Inventory of Ammonia Emissions from UK Agriculture

2012

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Summary

The National Ammonia Reduction Strategy Evaluation System (NARSES) model (spreadsheet version) was used to estimate ammonia (NH_3) emissions from UK agriculture for the year 2012. Year-specific livestock numbers and fertiliser N use were added for 2012 and revised for previous years. The estimate for 2012 was 237.7 kt NH_3, representing a 7.3 kt increase from the previously submitted estimate for 2011. This increase was due to inclusion of 'non-agricultural' horses (i.e. horses not kept on agricultural holdings) in the inventory; emissions from this source had previously been compiled separately by CEH and added to the agricultural inventory after submission of this report. Taking this into account for both inventory years, there was in fact a decrease in the emission estimate between 2011 and 2012 of 3.6 kt NH_3 due to a reduction in livestock numbers and N fertiliser use. Backward and forward projections using the 2012 model structure gave estimates of 319 and 233 kt NH_3 for the years 1990 and 2020, respectively. This inventory reports emission from livestock agriculture and from nitrogen fertilisers applied to agricultural land. There are a number of other minor sources reported as 'agriculture' in the total UK emission inventory, including emissions from composting and domestic fertiliser use, which are not reported here.

Table 1. Estimate of ammonia emission from UK agriculture for 2012

Source		kt NH_3 *	% of total
Livestock category			
Cattle		127.7	54
	Dairy	*70.7*	*30*
	Beef	*57.0*	*24*
Sheep†		9.7	4
Pigs		17.7	7
Poultry		29.8	13
Horses		15.0	6
Management category			
Grazing/outdoors		39.6	17
Housing		21.4	9
Hard standings		54.4	23
Manure storage		30.8	13
Manure application		53.6	23
Fertiliser application		37.9	16
TOTAL		**237.7**	**100**

† Including goats and deer

* Totals may differ from sum of components due to rounding

Estimate of ammonia emission from UK agriculture for 2012

The estimate of NH_3 emission from UK agriculture for 2012 was made using the spreadsheet version of the National Ammonia Reduction Strategy Evaluation System (NARSES) model (file: NH3inv2012_NARSES_ 131113_FINAL.xls). NARSES models the flows of total nitrogen and total ammoniacal N (TAN) through the livestock production and manure management system, with NH_3 losses given at each stage as a proportion of the TAN present within that stage (Webb and Misselbrook, 2004). NARSES was first used to provide the 2004 inventory estimate for UK agriculture, replacing the previously used UK Agricultural Emissions Inventory model (UKAEI). NARSES brings improvements over the UKAEI model in that emission sources are linked, such that changes in an upstream source will be reflected downstream, it has an internal accounting check that not more than 100% of TAN excreted can be emitted, it can incorporate trends in N excretion by certain livestock classes (e.g. dairy cattle, pigs, poultry) and it is much better suited to scenario testing. The NARSES model was therefore used to provide the NH_3 emissions estimate for UK agriculture for 2011 and projections to 2020. Emissions from fertiliser use within agriculture are estimated using a simple process-based model as described by Misselbrook et al. (2004), which has been incorporated into the NARSES spreadsheet model.

To compile the 2012 inventory of NH_3 emissions from UK agriculture, survey data were reviewed to derive livestock numbers, fertiliser use and other management practice data relevant to 2012. Currently-used emission factors were reviewed in the light of new experimental data and amended if considered appropriate.

Key areas of revision in the 2012 inventory were:

- Inclusion of 2012 livestock numbers
- Inclusion of 2012 N fertiliser use
- Inclusion of horses not kept on agricultural holdings

Derivations of emission factors and other data used in NARSES are detailed in Appendix 1.

The estimate of emission from UK agriculture for 2012 was 237.7 kt NH_3. Cattle represent the largest livestock source and housing and land spreading the major sources in terms of manure management (Table 1). The effect of sequential changes made to the inventory during the revision for 2012 are detailed below, with the impact on the total shown in Table 2. A breakdown of the estimate is given in Table 3, together with a comparison with the previously submitted 2011 inventory estimate.

Table 2. Sequential influence of revisions to individual components on the inventory total (NARSES model) during the 2012 revision

	Change (kt NH_3)	Total (kt NH_3)
2011 total		**230.4**
Livestock numbers 2012	-1.2	
Inclusion of 'non-agricultural' horses	+11.0	
N fertiliser use	-1.8	
Revision of dairy cow milk yield	-0.5	
Revision of manure management practices	-0.2	
2012 total		**237.7**

Table 3. Estimate of ammonia emissions (kt NH_3) from UK agriculture, 2012

Source	2011	2012*	Reasons for change
Cattle			
Grazing	15.5	**15.4**	Small reduction in cattle numbers, small reduction in N excretion by dairy cows
Landspreading	36.1	**35.8**	
Housing	32.1	**31.8**	
Hard standings	21.1	**20.9**	
Storage	24.0	**23.8**	
Total Cattle	128.9	**127.7**	
Sheep			
Grazing	7.1	**7.2**	
Landspreading	0.2	**0.2**	
Housing	1.0	**1.0**	
Hard standings	0.5	**0.5**	
Storage	0.8	**0.8**	
Total Sheep	9.5	**9.7**	Increase in sheep numbers
Horses	4.0	**15.0**	Inclusion of horses not on agricultural holdings
Pigs			
Outdoor	1.1	**1.1**	
Landspreading	3.7	**3.7**	
Housing	9.1	**9.1**	
Hard standings	0.0	**0.0**	
Storage	3.7	**3.7**	
Total Pigs	17.6	**17.7**	Small increase in total pig numbers
Poultry			
Outdoor	0.9	**0.9**	
Landspreading	14.2	**13.9**	
Housing	13.1	**12.5**	
Storage	2.6	**2.5**	
Total Poultry	30.8	**29.8**	Reduction in total poultry numbers
Fertiliser	39.7	**37.9**	Decrease in total N fertiliser use and small decrease in proportion applied as urea or UAN
TOTAL	230.4	**237.7**	

*Totals may differ from sum of components due to rounding

Major changes between 2011 and 2012

1. 2012 Livestock numbers

Headline changes from 2011 are:

Cattle – a 0.3% decline in total cattle numbers (0.1% decline for dairy cows)

Pigs – a 0.9% increase in pig numbers

Sheep – a 1.8% increase in sheep numbers

Poultry – a 1.5% decline in total poultry numbers, with a 5.4% decrease in the laying flock and a 0.1% increase in broiler numbers

Horses – all horses, not just those kept on agricultural holdings, were included in this inventory report for the first time. Previously, 'non-agricultural' horses had been reported separately by CEH and added to the agriculture inventory by Ricardo-AEA. This does not therefore represent an increase in UK reporting. A more detailed description of data sources and calculation method for horses has been added to the Appendix to this report.

2. 2012 N fertiliser use

Data were derived from BSFP for crop year 2012 for England, Wales and Scotland and from DARD statistics for Northern Ireland.

Total fertiliser N use declined by 1.8% between 2011 and 2012, and there was a small decrease in the proportion applied as urea and UAN (down from 25% in 2011 to 24% in 2012).

3. Poultry litter incineration

Data on tonnages of poultry litter incinerated at power stations were obtained from EPR Ltd, with no change in the estimated total of 572,000 t incinerated in 2012.

Past and Projected Trends: 1990 - 2020

Retrospective calculations based on the 2012 inventory methodology were made for the years 1990 to 2012 and projections to 2020 (Table 4). Projected changes in livestock numbers, N fertiliser use and management practices are detailed below. There has been a steady decline in emissions (24%) from UK agriculture over the period 1990 – 2012, largely due to declining livestock numbers (Fig. 1) and fertiliser N use (Fig. 2). The decline is projected to level off under a business as usual scenario, with an estimated 28% reduction from 1990-2020.

Table 4. Estimates of ammonia emission from UK agriculture 1990 – 2020 using the NARSES model

Source	1990	1995	2000	2005	2010	2012	2015	2020
							Projections	
Total	**312.4**	**291.8**	**270.3**	**258.7**	**240.4**	**237.7**	**234.1**	**232.6**
Cattle	149.3	145.3	139.3	135.6	129.7	127.7	127.1	124.5
Dairy cattle	*85.5*	*81.5*	*77.5*	*74.9*	*71.2*	*70.7*	*72.0*	*70.7*
Other cattle	*63.8*	*63.8*	*61.8*	*60.7*	*58.5*	*57.0*	*55.1*	*53.8*
Sheep	13.3	13.1	12.8	10.8	9.4	9.7	9.7	10.1
Pigs	42.7	40.5	31.8	22.6	17.7	17.7	16.9	17.8
Laying hens	13.4	11.7	9.8	9.3	8.5	7.9	7.7	7.6
Broilers	15.7	12.3	15.4	14.0	10.2	10.3	10.4	10.6
Other poultry	5.8	11.8	13.1	13.2	11.7	11.6	11.6	11.9
Horses	8.6	10.0	14.3	15.1	15.0	15.0	15.0	15.0
Fertiliser	63.7	47.1	33.7	38.1	38.2	37.9	35.7	35.2

Projections – methodology and assumptions

Livestock numbers

Livestock number projections are based on FAPRI modelling data (Defra project DO108), specifically the December 2012 scenario projections. In addition to these, trends in N excretion have been included: N excretion by dairy cows is a function of annual milk yield, which is forecast to increase as cattle numbers became fewer but total milk output maintained. N excretion by certain pig and poultry categories were forecast to decrease as dietary improvements were taken up by the industry. Past and projected trends in livestock numbers are shown in Figure 1.

Fertiliser use

Fertiliser use projections are based on FAPRI modelling data. Proportions of each fertiliser type applied for projection years were assumed to be the average for the years 2007-2011. Past and projected trends in fertiliser N use are shown in Figure 2.

Figure 1. Trends in livestock numbers 1990 – 2020. Changes are relative to a reference value of 100 in 1990. Dashed lines show projections derived from FAPRI December 2012 scenario output (Defra project DO108).

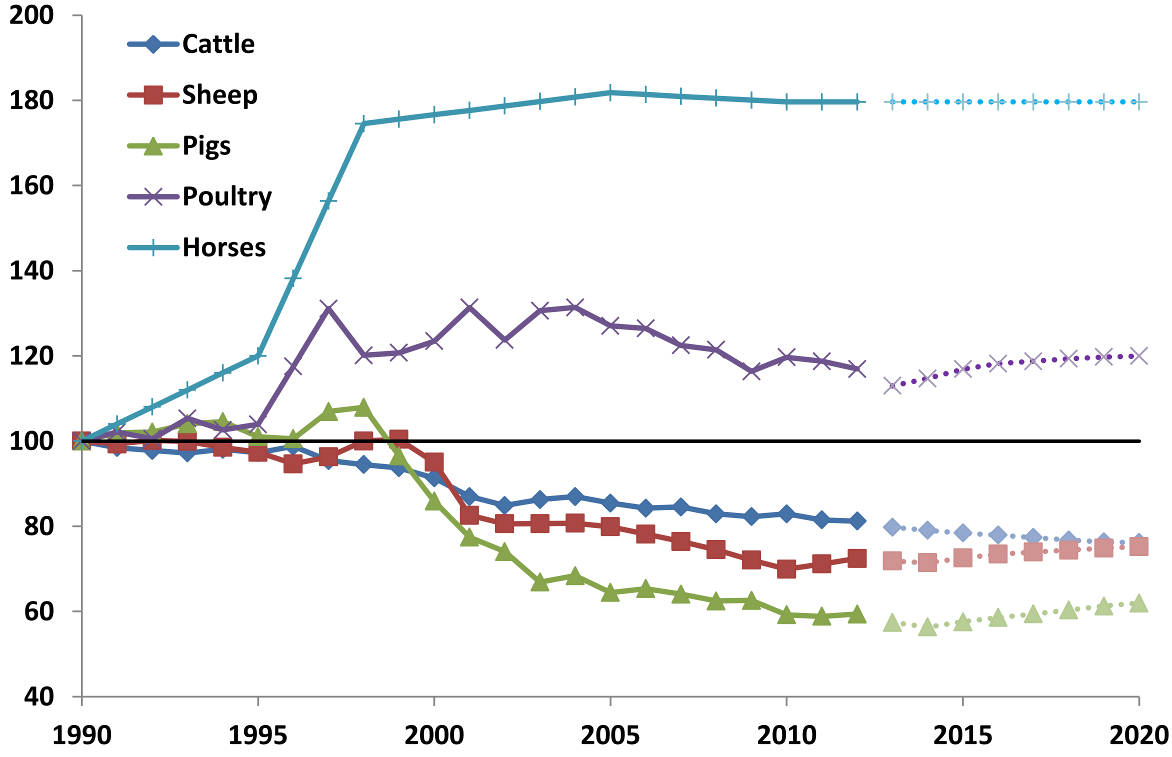
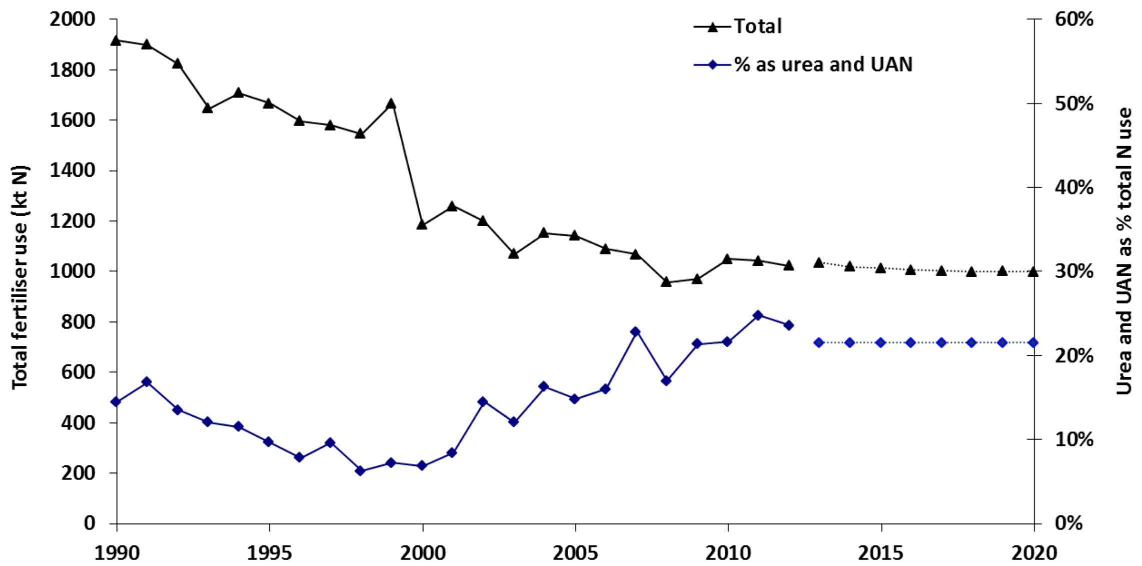


Figure 2. Changes in fertiliser N use 1990 – 2020. Dashed lines show projections derived from FAPRI December 2012 scenario output (Defra project DO108).



Farm management practices

Trends in changes in farm management practices (*e.g.* type and duration of livestock housing, manure storage and application methods) are difficult to quantify as there are relatively few surveys from which to obtain relevant data and those surveys which have been conducted are not always directly comparable. It is hoped that regular and consistent running of the Farm Practices Survey will be able to provide estimates of such trends in the future. For the default scenario, therefore, it has been assumed that no changes will take place in management practice in the absence of legislation or incentive schemes. IPPC legislation will impact on the practices of large pig and poultry farms from 2007 onwards; the assumptions regarding changes in livestock housing and manure management due to IPPC legislation are detailed below.

From 2007, all pig and poultry holdings above the livestock number thresholds have had to apply for a permit and will be required to comply with the legislation. In terms of ammonia emissions, the following assumptions have been made:

a) BAT housing is associated with a 30% reduction in ammonia emissions

b) Premises with existing housing will not be expected to modify immediately, but need to have plans showing how they will move towards compliance. It is assumed that 0% of holdings subject to IPPC complied in 2006 and that 100% will comply by 2020, with a linear trend in moving to compliance.

c) Slurry stores will require a rigid cover and lagoons a floating cover. Move to compliance will be as for housing above.

d) Applications of manure to own premises will have to comply with BAT, applications to other premises do not have to comply. From 2001 Farm Practices Survey, the proportions of manure exported are 25% of pig slurry, 29% of pig FYM and 69% of poultry manure. It is assumed that these proportions apply equally to IPPC and non-IPPC holdings.

e) Compliance will require incorporation within 24h of slurry, FYM or poultry manure to land to be tilled (assumed to be applicable for 50% of slurry, 90% of FYM and 70% of poultry manure applied to arable land), trailing hose application of pig slurry to growing arable crops and trailing shoe or shallow injection of pig slurry to grassland.

The proportion of the national pig herd and poultry flock that will be required to comply has been revised according to data provided by the agricultural statistics units of each of the devolved administrations and a weighted average for the UK (Table 5). These are based on 2006 census livestock numbers, but the proportions will be assumed to remain the same.

From these assumptions and data, the proportion of the UK flock or herd for which IPPC BAT should be applied in the inventory for housing and storage is given in Table 6 and the proportion of manure applications subject to BAT given in Table 7.

Table 5. Proportion (%) of poultry and pigs within each devolved administration and the UK kept on holdings above the IPPC thresholds (750 sows, 2,000 fattening pigs, 40,000 broilers, layers, ducks or turkeys)

Category	E	W	S	NI	UK
Poultry					
Broilers	95	98	94	67	92
Layers	67	49	74	54	66
Ducks	36	0	0	0	35
Turkeys	49	35	49*	0	43
Pigs					
Sows	29	0	23	27	28
Fatteners >20kg	40	0	53	49	42

*not disclosed for Scotland, so value for England used

Table 6. Proportion (%) of UK poultry flock and pig herd complying with IPPC BAT for housing and storage

Category	2006	2007	2010	2015	2020
Poultry					
Broilers	0	7	26	59	92
Layers	0	5	19	42	66
Ducks	0	3	10	23	35
Turkeys	0	3	12	28	43
Pigs					
Sows	0	2	8	18	28
Fatteners >20kg	0	3	12	27	42

Table 7. Proportion (%) of UK poultry and pig manure applied to land required to comply with IPPC BAT (from 2007 onwards)

Category*	%
Of that applied to arable land, % incorporated within 24h	
Poultry manure	18
Pig slurry	15
Pig FYM	26
Of that applied to arable land, % applied by trailing hose	
Pig slurry	15
Of that applied to grassland, % applied by trailing shoe/injection	
Pig slurry	30

*Using a weighted average of poultry numbers (83%) and pig numbers (40%) complying with IPPC (2006 data)

Emission factors

Emission factors associated with individual emission sources and management practices, as used in the current model, were kept constant for all model runs from 1990 – 2020.

Uncertainties

An analysis of the uncertainties in the emission inventory estimate was conducted by Webb and Misselbrook (2004) using @RISK software (Palisade Europe, London), in which a distribution was attached to each of the model inputs (activity or emission factor data), based on the distribution of raw data or, where no or only single estimates exist, on expert assumptions. A large number of model runs (2000) were then conducted in which input values were selected at random from within the given distribution (Latin hypercube sampling) and an uncertainty limit produced for each of the model outputs. The 95% confidence interval for the total inventory estimate was estimated to be ±20% (i.e. ±46.1 kt NH_3 for the 2011 estimate).

APPENDIX 1

DERIVATION OF EMISSION FACTORS FOR THE INVENTORY OF AMMONIA EMISSIONS FOR UK AGRICULTURE

In the NARSES model, all emission factors (EF) are expressed as a percentage of the total ammoniacal nitrogen (TAN) within a given emission ‘pool’ (livestock house, slurry store, etc.). Emission factors reported in many reports and publications are expressed in units other than this, so require conversion. As far as possible, data relevant to the published study are used to make these conversions, but in some cases where sufficient data are not reported standard values (e.g. for livestock weight or N excretion) have been used.

Cited sources are either scientific publications or Defra project Final Reports (given by Project Code), which are available from the Defra web-site (http://randd.defra.gov.uk).

CATTLE

Grazing

The average EF for cattle and sheep (there was no evidence to warrant differentiation) was derived from a number of grazing studies (Table A1) with a range of fertiliser N inputs to the grazed pasture. Emissions due to the fertiliser applied to the grazed pasture were discounted using a mean EF for ammonium nitrate applications to grassland (1.4% of N applied). The remaining emission was expressed as a percentage of the estimated urine N (equated here with the TAN in excreta) returned to the pasture by the grazing cattle or sheep.

Mean EF of 6 %TAN was derived.

Table A1: Cattle and sheep grazing emission factors

		N input	Urine N	NH_3 emission	Due to fertiliser	Due to urine	Emission Factor
				Kg N ha^{-1}			%TAN
CATTLE							
Bussink		*Fert Res 33 257-265*					
1987		550	425	42.2	7.7	34.5	8
1988		550	428	39.2	7.7	31.5	7
1988		250	203	8.1	3.5	4.6	2
Bussink		*Fert Res 38 111-121*					
1989		250	64.2	3.8	3.5	0.3	0
1989		400	76.2	12.0	5.6	6.4	8
1989		550	94.3	14.7	7.7	7	7
1990		250	217.4	9.1	3.5	5.6	3
1990		400	339	27.0	5.6	21.4	6
1990		550	407.1	32.8	7.7	25.1	6
Lockyer		*J Sci Food Agric 35, 837-848*					
	1	26	0.6455				2
	2	26	0.7025				3
Jarvis et al		*J Ag Sci 112, 205-216*					
1986/87		0	69	6.7	0	6.7	10
1986/87		210	81	9.6	2.94	6.66	8
1986/87		420	207	25.1	5.88	19.22	9
AC0102							
Beef, North Wyke		0			0		10
Beef, Cambridge		0			0		7
SHEEP							
Jarvis et al		*J Ag Sci 117, 101-109*					
GC		0	169	1.1	0	1.1	1
HN		420	321	8.0	5.88	2.08	1
AC0102							
Boxworth		0					4
North Wyke		0					10

Land spreading

Slurry

- EF derived from the MANNER_NPK model (KT0105)

The 'standard' EF for cattle slurry is given as 32.4 %TAN applied, which is then modified according to soil moisture, land use and slurry dry matter (DM) content at the time of application:

a) soil moisture ('season'):

Dry (summer) EF_1 = 'standard' EF x 1.3
Moist (rest of year) EF_1 = 'standard' EF x 0.7

b) land use:

Grassland $EF_2 = EF_1 \times 1.15$
Arable $EF_2 = EF_1 \times 0.85$

c) slurry DM content

$$EF_3 = EF_2 \times ((12.3 \times DM)+50.8)/100$$

Abatement techniques
Injection - abatement efficiency of 70% (assumed to be shallow injection)
Trailing shoe – abatement efficiency of 60%
Band spreading – abatement efficiency of 30%
(Misselbrook *et al.*, 2002; Smith *et al.*, 2000b)

Incorporation
Incorporation within 4h gives 60% reduction
Incorporation within 24h gives 30% reduction
Values derived from using MANNER_NPK(Project KT0105), assuming incorporation by plough.

FYM

- EF derived from the MANNER_NPK model (KT0105) as 68.3 %TAN applied. No modifiers for soil, manure or weather.

Abatement – incorporation
Incorporation within 4h gives 70% reduction
Incorporation within 24h gives 35% reduction
Values derived from using MANNER_NPK (Project KT0105), assuming most incorporation by plough.

Housing

Table A2. Housing emission factors for cattle

Study	Emission g N $lu^{-1}d^{-1}$	No. studies	Emission Factor % TAN	Notes
Slurry-based systems				
Demmers et al., 1997	38.6	1	31.1	Dairy cows 1995 Assume N excr of 100 kg N per year
WA0653	21.2	6	19.2	Dairy cows 1998/99 Assume N excr of 105 kg N per year
Dore et al., 2004	72.5	1	53.1	Dairy cows 1998/99 Assume N excr of 105 kg N per year
WAO632/AM110	50.8	3	39.4	Using actual N balance data
Hill, 2000	29.4	1	22.8	Dairy cows 1997 Assume N excr of 104 kg N per year
AM0102	30.5	2	23.7	Dairy cows 2003 Assume N excr of 113 kg N per year
Mean	40.5		31.6	
Weighted mean	34.3		**27.7**	
Straw-bedded systems				
WA0618 (PT)	20.6	1	18.3	Growing beef, assuming 56 kgN/hd/yr
WAO632/AM110 (PT)	35.0	3	21.6	Using actual N balance data
WA0722	33.2	1	22.9	Dairy cows, 6,500 kg milk per year, therefore assume 112 kgN/year
AM0103 (PT)	13.9	1	11.7	Growing beef, values directly from report
AM0103 (Comm farm)	16.7	1	13.4	Dairy cows, assuming 125 g TAN excretion per day (AM0103 report)
AC0102	14.0	3	12.5	Growing beef, assuming 56 kgN/hd/yr
Mean	22.2		16.7	
Weighted mean	23.1		**16.8**	
Calves				
Demmers et al. 1997	13.0	1	5.8	Assume calf weight 140 and N excretion 38 kg N per year
Koerkamp et al. 1998	6.2	1	2.6	Assume calf weight 140 and N excretion 38 kg N per year
Mean	9.6		**4.2**	

No distinction is made between dairy and beef cattle housing EF within either slurry or straw-bedded systems. Account is taken of the difference in N excretion between the housed winter and grazed summer periods, based on dietary changes.

Work by Phillips *et al*. (1998) suggests that summer emissions from dairy cattle housing, where the cattle come in for part of the day for milking, may be of a similar magnitude to winter emissions. An EF for summer housing emissions is not explicitly included in the inventory, but housing period is increased to account for the hours each day during the summer when the cattle are in. The EF for housing is likely to be greater in summer, because of higher temperatures. However, it is also likely that the floor area from which emission take place will be much reduced, as access to housing may be restricted.

Hard standings

A number of studies have been conducted to assess ammonia emissions from hard standings used by livestock (Misselbrook et al., 1998, 2001, 2006). Survey data, collected as part of project WA0504, indicate that 65% of dairy cattle have access to collecting yards and 30% have access to feeding yards while 45% of beef cattle have access to feeding yards. Survey data from FPS2006 indicates that dairy cows with access to collecting yards spend an average of 33% of the day on the yards, so the amount of excreta deposited is assumed to be pro-rata to the time spent. Data from project NT2601 indicate that 21% of daily N excretion is deposited on feeding yards by dairy cattle which have access to them. Expert opinion was that approximately 40% of daily excreta from beef cattle on feeding yards is deposited to the yard (FPS2006 indicates that the animals have access for the majority of the day, but they would also have access to housing during this period). Project AM0111 indicated that collecting yards, which are scraped at least once a day, are scraped with an efficiency of c. 60%. For feeding yards, which are scraped only once or twice a week on average, the scraping efficiency is assumed to be 30%. Based on Misselbrook et al. (2006) an EF of 75% of the TAN left after scraping is assumed.

Storage

Table A3. Cattle manure storage EF

Mean EF g N $m^{-2}d^{-1}$	Values g N $m^{-2}d^{-1}$	Derived from n values	Emission as % TAN	Source
Slurry stores and lagoons without crusts				
3.42				Assumed to be double that for crusted stores (WA0641, WA0714)
Slurry stores and lagoons with crusts, weeping wall stores				
1.71	0.6		**2.3	(Phillips *et al*., in press)
	1.27, 3.65, 5.7		NA	WA0625
	0.44	2	*6.0	WA0632*
	1.8		NA	WA0641
	1.7		NA	Hill (2000)
	0.48	2	NA	WA0714
	0.5,0.72,0.42,0.73		51.5 (lagoons) 5.3 (w.wall)	WA0717
	4.2		NA	AM0102
FYM heaps	**g N t^{-1} initial heap mass**			
265	421, 101, 106		NA	WA0618
	65, 618, 889		95.0	WA0519
	305, 140		22.0	WA0632
	250, 36, 26		12.0	WA0707

** Emissions expressed per day. This value assumes 90 d storage.

Slurry stores are assumed to develop a crust unless they are stirred frequently.
Values derived from measurements made using Ferm tubes have been corrected to account for incomplete recovery of ammonia by Ferm tubes (Phillips *et al*., 1998). (*IGER values have been corrected using a factor of **0.7**).

Emissions from FYM stores were previously based on surface area. However, it was considered that the estimates of store surface areas (Nicholson and Brewer survey, 1994) seriously underestimated solid manure storage areas (possibly because of multiple use of the same area or not accounting for short-term storage heaps). Therefore emissions are now calculated on a per tonne basis (using data from the same experimental studies).

NARSES EF were derived as a weighted mean of those studies which supplied information on the amounts of N and TAN put into store. Mean EF were derived as 5.0 and 51.5 % TAN for tanks (assumed to be crusted and equivalent to weeping wall store) and lagoons, respectively. For FYM a weighted mean EF of 35% was derived.

SHEEP

Grazing
See Table A1 under Cattle. An EF of 6 %TAN is assumed.

Land spreading
- FYM - value for cattle used.

Housing

NARSES EF was derived directly by back-calculation of the UKAEI, giving an EF of 21.6% TAN, since there are no reported measurements of NH_3 emission from buildings housing sheep.

Hard standings
Sheep collecting yards are scraped infrequently, if at all, so a scraping efficiency of 0% was applied and an EF of 75% TAN deposited.

Storage
- FYM - value for cattle used.

PIGS

Outdoors

Table A4. EF for outdoor pigs

	Emission g N $lu^{-1}d^{-1}$	EF %TAN	Source
Outdoor sows/piglets	25	26.1	Williams et al. (2000)
	66*	NA	Welch (2003)

*This value is probably an overestimate as emission rates were below the detection limit on a number of occasions (and those data were not included).

Emission factor for boars assumed to be the same. For fatteners, EF is based on the ratio of excretal outputs multiplied by the emission factor for outdoor sows.

NARSES EF was derived from the Williams et al (2000) study, assuming the standard N excretion value for sows and a body weight of 200kg, giving a mean EF of 25 %TAN (assumed to be the same across all animal sub-categories).

Land spreading

Slurry

- EF derived from the MANNER_NPK model (KT0105)

The 'standard' EF for pig slurry is given as 25.5 %TAN applied, which is then modified according to slurry dry matter (DM) content at the time of application:

a) slurry DM modifier:

$$EF_1 = \text{'standard' EF x } ((12.3 \text{ x DM})+50.8)/100$$

FYM

The same EF as for cattle FYM is used, 68.3 %TAN applied

Abatement techniques

Slurry injection – abatement efficiency of 70%
Band spreading (trailing hose) – abatement efficiency of 30%

Incorporation
Incorporation within 6h gives 60% reduction
Incorporation within 24h gives 30% reduction
Values derived from using MANNER_NPK (Project KT0105), assuming most incorporation by plough

Housing

Table A5. Housing EF for pigs

Study	Emission g N $lu^{-1}d^{-1}$	No. studies	Emission Factor % TAN	Notes
Dry sows on slats				
Peirson,1995	17.0	2	22.9	Assume N excr of 15.5kg
Dry sows on straw				
Peirson,1995	9.4	2	12.6	Assume N excr of 15.5kg
Koerkamp et al., 1998	14.7	1	19.8	Assume N excr of 15.5kg
OC9523	26.2	4	35.3	Assume N excr of 15.5kg
AM0102	50.6	5	68.1	Assume N excr of 15.5kg
Mean	25.2		34.0	
Weighted mean	15.7		**43.9**	
Farrowing sows on slats				
Peirson,1995	32.4	3	33.8	Assume N excr 22.5kg (1995 value)
Koerkamp et al., 1998	20.7	1	23.1	Assume N excr 22.5kg (1995 value), live weight 240 kg
AM0102	27.0	3	30.4	Assume N excr 15.5kg (2002/03 value)
Mean	26.7	7	29.1	
Weighted mean	20.7		**30.8**	
Farrowing sows on straw				
	Use dry sows value			
Boars on straw				
	Use dry sows value			
Finishers on slats				
Peirson, 1995	71.7	3	26.9	Assume fatteners 20-80 kg, N excr 13.9kg (1995 value)
Demmers, 1999	105.8	1	25.3	Mean weight 25.7kg, N excr 11.2kg (1995 value)
Koerkamp et al. 1998	51.2	1	16.7	Approx 35 kg finishers, assume N excretion 11.2 kg (1995 value)
WA0632	79.2	4	40.4	Using actual N balance data
WA0720 (fan vent, comm farm)	103.5	1	41.5	Assume fatteners 20-80 kg, N excr 13kg (mean of 2 weight ranges for year 2002)
WA0720 (acnv, comm farm)	77.2	3	31.0	Assume fatteners 20-80 kg, N excr 13kg (mean of 2 weight ranges for year 2002)
WA0720 (part slat, comm farm)	51.5	2	20.7	Assume fatteners 20-80 kg, N excr 13kg (mean of 2 weight ranges for year 2002)
WA0720 (fan vent, Terrington)	47.7	1	21.6	40-95 kg finishers, assume N excretion 15.5 kg per year
WA0720 (part slat, Terrington)	38.7	1	17.6	40-95 kg finishers, assume N excretion 15.5 kg per year
Mean	69.6	17	26.8	
Weighted mean	71.4		**29.4**	

Finishers on straw				
Peirson (1995)	54.2	2	20.3	Assume fatteners 20-80 kg, N excr 13.9kg (1995 value)
Koerkamp et al., 1998	28.2	1	9.2	Approx 35 kg finishers, assume N excretion 11.2 kg (1995 value)
WA0632	122.2	4	53.7	Using actual N balance data
AM0102	24.0	1	9.6	Assume fatteners 20-80 kg, N excr 13kg (mean of 2 weight ranges for year 2002)
AM0103 Terrington	47.0	2	23.6	Values directly from report
AM0103 Commercial	34.1	1	10.9	Finishers 20-60 kg, N excr 13kg (mean of 2 weight ranges for year 2002)
AC0102	42.0	4	16.6	Finishers 30-60 kg, N excr 11.9kg (mean of 2 weight ranges for year 2002)
Mean	50.2	15	20.6	
Weighted mean	63.0		**26.6**	
Weaners on slats				
Peirson, 1995	34.8	1	9.9	Assume N excr 4.4kg (1995 value)
Koerkamp et al. 1998	20.7	1	5.9	Assume N excr 4.4kg (1995 value)
Mean	27.7		**7.9**	
Weaners on straw				
			7.2	Based on ratio slurry/straw for finishers

Hard standings
EF assumed as 75% of TAN estimated to be deposited by finished pigs as they await loading for dispatch to market (with scraping efficiency assumed to be 30%). 5% of daily excretal output is assumed to be deposited to the loading areas.

Storage
Table A6. EF for pig manure storage

Mean EF g N m^{-2} d^{-1}	Values g N m^{-2} d^{-1}	Derived from n values	Emission as %TAN	Source
Slurry stores and lagoons				
3.16	1.34	4	13.0	WA0632
	2.47, 6.2		NA	WA0625
	2.4		NA	Phillips *et al*. (1997)
	1.56		NA	WA0708
	5.0		NA	Phillips *et al*. (1997)
FYM heaps	**g N t^{-1} initial heap mass**			
1224	539	4	20.0	WA0632
	1015	1	68.0	WA0716

Values derived from measurements made using Ferm tubes have been corrected to account for incomplete recovery of ammonia by Ferm tubes (Phillips *et al*., 1998).
NARSES EF for slurry tanks was derived as 13 %TAN and for lagoons the same values as for cattle slurry lagoons (52 %TAN) was used. The weighted mean of measurements made during storage of FYM is 30% of TAN, similar to that for emissions during storage of cattle FYM.

POULTRY

Outdoors

An EF of 35 %UAN has been assumed, as it is likely that emissions from freshly dropped excreta will be substantially lower than from applications of stored manure in which hydrolysis of the uric acid will have occurred to a greater extent. 20% of poultry droppings are estimated to be voided outside the house (Pers. comm. Elson, ADAS); this is an increase on the previous estimate of 12%, and represents a real change in that newer systems are designed such that birds do spend longer outside.

Land spreading

For poultry manure a standard EF of 52.3 %UAN applied is used, with no further modifiers for soil, manure or weather (KT0105, MANNER_NPK)

For Duck manure, which is very similar to cattle/pig FYM, an EF of 68.3 %UAN applied is used.

Abatement – incorporation
Incorporation within 4h gives 85% reduction
Incorporation within 24h gives 55% reduction
Values derived from using MANNER_NPK (Project KT0105), assuming incorporation by plough.

Housing

Table A7. EF for poultry housing

Study	Emission g N $lu^{-1}d^{-1}$	No. studies	Emission Factor % TAN	Notes
Layers – deep-pit (cages, perchery, free-range)				
Peirson, 1995	79.0	3	22.1	Assume N excr 0.82 kg (1995 value)
G Koerkamp, 1998	184.1	1	49.2	Assume N excr 0.82 kg (1995 value)
G Koerkamp, 1998	146.1	1	39.0	Assume N excr 0.82 kg (1995 value)
WA0368	139.2	1	36.8	Assume N excr 0.79 kg (1998 value)
WA0651	196.8	1	57.9	Assume N excr 0.78 kg (2000 value)
Mean	149.0		41.0	
Weighted mean	107.0		**35.6**	
Layers – belt-cleaned (cages)				
Peirson, 1995	36.0	3	10.1	Assume N excr 0.82 kg (1995 value)
WA0651 Gleadthorpe	79.2	1	23.3	Assume N excr 0.78 kg (2000 value)
WA0651 comm. farm	64.8	1	19.1	Assume N excr 0.78 kg (2000 value)
Mean	60.0		17.5	
Weighted mean	50.4		**14.5**	
Broilers				
Demmers et al. 1999	42.0	1	7.0	Assume N excr 0.56 kg (1995 value)
Robertson et al 2002	44.0	4	8.3	Assume N excr 0.55 kg (2000 value)
Frost et al 2002	54.0	4	9.2	Assume N excr 0.55 kg (2000 value)
WA0651 winter	36.0	4	9.5	Derived N excretion from N balance
WA0651 summer	67.2	4	15.6	Derived N excretion from N balance
WA0651 drinkers	52.8	2	10.9	Derived N excretion from N balance
Mean	49.3	19	10.1	
Weighted mean	37.9		**10.5**	
Turkeys				
Peirson et al, 1995	93.0	3	**36.6**	

Layers in cages – systems where manure is scraped from a collection shelf through a floor slot to a deep-pit are included in the cages deep-pit category. Measurements under WA0651 indicated that a much lower emission factor was obtained for a daily belt-cleaning system as compared with weekly cleaning. However, such frequent cleaning would not be practised on commercial farms and the value is therefore not included here.

A measurement from Groot Koerkamp *et al*. (1998) for broiler housing (164 g N lu^{-1} d^{-1}) has been excluded from the inventory. This measurement was from an old housing system, no longer representative of current broiler housing, and was also based on a single measurement in time rather than an integrated measurement over the duration of the crop.

For pullets, breeding hens and other classes of poultry not categorised in the table above, a weighted average of the broiler and turkey data were used to derive an emission factor of 14.1%.

Storage

Storage losses can be divided into storage and 'break-out' (*i.e.* when loading to trailer/spreader takes place).

Storage losses

Mean EF **g N t^{-1} initial heap mass**	Values	Derived from n values	Emission as %TAN	Source
Layer manure				
1956	318	2	2.2	WA0712
	3172	4	15.1	WA0651 (belt scraped)
	3141	4	29.4	WA0651 (deep pit)
	1193	1	13.4	WA0651 (belt scraped)
Litter				
1435	478	1	2.2	WA0712
	1949	4	19.9	WA0651 (winter)
	158	4	2.0	WA0651 (summer)
	639	2	7.2	WA0651 (drinkers)
	3949		NA	WA0716

NARSES EF were derived from weighted means as 17.8 %UAN for layer manure and 8.7% for poultry litter. Duck manure was assumed to have the same EF during storage as cattle FYM (35%).

DEER

Grazing

- Sheep grazing (lowland sheep) emission factor used as live weights similar.

Land spreading

- Emission factor for cattle FYM used.

Housing

- Emission factor for sheep housing used.

Storage

- Emission factor for cattle FYM used.

HORSES

Emissions from horses do not currently follow the N-flow approach of the NARSES inventory model, but rather are estimated using fixed emission factors (kg NH_3-N horse^{-1} year^{-1}). This is largely because of a lack of information on horse housing and manure management. As this is a relatively large source, a more detailed approach is warranted.

Emission source strength estimates have been derived for both race/competition horses (with higher protein content in feed and therefore higher N excretion) and other horses (including ponies, donkeys and mules), using a range of scientific literature (Hanson et al. 1996, Coverdale et al. 2004, Davis and Swinker (2002), Hainze et al. 2004, McKiernan 1999, Olsen 1996). The calculations take into account N excretion rates according to different feeding regimes and horse bodyweight (from small ponies to large cart horses), and result in best estimates and uncertainty ranges. An average race/competition horse is estimated to emit 27.3 kg NH_3-N horse^{-1} year^{-1} (previously estimated at 32.6 kg NH_3-N), with a range of 12.4-53.5 kg NH_3-N horse^{-1} year^{-1}. Other horses are estimated to emit 10.55 kg NH_3-N horse^{-1} year^{-1} (previously estimated at 10.6 kg NH_3-N), with a range of 2.3 to 45.7 kg NH_3-N horse^{-1} year^{-1}. For up-scaling to the UK, these wide uncertainty ranges (which include small ponies on a low N/protein diet spending a large proportion of the year outdoors as well as very large horses fed a high N/protein diet) were not used directly, but statistically treated to reduce the overall uncertainty by generating confidence intervals (R. Smith, CEH, pers. comm.).

For more details, see: Dragosits U., Jones S.K., Vogt E. and Sutton M.S. (2006) 2005 Update on Ammonia emissions from non-agricultural sources for the NAEI. CEH Report AS06/20. Centre for Ecology & Hydrology Edinburgh, Bush Estate, Penicuik. 14pp.

CONSERVED GRASSLAND & TILLAGE

A model based on Misselbrook et al. (2004) but modified according to data from the NT26 project is used to estimate EF for different fertiliser types:

- Ammonium nitrate (and 'other N' category) – a fixed emission factor of 1.8% N applied is now used as there was no consistent evidence of temperature, rainfall, land-use or crop height effects on emission. The only modifier applied is for direct placement of fertiliser into soil on tillage, where a reduction efficiency of 80% is assumed.
- Ammonium sulphate, diammonium phosphate – for this minor category of fertilisers, soil pH has an influence on emissions. The rules for ammonium nitrate are applied for applications to non-calcareous soils and the rules for urea are applied for applications to calcareous soils.
- Urea ammonium nitrate – a maximum EF of 23% is applied (from NT26 data-set) and the rules for urea applications are applied.
- Urea – EF is derived according to EF_{max}, application rate, rainfall and temperature. EF_{max}, is 45% (from NT26 data-set). The modifiers for application rate, rainfall and temperature were revised to be consistent with the NT26/*AE* model.
- 10% of fertiliser applied to tillage is assumed to be by soil placement
- Mean application rate of urea for a given application timing is assumed to be 60 kg ha^{-1} N (previously 120)

Sources of Activity Data

Animal numbers and weights

Livestock numbers are obtained from June agricultural survey statistics provided by each devolved administration (England, Scotland, Wales and Northern Ireland). The UK total is derived as the sum of the DA values.

Livestock weights (required in UKAEI but not NARSES) are from ADAS unpublished data:

Animal	Weight (kg)
Dairy cow (inc. heifers)	550
Dairy heifer in calf	400
Beef cow (inc. heifers)	
Beef heifer in calf	
Bull	340
Others > 2 yr	
Others 1-2 yr	
Others < 1yr	140

Animal	Weight (kg)
Sow	200
Farrower	225
Boar	250
Fattener >110 kg	120
Fattener 20 – 110 kg	65
Fattener <20 kg	12
Layer	2.2
Broiler	0.9
Pullet	1.0
Breeding hen	2.0
All other poultry	4.0

Proportion of sheep in uplands from ADAS (pers. comm. Diane Spence).

Excretal outputs and TAN contents

Manure output values per animal are from Smith and Frost (2000) and Smith *et al*., (2000). Account is taken of time spent indoors and litter/bedding is included for FYM outputs. For milking dairy cattle, time indoors is increased to account for time in summer spent in buildings or yards for milking operation (equivalent to 3h per day throughout the grazing period). N excretion values are derived from Cottrill, B.R. and Smith,K.A. (2007) 'Nitrogen output of livestock excreta', Final report, Defra Project WT0715NVZ.

The proportion of waste produced as slurry or FYM was derived from ADAS Surveys of Animal Manure Practices in the Dairy, Beef, Pig and Poultry Industries (Smith *et al*., 2000c, 2001a, 2001b).

Tonnage of poultry litter incinerated were obtained directly from EPRL and Fibropower websites (K Smith, ADAS).

Manure output and N excretion by livestock category (2012 values)

Livestock type	Manure output kg d^{-1}		% manure produced as …		N excretion kg yr^{-1}	%TAN at excretion
	Slurry	FYM	Slurry	FYM		
Cattle						
Dairy cows & heifers	54.6	68.9	83	17	122.6	60
Dairy heifers in calf	41.2	52.0	35	65	67	60
Dairy replacements	33.0	41.6	35	65	56	60
Dairy calves <1yr	20.6	26.0	0	100	38	60
Beef cows & heifers	45.7	51.8	18	82	79	60
Beef heifers in calf	32.5	36.8	18	82	56	60
All other beef >1yr	32.5	36.8	18	82	56	60
Beef calves <1yr	20.3	23.0	0	100	38	60
Sheep						
Ewes - lowland		5.8	0	100	9.0	60
Ewes - upland		3.8	0	100	9.0	60
Lambs - lowland		2.1	0	100	1.62	60
Lambs - upland		2.1	0	100	1.62	60
Goats		4.0			20.6	60
Deer		15.0			13	60
Pigs						
Maiden gilts	5.7	6.4	20	80	15.5	70
Sows	11.1	12.5	60	40	18.1	70
Boars	8.8	10.0	0	100	21.8	70
Fatteners >110 kg	5.2	5.9	35	65	15.4	70
Fatteners 80-110 kg	5.2	5.9	35	65	15.4	70
Fatteners 50-80 kg	3.8	4.3	35	65	13.3	70
Fatteners 20-50 kg	3.8	4.3	35	65	8.9	70
Weaners (<20 kg)	1.3	1.5	46	54	3.4	70
Poultry						
Laying hens (cages)		0.12	0	100	0.67	70
Laying hens (free-range)		0.12	0	100	0.75	70
Broilers		0.07	0	100	0.40	70
Pullet		0.04	0	100	0.33	70
Breeding Hens		0.12	0	100	1.02	70
Turkeys (m)		0.18	0	100	2.18	70
Turkeys (f)		0.13	0	100	1.46	70
Ducks		0.1	0	100	1.71	70
Horses		28.2	0	100	50	60

Manure volume output data were derived by K Smith (ADAS) using data from Smith et al. (2000c, 2001a, 2001b) with interpretation for animal place and annual outputs – see spreadsheets 'UK excreta_2010_02May.xls' and 'Livestock excretal outputs.xls'. Nitrogen excretion data were derived from project WT0715NVZ with interpretation by B Cotteril and K Smith (ADAS) – see document 'NExcr190506 bc.doc'.

Land spreading

The proportion of pig or cattle manure applied to grassland and arable, the proportion applied in summer (May-July), the proportion applied by injection or irrigated and the proportion incorporated within 1d or 1wk of application were obtained from ADAS Surveys of Animal Manure Practices in the Dairy, Beef, Pig and Poultry Industries (Smith *et al.*, 2000c, 2001a, 2001b). The proportion of cattle and pig FYM spread to land without storage was also obtained from the same source. The proportion of poultry manure applied to grassland and arable was obtained from the Farm Practices Survey (Defra 2001).

The proportion of slurry in each dry matter category was derived from ADAS unpublished (K Smith, B Chambers).

Housing

The proportion of animals in each housing type: cattle from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (1998), pigs from Sheppard (1998, 2002). The proportion of pigs outdoors was derived from Sheppard (1998, 2002). Poultry housing details and the % of manure dropped outdoors were estimated by A Elson (ADAS). Regular revisions are made using data from the Farm Practices Surveys (England). Although surveys are often only for England or England and Wales, data are extrapolated across the whole UK.

Cattle housing

	Smith et al 2001 2000	FPS2010 2010
Dairy cows kept on slurry (%)	66%	83%
Dairy followers kept on slurry (%)	18%	35%
Beef cattle kept on slurry (%)	18%	17%

The proportion of beef cattle on slurry is kept constant across the time series at 18%. Values for dairy cows and dairy followers on slurry are interpolated between 2000 and 2010 and are assumed fixed before and after these years.

Cattle housing periods were estimated from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (1998), with the housing period for milking dairy cattle extended to account for time in for milking during the summer months. For sheep, ewes are assumed to be indoors for 30 d, lambs not indoors at all. For poultry and pigs we assume a 100 % occupancy for housing, as the June agricultural surveys take snapshots of animal numbers which will reflect the actual % occupancy.

Pig housing

	Smith et al., 2000c	Sheppard 1998	Sheppard 2002	FPS2009	FPS2009
	1993	1998	2002	2006	2009
Dry sows on full slats (%)	3%	3%	3%	1%	2%
Dry sows on part slats (%)	24%	22%	22%	2%	10%
Dry sows on straw (%)	52%	47%	47%	68%	47%
Dry sows outdoors (%)	20%	28%	28%	29%	41%
Farrowing sows on full slats (%)	13%	11%	10%	10%	12%
Farrowing sows on part slats (%)	48%	42%	39%	17%	22%
Farrowing sows on straw (%)	20%	18%	17%	46%	23%
Farrowing sows outdoors (%)	20%	30%	34%	27%	43%
Boars on full slats (%)	0%	0%	0%	0%	0%
Boars on part slats (%)	0%	0%	0%	0%	0%
Boars on straw (%)	80%	72%	72%	72%	72%
Boars outdoors (%)	20%	28%	28%	28%	28%
Fatteners (20-110kg) on full slats (%)	25%	15%	15%	18%	9%
Fatteners (20-110kg) on part slats (%)	25%	20%	20%	26%	25%
Fatteners (20-110kg) on straw (%)	50%	64%	64%	53%	64%
Fatteners (20-110kg) outside (%)	0%	1%	1%	3%	2%
Weaners (<20kg) on full slats (%)	35%	27%	24%	19%	9%
Weaners (<20kg) on part slats (%)	55%	23%	20%	25%	27%
Weaners (<20kg) on straw (%)	10%	50%	45%	40%	43%
Weaners (<20kg) outside (%)	0%	1%	11%	16%	21%

Data are interpolated between years to derive the trend. FPS2010 gives some information on pig housing types, but does not break down into sub-categories of pig.

Poultry housing

	Smith et al., 2001a 2000	FPS2009 2009	FPS2010 2010
Layers free-range (%)	13%		44%
Layers in perchery (%)	5%		7%
Layers free-range/perchery on BAT	0%		1%
Layers in cages, deep-pit (%)	57%		25%
Layers in cages, belt-cleaned (%)	25%		24%
Broilers free-range (%)	1%	7%	
Broilers indoors, standard housing (%)	99%	74%	
Broilers indoors, reduced emission housing (%)	0%	19%	
Pullets free-range (%)	10%	6%	
Pullets indoors, standard housing (%)	90%	70%	
Pullets indoors, reduced emission housing (%)	0%	24%	
Breeding hens free-range (%)	10%	1%	
Breeding hens indoors, standard housing (%)	90%	99%	
Breeding hens indoors, reduced emission housing (%)	0%	0%	
Turkeys free-range (%)	10%	18%	
Turkeys indoors, standard housing (%)	90%	73%	
Turkeys indoors, reduced emission housing (%)	0%	9%	
Ducks free-range (%)	10%		
Ducks indoors, standard housing (%)	90%		
Ducks indoors, reduced emission housing (%)	0%		

FPS2009 data for laying hens was considered to be insufficiently robust (free-range laying hens were estimated at 5%, far below industry and expert opinion).

Storage

The proportions of manure stored in different store categories was derived from Farm Practices Surveys.

The proportion of cattle stores crusted estimated from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (1998), with stores stirred never or only occasionally assumed to be crusted.

Hard standings
UKAEI input data
Usage derived from survey conducted under WA0528 (Webb *et al.*, 2001) and from NT2402†.

Hard standing	Area per animal (m^2)	% animals using hard standing	Usage (Days per year)
Dairy cow collecting yard	2.15 (1.74, 2.55†)	65	358 (365, 358†)
Dairy cow feeding/loafing yard	3.03 (1.70, 3.03†)	30	303 (365, 240†)
Dairy cow self-feed silage yard	4.75	14	180
Beef cattle feeding/loafing yard	4.32	45	180
Beef cattle self-feed silage	4.71	9	180
Sheep handling area – lowland sheep	0.92	67	24
- upland sheep	0.92	67	6
Pig loading area	1.00	19	4

NB Area per animal not actually used in calculation, but included here for reference.

Fertiliser

Fertiliser usage in England, Wales and Scotland derived from British Survey of Fertiliser Practice 2008 (http://www.defra.gov.uk/environ/pollute/bsfp/index.htm) and for Northern Ireland from DARDNI stats (http://www.dardni.gov.uk/econs/.htm).

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DEFRA Projects

Final reports from the following projects are available from Defra:

AM0101	National ammonia reduction strategy evaluation system (NARSES)
AM0102	Modelling and measurement of ammonia emissions from ammonia mitigation pilot farms
AM0103	Evaluation of targeted or additional straw use as a means of reducing ammonia emissions from buildings for housing pigs and cattle
AM0110	Additional housing measurements for solid vs. liquid manure management systems
AM0111	Measurement and abatement of ammonia emissions from hard standings used by livestock
AM0115	Investigation of how ammonia emissions from buildings housing cattle vary with the time cattle spend inside them
DO108	Food and Agriculture Policy Research Institute – UK Project
KT0105	Manure Nutrient Evaluation Routine (MANNER-NPK)
LK0643	UK Poultry Industry IPPC Compliance (UPIC)
NT2001	Integration of animal manures in crop and livestock farming systems: nutrient demonstration farms
NT2402	Impact of nutrition and management on N and P excretions by dairy cows
NT2605	The behaviour of some different fertiliser-N materials - Main experiments
OC9117	Ammonia emission and deposition from livestock production systems
WA0519	Enhancing the effective utilisation of animal manures on-farm through effective compost technology
WA0618	Emissions from farm yard manure based systems for cattle

WA0625	The effects of covering slurry stores on emissions of ammonia, methane and nitrous oxide
WA0632	Ammonia fluxes within solid and liquid manure management systems
WA0633	Predicting ammonia loss following the application of organic manures to land
WA0638	Low cost, aerobic stabilisation of poultry layer manure
WA0641	Low-cost covers to abate gaseous emissions from slurry stores
WA0651	Ammonia fluxes within broiler litter and layer manure management systems
WA0652	Field ammonia losses in sustainable livestock LINK Project LK0613
WA0653	Quantifying the contribution of ammonia loss from housed dairy cows to total N losses from dairy systems (MIDaS2)
WA0707	Effect of storage conditions on FYM composition, gaseous emissions and nutrient leaching during storage
WA0708	Covering a farm scale lagoon of pig slurry
WA0712	Management techniques to minimise ammonia emissions during storage and land spreading of poultry manures
WA0714	Natural crusting of slurry storage as an abatement measure for ammonia emission on dairy farms
WA0716	Management techniques to reduce ammonia emissions from solid manures
WA0717	Ammonia emissions and nutrient balance in weeping-wall stores and earth banked lagoons for cattle slurry storage
WA0720	Demonstrating opportunities of reducing ammonia emissions from pig housing
WA0722	Ammonia emission from housed dairy cows in relation to housing system and level of production
WT0715NVZ	Nitrogen and phosphorus output standards for farm livestock