Inventory of Ammonia Emissions from UK Agriculture

2011

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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 2011. Year-specific livestock numbers and fertiliser N use were added for 2011 and revised for previous years. The estimate for 2011 was 230.4 kt NH_3, representing a 2.9 kt decrease from the previously submitted estimate for 2010. Much of this decrease was due to a revision of emission factors; using the 2011 inventory methodology, there was an increase of 0.7 kt NH_3 between 2010 and 2011, because of an increase in emissions from N fertiliser use. Backward and forward projections using the 2010 model structure gave estimates of 306 and 216 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 horses not kept on agricultural holdings, emissions from composting and domestic fertiliser use, which are not reported here.

Table 1. Estimate of ammonia emission from UK agriculture for 2011

Source	kt NH_3[*]	% of total
Livestock category		
Cattle	128.9	56
Dairy	*71.3*	*31*
Beef	*57.6*	*25*
Sheep[†]	9.5	4
Pigs	17.6	8
Poultry	30.8	13
Horses	4.0	2
Management category		
Grazing/outdoors	28.6	13
Housing	55.3	24
Hard standings	21.7	9
Manure storage	31.0	13
Manure application	54.2	24
Fertiliser application	39.7	17
TOTAL	**230.4**	

[†]Including goats and deer

[*] Totals may differ from sum of components due to rounding

Estimate of ammonia emission from UK agriculture for 2011

The estimate of NH_3 emission from UK agriculture for 2011 was made using the spreadsheet version of the National Ammonia Reduction Strategy Evaluation System (NARSES) model (file: NH3inv2011_NARSES_ 261112_FINAL_corrected.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 2011 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 2011. Currently-used emission factors were reviewed in the light of new experimental data and amended if considered appropriate.

Key areas of revision in the 2011 inventory were:

- Inclusion of 2011 livestock numbers

- Inclusion of 2011 N fertiliser use

- Revision of livestock housing emission factors

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

The estimate of emission from UK agriculture for 2011 was 230.4 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 2011 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 2010 inventory estimate.

Table 2. Sequential influence of revisions to individual components on the inventory total (NARSES model) during the 2011 revision

	Change (kt NH_3)	Total (kt NH_3)
2010 total		**233.3**
Livestock numbers 2011	-2.3	
N fertiliser use 2011	+1.5	
Revision to 2011 poultry litter incineration data	+0.6	
Revision to livestock housing emission factors	-3.2	
Revision to sheep N excretion	-0.5	
Revision to 2011 dairy cow milk yield	+1.2	
Other minor changes	-0.3	
2011 total		**230.4**

Table 3. Estimate of ammonia emissions (kt NH$_3$) from UK agriculture, 2011

Source	2010	2011[*]	Reasons for change
Cattle			Major revision to cattle housing EF
Grazing	15.7	**15.5**	Small reduction in cattle numbers, increase in N excretion by dairy cows
Landspreading	34.1	**36.1**	
Housing	40.6	**32.1**	
Hard standings	21.3	**21.1**	
Storage	22.4	**24.0**	
Total Cattle	134.1	**128.9**	
Sheep			
Grazing	7.1	**7.1**	
Landspreading	0.2	**0.2**	
Housing	1.1	**1.0**	
Hard standings	0.6	**0.5**	
Storage	0.9	**0.8**	
Total Sheep	10.0	**9.5**	Revision to sheep N excretion values
Horses	4.0	**4.0**	
Pigs			Revision to pig housing EF
Outdoor	1.1	**1.1**	Small reduction in pig numbers
Landspreading	3.9	**3.7**	
Housing	8.5	**9.1**	
Hard standings	0.0	**0.0**	
Storage	3.9	**3.7**	
Total Pigs	17.4	**17.6**	
Poultry			Revision to poultry housing EF
Outdoor	0.9	**0.9**	Reduction in total poultry numbers
Landspreading	13.8	**14.2**	
Housing	12.5	**13.1**	
Storage	2.5	**2.6**	
Total Poultry	29.7	**30.8**	
Fertiliser	38.2	**39.7**	Small decrease in total N use, but substantial increase in proportion as urea
TOTAL	233.3	**230.4**	

[*]Totals may differ from sum of components due to rounding

Major changes between 2010 and 2011

1. 2011 Livestock numbers

Headline changes from 2010 are:

Cattle – a 1.7% decline in total cattle numbers (1.8% decline for dairy cows)

Pigs – a 0.6% decline in pig numbers

Sheep – a 1.8% increase in sheep numbers

Poultry – a 0.8% decline in total poultry numbers, with a 1.1% decrease in the laying flock and a 2.7% decrease in broiler numbers

2. 2011 N fertiliser use

Data were derived from BSFP for crop year 2011 for England, Wales and Scotland and from DARD statistics for Northern Ireland.

Total fertiliser N use declined by 0.6% between 2010 and 2011, and there was a further increase in the proportion applied as urea (up from 22% in 2010 to 25% in 2011). The increase in urea use outweighed the overall decline in total fertiliser N use, resulting in an increase in emissions from fertiliser applications to land.

3. Poultry litter incineration

Data on tonnages of poultry litter incinerated at power stations were obtained from EPR Ltd, with an estimated total of 572,000 t incinerated in 2011, a decline of 98,000 t on the previous year.

4. Livestock housing emission factors

New data on ammonia emissions from cattle and finishing pigs housed on straw were incorporated from Defra project AC0102. In addition, the derivation of all existing emission factors, expressed as a percentage of TAN excreted in the house, were reviewed partly as there had been historical revisions to N excretion estimates for some livestock categories and partly because the original derivation had not been clearly documented. Full derivation of emission factors is given in the Appendix to this report, but the changes for those relevant to livestock housing and their impact on the emission total are given in Table 4. Emission factors for cattle housing, in particular, changed substantially, with revised values being much lower. This was mostly because of revising downwards the values (expressed as %TAN) derived from Defra projects WA0632/AM0110, project WA0722 and the value from Hill (2000). These values had previously stood out as being much greater than those from most other studies.

5. Revision to N excretion estimate for sheep

Corrections were made to the N excretion estimates used for ewes and lambs. The values previously used were from Defra project WT0715NVZ, but the value given there for ewes includes an amount for lambs from birth to 40kg. Therefore the value for ewes alone has been corrected according to that given by Smith and Frost (2000) of 9.0 kg N per ewe per year. For lambs, the daily output from Smith and Frost (2000) has been multiplied by the average

lifespan of lambs of 8.1 months as derived from a recent survey by Wheeler et al. (2012), giving an estimated 1.6 kg N per lamb per year.

Table 4. Revisions to emission factors used for livestock housing

Source	Previous EF (%TAN)	Revised EF (%TAN)	Impact on inventory (kt NH_3)
Cattle on slurry	31.5	27.7	-1.6
Cattle on straw	22.9	16.8	-2.0
Calves on straw	7.6	4.2	-0.6
Dry sows on slats	13.0	22.9	0
Dry sows on straw	25.0	43.9	+0.2
Farrowing sows on slats	19.0	30.8	+0.1
Farrowing sows on straw	25.0	43.9	0
Boars on straw	25.0	43.9	0
Finishing pigs on slats	33.2	29.4	-0.2
Finishing pigs on straw	22.4	26.6	+0.4
Weaners on slats	14.8	7.9	-0.1
Weaners on straw	26.2	7.2	-0.1
Layers – deep-pit	37.4	35.6	-0.1
Layers - belt-clean	16.5	14.5	0
Broilers	8.1	10.5	+0.6
Turkeys	19.2	36.6	+0.8
Other poultry	17.5	14.1	-0.5

Past and Projected Trends: 1990 - 2020

Retrospective calculations based on the 2010 inventory methodology were made for the years 1990 to 2010 and projections to 2020 (Table 5). Projected changes in livestock numbers, N fertiliser use and management practices are detailed below. There has been a steady decline in emissions (25%) from UK agriculture over the period 1990 – 2011, 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 30% reduction from 1990-2020. These projections are subject to much uncertainty and further work is required to both generate more robust projections in agricultural activity data and an estimate of uncertainties relating to the assumptions made in deriving the projections. In particular, the inventory total is very sensitive to projections regarding urea fertiliser use. Additionally, projections of activity to 2030 are required for future policy development.

Table 5. Estimates of ammonia emission from UK agriculture 1990 – 2020 using the NARSES model

Source	1990	1995	2000	2005	2010	2011	2015	2020
							Projections	
Total	**306.4**	**285.2**	**259.7**	**248.0**	**229.7**	**230.4**	**221.5**	**215.7**
Cattle	149.3	145.3	139.3	135.6	129.9	128.9	126.3	121.4
Dairy cattle	*85.5*	*81.5*	*77.5*	*74.9*	*71.4*	*71.3*	*70.5*	*66.9*
Other cattle	*63.8*	*63.8*	*61.8*	*60.7*	*58.5*	*57.6*	*55.8*	*54.4*
Sheep	13.3	13.1	12.8	10.8	9.4	9.5	9.4	9.4
Pigs	42.7	40.5	31.8	22.6	17.7	17.6	14.4	14.5
Laying hens	13.4	11.7	9.8	9.3	8.5	8.4	8.0	7.6
Broilers	15.7	12.3	15.4	14.0	10.2	10.3	11.0	10.9
Other poultry	5.8	11.8	13.1	13.2	11.7	12.1	12.4	12.4
Horses	2.6	3.4	3.7	4.5	4.0	4.0	4.0	4.0
Fertiliser	63.7	47.1	33.7	38.1	38.2	39.7	36.1	35.6

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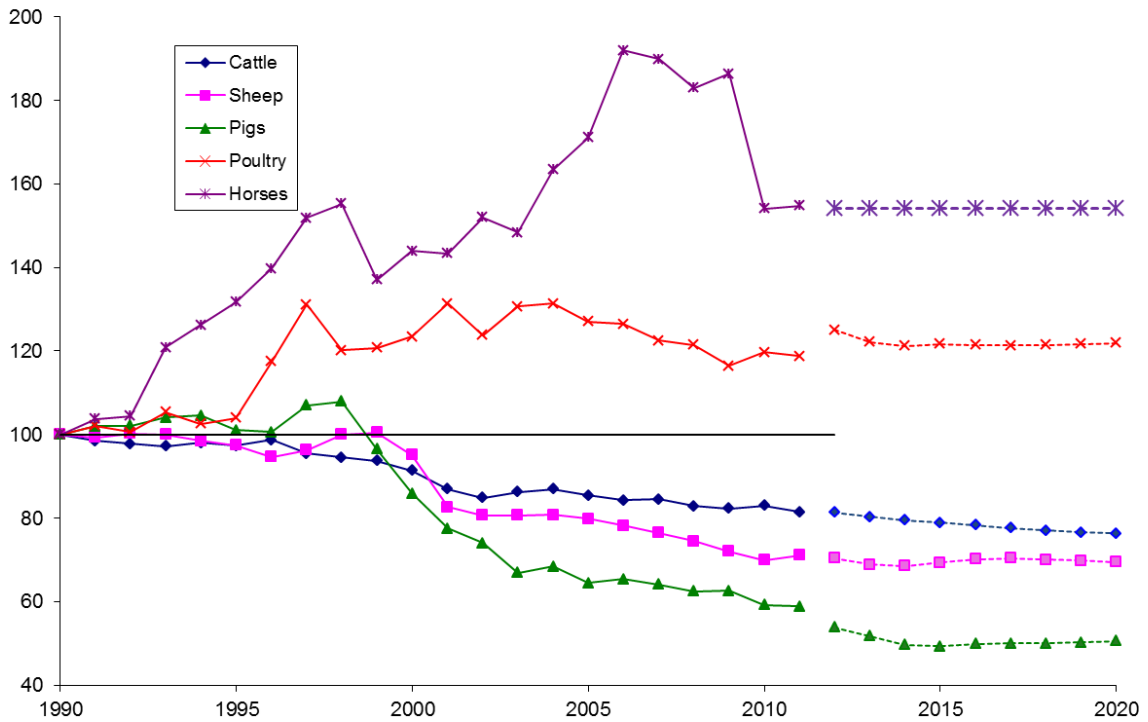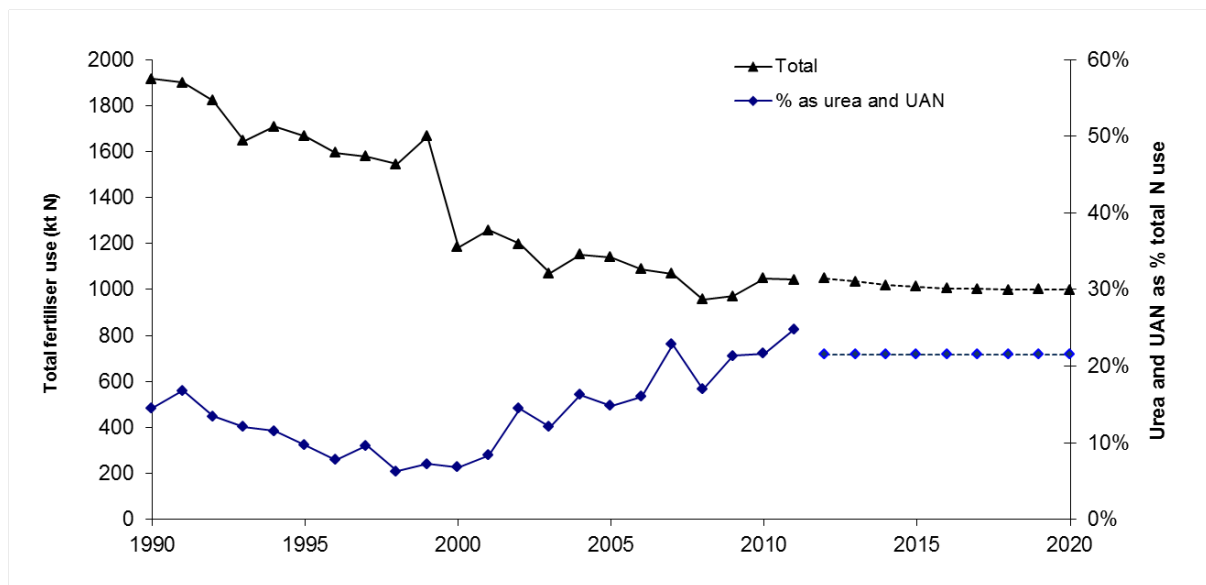

Figure 2. Changes in fertiliser N use 1990 – 2020. Dashed lines show projections from derived from FAPRI data (Defra project DO108).

Projections – methodology and assumptions

Livestock numbers

Livestock number projections are based on FAPRI modelling data. In addition, trends in N excretion have been included: N excretion by dairy cattle was forecast to increase as cattle numbers became fewer but milk quota was 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.

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

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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 6). These are based on 2006 census livestock numbers, but the proportions will be assumed to remain the same.

Table 6. 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

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 7 and the proportion of manure applications subject to BAT given in Table 8.

Table 7. 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 8. 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 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 $EF_2 = EF_1$ x 1.15
Arable $EF_2 = EF_1$ x 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.

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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 divided by **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	Values	Derived from n values	Emission as %TAN	Source
g N t^{-1} initial heap mass				
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

Mean EF of 10.6 kg NH$_3$-N per animal per year used, as for 'other horses' in non-agricultural emissions inventory (Sutton *et al*., 2000).

NARSES EF derived using reverse-engineering as 35 %TAN, based on the UKAEI EF.

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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 census 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 (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.

Proportion of waste produced as slurry or FYM 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 obtained directly from EPRL and Fibropower websites (K Smith, ADAS).

Manure output and N excretion by livestock category (2011 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	52.7	68.5	66	34	123.5	60
Dairy heifers in calf	31.9	41.5	66	34	67	60
Dairy replacements >2 yrs	31.9	41.5	18	82	56	60
Dairy replacements 1-2 yrs	25.8	33.5	18	82	56	60
Dairy bulls > 2 yrs	31.9	41.5	18	82	53	60
Dairy bulls 1-2 yrs	25.8	33.5	18	82	56	60
Dairy calves	14.5	18.9	0	100	38	60
Beef cows & heifers	31.9	41.5	18	82	79	60
Beef heifers in calf	25.8	33.5	18	82	56	60
Bulls >2 yrs	31.9	41.5	18	82	53	60
Bulls 1-2 yrs	25.8	33.5	18	82	56	60
Beef > 2 yrs	31.9	41.5	18	82	56	60
Beef 1-2 yrs	25.8	33.5	18	82	56	60
Beef calves	14.5	18.9	0	100	38	60
Sheep						
Ewes - lowland		5.3	0	100	10.5	60
Ewes - upland		5.3	0	100	9.9	60
Lambs - lowland		2.6	0	100	0.6	60
Lambs - upland		2.6	0	100	0.7	60
Goats					20.6	60
Deer					13	60
Pigs						
Maiden gilts	10.9	13.6	35	65	15.5	70
Sows			35	65	18.1	70
Boars	10.9	13.6	0	100	21.8	70
Fatteners >110 kg			33	67	15.4	70
Fatteners 80-110 kg			33	67	15.4	70
Fatteners 50-80 kg			33	67	13.3	70
Fatteners 20-50 kg			33	67	8.9	70
Weaners (<20 kg)	1.3	1.4	53	47	3.4	70
Poultry						
Laying hens (cages)		0.11	0	100	0.67	70
Laying hens (free-range)		0.11	0	100	0.75	70
Broilers		0.05	0	100	0.40	70
Pullet		0.02	0	100	0.33	70
Breeding Hens		0.11	0	100	1.02	70
Turkeys (m)		0.09	0	100	2.18	70
Turkeys (f)		0.09	0	100	1.46	70
Ducks		0.09	0	100	1.71	70
Horses			0	100	50	60

Manure volume output data derived from Smith et al. (2000c, 2001a, 2001b) with interpretation for animal place and annual outputs by K Smith (ADAS). Nitrogen excretion data from project WT0715NVZ with interpretation by B Cotteril and K Smith (ADAS).

Land spreading

Proportion of pig or cattle manure applied to grassland and arable, proportion applied in summer (May-July), proportion applied by injection or irrigated and proportion incorporated within 1d or 1wk of application obtained from ADAS Surveys of Animal Manure Practices in the Dairy, Beef, Pig and Poultry Industries (Smith *et al*., 2000c, 2001a, 2001b). Proportion of

cattle and pig FYM spread to land without storage also obtained from the same source. Proportion of poultry manure applied to grassland and arable obtained from Farm Practices Survey (Defra 2001).

Proportion of slurry in each dry matter category from ADAS unpublished (K Smith, B Chambers).

Housing

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). Proportion of pigs outdoors from Sheppard (1998, 2002). Poultry housing and % manure dropped outdoors provided 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	FPS2010
	2000	2010
Dairy cows kept on slurry (%)	66%	83%
Dairy followers kept on slurry (%)	18%	35%
Beef cattle kept on slurry (%)	18%	17%

Beef cattle on slurry are kept at a constant 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 obtained from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (1998), with housing period of milking dairy cattle extended to account for time in for milking during the summer months. For sheep, ewes indoors for 30 d, lambs not indoors at all. Poultry and pigs assume 100 % occupancy as June census takes a snapshot 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	FPS2009	FPS2010
	2000	2009	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

Proportions of manure stored in different store categories 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