SWED	DS	99.3	0.0	0.0	0.0	0.0	89.4	74.5
SWED	OL	0.0	0.0	0.0	100.0	90.0	93.0	50.0
SWED	OS	0.0	0.0	0.0	0.0	0.0	84.7	70.6
SWED	PL	100.0	10.0	90.0	100.0	99.0	95.0	50.0
SWED	PS	97.8	0.0	88.0	0.0	0.0	92.9	73.3
SWED	LH	49.6	89.2	94.2	0.0	89.2	79.3	89.2
SWED	OP	50.0	95.0	95.0	0.0	95.0	80.0	95.0
SWED	SH	0.0	0.0	0.0	0.0	0.0	56.8	30.5
SWIT	DL	100.0	55.0	0.0	85.0	85.0	32.0	6.0
SWIT	DS	65.4	0.0	0.0	0.0	0.0	52.3	52.3
SWIT	OL	0.0	10.0	0.0	85.0	85.0	32.0	6.0
SWIT	OS	0.0	0.0	0.0	0.0	0.0	60.7	60.7
SWIT	PL	97.8	47.0	68.5	68.5	68.5	31.3	5.9
SWIT	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SWIT	LH	89.3	71.4	80.3	0.0	44.6	71.4	71.4
SWIT	OP	92.5	74.0	83.3	0.0	46.3	74.0	74.0
SWIT	SH	0.0	0.0	0.0	0.0	0.0	27.5	27.5
UKRA	DL	80.0	52.0	0.0	68.0	68.0	90.0	30.0
UKRA	DS	30.8	0.0	0.0	0.0	0.0	37.3	11.0
UKRA	OL	0.0	0.0	0.0	68.0	68.0	90.0	30.0
UKRA	OS	0.0	0.0	0.0	0.0	0.0	41.1	12.1
UKRA	PL	100.0	100.0	70.0	50.0	25.0	95.0	35.0
UKRA	PS	71.5	0.0	50.0	0.0	0.0	67.9	35.7
UKRA	LH	56.1	59.9	52.4	15.0	29.9	59.9	37.4
UKRA	OP	67.4	80.9	71.9	18.0	35.9	80.9	62.9
UKRA	SH	0.0	0.0	0.0	0.0	0.0	23.0	6.9
UNKI	DL	80.0	100.0	0.0	80.0	26.0	100.0	76.6
UNKI	DS	69.5	0.0	0.0	0.0	0.0	34.8	34.8
UNKI	OL	0.0	0.0	0.0	80.0	26.0	100.0	76.6
UNKI	OS	0.0	0.0	0.0	0.0	0.0	34.3	34.3
UNKI	PL	100.0	100.0	20.0	43.0	23.0	86.2	86.2
UNKI	PS	98.4	0.0	19.7	0.0	0.0	76.8	76.8

Region	Livestock Cat.	LNF	SA	BF	CS_ low	CS_ high	LNA_ low	LNA_ high
UNKI	LH	49.3	88.7	19.7	45.3	45.3	98.6	52.2
UNKI	OP	50.0	100.0	20.0	28.4	28.4	35.0	35.0
UNKI	SH	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMO	DL	80.0	40.0	0.0	40.0	40.0	90.0	24.0
SEMO	DS	18.2	0.0	0.0	0.0	0.0	22.1	6.5
SEMO	OL	0.0	0.0	0.0	38.4	38.4	86.5	23.1
SEMO	OS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMO	PL	66.8	66.8	46.7	33.4	16.7	63.4	23.4
SEMO	PS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEMO	LH	36.8	36.3	14.7	19.6	36.3	39.2	24.5
SEMO	OP	72.6	77.4	58.1	67.7	77.4	87.1	67.7