CHAPTER 10

EMISSIONS FROM LIVESTOCK AND MANURE MANAGEMENT

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10.1 INTRODUCTION

This chapter provides guidance on methods to estimate emissions of methane from Enteric Fermentation in livestock, and methane and nitrous oxide emissions from Manure Management. CO_2 emissions from livestock are not estimated because annual net CO_2 emissions are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2. A portion of the C is returned as CH_4 and for this reason CH_4 requires separate consideration.

Livestock production can result in methane (CH_4) emissions from enteric fermentation and both CH_4 and nitrous oxide (N_2O) emissions from livestock manure management systems. Cattle are an important source of CH_4 in many countries because of their large population and high CH_4 emission rate due to their ruminant digestive system. Methane emissions from manure management tend to be smaller than enteric emissions, with the most substantial emissions associated with confined animal management operations where manure is handled in liquid-based systems. Nitrous oxide emissions from manure management vary significantly between the types of management system used and can also result in indirect emissions due to other forms of nitrogen loss from the system. The calculation of the nitrogen loss from manure management systems is also an important step in determining the amount of nitrogen that will ultimately be available in manure applied to managed soils, or used for feed, fuel, or construction purposes – emissions that are calculated in Chapter 11, Section 11.2 (N_2O emissions from managed soils).

The methods for estimating CH_4 and N_2O emissions from livestock require definitions of livestock subcategories, annual populations and, for higher Tier methods, feed intake and characterisation. The procedures employed to define livestock subcategories, develop population data, and characterize feed are described in Section 10.2 (Livestock Population and Feed Characterisation). Suggested feed digestibility coefficients for various livestock categories have been provided to help estimation of feed intake for use in calculation of emissions from enteric and manure sources. A coordinated livestock characterisation as described in Section 10.2 should be used to ensure consistency across the following source categories:

- Section 10.3 - CH_4 emissions from Enteric Fermentation;
- Section 10.4 - CH_4 emissions from Manure Management;
- Section 10.5 - N_2O emissions from Manure Management (direct and indirect);
- Chapter 11, Section 11.2 - N_2O emissions from Managed Soils (direct and indirect).

10.2 LIVESTOCK POPULATION AND FEED CHARACTERISATION

10.2.1 Steps to define categories and subcategories of livestock

10.2.2 Choice of method

This section contains updated guidance

TIER 1: BASIC CHARACTERISATION FOR LIVESTOCK POPULATIONS

Basic characterisation for Tier 1 is likely to be sufficient for most animal species in most countries. For this approach it is *good practice* to collect the following livestock characterisation data to support the emissions estimates:

Livestock species and categories: A complete list of all livestock populations that have default emission factor values must be developed (e.g., dairy cows, other cattle, buffalo, sheep, goats, camels, llamas, alpacas, deer, horses, rabbits, mules and asses, swine, and poultry) if these categories are relevant to the country. More detailed categories should be used if the data are available. For example, more accurate emission estimates can be made if poultry populations are further subdivided (e.g., layers, broilers, turkeys, ducks, and other poultry), as the waste characteristics among these different populations vary significantly.

Annual population: If possible, inventory compilers should use population data from official national statistics or industry sources. Food and Agriculture Organisation (FAO) data can be used if national data are unavailable. Seasonal births or slaughters may cause the population size to expand or contract at different times of the year which will require the population numbers to be adjusted accordingly. It is important to fully document the method used to estimate the annual population, including any adjustments to the original form of the population data as it was received from national statistical agencies or from other sources.

Annual average populations are estimated in various ways, depending on the available data and the nature of the animal population. In the case of static animal populations (e.g. dairy cows, breeding swine, layers), estimating the annual average population may be as simple as obtaining data related to one-time animal inventory data. However, estimating annual average populations for a growing population (e.g., meat animals, such as broilers, turkeys, beef cattle, and market swine) requires more evaluation. Most animals in these growing populations are alive for only part of a complete year. Animals should be included in the populations regardless if they were slaughtered for human consumption or die of natural causes. Equation 10.1 estimates the annual average of livestock population.

EQUATION 10. 1
ANNUAL AVERAGE POPULATION

$$AAP = Days\_alive \bullet \left(\frac{NAPA}{365}\right)$$

Where:

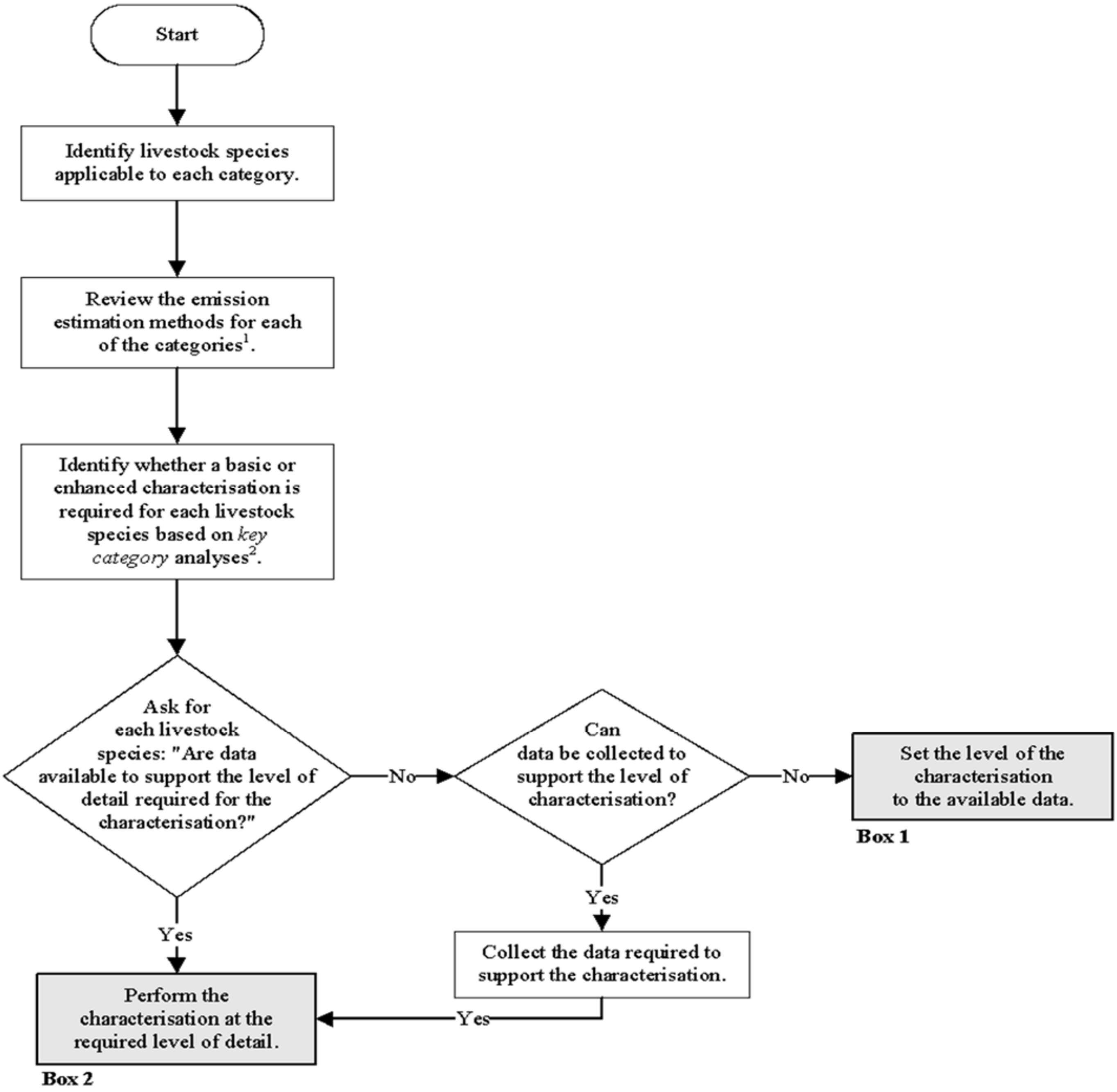
AAP = annual average population

NAPA = number of animals produced annually

Broiler chickens are typically grown approximately 60 days before slaughter. Estimating the average annual population as the number of grown and slaughtered over the course of a year would greatly overestimate the population, as it would assume each lived the equivalent of 365 days. Instead, one should estimate the average annual population as the number of animals grown divided by the number of growing cycles per year. For example, if broiler chickens are typically grown in flocks for 60 days, an operation could turn over approximately 6 flocks of chickens over the period of one year. Therefore, if the operation grew 60,000 chickens in a year, their average annual population would be 9,863 chickens. For this example the equation would be:

Annual average population = 60 days • 60,000 / 365 days / yr = 9,863 chickens

Figure 10. 1 Decision tree for livestock population characterisation



Note:
1: These categories include: CH_4 Emission from Enteric Fermentation, CH_4 Emission from Manure Management, and N_2O Emission from Manure Management.
2: See Volume 1 Chapter 4, "Methodological Choice and Identification of Key Categories" (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.

Consideration of differing Productivity Classes

In certain countries agricultural production systems may be transitioning from low productivity local subsistence systems to higher productivity systems aimed at fulfilling national and export commodity markets or may simply have dual agricultural systems, with coexistence of low and high productivity systems. In these cases inventory compilers may wish to use the Tier 1b system in which they are able to better track the transitions and changes of their agricultural systems productivity and related emissions over time.

In this case animal populations may be divided by productivity classes. For each animal category high and low productivity classes may be defined according to the following characteristics; Tier 1, per head emission factors have been developed for use with basic population estimates separated by low and high productivity classes according to the following definitions.

Definitions of High and Low Productivity Systems

Dairy Cattle and milk production:

The dairy cow population is estimated separately from other cattle (see Table 10.1). Dairy cows are defined in this method as mature (first lactation and beyond) cows that are producing milk in commercial quantities for human consumption. This definition corresponds to the dairy cow population reported in the FAO Production Yearbook. In some countries the dairy cow population is comprised of two well-defined segments:

- **High-productivity systems** are based on animal feeding systems adapted for medium- or large-scale (herd size) farms and high-yielding dairy cows that are concentrated in confinement production systems or grazing with supplements or on improved pastures. The farms are 100-percent market oriented for commercial milk production, sale and export; Cows are genetically improved for milk production and either be purebred or crossbred. (Fao and Idf and 2014).
- **Low productivity systems** are based on animal feeding systems occurring in small-scale (herd size), with low-yielding dairy cows, where locally produced roughage (e.g. crop residues) and/or rangelands represents the major source of feed utilized. Cows are not genetically improved for milk production and are either local or introduced breeds and sometimes may be crossbred. Milk production is mostly for local market and self-consumption (Fao and Idf and 2014).

Dairy buffalo may be categorized in a similar manner to dairy cows.

Data on the average milk production of dairy cows are also required. Milk production data are used in estimating an emission factor for enteric fermentation using the Tier 2 method. Country-specific data sources are preferred, but FAO data may also be used. These data are expressed in terms of kilograms of whole fresh milk or fat corrected milk produced per year per dairy cow. If two or more dairy cow categories are defined, the average milk production per cow is required for each category. The dairy cow category does not include cows kept principally to produce calves for meat or to provide draft power. Low productivity multi-purpose cows should be considered as other cattle.

Non Dairy cows:

- **High-productivity systems** are based on animal feeding systems adapted for medium- or large-scale (herd size) farms and medium and high-weight gaining animals using locally produced roughage (e.g. high-quality grass) and **concentrated** in confinement production systems or grazing with supplements or on improved pastures. Animals are genetically improved for commercial meat production in national or export markets and either be purebred or crossbred. Growing cattle may be finished in feedlot, and meat is produced for national scale markets and/or export (FAO, 2014).
- **Low productivity systems** are based on animal feeding systems for small-scale (herd size) low- weight gaining animals, where locally produced roughage (e.g. crop residues) or rangelands represents the major source of feed utilized. Animals are normally not genetically improved for meat production and are either local or introduced breeds, sometimes may be crossbred and can also be used for multiple purposes such as draft or milk production). Meat production goes to local markets. (FAO, 2014).

Other livestock categories

- **High-productivity systems** are based on animal feeding systems for medium- or large-scale (herd size) farms, which are 100 percent market oriented with high level of capital input requirements and high level of overall herd (flock) performance. Feed is purchased from local or *international* market or intensively produced on farm. Animals are genetically improved for commercial production. The high-productivity systems are common in swine, poultry, goats and sheep (MacLeod *et al.* 2017) production. The farming practice and animal breeds associated with high productivity systems of such animals as camels, mules, asses, deer and alpacas refers to production systems established in developed countries.
- **Low productivity systems are** based on animal feeding systems for small- or medium-scale (herd size), which are mainly driven by local market or by self-consumption, with low capital input requirements and low level of overall herd (fowl) typically using large areas for production. Locally produced feed represents the major source of feed utilized or animals are kept-free range for major part or all of their production cycle, the yield of the activity being linked to the natural fertility of the land and the seasonal production of the pastures. The farming practice and animal breeds associated with low productivity systems of such animals as camels, mules, asses, deer and alpacas refers to production systems established in developing countries. (MacLeod *et al.* 2017)

TIER 2: ENHANCED CHARACTERISATION FOR LIVESTOCK POPULATIONS

The Tier 2 livestock characterisation requires detailed information on:

- Definitions for livestock subcategories;
- Livestock population by subcategory, with consideration for estimation of annual population as per Tier 1; and
- Feed intake estimates for the typical animal in each subcategory.

The livestock population subcategories are defined to create relatively homogenous sub-groupings of animals. By dividing the population into these subcategories, country-specific variations in age structure and animal performance within the overall livestock population can be reflected.

The Tier 2 characterisation methodology seeks to define animals, animal productivity, diet quality and management circumstances to support a more accurate estimate of feed intake for use in estimating methane production from enteric fermentation. The same feed intake estimates should be used to provide harmonised estimates of manure and nitrogen excretion rates to improve the accuracy and consistency of CH_4 and N_2O emissions from manure management.

Definitions for livestock subcategories

It is *good practice* to classify livestock populations into subcategories for each species according to age, type of production, and sex. Representative livestock categories for doing this are shown in Table 10.1. Further subcategories are also possible:

- Cattle and buffalo populations should be classified into at least three main subcategories: mature dairy, other mature, and growing cattle. Depending on the level of detail in the emissions estimation method, subcategories can be further classified based on animal or feed characteristics. For example, growing / fattening cattle could be further subdivided into those cattle that are fed with a high-grain diet and housed in dry lot vs. those cattle that are grown and finished solely on pasture.
- Subdivisions similar to those used for cattle and buffalo can be used to further segregate the sheep population in order to create subcategories with relatively homogenous characteristics. For example, growing lambs could be further segregated into lambs finished on pasture vs. lambs finished in a feedlot. The same approach applies to national goat herds.
- Subcategories of swine could be further segregated based on production conditions. For example, growing swine could be further subdivided into growing swine housed in intensive production facilities vs. swine that are grown under free-range conditions.
- Subcategories of poultry could be further segregated based on production conditions. For example, poultry could be divided on the basis of production under confined or free-range conditions.

For large countries or for countries with distinct regional differences, it may be useful to designate regions and then define categories within those regions. Regional subdivisions may be used to represent differences in climate, feeding systems, diet, and manure management. However, this further segregation is only useful if correspondingly detailed data are available on feeding and manure management system usage by these livestock categories.

Table 10. 1 Representative livestock categories[1,2]

Main categories	Production categories Tier 1b	Subcategories
Mature Dairy Cow or Mature Dairy Buffalo	High Productivity Systems	· High-producing cows that have calved at least once and are used principally for milk production
	Low Productivity Systems	· Low-producing cows that have calved at least once and are used principally for milk production
Other Mature Cattle or Mature Non-dairy Buffalo	High Productivity Systems	Females: · Cows used to produce offspring for meat · Cows used for more than one production purpose: milk, meat, draft Males: · Bulls used principally for breeding purposes.
	Low Productivity Systems	Females: · Cows that may be used for more than one production purpose: milk, meat, draft

		Males: · Bulls used principally for draft power
Growing Cattle or Growing Buffalo	High Productivity Systems	· Calves pre-weaning · Replacement dairy heifers · Growing / fattening cattle or buffalo post-weaning · Feedlot-fed cattle on diets containing > 85 % concentrates
	Low Productivity Systems	· Calves pre-weaning · Growing / fattening cattle or buffalo post-weaning
Mature Ewes	· Breeding ewes for production of offspring and wool production · Milking ewes where commercial milk production is the primary purpose	
Other Mature Sheep (>1 year)	· No further sub-categorisation recommended	
Growing Lambs	· Intact males · Castrates · Females	
Goats	. Dairy Does . Breeding does . Yearlings . Bucks . Kids (<1 yr)	
Mature Swine	High Productivity Systems	· Sows in gestation · Sows which have farrowed and are nursing young · Boars that are used for breeding purposes
	Low Productivity Systems	· Sows in gestation · Sows which have farrowed and are nursing young · Boars that are used for breeding purposes
Growing Swine	High Productivity Systems	· Nursery · Finishing · Gilts that will be used for breeding purposes · Growing boars that will be used for breeding purposes
	Low Productivity Systems	· Growing / fattening swine · Gilts/boars will be used for breeding purposes
Chickens	High Productivity Systems	· Broiler chickens grown for producing meat in confinement systems · Breeder Broiler chickens grown in confinement systems · Layer chickens for producing eggs, where manure is managed in dry systems (e.g., high-rise houses) · Layer chickens for producing eggs, where manure is managed in wet systems (e.g., lagoons) · Chickens under free-range conditions for egg or meat production
	Low Productivity Systems	· Chickens under free-range conditions for egg or meat production
Turkeys	High Productivity Systems	· Breeding turkeys in confinement systems · Turkeys grown for producing meat in confinement systems · Turkeys under free-range conditions for meat production
	Low Productivity Systems	· Turkeys under free-range conditions for meat production
Ducks	· Breeding ducks · Ducks grown for producing meat	
Others (for example)	· Camels	

	· Mules and Asses · Llamas, Alpacas · Fur bearing animals · Rabbits · Horses · Deer · Ostrich · Geese
[1] Source IPCC Expert Group [2] Emissions should only be considered for livestock species used to produce food, fodder or raw materials used for industrial processes.	

For each of the representative animal categories defined, the following information is required:

- annual average population (number of livestock or poultry as per calculations for Tier 1);
- average daily feed intake (megajoules (MJ) per day or kg per day); and
- methane conversion factor (percentage of feed energy converted to methane).

Generally, data on average daily feed intake are not available, particularly for grazing livestock. Consequently, the following general data should be collected for estimating the feed intake for each representative animal category:

- weight (kg);
- average weight gain per day (kg)[1];
- feeding situation: confined, grazing, pasture conditions;
- milk production per day (kg/day), fat and protein content;
- average amount of work performed per day (hours day^{-1});
- percentage of females that give birth in a year[2];
- wool growth;
- number of offspring; and
- digestibility of feed, expressed as the percentage of digestible energy in feed gross energy (%).

Feed intake estimates

Tier 2 emissions estimates require feed intakes for a representative animal in each subcategory. Feed intake is typically measured in terms of gross energy (e.g., mega Joules (MJ) per day) or dry matter (e.g., kilograms (kg)) consumed per day. Dry matter is the amount of feed consumed (kg) after it has been corrected for the water content in the complete diet. For example, consumption of 10 kg of a diet that contains 70% dry matter would result in a dry matter intake of 7 kg. To support the enteric fermentation Tier 2 method for cattle, buffalo, and sheep (see Section 10.3), detailed data requirements and equations to estimate feed intake are included in the guidance below. Constants in the equations have been combined to simplify overall equation formats. The remainder of this subsection presents the typical data requirements and equations used to estimate feed intake for cattle, buffalo, and sheep. Feed intake for other species can be estimated using similar country-specific methods appropriate for each.

For all estimates of feed intake, *good practice* is to:

- Collect data to describe the animal's typical diet and performance in each subcategory;
- Estimate feed intake required from the animal performance and diet data for each subcategory.

[1] This may be assumed to be zero for mature animals.

[2] This is only relevant for mature females.

In some cases, the equations may be applied on a seasonal basis, for example under conditions in which livestock gain weight in one season and lose weight in another. This approach may require a more refined variation of Tier 2 or more complex Tier 3 type methodology.

The following animal performance data are required for each animal subcategory to estimate feed intake for the subcategory:

- **Weight (W), kg:** Live-weight data should be collected for each animal subcategory. It is unrealistic to perform a complete census of live-weights, so live-weight data should be obtained from representative sample studies or statistical databases if these already exist. Comparing live-weight data with slaughter-weight data is a useful cross-check to assess whether the live-weight data are representative of country conditions. However, slaughter-weight data should not be used in place of live-weight data as it fails to account for the complete weight of the animal. Additionally, it should be noted that the relationship between live-weight and slaughter-weight varies with breed and body condition. For cattle, buffalo and mature sheep, the yearly average weight for each animal category (e.g., mature beef cows) is needed. For young animals, weights are needed at birth, weaning, one year of age or at slaughter if slaughter occurs within the year.

- **Average weight gain per day (WG), kg day^{-1}**: Data on average weight gain are generally collected for feedlot animals and young growing animals. Mature animals are generally assumed to have no net weight gain or loss over an entire year. Mature animals frequently lose weight during the dry season or during temperature extremes and gain weight during the following season. However, increased emissions associated with this weight change are likely to be small. Reduced intakes and emissions associated with weight loss are largely balanced by increased intakes and emissions during the periods of gain in body weight.

- **Mature weight (MW), kg**: The mature weight of the adult animal of the inventoried group is required to define a growth pattern, including the feed and energy required for growth. For example, mature weight of a breed or category of cattle or buffalo is generally considered to be the body weight at which skeletal development is complete. The mature weight will vary among breeds and should reflect the animal's weight when in moderate body condition. This is termed 'reference weight' (ACC, 1990) or 'final shrunk body weight' (NRC, 1996). Estimates of mature weight are typically available from livestock specialists and producers.

- **Average number of hours worked per day:** For draft animals, the average number of hours worked per day must be determined.

- **Feeding situation:** The feeding situation that most accurately represents the animal subcategory must be determined using the definitions shown below (Table 10.5). If the feeding situation is intermediate to the definitions given, the feeding situation should be described in detail. This detailed information may be needed when calculating the enteric fermentation emissions, because interpolation between the feeding situations may be necessary to assign the most appropriate coefficient value. Table 10.5 defines the feeding situations for cattle, buffalo, and sheep. For poultry and swine, the feeding situation is assumed to be under confinement conditions and consequently the activity coefficient (C_a) is assumed to be zero as under these conditions very little energy is expended in acquiring feed. Activity coefficients have not been developed for free-ranging swine or poultry, but in most instances these livestock subcategories are likely to represent a small proportion of the national inventory.

- **Mean winter temperature (°C)**: Detailed feed intake models consider ambient temperature, wind speed, hair and tissue insulation and the heat of fermentation (NRC, 2001; AAC, 1990) and are likely more appropriate in Tier 3 applications. A more general relationship adapted from North America data suggest adjusting the Cf_i of Equation 10.2 during the cold months for maintenance requirements of open-lot fed cattle in colder climates according to the following equation (Johnson, 1986):

EQUATION10. 2
COEFFICIENT FOR CALCULATING NET ENERGY FOR MAINTENANCE

$$Cf_i(in\_cold) = Cf_i + 0.0048 \bullet (20 - °C)$$

Where:

Cf_i = a coefficient which varies for each animal category as shown in Table 10.4 (Coefficients for calculating NE_m), MJ day^{-1} kg^{-1}

°C = mean daily temperature during winter season

Considering the average temperature during winter months, net energy for maintenance (NE_m) requirements may increase by as much as 30% in northern North America. This increase in feed use for maintenance leads to a greater methane emissions. The Nutrient Requirements of Beef Cattle, 8th Revised Edition (2016)cautions that the general response to cold temperature can vary with thermal susceptibility of the animal, acclimation, and diet. Thus, Eq. 10.2 may not be applicable for adapted animals, or for those protected by wind-breaks or shelter during cold weather.

- **Average daily milk production (kg day^{-1}):** These data are for milking ewes, milking does, dairy cows and buffalo. The average daily production should be calculated by dividing the total annual production by 365, or reported as average daily production along with days of lactation per year, or estimated seasonal production divided by number of days per season. If using seasonal production data, the emission factor must be developed forseasonal period.

- **Fat content (%):** Average fat content of milk is required for lactating cows, buffalo, sheep, and goats producing milk for human consumption.

- **Percent of females that give birth in a year:** This is collected only for mature cattle, buffalo, sheep and goats

- **Number of off spring produced per year:** This is relevant to female livestock that have multiple births per year (e.g., ewes).

- **Feed digestibility (DC):** The portion of gross energy (GE) in the feed not excreted in the faeces is known as digestible energy. Feed digestibility is commonly expressed as a percentage of GE or as TDN (total digestible nutrients). The percentage of feed that is not digested represents the % of GE intake that will be excreted as faeces. Typical digestibility (DC) values for a range of livestock classes and diet types are presented in Table 10.2 as a guideline. For ruminants, common ranges of feed digestibility are 45-55% for crop by-products and range lands; 55-80% for good pastures, good preserved forages, crop by-products and grain supplemented forage-based diets; and 72-85% for grain-based diets fed in feedlots. Variation in diet digestibility results directly in major variation in the estimated amount of feed needed to meet animal requirements and consequently is a main cause of variation in associated methane emissions and in the amounts of manure excreted (next to variation in yield of methane per unit of digested GE as explained further in chapter 10.3). For example, a low digestibility feed will lead to lower feed intake and consequently reduced growth, and relatively larger amount of feed required and associated methane per unit of growth. Conversely, feeds with high digestibility will often result in a higher feed intake and increased growth and a relatively smaller amount of feed required per unit of growth. A 10% error in estimating DC will be magnified to 12 to 20% when estimating methane emissions and even more (20 to 45%) for amounts of manure excreted (volatile solids). It is important to note that feed requirements, feed digestibility, production and growth, and yield of methane from digested GE (explained further in chapter 10.3) are co-dependent phenomena.

  Digestibility data should be based on measured values for the dominant feeds or forages being consumed by livestock with consideration for seasonal variation. In general, the digestibility of forages decreases with increasing maturity and is typically lowest during hot weather or dry season. Due to significant variation, digestibility values should be obtained from local scientific data wherever possible. Although a complete census of digestibility is considered unrealistic, at a minimum digestibility data from research studies should be consulted. While developing the digestibility data, associated feed characteristic data should also be recorded when available, such as feed content of neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein, crude fat, ash and the presence of anti-nutritional factors (e.g., alkaloids, phenolics). NDF and ADF are feed characteristics measured in the laboratory that are used to indicate the nutritive value of the feed for ruminant livestock. Determination of these values can enable DC to be predicted as defined in the last dairy National Research Council (2008) publication. The concentration of crude protein in the feed can be used in the process of estimating nitrogen excretion (Section 10.5.2). Accurate estimation of the crude fat content of feed is important, especially in the case of high-fat feeds, for accurate estimation of the GE content in feed, which is needed to calculate feed intake needed to achieve GE requirements (Section 10.2.2.).

- **Average annual wool production per sheep and goats (kg yr^{-1}):** The amount of wool produced in kilograms (after drying out but before scouring) is needed to estimate the amount of energy allocated for wool production. For goats this is only applicable if the country has relevant numbers of fibre-producing goats.

Table 10. 2 REPRESENTATIVE FEED DIGESTIBILITY FOR VARIOUS LIVESTOCK CATEGORIES

Main categories	Class	Digestibility (DC as %)

Swine	• Mature Swine – confinement • Growing Swine - confinement • Swine – free range	• 70 - 80% • 80 - 90% • 50 - 70% [1]
Cattle and other ruminants	• Feedlot animals fed with > 85% concentrate or high-grain diet; • Pasture / mixed-diet fed animals; • Animals fed – low quality forage	• 72 - 85% • 55 - 80% • 45 - 55%
Poultry	• Broiler Chickens –confinement • Layer Hens – confinement • Poultry – free range • Turkeys – confinement • Geese – confinement	• 85 - 93% • 70 - 80% • 55 - 90% [1] • 85 - 93% • 80 - 90%

[1] The range in digestibility of feed consumed by free-range swine and poultry is extremely variable due to the selective nature of these diets. Often it is likely that the amount of manure produced in these classes will be limited by the amount of feed available for consumption as opposed to its degree of digestibility. In instances where feed is not limiting and high quality feed sources are readily accessible for consumption, digestibility may approach values that are similar to those measured under confinement conditions.

Gross energy calculations

Animal performance and diet data are used to estimate feed intake the amount of energy (MJ/day) animal needs for maintenance and for such as growth, lactation, and pregnancy. For inventory compilers who have well-documented and recognised country-specific methods for estimating intake based on animal performance data, it is *good practice* to use the country-specific methods. The following section provides methods for estimating gross energy intake for the key ruminant categories of cattle, buffalo and sheep. The equations listed in Table 10.3 are used to derive this estimate. If no country-specific methods are available, intake should be calculated using the equations listed in Table 10.3. As shown in the table, separate equations are used to estimate net energy requirements for sheep and goats as compared with cattle and buffalo. The equations used to calculate GE are as follows:

Table 10. 3 SUMMARY OF THE EQUATIONS USED TO ESTIMATE DAILY GROSS ENERGY INTAKE FOR CATTLE, BUFFALO AND SHEEP AND GOATS

Metabolic functions and other estimates	Equations for cattle and buffalo	Equations for sheep and goats
Maintenance (NE_m)	Equation 10.3	Equation 10.3
Activity (NE_a)	Equation 10.4	Equation 10.5
Growth (NE_g)	Equation 10.6	Equation 10.7
Lactation (NE_l)*	Equation 10.8	Equations 10.9 and 10.10
Draft Power (NE_{work})	Equation 10.11	NA
Wool Production (NE_{wool})	NA	Equation 10.12
Pregnancy (NE_p)*	Equation 10.13	Equation 10.13
Ratio of net energy available in diet for maintenance to digestible energy consumed (REM)	Equation 10.14	Equation 10.14
Ratio of net energy available for growth in a diet to digestible energy consumed (REG)	Equation 10.15	Equation 10.15
Gross Energy	Equation 10.16	Equation 10.16

Source: Cattle and buffalo equations based on NRC (2013) and sheep and goats based on AFRC (1990, 1995).
NA means 'not applicable'.
* Applies only to the proportion of females that give birth.

***Net energy for maintenance*:** (NE_m) is the net energy required for maintenance, which is the amount of energy needed to keep the animal in equilibrium where body energy is neither gained nor lost (Jurgen, 1988).

EQUATION 10. 3
NET ENERGY FOR MAINTENANCE

$$NE_m = Cf_i \bullet (Weight)^{0.75}$$

Where:

NE_m = net energy required by the animal for maintenance, MJ day^{-1}

Cf_i = a coefficient which varies for each animal category as shown in Table 10.4 (Coefficients for calculating NE_m), MJ day^{-1} kg^{-1}

Weight = live-weight of animal, kg

Net energy for activity: **(**NE_a) is the net energy for activity, or the energy needed for animals to obtain their food, water and shelter. It is based on its feeding situation rather than characteristics of the feed itself. As presented in Table 10.3, the equation for estimating NE_a for cattle and buffalo is different from the equation used for sheep and goats. Both equations are empirical with different definitions for the coefficient C_a.

EQUATION10. 4
NET ENERGY FOR ACTIVITY (FOR CATTLE AND BUFFALO)

$$NE_a = C_a \bullet NE_m$$

Where:

NE_a = net energy for animal activity, MJ day^{-1}

C_a = coefficient corresponding to animal's feeding situation (Table 10.5, Activity coefficients)

NE_m = net energy required by the animal for maintenance (Equation 10.3), MJ day^{-1}

EQUATION10. 5
NET ENERGY FOR ACTIVITY (FOR SHEEP AND GOATS)

$$NE_a = C_a \bullet (weight)$$

Where:

NE_a = net energy for animal activity, MJ day^{-1}

C_a = coefficient corresponding to animal's feeding situation (Table 10.5), MJ day^{-1} kg^{-1}

weight = live-weight of animal, kg

For Equations 10.4 and 10.5, the coefficient C_a corresponds to a representative animal's feeding situation as described earlier. Values for C_a are shown in Table 10.5. If a mixture of these feeding situations occurs during the year, NE_a must be weighted accordingly.

Table 10. 4 COEFFICIENTS FOR CALCULATING NET ENERGY FOR MAINTENANCE (NE_M)

Animal category	Cf_i (MJ d^{-1} kg^{-1})	Comments
Cattle/Buffalo (except non-lactating cows)	0.322	
Cattle/Buffalo (lactating cows)	0.386	Maintenance energy requirements are 20% higher during lactation
Cattle/Buffalo (bulls)	0.37	Maintenance energy requirements are 15% higher for intact males
Sheep (lamb to 1 year	0.236	This value can be increased by 15% for intact males
Sheep (older than 1 year)	0.217	This value can be increased by 15% for intact males.
Goats	0.315	

Source: NRC (1996) and AFRC (1993, 1995).

Table 10. 5 ACTIVITY COEFFICIENTS CORRESPONDING TO ANIMAL'S FEEDING SITUATION

Situation	Definition	C_a
Cattle and Buffalo (unit for C_a is dimensionless)		
Stall	Animals are confined to a small area (i.e., tethered, pen, barn) with the result that they expend very little or no energy to acquire feed.	0
Pasture	Animals are confined in areas with sufficient forage requiring modest energy expense to acquire feed.	0.17
Grazing large areas	Animals graze in open range land or hilly terrain and expend significant energy to acquire feed.	0.36
Sheep and goats (unit for C_a = MJ d^{-1} kg^{-1})		
Housed ewes	Animals are confined due to pregnancy in final trimester (50 days).	0.0096
Grazing flat pasture	Animals walk up to 1000 meters per day and expend very little energy to acquire feed.	0.0107
Grazing hilly pasture	Animals walk up to 5,000 meters per day and expend significant energy to acquire feed.	0.024
Housed fattening lambs	Animals are housed for fattening.	0.0067
lowland goats	Animals walk and graze in lowland pasture	0.019
hill and mountain goats	Animals graze in open range land or hilly terrain and expend significant energy to acquire feed.	0.024
Source: NRC (1996) and AFRC (1993, 1995).		

***Net energy for growth*: (NE_g) is the net energy needed for growth (i.e., weight gain). Equation 10.6 is based on NRC (1996). Equation 10.7 is based on Gibbs *et al*. (2002). Constants for conversion from calories to joules and live to shrunk and empty body weight have been incorporated into the equation.

EQUATION 10. 6
NET ENERGY FOR GROWTH (FOR CATTLE AND BUFFALO)

$$NE_g = 22.02 \bullet \left(\frac{BW}{C \bullet MW} \right)^{0.75} \bullet WG^{1.097}$$

Where:

NE_g = net energy needed for growth, MJ day^{-1}

BW = the average live body weight (BW) of the animals in the population, kg

C = a coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls (NRC, 1996)

MW = the mature body weight of an adult animal in moderate body condition, kg

WG = the average daily weight gain of the animals in the population, kg day^{-1}

EQUATION10. 7
NET ENERGY FOR GROWTH (FOR SHEEP AND GOATS

$$NE_g = \frac{WG_{lamb/kid} \bullet \left(a + 0.5b\left(BW_i + BW_f\right)\right)}{365}$$

Where:

NE_g = net energy needed for growth, MJ day^{-1}

$WG_{lamb/kid\ (goats)}$ = the weight gain (BW_f – BW_i), kg yr^{-1}

BW_i = the live bodyweight at weaning, kg

BW_f = the live bodyweight at 1-year old or at slaughter (live-weight) if slaughtered prior to 1 year of age, kg

a, b = constants as described in Table 10.6.

Note that lambs will be weaned over a period of weeks as they supplement a milk diet with pasture feed or supplied feed. The time of weaning should be taken as the time at which they are dependent on milk for half their energy supply.

The NE_g equation used for sheep includes two empirical constants (a and b) that vary by animal species/category (Table 10.6).

Table 10. 6 CONSTANTS FOR USE IN CALCULATING NE_G FOR SHEEP AND GOATS

Animal species/category	a (MJ kg^{-1})	b (MJ kg^{-2})
Intact males (Sheep)	2.5	0.35
Castrates (Sheep)	4.4	0.32
Females (Sheep)	2.1	0.45
Goats (all categories)	4.972	0.3274
Source: AFRC (1993, 1995).		

***Net energy for lactation*: (NE_l)** is the net energy for lactation. For cattle and buffalo the net energy for lactation is expressed as a function of the amount of milk produced and its fat content expressed as a percentage (e.g., 4%) (NRC, 1989):

EQUATION 10.8
NET ENERGY FOR LACTATION (FOR BEEF CATTLE, DAIRY CATTLE AND BUFFALO)

$$NE_1 = Milk \bullet \left(1.47 + 0.40 \bullet Fat\right)$$

Where:

NE_l = net energy for lactation, MJ day^{-1}

Milk = amount of milk produced, kg of milk day^{-1}

Fat = fat content of milk, % by weight.

Two methods for estimating the net energy required for lactation (NE_l) are presented for sheep. The first method (Equation 10.9) is used when the amount of milk produced is known, and the second method (Equation 10.8) is used when the amount of milk produced is not known. Generally, milk production is known for ewes kept for commercial milk production, but it is not known for ewes that suckle their young to weaning. With a known amount of milk production, the total annual milk production is divided by 365 days to estimate the average daily milk production in kg/day (Equation 10.9). When milk production is not known, AFRC (1990) indicates that for a single birth, the milk yield is about 5 times the weight gain of the lamb. For multiple births, the total annual milk production can be estimated as five times the increase in combined weight gain of all lambs birthed by a single ewe. The daily average milk production is estimated by dividing the resulting estimate by 365 days as shown in Equation 10.10.

EQUATION 10.9
NET ENERGY FOR LACTATION FOR SHEEP AND GOATS (MILK PRODUCTION KNOWN)

$$NE_1 = Milk \bullet EV_{milk}$$

Where:

NE_l = net energy for lactation, MJ day^{-1}

Milk = amount of milk produced, kg of milk day^{-1}

EV_{milk} = the net energy required to produce 1 kg of milk.

A default EV_{milk} value of 4.6 MJ/kg (sheep) (AFRC, 1993, 1995) and 3 MJ/kg (goats) (AFRC, 1998) can be used which corresponds to a milk fat content of 7% and 3.8% by weight for sheep and goats, respectively.

EQUATION 10.10
NET ENERGY FOR LACTATION FOR SHEEP AND GOATS (MILK PRODUCTION UNKNOWN)

$$NE_1 = \left[\frac{(5 \bullet WG_{wean})}{365} \right] \bullet EV_{milk}$$

Where:

NE_l = net energy for lactation, MJ day^{-1}

WG_{wean} = the weight gain of the lamb between birth and weaning, kg

EV_{milk} = the energy required to produce 1 kg of milk, MJ kg^{-1}. Default values of 4.6 MJ kg^{-1} (AFRC, 1993, 1995) and 3 MJ kg^{-1} (AFRC, 1998) can be used for sheep and goats, respectively.

Net energy for work**:** (NE_{work}) is the net energy for work. It is used to estimate the energy required for draft power for cattle and buffalo. Various authors have summarised the energy intake requirements for providing draft power (e.g., Lawrence, 1985; Bamualim and Kartiarso, 1985; and Ibrahim, 1985). The strenuousness of the work performed by the animal influences the energy requirements, and consequently a wide range of energy requirements have been estimated. The values by Bamualim and Kartiarso show that about 10 percent of a day's NE_m requirements are required per hour for typical work for draft animals. This value is used as follows:

EQUATION 10. 11
NET ENERGY FOR WORK (FOR CATTLE AND BUFFALO)

$$NE_{work} = 0.10 \bullet NE_m \bullet Hours$$

Where:

NE_{work} = net energy for work, MJ day^{-1}

NE_m = net energy required by the animal for maintenance (Equation 10.3), MJ day^{-1}

Hours = number of hours of work per day

Net energy for wool production**:** (NE_{wool}) is the average daily net energy required for sheep to produce a year of wool. The NE_{wool} is calculated as follows:

EQUATION 10. 12
NET ENERGY TO PRODUCE WOOL (FOR SHEEP AND GOATS)

$$NE_{wool} = \left(\frac{EV_{wool} \bullet Production_{wool}}{365} \right)$$

Where:

NE_{wool} = net energy required to produce wool, MJ day^{-1}

EV_{wool} = the energy value of each kg of wool produced (weighed after drying but before scouring), MJ kg^{-1}. A default value of 24 MJ kg^{-1} (AFRC, 1995) can be used for sheep estimate. For goats this energy value is not considered unless fibre-producing goat numbers are relevant for a country.

For fibre-producing sheep NE_{wool} can be estimated that 0.25 MJ/day is retained in the fibre (AFRC, 1993, 1995). For fibre-producing goats 0.25 and 0.08 MJ/day for angora and cashmere breeds (AFRC, 1993, 1995), respectively.

$Production_{wool}$ = annual wool production per sheep/goat, kg yr^{-1}

***Net energy for pregnancy*:** (NE_p) is the energy required for pregnancy. For cattle and buffalo, the total energy requirement for pregnancy for a 281-day gestation period averaged over an entire year is calculated as 10% of NE_m. For sheep, the NE_p requirement is similarly estimated for the 147-day gestation period, although the percentage varies with the number of lambs born (Table 10.7, Constant for Use in Calculating NE_p in Equation 10.13). Equation 10.13 shows how these estimates are applied.

Equation10. 13

NET ENERGY FOR PREGNANCY (FOR CATTLE/BUFFALO AND SHEEP AND GOATS)

$$NE_p = C_{pregnancy} \bullet NE_m$$

Where:

NE_p = net energy required for pregnancy, MJ day^{-1}

$C_{pregnancy}$ = pregnancy coefficient (see Table 10.7)

NE_m = net energy required by the animal for maintenance (Equation 10.3), MJ day^{-1}

Table 10. 7 CONSTANTS FOR USE IN CALCULATING NE_P IN EQUATION 10.13

Animal category	$C_{pregnancy}$
Cattle and Buffalo	0.10
Sheep/Goats	
Single birth	0.077
Double birth (twins)	0.126
Triple birth or more (triplets)	0.150

Source: Estimate for cattle and buffalo developed from data in NRC (1996). Estimates for sheep developed from data in AFRC (1993, 1995), taking into account the inefficiency of energy conversion.

When using NE_p to calculate GE for cattle, sheep and goats, the NE_p estimate must be weighted by the portion of the mature females that actually go through gestation in a year. For example, if 80% of the mature females in the animal category give birth in a year, then 80% of the NE_p value would be used in the GE equation below.

To determine the proper coefficient for sheep/goats, the portion of ewes/doesthat have single births, double births, and triple births is needed to estimate an average value for $C_{pregnancy}$. If these data are not available, the coefficient can be calculated as follows:

- If the number of lambs/kids born in a year divided by the number of ewes that are pregnant in a year is less than or equal to 1.0, then the coefficient for single births can be used.
- If the number of lambs/kids born in a year divided by the number of ewes/does that are pregnant in a year exceeds 1.0 and is less than 2.0, calculate the coefficient as follows:

$$C_{pregnancy} = [(0.126 \times \text{Double birth fraction}) + (0.077 \times \text{Single birth fraction})]$$

Where:

Double birth fraction = [(lambs born / pregnant ewes) – 1]

Single birth fraction = [1 – Double birth fraction]

Ratio of net energy available in diet for maintenance to digestible energy consumed (REM)**:** For cattle, buffalo ,sheep and goats, the ratio of net energy available in a diet for maintenance to digestible energy (REM) is estimated using the following equation (Gibbs and Johnson, 1993):

EQUATION10. 14 RATIO OF NET ENERGY AVAILABLE IN A DIET FOR MAINTENANCE TO DIGESTIBLE ENERGY

$$REM = \left[1.123 - \left(4.092 \bullet 10^{-3} \bullet DC\right) + \left[1.126 \bullet 10^{-5} \bullet (DC)^2\right] - \left(\frac{25.4}{DC}\right)\right]$$

Where:

REM = ratio of net energy available in diet for maintenance to digestible energy

DC = digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy)

Ratio of net energy available for growth in a diet to digestible energy consumed (REG)**:** For cattle, buffalo, sheep and goats the ratio of net energy available for growth (including wool growth) in a diet to digestible energy consumed (REG) is estimated using the following equation (Gibbs and Johnson, 1993):

EQUATION10. 15

RATIO OF NET ENERGY AVAILABLE FOR GROWTH IN A DIET TO DIGESTIBLE ENERGY CONSUMED

$$REG = \left[1.164 - \left(5.16 \bullet 10^{-3} \bullet DC\right) + \left[1.308 \bullet 10^{-5} \bullet (DC)^2\right] - \left(\frac{37.4}{DC}\right)\right]$$

Where:

REG = ratio of net energy available for growth in a diet to digestible energy consumed

DC = digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy)

Gross energy, GE**:** As shown in Equation 10.16, GE requirement is derived based on the summed net energy requirements and the energy availability characteristics of the feed(s). Equation 10.16 represents *good practice* for calculating GE requirements for cattle and sheep using the results of the equations presented above.

In using Equation 10.16, only those terms relevant to each animal category are used (see Table 10.3).

EQUATION10. 16

GROSS ENERGY FOR CATTLE/BUFFALO, SHEEP AND GOATS

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM}\right) + \left(\frac{NE_g + NE_{wool}}{REG}\right)}{DC}\right]$$

Where:

GE = gross energy, MJ day^{-1}

NE_m = net energy required by the animal for maintenance (Equation 10.3), MJ day^{-1}

NE_a = net energy for animal activity (Equations 10.4 and 10.5), MJ day^{-1}

NE_l = net energy for lactation (Equations 10.8, 10.9, and 10.10), MJ day^{-1}

NE_{work} = net energy for work (Equation 10.11), MJ day^{-1}

NE_p = net energy required for pregnancy (Equation 10.13), MJ day^{-1}

REM = ratio of net energy available in a diet for maintenance to digestible energy (Equation 10.14)

NE_g = net energy needed for growth (Equations 10.6 and 10.7), MJ day^{-1}

NE_{wool} = net energy required to produce a year of wool (Equation 10.12), MJ day^{-1}

DC = digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy)

Once the values for GE are calculated for each animal subcategory, the feed intake in units of kilograms of dry matter per day (kg day^{-1}) should also be calculated. To convert from GE in energy units to dry matter intake (DMI), divide GE by the energy density of the feed. A default value of 18.45 MJ kg^{-1} of dry matter can be used if feed-specific information is not available. The resulting daily dry matter intake should be in the order of 2% to 3% of the body weight of the mature or growing animals. In high producing milk cows, intakes may exceed 4% of body weight.

Feed intake estimates using a simplified Tier 2 method

Prediction of DMI for cattle based on body weight and estimated dietary net energy concentration (NE_{mf}) or digestiblity values (DC%): It is also possible to predict dry matter intake for mature and growing cattle based on body weight of the animal, either the net energy of maintenance concentration of the feed NE_{mf} (MJ kg^{-1} DM) concentration of the feed (National Academies of Sciences & Medicine 2016) or DE%, and if lactating dairy cow, fat corrected milk production. Dietary NE_{ma} concentration can range from 3.0 to 9.0 MJ kg^{-1} of dry matter. Typical values for high, moderate and low quality diets are presented in Table 10.9. These figures can also be used to estimate NE_{mf} values for mixed diets based on estimate of diet quality. For example, a mixed forage-grain diet could be assumed to have a NE_{mf} value similar to that of a high-quality forage diet. A mixed grain-straw diet could be assumed to have a NE_{mf} value similar to that of a moderate quality forage. Nutritionists within specific geographical areas should be able to provide advice with regard to the selection of NE_{mf} values that are more representative of locally fed diets.

Dry matter intake for calves is estimated using the following equation:

Equation10. 17

ESTIMATION OF DRY MATTER INTAKE FOR CALVES

$$DMI = BW^{0.75} \bullet \left[\frac{\left(0.0582 \bullet NE_{mf} - 0.00266 \bullet NE_{mf}^{\ 2} - 0.1128\right)}{0.239 \bullet NE_{mf}} \right]$$

Where:

DMI = dry matter intake, kg day^{-1}

BW = live body weight, kg

NE_{mf} = estimated dietary net energy concentration of diet or default values in Table 10.9, MJ kg^{-1}

Dry matter intake for growing cattle is estimated using the following equation:

EQUATION10. 18

ESTIMATION OF DRY MATTER INTAKE FOR GROWING CATTLE

$$DMI = BW^{0.75} \bullet \left[\frac{\left(0.0582 \bullet NE_{mf} - 0.00266 \bullet NE_{mf}^{\ 2} - 0.0869\right)}{0.239 \bullet NE_{mf}} \right]$$

Where:

DMI = dry matter intake, kg day^{-1}

BW = live body weight, kg

NE_{mf} = estimated dietary net energy concentration of the feed or diet with default values in Table 10.9, MJ kg^{-1} DM^{-1}

Dry matter intake for feedlot cattle (on high grain diets) is estimated using the following equation:

EQUATION10. 19

ESTIMATION OF DRY MATTER INTAKE FOR STEERS AND HEIFERS

$$DMI = 3.83 + 0.0143 \bullet BW \bullet 0.96$$

ESTIMATION OF DRY MATTER INTAKE FOR HEIFERS

$$DMI = 3.184 + 0.01536 \bullet BW \bullet 0.96$$

Where:

DMI = dry matter intake, kg day^{-1}

BW = live body weight, kg

For mature beef cows use the following values (National Academies of Sciences & Medicine 2016)

Table 10. 8 DMI REQUIRED BY MATURE NON DAIRY COWS BASED ON FORAGE QUALITY

Forage type	Digestibility (DC)	Forage DMI Capacity (kg/day), % of BW (kg)	
		Non-lactating	Lactating
Low quality	<52	1.8	2.2
Average quality	52-59	2.2	2.5
High quality	>59	2.5	2.7

For lactating dairy cows the following equation can be used (Cornell Net Carbohydrate and Protein System (CNCPS; Fox et al., 1992) as modified by Arnerdal (2005)

EQUATION10. 20

ESTIMATION OF DRY MATTER INTAKE FOR LACTATING DAIRY COWS

$$DMI = 0.0185 \bullet BW + 0.305 \bullet FCM$$

Where:

DMI = dry matter intake, kg day^{-1}

BW = live body weight, kg

FCM = Fat corrected milk kg day^{-1} 3.5% [(0.4324 × kg of milk) + (16.216 x kg of fat)].

Equations 10.17a, 10.17b, 10.17c and 10.18 provide a good check to the main Tier 2 method to predict feed intake. They can be viewed as asking ‘what is an expected intake for a given diet quality?’ and used to independently predict DMI from BW, diet quality (NE_{mf} or DC%) and milk production. In contrast, the main Tier 2 method predicts DMI based on how much feed must be consumed to meet estimated requirements (i.e., NE_m and NE_g) and does not consider the biological capacity of the animal to in fact consume the predicted quantity of feed. Consequently, the simplified Tier 2 method can be used to confirm that DMI values derived from the main Tier 2 method are biologically realistic. These estimates are also subject to the cross check that dry matter intake should be in the order of 2% to 3% of the bodyweight of the mature or growing animals and up to 4% for high yielding lactating dairy cattle.

Table 10. 9 Examples of NE_{mf} content of typical diets fed to Cattle for estimation of dry matter intake in Equations 10.17 and 10.18

Diet type	NE_{mf} (MJ (kg dry matter)$^{-1}$)
High grain diet > 90%	7.5 - 8.5
High quality forage (e.g., vegetative legumes & grasses)	6.5 - 7.5
Moderate quality forage (e.g., mid-season legume & grasses)	5.5 - 6.5
Low quality forage (e.g., straws, mature grasses)	3.5 - 5.5

Source: Estimates obtained from predictive models in NRC (1996), NE_{ma} can also be estimated using the equation: NE_{ma} = REM x 18.45 x DC% / 100.

10.2.3 Uncertainty assessment

THIS SECTION IS NOT BEING REFINED

10.2.4 Characterisation for livestock without species: Specific emission estimation methods

THIS SECTION IS NOT BEING REFINED

10.3 METHANE EMISSIONS FROM ENTERIC FERMENTATION

This section contains updated and elaborated guidance

Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which organic matter is broken down by micro-organisms into simple molecules for their own biosynthesis and for the generation of energy by the fermentation of these simple molecules into end-products, including methane gas. The amount of methane released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of methane with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). The ruminant gut structure fosters extensive enteric fermentation of their diet.

Digestive system

The type of digestive system has a significant influence on the rate of methane emission. Ruminant livestock have an expansive chamber known as the rumen, located at the fore-part of their digestive tract. The rumen supports intensive microbial fermentation of the diet, which yields several nutritional advantages including the capacity to digest cellulose (the major component of fiber). The main ruminant livestock are cattle, buffalo, goats, sheep, deer and camelids. Non-ruminant livestock (horses, mules, asses) and monogastric livestock (swine) have relatively lower methane emissions because much less methane-producing fermentation takes place in their digestive systems.

Feed intake

Methane is produced by the fermentation of feed within the animal's digestive system. Generally, the higher the feed intake, the higher the methane emission. Although, methane production is also affected by the composition of the diet. Feed intake is positively related to animal size, growth rate, and production (e.g., milk production, wool growth, or pregnancy).

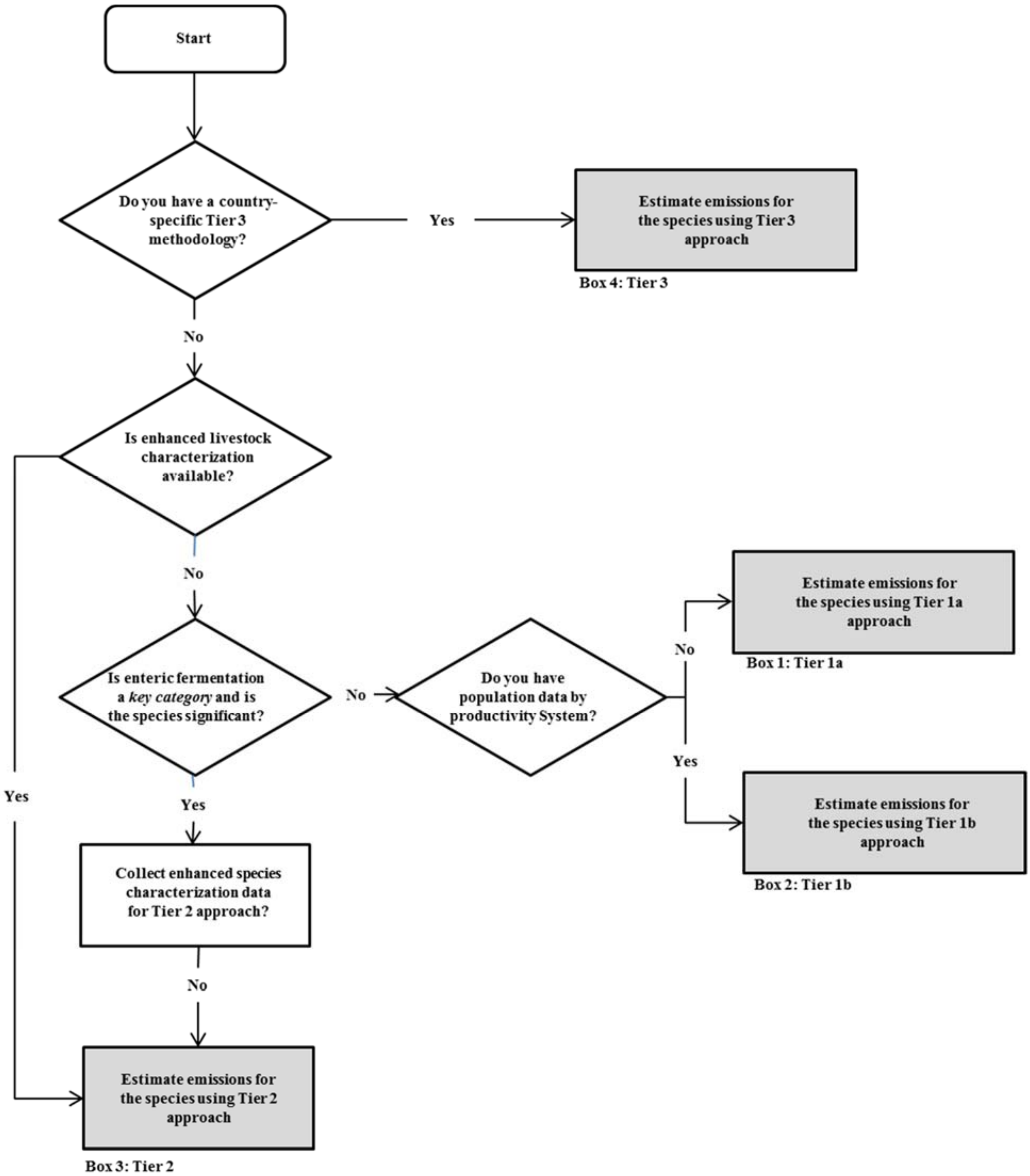
To reflect the variation in emission rates among animal species, the population of animals should be divided into subgroups, and an emission rate per animal is estimated for each subgroup. Types of population subgroups are provided in Section 10.2 (Livestock and Feed Characterisation). The amount of methane emitted by a population subgroup is calculated by multiplying the emission rate per animal by the number of animals within the subgroup.

Natural wild ruminants are not considered in the derivation of a country’s emission estimate. Emissions should only be considered from animals under domestic management (e.g., farmed deer, elk, and buffalo).

10.3.1 Choice of method

It is *good practice* to choose the method for estimating methane emissions from enteric fermentation according to the decision tree in Figure 10.2. The method for estimating methane emission from enteric fermentation requires three basic steps:

Figure 10. 2 Decision Tree for CH_4 Emissions from Enteric Fermentation



Step 1: Divide the livestock population into subgroups and characterize each subgroup as described in Section 10.2. It is recommended that national experts use annual averages estimated with consideration for the impact of production cycles and seasonal influences on population numbers.

Step 2: Estimate emission factors for each subgroup in terms of kilograms of methane per animal per year.

Step 3: Multiply the subgroup emission factors by the subgroup populations to estimate subgroup emission, and sum across the subgroups to estimate total emission.

These three steps can be performed at varying levels of detail and complexity. This chapter presents the following three approaches:

Tier 1a

A simplified approach that relies on default emission factors either drawn from the literature or calculated using the more detailed Tier 2 methodology. The Tier 1 method is likely to be suitable for most animal species in countries where enteric fermentation is not a key source category, or where enhanced characterization data are not available. When approximate enteric emissions are derived by extrapolation from main livestock categories they should be considered to be a Tier 1 method.

Tier 1b

An intermediary approach, applicable in particular to countries that simultaneously have highly differentiated production systems with coexistence of low and high productivity systems, or whose agricultural production systems are transitioning from low to high productivity. Countries can consider the split in their production systems, yet still use default emission factors, to customize their emission estimates based on splits between populations of high and low productivity animals.

Tier 2

A more complex approach that requires detailed country-specific data on gross energy intake and methane conversion factors for specific livestock categories. The Tier 2 method should be used if enteric fermentation is a key source category for the animal category that represents a large portion of the country's total emissions.

Tier 3

Some countries for which livestock emissions are particularly important may wish to go beyond the Tier 2 method and incorporate additional country-specific information in their estimates. This approach could employ the development of sophisticated models that consider diet composition in detail, concentration of products arising from ruminant fermentation, seasonal variation in animal population or feed quality and availability, and possible mitigation strategies. Many of these estimates would be derived from direct experimental measurements. Although countries are encouraged to go beyond the Tier 2 method presented below when data are available, these more complex analyses are only briefly discussed here. A Tier 3 method should be subjected to a wide degree of international peer review such as that which occurs in peer-reviewed publications to ensure that they improve the accuracy and / or precision of estimates.

Countries with large populations of domesticated animal species for which there are no IPCC default emission factors (e.g., llamas and alpacas) are encouraged to develop national methods that are similar to the Tier 2 method and are based on well-documented research (if it is determined that emissions from these livestock are significant). The approach is described in Section 10.2.4 under the heading 'Characterisation for livestock without species-specific emission estimation methods' for more information.

Table 10.9 summarises the suggested approaches for the livestock emissions included in this inventory.

10.3.2 Choice of emission factors

Tier 1 Approach for methane emissions from Enteric Fermentation

This Tier 1 method is simplified so that only readily-available animal population data are needed to estimate emissions. Default emission factors are presented for each of the recommended population subgroups. Each step is discussed in turn.

Step 1: Animal population and productivity system

The animal population data should be obtained using the approach described in Section 10.2.

Step 2: Emission factors

The purpose of this step is to select emission factors that are most appropriate for the country's livestock characteristics. Default emission factors for enteric fermentation have been drawn from previous studies, and are organised by region for ease of use.

The data used to estimate the default emission factors for enteric fermentation are presented in Annex 10A.1a and Table 10A.1b at the end of this section.

Table 10. 10 SUGGESTED EMISSIONS INVENTORY METHODS FOR ENTERIC FERMENTATION	
Livestock	**Suggested emissions inventory methods**
Dairy Cow	Tier 2[a]/Tier 3
Other Cattle	Tier 2[a]/Tier 3
Buffalo	Tier 1/Tier 2
Sheep	Tier 1/Tier 2
Goats	Tier 1/Tier 2
Camels	Tier 1
Horses	Tier 1
Mules and Asses	Tier 1
Swine	Tier 1
Poultry	Not developed
Other (e.g., Llamas, Alpacas, Deer)	Tier 1

[a] The Tier 2 method is recommended for countries with large livestock populations. Implementing the Tier 2 method for additional livestock subgroups may be desirable when the category emissions are a large portion of total methane emissions for the country.

Table 10.11 shows the enteric fermentation emission factors for each of the animal species except cattle. As shown in the table, emission factors for sheep and swine vary for low and high productivity systems and it is important to consider that these conditions may exist within individual countries. The differences in the emission factors are driven by differences in feed intake and feed characteristic assumptions (see Annex 10A.1a and Annex 10A.1b). Table 10.12 presents the enteric fermentation emission factors for cattle. A range of emission factors is shown for typical regional conditions. As shown in the table, the emission factors vary by over a factor of four on a per head basis.

While the default emission factors shown in Table 10.12 are broadly representative of the emission rates within each of the regions described, emission factors vary within each region. Animal size and milk production are important determinants of emission rates for dairy cows. Relatively smaller dairy cows with low levels of production are found in Asia, Africa, and the Indian subcontinent. Relatively larger dairy cows with high levels of production are found in North America, Western Europe and several countries of Latin America.

Animal size and population structure and production systems implemented are important determinants of emission rates for other cattle. Relatively smaller other cattle are found in Asia, Africa, and the Indian subcontinent. Also, many of the other cattle in these regions are young. Other cattle in North America, Western Europe and Oceania are larger, and young cattle constitute a smaller portion of the population.

For countries with highly differentiated agricultural systems in which there is a coexistence of very low and high productivity systems or whose agricultural systems are transitioning from local low input productivity systems to higher productivity systems and do not have the information necessary for implementing Tier 2 systems, the use of the diversification of emission factors given for an animal category provides an alternative or intermediary option. This approach can reflect changes in activity data and productivity with time, whereas the Tier 1a approach only take into account changes in the number of animals in a country.

To select emission factors from Tables 10.11, 10.12 and 10.13 identify the region most applicable to the country being evaluated. Scrutinise the tabulations in Annex 10A.1 to ensure that the underlying animal characteristics such as weight, growth rate and milk production used to develop the emission factors are similar to the conditions in the country. The data collected on the average annual milk production by dairy cows should be used to help select a dairy cow emission factor. If necessary, interpolate between dairy cow emission factors shown in the table using the data collected on average annual milk production per head.

Note that using the same Tier 1 emission factors for the inventories of successive years means that no allowance is being made for changing livestock productivity, such as increasing milk productivity or trend in live weight. If it is important to capture the trend in methane emission that results from a trend in livestock productivity, then livestock emissions can become a key source category based on trend and a Tier 2 calculation should be used.

Table 10. 1 1 Enteric fermentation emission factors for Tier 1 method[1](kg CH_4 head^{-1} yr^{-1})

Livestock	High Productivity Systems	Low Productivity Systems	Liveweight
Sheep	TBD	TBD	TBD kg - high productivity systems; TBD kg - low productivity systems;
Swine	1.5	1	TBD kg - high productivity systems; TBD kg - low productivity systems;
Horses	TBD	TBD	TBD kg - high productivity systems; TBD kg - low productivity systems;
Goats	5	5	40 kg
Camels	46	46	570 kg
Mules and Asses	10	10	245 kg
Deer	20	20	120 kg
Alpacas	8	8	65 kg
Poultry	Not developed		
Llamas	TBD	TBD	TBD
Alpacas	8	8	65 kg
Other (e.g., bison)	To be determined[1]		

All estimates have an uncertainty of ±30-50%.

Sources: Emission factors for buffalo and camels from Gibbs and Johnson (1993). Emission factors for other livestock from Crutzen *et al*., (1986), Alpacas from Pinares-Patino *et al*., 2003; Deer from Clark *et al*., 2003 .

[1] One approach for developing the approximate emission factors is to use the Tier 1 emissions factor for an animal with a similar digestive system and to scale the emissions factor using the ratio of the weights of the animals raised to the 0.75 power. Liveweight values have been included for this purpose. Emission factors should be derived on the basis of characteristics of the livestock and feed of interest and should not be restricted solely to within regional characteristics.

Step 3: Total emission

To estimate total emission, the selected emission factors are multiplied by the associated animal population (Equation 10.21, Equation 10.22) and summed (Equation 10.23):

EQUATION10. 21
(TIER 1A)ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

$$E_T = EF_T \cdot \left(\frac{N_{(T)}}{10^6}\right)$$

Where:

Emissions (E_T) = methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 head^{-1} yr^{-1}

$N_{(T)}$ = the number of head of livestock species / category T in the country

T = species/category of livestock

EQUATION10. 22
(TIER 1B) ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

$$\boldsymbol{E_T = EF_{(TH)} \cdot \left(\frac{N_{TH}}{10^6}\right) + EF_{(TL)} \cdot \left(\frac{N_{TL}}{10^6}\right)}$$

Where:

E_T = methane emissions from Enteric Fermentation in animal category T, Gg CH_4 yr^{-1}

$EF_{(TL)}$ = emission factor for the defined livestock population --- low-productivity system, kg CH_4 $head^{-1}$ yr^{-1}

$EF_{(TH)}$ = emission factor for the defined livestock population --- high-productivity system, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(TL)}$ = the number of head of livestock species / category T in the country --- low-productivity system

$N_{(TH)}$ = the number of head of livestock species / category T in the country --- high-productivity system

T = species/category of livestock

EQUATION10. 23(TIER 1)
TOTAL EMISSIONS FROM LIVESTOCK ENTERIC FERMENTATION

$$\text{Total } CH_{4_{\text{Enteric}}} = \sum_i E_i$$

Where:

Total $CH_{4\text{Enteric}}$ = total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

E_i = is the emissions for the i^{th} livestock categories and subcategories based on production system

Table 10. 12 Enteric fermentation emission factors for Cattle (Tier 1a)

Regional characteristics	Cattle category	Tier 1a Emission Factor (kg CH_4 $head^{-1}$ yr^{-1})	Comments
North America: Highly productive commercialized dairy sector feeding high quality forage and grain. Separate beef cow herd, primarily grazing with feed supplements seasonally. Fast-growing beef steers/heifers finished in feedlots on grain. Dairy cows are a small part of the population. There are no buffalo herds, but American bison may be raised.	**Cattle**		
	Dairy	124	Average milk production of 10,400 kg $head^{-1}$ yr^{-1}.
	Other cattle	60	Includes beef cows, bulls, calves, growing steers/heifers, and feedlot cattle.
Western Europe: Highly productive commercialised dairy sector feeding high quality forage and grain. Dairy cows also used for beef calf	**Cattle**		
	Dairy	117	Average milk production of 6,720 kg $head^{-1}$ yr^{-1}.

production. Very small dedicated beef cow herd. Minor amount of feedlot feeding with grains.	**Other cattle**	52	Includes bulls, calves, and growing steers/heifers.
	Buffalo		
	Dairy	TBD	Average milk production of 1,095 kg head^{-1} yr^{-1}.
	Other Buffaloes	TBD	Includes bulls, growing animals and calves.
Eastern Europe: Commercialised dairy sector feeding mostly forages. Separate beef cow herd, primarily grazing. Minor amount of feedlot feeding with grains.	**Cattle**		
	Dairy	88	Average Milk Production Of 3,740 Kg Head^{-1} Yr^{-1}.
	Other cattle	57	Includes beef cows, bulls, growing steers/heifers and calves.
	Buffalo		
	Dairy	TBD	Average milk production of 1,535 kg head^{-1} yr^{-1}.
	Other Buffaloes	TBD	Includes bulls, growing animals and calves.
Oceania: Commercialised dairy sector based on grazing. Separate beef cow herd, primarily grazing rangelands of widely varying quality. Growing amount of feedlot feeding with grains. Dairy cows are a small part of the population. No Buffalo herd.	**Cattle**		
	Dairy	TBD	Average milk production of 5,760 kg head^{-1} yr^{-1}.
	Other cattle	TBD	Includes beef cows, bulls, and young.
Latin America: Commercialised dairy sector based on grazing. Separate beef cow herd grazing pastures and rangelands. Minor amount of feedlot feeding with grains. Growing non-dairy cattle comprise a large portion of the population.	**Cattle**		
	Dairy	78	Average milk production of 1825 kg head^{-1} yr^{-1}
	Other cattle	TBD	Includes beef cows, bulls, growing steers/heifers and calves.
	Buffalo		
	Dairy	97	Average milk production of TBD kg head^{-1} yr^{-1}
	Other Buffaloes	44	TBD
Asia: Small commercialised dairy sector. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Small grazing population. Cattle of all types are smaller than those found in most other regions.	**Cattle**		
	Dairy	TBD	Average milk production of 6,730 kg head^{-1} yr^{-1}
	Other cattle	TBD	Includes beef cows, bulls, growing steers/heifers and calves.
	Buffalo		

	Dairy	TBD	Average milk production of … kg head^{-1} yr^{-1}
	Other Buffaloes	TBD	Includes ….
Africa: Commercialised dairy sector based on grazing with low production per cow. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Some cattle graze over very large areas. Cattle are smaller than those found in most other regions.	**Cattle**		
	Dairy	TBD	Average milk production of TBD kg head^{-1} yr^{-1}
	Other cattle	TBD	Includes beef cows, bulls, growing steers/heifers and calves.
	Buffalo		
	Dairy	TBD	Average milk production of 950 kg head^{-1} yr^{-1}
	Other Buffaloes	TBD	Includes breeding and working bulls, growing animals and calves
Middle East: TBD	**Cattle**		
	Dairy	91	Average milk production of 3,000 kg head^{-1} yr^{-1}
	Other cattle	50	Includes beef cows, bulls, growing steers/heifers and calves.
	Buffalo		
	Dairy	TBD	Average milk production of 1350 kg head^{-1} yr^{-1}
	Other Buffaloes	TBD	Includes breeding and working bulls, growing animals and calves
Indian Subcontinent: Commercialised dairy sector based on crop by-product feeding with low production per cow. Most bullocks provide draft power and cows provide some milk in farming regions. Small grazing population. Cattle in this region are the smallest compared to cattle found in all other regions.	**Cattle**		
	Dairy	66	Average milk production of 1,730 kg head^{-1} yr^{-1}
	Other Cattle	TBD	Includes cows, bulls, growing steers/heifers and calves.
	Buffalo		
	Dairy	TBD	Average milk production of 1500 kg head^{-1} yr^{-1}
	Other Buffaloes	TBD	Includes breeding and working bulls, growing animals and calves

1 Uncertainty estimates are under developement

2 Emission factors should be derived on the basis of the characteristics of the cattle and feed of interest and need not be restricted solely to within regional characteristics.

3 IPCC Expert Group, Existing values were derived using Tier 2 method and the data in Tables 10 A.1 and 10A. 2.

[4] The following assumptions have been made in deriving these values: i) mature weights of animals have been used; ii) cows have been assumed to be non-lactating as lactation levels were low and, iii) the mix of bulls and castrates among "males" was undetermined as Cfi value for castrates was not specified.

For details on the development of these values, refer to Annex 10.B.3

Table 10. 13 Enteric fermentation emission factors for Cattle (Tier 1b)

Regional characteristics	Cattle category	Productivity System Tier 1b	Tier 1b Emission Factor (kg CH4 head^{-1} yr^{-1})	Comments
Latin America	Dairy	**High Productivity Systems**	124	Average milk production of 6,300 kg head^{-1} yr^{-1}
		Low Productivity Systems	78	Average milk production of 1,540 kg head^{-1} yr^{-1}
	Other Cattle	**High Productivity Systems**	TBD	Includes beef cows, bulls, growing steers/heifers and calves.
		Low Productivity Systems	TBD	
Asia	Dairy	**High Productivity Systems**	TBD	Average milk production of TBD kg head^{-1} yr^{-1}
		Low Productivity Systems	TBD	Average milk production of TBD kg head^{-1} yr^{-1}
	Other Cattle	**High Productivity Systems**	TBD	Includes multi-purpose cows, bulls, and young
		Low Productivity Systems	TBD	
Africa	Dairy	**High Productivity Systems**	TBD	Average milk production of TBD kg head^{-1} yr^{-1}
		Low Productivity Systems	TBD	Average milk production of TBD kg head^{-1} yr^{-1}
	Other Cattle	**High Productivity Systems**	TBD	Includes multi-purpose cows, bulls, and young
		Low Productivity Systems	TBD	
Middle East	Dairy	**High Productivity Systems**	112	Average milk production of 5,600 kg head^{-1} yr^{-1}
		Low Productivity Systems	55	Average milk production of 1,000 kg head^{-1} yr^{-1}
	Other Cattle	**High Productivity Systems**	TBD	Includes beef cows, bulls, growing steers/heifers and calves.
		Low Productivity Systems	TBD	
Indian Subcontinent	Dairy	**High Productivity Systems**	71	Average milk production of 2,600 kg head^{-1} yr^{-1}
		Low Productivity Systems	64	Average milk production of 1,500 kg head^{-1} yr^{-1}

	Other Cattle	**High Productivity Systems**	27	Includes beef cows, bulls, growing steers/heifers and calves.
		Low Productivity Systems	42	
1 Uncertainty is under development 2 Emission factors should be derived on the basis of the characteristics of the cattle and feed of interest and need not be restricted solely to within regional characteristics. 3 IPCC Expert Group, Existing values were derived using Tier 2 method and the data in Tables 10 A.1 and 10A. 2. 4 The following assumptions have been made in deriving these values: i) mature weights of animals have been used; ii) cows have been assumed to be non-lactating as lactation levels were low and, iii) the mix of bulls and castrates among "males" was undetermined as Cfi value for castrates was not specified. For details on the development of these values, refer to Annex 10.B.3				

Tier 2 Approach for methane emissions from Enteric Fermentation

The Tier 2 method is applied to more disaggregated livestock population categories and used to calculate emission factors, as opposed to default values. The key considerations for the Tier 2 method are the development of emission factors and the collection of detailed activity data.

Step 1: Livestock population

The animal population data and related activity data should be obtained following the approach described in Section 10.2.

Step 2: Emission factors

When the Tier 2 method is used, emission factors are estimated for each animal category using the detailed data developed in Step 1.

The emission factors for each category of livestock are estimated based on the gross energy intake and methane conversion factor for the category. The gross energy intake data should be obtained using the approach described in Section 10.2. The following two sub-steps need to be completed to calculate the emission factor under the Tier 2 method:

1. Obtaining the methane conversion factor (Y_m)

The extent to which feed energy is converted to CH_4 depends on several interacting feed and animal factors. If CH_4 conversion factors are unavailable from country-specific research, the values provided in Table 10.13, Cattle/Buffalo CH_4 conversion factors, can be used for cattle and buffalo. These general estimates are a rough guide based on the general feed characteristics and production practices found in many developed and developing countries. When high quality feed is available (i.e., high digestibility and high net energy value) the lower bounds should be used. When poorer quality feed is available, the higher bounds are more appropriate. A CH_4 conversion factor of zero is assumed for all juveniles consuming only milk (i.e., milk-fed lambs and calves).

Due to the importance of Y_m in driving emissions, substantial ongoing research is aimed at improving estimates of Y_m for different livestock and feed combinations. Such improvement is most needed for animals fed on tropical pastures as the available data are sparse. However, in a study by Kennedy and Charmley (2012a) the Y_m values for tropical grasses and legumes were within the ranges described in Table 10.14.

Table 10. 1 4 CATTLE/BUFFALO CH4 CONVERSION FACTORS (YM)

Livestock category	Description	Digestibility (DC)	EF_DMI CH_4 g kg DMI^{-1}	Ym^3 (TBD)
[1]**Dairy Cows (Cattle and Buffalo)**	High-producing cows (>7000 L/yr)	⩾ 75%	19.2 (TBD)	5.7 (TBD)
	Medium producing cows (<7000 L/yr)	61-74	21.3 (TBD)	6.3 (TBD)

	Low producing cows (<7000 L/yr)	< 60	22 (TBD)	6.5 (TBD)
[2]**Non dairy and multi-purpose cattle**	Unknown diet (not feedlot)		22.7 (TBD)	6.80 (TBD)
	> 70% forage		23.5 (TBD)	7.00 (TBD)
	15-70% forage mixed diets		21.0 (TBD)	6.30 (TBD)
	Feedlot (all other grains, 0-15% forage)	> 72%	11.7 (TBD)	3.5 (TBD)
	Feedlot (corn grain, distillers grains, 0-15% forage)	> 72%	10 (TBD)	3 (TBD)

[1](Appuhamy *et al.* 2016)
[2]References: (Boadi & Wittenberg 2002; Pinares-Patiño *et al.* 2003; Boadi *et al.* 2004; Beauchemin & McGinn 2006b; Beauchemin & McGinn 2006a; Chaves *et al.* 2006; Jordan *et al.* 2006a; Jordan *et al.* 2006b; Beauchemin *et al.* 2007; Hegarty *et al.* 2007; Hart *et al.* 2009; McGinn *et al.* 2009; Mc Geough *et al.* 2010a; Mc Geough *et al.* 2010b; Doreau *et al.* 2011; Hales *et al.* 2012; Kennedy & Charmley 2012b; Staerfl *et al.* 2012; Chung *et al.* 2013; Hünerberg *et al.* 2013; Fiorentini *et al.* 2014; Hales *et al.* 2014; Beauchemin & McGinn 2015; Hales *et al.* 2015; Troy *et al.* 2015; Nascimento *et al.* 2016; Vyas *et al.* 2016a; Vyas *et al.* 2016b; Baron *et al.* 2017; Hales *et al.* 2017)
[3] Uncertainty values are underdevelopment
For details on the development of these values, refer to Annex 10.B.4

Regional, national and global estimates of enteric methane generation rely on small scale determinations both of Y_m and of the influence of feed and animal properties upon Y_m. Traditional methods for measuring Y_m include the use of respiration calorimeters and head enclosures for housing individual animals (Johnson & Johnson 1995). A tracer technique using SF_6 enables methane emissions from individual animals to be estimated under both housed or grazing conditions (Johnson *et al.* 1994). Hammond et al.(2015) present an in-depth review of the advantages and limitations of methane measurement techniques used to determine Y_m values.

It is also important to examine the influences of feed properties and animal attributes on Y_m. Such influences are important to better understand the microbiological mechanisms involved in methanogenesis with a view to designing emission abatement strategies, as well as to identify different values for Y_m according to animal husbandry practices. To date, the search for such influences is equivocal, and consequently there is little variability evident both in the values reported in Table 10.14 as supported by the survey of Y_m measurements in the literature (Lassey 2007).

Table 10.15 proposes a common Y_m value for all sheep irrespective of feed quality values. This value is based on New Zealand data collated between 2009 and 2015 (Swainson *et al.* 2016). Data were derived from respiration chamber measurements where intake was accurately measured and covered a range of diet qualities. These replace values in the 2006 guidelines which were based on indirect measurements using the sulphur hexafluoride tracer technique where dry matter intake was generally estimated in grazing animals (Ulyatt *et al.* 2002a; Ulyatt *et al.* 2002b; Ulyatt *et al.* 2005). The mean value is most appropriate for situations where average dry matter intake per day is between 0.6 and 0.8kg/day with the upper limit being more appropriate where average intake is <0.6kg/day, and the lower limit being more appropriate where average intakes are >0.8kg/day.

Table 10. 1 5 **SHEEP AND GOATS CH_4 CONVERSION FACTORS (YM)**

Category	Ym [a]
Sheep	TBD% ± TBD %
Goats	TBD% ± TBD%

[a] The ± values represent the range.

Note that in some cases, CH_4 conversion factors may not exist for specific livestock types. In these instances, CH_4 conversion factors from the reported livestock that most closely resembles those livestock types can be reported. For examples, CH_4 conversion factors for other cattle or buffalo could be applied to estimate an emission factor for camels.

2. Emission factor development

Using the energy balance Tier 2 approach an emission factor for each animal category should be developed following Equation 10.24:

EQUATION10.24

CH_4 EMISSION FACTORS FOR ENTERIC FERMENTATION FROM A LIVESTOCK CATEGORY

$$EF = \left[\frac{GE \bullet \left(\frac{Y_m}{100} \right) \bullet 365}{55.65} \right]$$

Where:

EF = emission factor, kg CH_4 head^{-1} yr^{-1}

GE = gross energy intake, MJ head^{-1} day^{-1}

Y_m = methane conversion factor, per cent of gross energy in feed converted to methane

The factor 55.65 (MJ/kg CH_4) is the energy content of methane

In cases in which the inventory compiler has used the simplified Tier 2 the emission factors should be calculated following equation 10.25:

EQUATION10. 25

CH4 EMISSION FACTORS FOR ENTERIC FERMENTATION FROM A LIVESTOCK CATEGORY

$$EF = DMI \bullet 365 \bullet \left(\frac{\text{EF\_DMI}}{1000} \right)$$

Where:

EF = emission factor, kg CH_4 head^{-1} yr^{-1}

DMI = kg DMI day^{-1}

EF_DMI = CH_4 rate emissions kg CH4 kg DMI^{-1} (Tables 10.14)

365= days per year

1000 = conversion from g CH_4 to kg CH_4

This emission factor equation assumes that the emission factors are being developed for an animal category for an entire year (365 days). While a full year emission factor is typically used, in some circumstances the animal category may be defined for a shorter period (e.g., for the wet season of the year or for a 150-day feedlot feeding period). In this case, the emission factor would be estimated for the specific period (e.g., the wet season) and the 365 days would be replaced by the number of days in the period. The definition of the period to which the emission factor applies is described in Section 10.2.

Step 3: Total emissions

To estimate total emissions, the selected emission factors are multiplied by the associated animal population and summed. As described above under Tier 1, the emissions estimates should be reported in gigagrams (Gg).

Potential for refinement of Tier 2 or development of a Tier 3 method to enteric methane emission inventories

Increased accuracy and identification of causes of variation in emissions are at the heart of inventory purpose. Improvements in country methodology, whether as components of current Tier 1 or 2 or if additional refinements are implemented with Tier 3, are encouraged.

Current Tier 1 and Tier 2 enteric methane emissions factors and estimation procedures are driven by first estimating daily and annual gross energy consumption by individual animals within an inventory class which are then multiplied by an estimate of CH_4 loss per unit of feed (Y_m). There is considerable room for improvement in Tier 2 prediction of both feed intake and in Y_m. Factors potentially impacting feed requirements and/or consumption that are not considered may include:

- depression in digestibility with increasing levels of consumption or due to rumen acidification, feed preparation or diet composition putting limits to feed intake;
- breed or genotype variation in maintenance requirement; and
- heat and cold stress effects on feed intake and maintenance requirements.

Likewise, a host of interacting factors cause variation in the rumen microbiome and its fermentation profile, and hence in hydrogen production which delivers the main substrate for methanogens. These factors lead to variation in Y_m that is not included in Tier 2 methodology and may include:

- variation in feed digestibility (DC);
- level of feed intake chemical composition of feed;
- kinetics of particle and fluid passage and of digestion, rumen volume, rumen fermentation profile; and
- other factors (such as secondary plant compounds) affecting the rumen microbiome.

Accurate estimation of diet DC is singularly important in the estimation of feed intake and thus of enteric methane emission, as previously emphasized. A 10% error in DC will result in errors in CH_4 emissions ranging from 12 to 20% depending on the dietary circumstances for which calculations are made. The depression in DC with increasing daily amounts of feed consumed is not considered with Tier 2. This neglect would underestimate feed intakes of high producing dairy cows consuming mixtures of concentrates and forages as is common in the North America and Europe, and hence underestimate methane emission. Methods to estimate depression of DC have been described (NRC, 1996; NRC, 2001). However, simultaneously not accounting for the reduction of Y_m with increased feed intake may compensate this underestimation again. The balance between both effects (i.e. a reduction of feed digestibility and of Y_m) determines the net effect on methane emission which may vary with dietary circumstances. More complex models may be developed as Tier 3 to capture such effects.

There have been many attempts to refine estimates of Y_m. Several researchers have developed models which relate the chemical composition of the diet consumed, or in more detail, the composition of digested carbohydrate and other chemical components to Y_m. These models typically predict diet particle and chemical component rates of passage and digestion in each enteric compartment at varying intake and the resulting H_2 balance, volatile fatty acids, and microbial and CH_4 yields. These approaches have generated Y_m values that are consistent with direct measurements (Bannink et al., 2001; Dougherty et al. 2017; Gregorini et al. 2013; Huhtanen et al., 2015). The Netherlands employ Tier 3 approach using a mechanistic model (Bannink *et al.* 2011) to estimate CH_4 yield from dairy cattle while the US use mechanistic models (Baldwin et al., 1995;(Kebreab *et al.* 2008) to refine estimates of Ym for dairy and beef in different states within the US.

The literature contains many examples of the positive relationship of plant cell wall digestion to high acetic to propionic end-product ratios, and to high CH_4 yields. While fibrous carbohydrate digestion is the strongest indicator of CH_4 yield, the CH_4 per digested fiber is not constant and enteric fermentation of similar fibrous feeds can result in different Y_m values. For example, grass silage made from grass cut at different stages of maturity resulted in strongly different carbohydrate and protein composition, resulting in Y_m values varying from 5.5 to 6.9% with increased maturity and intake (Warner et al., 2017). Exchange of carbohydrates may also lead to a lower Y_m as demonstrated in studies where an increased dietary starch content through a higher proportion of corn silage (Hassanat et al., 2013; Benchaar et al., 2014) or through a higher proportion of starch containing concentrates (Augerre et al., 2011). Prerequisite for the use of more complex prediction models for broad country inventories is that the data need to be provided to drive these more complex models of feed intake or Y_m. It is often difficult to define animal characteristics, productivity, and DC accurately for a livestock category in various regions or various production systems in a country. Of particular importance is a good characterization of roughages when they constitute a main part of the diet.

Ongoing global research on mitigation strategies currently, such as the use of direct methanogen inhibitors, oxygen-rich anions, fats and oils, ionophores or condensed tannins, suggests a need to address how they should be reflected in inventory compilation at Tier 2 or Tier 3. First, the inventory should reflect only those technologies that conform to QA/QC principles and have attracted a wide degree of international acceptance such as through peer-reviewed articles that include a description of the technology, its efficacy and its validation under field conditions. Second, the inventory should be accompanied by evidence of the take-up of the technology in agricultural practice, and apply it only to emissions by those livestock where take-up can be validated. Mitigation measures and their representation in inventory compilation should be supported by peer-reviewed publications.

Concluding, approaches to improve estimates of feed intake (i.e. of diet composition, DC and dietary GE content) and Ym, and approaches to account for specific mitigation measures are to be encouraged, given due care on limitations of the scope and on production circumstances where mitigation measures are applied and to which predictive models or relationships must apply as well.

10.3.3 Choice of activity data

Livestock population data should be obtained using the approach described in Section 10.2. If using default enteric emission factors for livestock (Tables 10.11, 10.12,10.13) to estimate enteric emissions, a basic (Tier 1) livestock population characterisation is sufficient. To estimate enteric emissions from livestock using estimation of Gross Energy Intake (Equations 10.16, 10.17 or 10.18), a Tier 2 characterisation is needed. As noted in Section 10.2, *good practice* in characterising livestock populations is to conduct a single characterisation that will provide the activity data for all emissions sources that depend on livestock population data.

10.3.4 Uncertainty assessment

Emission factors

NO CHANGES TO THIS SECTION

Activity data

NO CHANGES TO THIS SECTION

10.3.5 Completeness, Time series, Quality Assurance/Quality Control and Reporting

NO CHANGES TO THIS SECTION

10.4 METHANE EMISSIONS FROM MANURE MANAGEMENT

This section describes how to estimate CH_4 produced during the storage and treatment of manure, and from manure deposited on pasture. In the 2019 IPCC refinement, a new approach of Tier 1 based per unit VS emission factors, updated Tier 2 based per unit VS and parameters for different manure management systems, and revised equation on how to deal with non-CO_2 emissions due to biogas production which consider fugitive emissions, digestate storage and housing emissions were developed.

The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock. The emissions associated with the burning of dung for fuel are to be reported under Volume 2 (Energy), or under Volume 5 (Waste) if burned without energy recovery. The decomposition of manure under anaerobic conditions (i.e., in the absence of oxygen), during storage and treatment, produces CH_4. These conditions occur most readily when large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid-based systems. Emissions of CH_4 related to manure handling and storage are reported under 'Manure Management.'

The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significant quantity of CH_4. The temperature and the retention time of the storage unit greatly affect the amount of methane produced. When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced.

10.4.1 Choice of method

There are three tiers to estimate CH_4 emissions from livestock manure as shown in 2006 IPCC guideline.

To be consistence with consideration of differing productivity classes in section of enteric fermentation, a new tier 1 was developed. In regions, particularly in developing countries production systems can vary between high productivity systems aimed at commercial food production and low productivity systems, largely serving local food production. In this case countries may choose to use a Tier 1 method in which emission factors are defined for low and high productivity systems based on the updated volatile solids and B_0, and the values of volatile solids was aligned with updated enteric fermentation section.

Guidance for determining which methods to use is shown in Figure 10.3 decision tree.

Tier 1

A simplified method that requires livestock population data by animal species/category and climate region or temperature, in combination with IPCC default emission factors per unit of volatile solid, default volatile solid data, and country-specific manure management system data to estimate emissions. Manure management system data have been collected for regions and countries by the FAO and are presented in Annex 10A.2, Table 10A4 to Tabel 10A19 . Because some emissions from manure management systems are highly temperature dependent, it is *good practice* to consider the climate zone associated with the locations where manure is managed.

Tier 2

A more complex method for estimating CH_4 emissions from manure management should be used where a particular livestock species/category represents a significant share of a country's emissions. This method requires detailed information on animal characteristics and manure management practices, which is used to develop emission factors specific to the conditions of the country.

Tier 3

Some countries for which livestock emissions are particularly important may wish to go beyond the Tier 2 method and develop models for country-specific methodologies or use measurement–based approaches to quantify emission factors.

The method chosen will depend on data availability and national circumstances. *Good practice* in estimating CH_4 emissions from manure management systems entails making every effort to use the Tier 2 method, including calculating emission factors using country-specific information. The Tier 1 method should only be used if all possible avenues to use the Tier 2 method have been exhausted and/or it is determined that the source is not a key category or subcategory.

Regardless of the method chosen, the animal population must first be divided into categories as described in Section 10.2 that reflect the varying amounts of manure produced per animal.

The following four steps are used to estimate CH_4 emissions from manure management:

Step 1: Collect population data from the Livestock Population Characterization (see Section 10.2).

Step 2: Use default values or develop country-specific emission factors for each livestock subcategory in terms of kilograms of methane per animal per year.

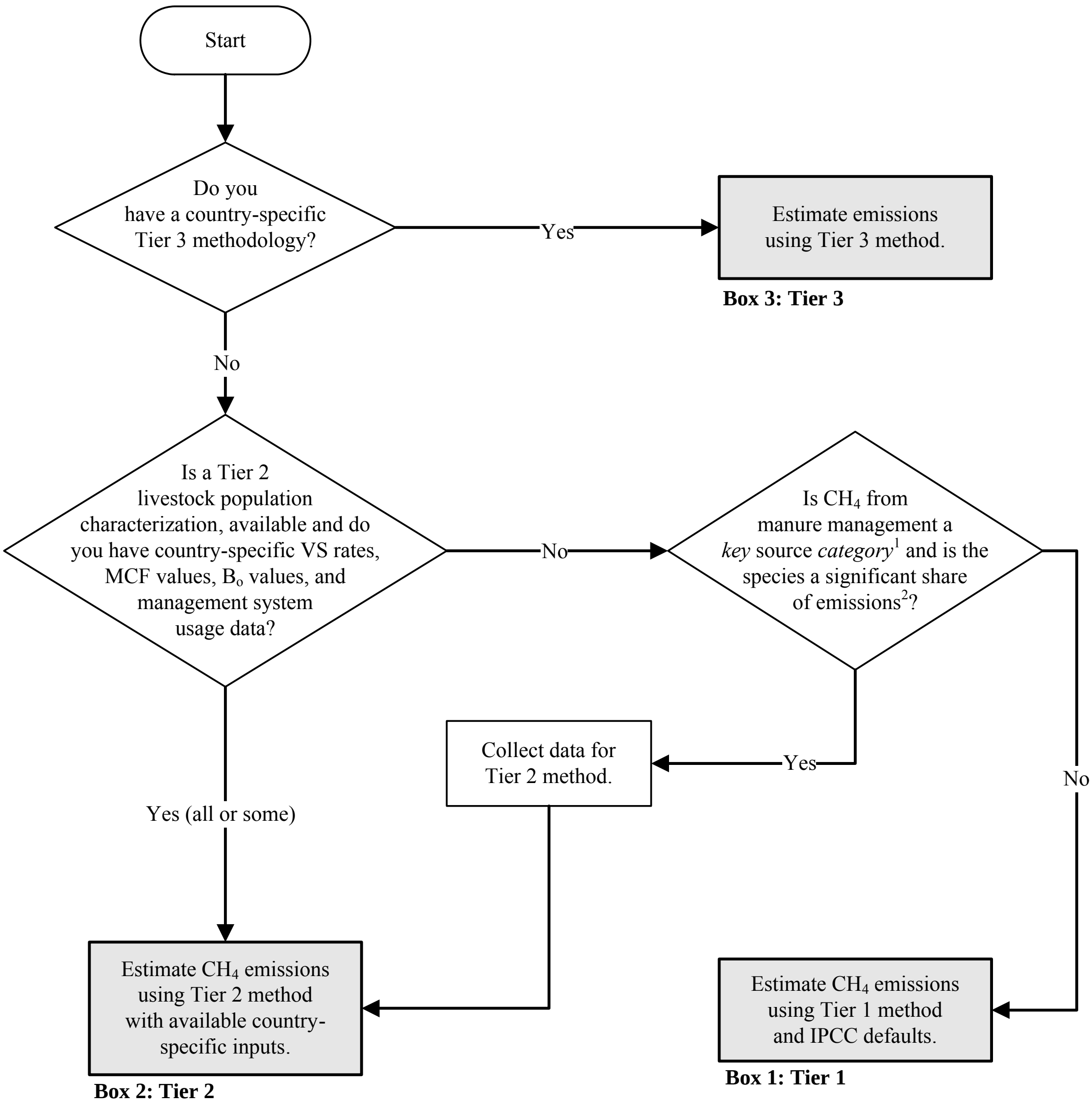
- Tier 1: Identify default values (Table10 A4- Table 10A20) on the proportion of different manure management and storage facilities; Use default values of the quantity of volatile solids produced by each livestock subcategory in terms of kilograms of VS per animal per day. then multiply manure management specific methane emission factors (Table 10.17- Table 10.20) by the animal category specific volatile solid excretion estimate to develop a per head emission factor

- Tier 2: Collect information on the proportion of manure that is managed in different types of manure management and storage facilities, develop country-specific estimates of the quantity of volatile solids produced by each livestock subcategory in terms of kilograms of VS per animal per year , then multiply local manure management specific methane conversion factors, Table 10.17 - Table 10.20 provided default characteristics for different climate zones by the animal category specific volatile solid estimate to develop a per head emission factor,

Step 3: Multiply the livestock subcategory emission factors by the subcategory populations to estimate subcategory emissions, and sum across the subcategories to estimate total emissions by primary livestock species.

Step 4: Sum emissions from all defined livestock species to determine national emissions.

Figure 10. 3 Decision tree for CH_4 emissions from Manure Management



Note:
1: See Volume 1 Chapter 4, "Methodological Choice and Identification of Key Categories" (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.
2: As a rule of thumb, a livestock species would be significant if it accounts for 25-30% or more of emissions from the source category.

The calculation of CH_4 emissions from manure management for Tier 1 is based on the following equation:

EQUATION10. 26
CH_4 EMISSIONS FROM MANURE MANAGEMENT

$$CH_{4(mm)} = \left[\sum_{T,S} \left(N_{(T)} \bullet VS_{(T)} \bullet MS_{(T,S)} \right) \bullet EF_{(T,S)} / 1000 \right]$$

Where:

$CH_{4(mm)}$ = CH_4 emissions from Manure Management in the country, kg CH_4 yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

$VS_{(T)}$ = annual average VS excretion per head of species/category *T*, kg VS $animal^{-1}$ yr^{-1} (Table 10.16 by Equation 10.27)

$MS_{(T,S)}$ = fraction of total annual VS for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$EF_{(T,S)}$ = emission factor for direct CH_4 emissions from manure management system *S,* by animal species/category in the country, g CH_4 kg VS^{-1} in manure management system *S* (Table 10.17 - Table 10.20)

S = manure management system

T = species/category of livestock

10.4.2 Choice of emission factors

The best way to determine emission factors is to conduct non-invasive or non-disturbing measurements of emissions in actual systems representative of those in use in the country. These field results can be used to develop models to estimate emission factors (Tier 3). Such measurements are difficult to conduct, and require significant resources and expertise, and equipment that may not be available. Thus, while such an approach is recommended to improve accuracy, it is not required for *good practice*. This section provides two alternatives for developing emission factors, with the selection of emission factors depending on the method (i.e., Tier 1or Tier 2) chosen for estimating emissions.

Tier 1 :

When using the Tier 1 method, methane emission factors per unit of VS by livestock category or subcategory are used. Default emission factors by average annual temperature are presented in Table 10.17 to Table 10.20 for each of the recommended population subcategories. These emission factors represent the range in manure management practices used in each region, as well as the difference in emissions due to temperature.

Tables 10A-4 through 10A-20 located in Annex 10A.2 present the underlying assumptions used for each region. Countries using a Tier 1 method to estimate methane emissions from manure management should review the regional variables in these tables to identify the region that most closely matches their animal operations, and use the default emission factors for that region.

Annual volatile solid rates should be determined for each livestock category defined by the livestock population characterization. Country-specific rates may either be taken directly from documents or reports such as agricultural industry and scientific literature, or calculated based on dry matter input (DMI), ash content and urinary energy (as explained below). In some situations, it may be appropriate to use excretion rates developed by other countries that have livestock with similar characteristics.

If country-specific data cannot be collected or derived, or appropriate data are not available from another country, the IPCC default volatile solid excretion rates presented in Table 10.16 can be used. These rates are presented in units of volatile solid excreted per 1000 kg of animal per day. These rates can be applied to livestock sub-categories of varying ages and growth stages using a typical average animal mass (TAM) for that population sub-category, as shown in Equation 10.27.

EQUATION10. 27
ANNUAL VS EXCRETION RATES

$$VS_{(T)} = VS_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where:

$VS_{(T)}$ = annual VS excretion for livestock category *T*, kg VS animal^{-1} yr^{-1}

$VS_{rate(T)}$ = default VS excretion rate, kg VS (1000 kg animal mass)$^{-1}$ day^{-1} (see Table 10.16)

$TAM_{(T)}$ = typical animal mass for livestock category *T*, kg animal^{-1}

Default TAM values are provided in Tables 10A-4 to 10A-20 in Annex 10A.2. However, it is preferable to collect country-specific TAM values to be able to track changes in emissions with changes in productivity in certain animal categories. For example, market swine may vary from nursery pigs weighing less than 30 kilograms to finished pigs that weigh over 90 kilograms. By constructing animal population groups that reflect the various growth stages of market pigs, countries will be better able to estimate the total volatile solid excreted by their swine population.

Table 10.17 and Table 18 shows the default emission factors per kg of volatile solid excretion and year for cattle, swine for each manure management and climate zone. Emission factors are listed for the climate zone where the livestock manure is managed. The temperature data should be based on national meteorological statistics where available. It is good practice for countries to estimate the percentage of animal populations in different climate zones and compute a weighted average emission factor. Where this is not possible, an estimate should be made based on the proportion of area in each climate zone; however, this may not give an accurate estimate of emissions that are highly sensitive to temperature variations (e.g., liquid/slurry systems).

Separate emission factors are shown for high and low productivity systems in these Tables, reflecting the general differences in feed intake and feed characteristics of the animals in regions that have highly differential production systems existing in the same country. Except for poultry "layers (wet)," these emission factors reflect the fact that virtually all the manure from these animals is managed in 'dry' manure management systems, including pastures paddocks and ranges, drylots, and daily spreading on fields (Woodbury and Hashimoto, 1993).

Table 10. 16 Default values for volatile solid excretion rate (kg VS (1000 kg animal mass)$^{-1}$ day^{-1})

Category of animal	Region (Calculated based on Table A 4- A20 of 2006 IPCC guideline, it will be updated to be consistenct with enteric fermentation																		
	North America	Western Europe	Eastern Europe	Oceania	Latin America			Africa			Middle East			Asia			India sub-continent		
					Average	High productivity	Low productivity	Average	High productivity	Low productivity	Average	High productivity	Low productivity	Average	High productivity	Low productivity	Average	High productivity	Low productivity
Dairy cattle	8.0	7.1	6.5	6.8	7.4	8.5	10.6	8.0	TBD	TBD	10.0	8.2	12.2	9.4	9.2	9.5	12.8	9.1	13.6
Mature cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Other cattle	7.1	5.5	7.5	5.6	8.5	7.4	10.2	TBD	TBD	TBD	10.7	10.3	16.4	8.4	TBD	TBD	12.0	TBD	12.0
Mature cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Growing cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Feedlot Cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Swine																			
Finishing	5.87	6.00	6.00	6.22	10.71	TBD	TBD	10.71	TBD	TBD	10.71	TBD	TBD	10.71	TBD	TBD	10.71	TBD	TBD
Breeding	2.53	2.32	2.78	2.78	10.71	TBD	TBD	10.71	TBD	TBD	10.71	TBD	TBD	10.71	TBD	TBD	10.71	TBD	TBD
Poultry																			
Layers	11.11	11.11	11.11	11.11	TBD	11.11	TBD	TBD	11.11	TBD	TBD	11.11	TBD	TBD	11.11	TBD	TBD	11.11	TBD
Broilers	11.11	11.11	11.11	11.11	TBD	11.11	TBD	TBD	11.11	TBD	TBD	11.11	TBD	TBD	11.11	TBD	TBD	11.11	TBD
Turkeys	10.29	10.29	10.29	10.29	TBD	10.29	TBD	TBD	10.29	TBD	TBD	10.29	TBD	TBD	10.29	TBD	TBD	10.29	TBD
Ducks	7.41	7.41	7.41	7.41	TBD	7.41	TBD	TBD	7.41	TBD	TBD	7.41	TBD	TBD	7.41	TBD	TBD	7.41	TBD
Sheep	8.25	8.25	8.25	8.25	9.47	8.25	11.43	9.47	8.25	11.43	9.47	8.25	11.43	9.47	8.25	11.43	9.47	8.25	11.43
Goats	9.09	9.09	9.09	9.09	9.71	9.09	10.00	9.71	9.09	10.00	9.71	9.09	10.00	9.71	9.09	10.00	9.71	9.09	10.00
Horses	5.65	5.65	5.65	5.65	6.27	5.65	7.23	6.27	5.65	7.23	6.27	5.65	7.23	6.27	5.65	7.23	6.27	5.65	7.23
Mules/Asses	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23	7.23
Camels	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47	11.47
Buffalo	NR	10.26	10.26	NR	9.0			NR			10.26			10.26			10.51		
Mink and Polecat	NR	NR	NR	NR	NR	NR		NR			NR			NR			NR		
Rabbits	62.50	62.50	62.50	62.50	62.50			62.50			62.50			62.50			62.50		

Fox and Racoon	NR	NR	NR	NR	NR	NR		NR			NR			NR			NR		

Table 10. 1 7 Average regional CH_4 emission factors of cattle by climate zone (g CH_4/kg VS) will be updated to be consistent with enteric

Livestock species	Manure Storage System	Productivity Class	Average regional CH_4 emission factors by average IPCC climate zone (g CH_4/kg VS)		
			Cool	Temperate	Warm
Dairy Cattle	Uncovered anaerobic lagoon	High Productivity	90.85	119.80	127.03
	Liquid/Slurry and pit >1 month		30.15	62.71	113.36
	Pit storage				
	Pasture/Range/Paddock			0.58	
	Burned for fuel		16.08	TBD	16.08
	Compost (forced aeration)		1.61	3.22	4.02
	Solid storage		3.22	6.43	8.04
	Dry lot		1.61	TBD	2.41
	Daily spread		0.16	TBD	0.80
	Deep bedding <1 month		4.82	TBD	4.82
	Deep bedding >1 month		31.36	45.83	52.26
	Aerobic treatment		TBD	TBD	TBD
	Uncovered anaerobic lagoon	Low Productivity	49.21	64.89	68.81
	Liquid/Slurry and pit >1 month		16.33	33.97	61.41
	Pit storage				
	Pasture/Range/Paddock			0.58	
	Burned for fuel			8.71	
	Compost (forced aeration)		0.87	1.74	2.18
	Solid storage		1.74	3.48	4.36
	Dry lot		0.87	TBD	1.31
	Daily spread		0.09	TBD	0.44
	Deep bedding <1 month		2.61	TBD	2.61
	Deep bedding >1 month		16.98	24.82	28.31
	Aerobic treatment		TBD	TBD	TBD
Other Cattle	Uncovered anaerobic lagoon	High Productivity	71.92	94.84	100.57
	Liquid/Slurry and pit >1 month		23.87	49.65	89.75
	Pit storage				
	Pasture/Range/Paddock			0.58	
	Burned for fuel		12.73	TBD	12.73
	Compost (forced aeration)		1.27	2.55	3.18
	Solid storage		2.55	5.09	6.37
	Dry lot		1.27	TBD	1.91
	Daily spread		0.13	TBD	0.64
	Deep bedding <1 month		3.82	TBD	3.82
	Deep bedding >1 month		24.82	36.28	41.37
	Aerobic treatment		TBD	TBD	TBD
	Uncovered anaerobic lagoon	Low Productivity	37.86	49.92	52.93
	Liquid/Slurry and pit >1 month		12.56	26.13	47.24
	Pit storage				
	Pasture/Range/Paddock		0.58	0.58	0.58
	Burned for fuel		6.70	TBD	6.70
	Compost (forced aeration)		0.67	1.34	1.68
	Solid storage		1.34	2.68	3.35
	Dry lot		0.67	TBD	1.01
	Daily spread		0.07	TBD	0.34
	Deep bedding <1 month		2.01	TBD	2.01
	Deep bedding >1 month		13.07	19.10	21.78
	Aerobic treatment		TBD	TBD	TBD

Table 10. 1 8 Average regional CH_4 emission factors of swine by climate zone (g CH_4/kg VS) (will be updated to be consistent with enteric)

Livestock species	Manure Storage System	Productivity Class	Average regional CH_4 emission factors by average IPCC climate zone (g CH_4/kg VS)		
			Cool	Temperate	Warm
Finishing Swine	Uncovered anaerobic lagoon	High Productivity	181.70	239.59	254.06
	Liquid/Slurry and pit >1 month		60.30	125.42	226.73
	Pit storage		8.84	20.90	56.28
	Burned for fuel				
	Compost (forced aeration)		3.22	6.43	8.04
	Solid storage		6.43	12.86	16.08
	Dry lot		3.22	TBD	4.82
	Daily spread		0.32	TBD	1.61
	Deep bedding <1 month		9.65	TBD	9.65
	Deep bedding >1 month		62.71	91.66	104.52
	Aerobic treatment		TBD	TBD	TBD
	Uncovered anaerobic lagoon	Low Productivity	109.78	144.75	153.50
	Liquid/Slurry and pit >1 month		36.43	75.78	136.98
	Pit storage		5.34	12.63	34.00
	Burned for fuel				
	Compost (forced aeration)		1.94	3.89	4.86
	Solid storage		3.89	7.77	9.72
	Dry lot		1.94	TBD	2.91
	Daily spread		0.19	TBD	0.97
	Deep bedding <1 month		5.83	TBD	5.83
	Deep bedding >1 month		37.89	55.38	63.15
	Aerobic treatment		TBD	TBD	TBD
Breeding swine	Uncovered anaerobic lagoon	High Productivity	181.70	239.59	254.06
	Liquid/Slurry and pit >1 month		60.30	125.42	226.73
	Pit storage		8.84	20.90	56.28
	Burned for fuel				
	Compost (forced aeration)		3.22	6.43	8.04
	Solid storage		6.43	12.86	16.08
	Dry lot		3.22	TBD	4.82
	Daily spread		0.32	TBD	1.61
	Deep bedding <1 month		9.65	TBD	9.65
	Deep bedding >1 month		62.71	91.66	104.52
	Aerobic treatment		TBD	TBD	TBD
	Uncovered anaerobic lagoon	Low Productivity	109.78	144.75	153.50
	Liquid/Slurry and pit >1 month		36.43	75.78	136.98
	Pit storage		5.34	12.63	34.00
	Burned for fuel				
	Compost (forced aeration)		1.94	3.89	4.86
	Solid storage		3.89	7.77	9.72
	Dry lot		1.94	TBD	2.91
	Daily spread		0.19	TBD	0.97
	Deep bedding <1 month		5.83	TBD	5.83
	Deep bedding >1 month		37.89	55.38	63.15
	Aerobic treatment		TBD	TBD	TBD

Table 10. 1 9 Manure management methane emission factors by temperature for Sheep, Goats, Camels, Horses, Mules and Asses, and Poultry (g CH_4 kg VS^{-1})

Livestock	Manure Management System	CH4 emission factor by average annual temperature (°C)		
		Cool (<15°C)	Temperate (15 to 25°C)	Warm (>25°C)
Sheep				
High Productivity	Pasture Range and Paddock	0.58		
	Solid	2.5	5.1	6.4
	Drylot	1.3	1.9	2.5
Low Productivity	Pasture Range and Paddock	0.45		
	Solid	1.7	3.5	4.4
	Drylot	0.9	1.3	1.7
Goats				
High Productivity	Pasture Range and Paddock	0.58		
	Solid	2.4	4.8	6.0
	Drylot	1.2	1.8	2.4
Low Productivity	Pasture Range and Paddock	0.45		
	Solid	1.7	3.5	4.4
	Drylot	0.9	1.3	1.7
Camels				
High Productivity	Pasture Range and Paddock	0.58		
	Solid	3.5	7.0	8.7
	Drylot	1.7	2.6	3.5
Low Productivity	Pasture Range and Paddock	0.45		
	Solid	2.8	5.6	7.0
	Drylot	1.4	2.1	2.8
Horses				
High Productivity	Pasture Range and Paddock	0.58		
	Solid	4.0	8.0	10.1
	Drylot	2.0	3.0	4.0
Low Productivity	Pasture Range and Paddock	0.45		
	Solid	3.5	7.0	8.7
	Drylot	1.7	2.6	3.5
Mules and Asses				
High Productivity	Pasture Range and Paddock	0.58		
	Solid	4.4	8.8	11.1
	Drylot	2.2	3.3	4.4
Low Productivity	Pasture Range and Paddock	0.45		
	Solid	3.5	7.0	8.7
	Drylot	1.7	2.6	3.5
Poultry				
High Productivity				
Layers (dry)b		3.9		
Layers (wet)c		TBD	TBD	TBD
Broilers/ Turkeys /Ducks		3.6		

Low Productivity		1.9
The uncertainty in these emission factors is +30 %.		

Table 10. ２０ Manure management methane emission factors for Deer, Reindeer, Rabbits, and fur-bearing animals （ **need to be update**）

Livestock	**CH_4 emission factor** (g CH_4 kg VS^{-1})
Deer[a]	TBD
Reindeer[b]	2.55
Rabbits[c]	2.14
Fur-bearing animals (e.g., fox, mink)[b]	13.4
Ostrich	13.4

The uncertainty in these emission factors is +30 %.

[a] Sneath *et al.* (1997)

[b] Estimations of Agricultural University of Norway, Institute of Chemistry and Biotechnology, Section for Microbiology.

[c] Judgement of the IPCC Expert Group

Tier 2

The Tier 2 method is applicable when Manure Management is a key source or when the data used to develop the default values do not correspond well with the country's livestock and manure management conditions. Because cattle, buffalo and swine characteristics and manure management systems can vary significantly by country, countries with large populations of these animals should consider using the Tier 2 method for estimating methane emissions. The Tier 2 method relies on two primary types of inputs that affect the calculation of methane emission factors from manure:

Manure characteristics*:* Includes the amount of volatile solids (VS) produced in the manure and the maximum amount of methane able to be produced from that manure (B_o). Production of manure VS can be estimated based on feed intake and digestibility, which are the variables also used to develop the Tier 2 enteric fermentation emission factors. Alternatively, VS production rates can be based on laboratory measurements of livestock manure. B_o varies by animal species and feed regimen and is a theoretical methane yield based on the amount of VS in the manure. Bedding materials (straw, sawdust, chippings, etc.) are not included in the VS modelled under the Tier 2 method. The type and use of these materials is highly variable from country to country. Since they typically are associated with solid storage systems, their contribution would not add significantly to overall methane production.

Manure management system characteristics*:* Includes the types of systems used to manage manure and a system-specific methane conversion factor (MCF) that reflects the portion of B_o that is achieved. Regional assessments of manure management systems are used to estimate the portion of the manure that is handled with each manure management technique. A description of manure management systems is included in Table 10.22. The system MCF varies with the manner in which the manure is managed and the climate, and can theoretically range from 0 to 100%. Both temperature and retention time play an important role in the calculation of the MCF. Manure that is managed as a liquid under warm conditions for an extended period of time promotes methane formation. These manure management conditions can have high MCFs, of 65 to 80%. Manure managed as dry material in cold climates does not readily produce methane, and consequently has an MCF of about 1%.

Development of Tier 2 emission factors involves determining a weighted average MCF using the estimates of the manure managed by each waste system within each climate region. The average MCF is then multiplied by the VS excretion rate and the B_o for the livestock categories. In equation form, the estimate is as follows:

EQUATION10. 28

CH_4 EMISSION FACTOR FROM MANURE MANAGEMENT

$$EF_{(T)} = \left[B_{o(T)} \bullet 0.67 \bullet \sum_{S,k} \frac{MCF_{S,k}}{100} \bullet MS_{(T,S,k)} \right] \bullet 1000$$

Where:

$EF_{(T)}$ = annual CH_4 emission factor for livestock category *T*, g CH_4 kg VS^{-1}

$B_{o(T)}$ = maximum methane producing capacity for manure produced by livestock category *T*, m^3 CH_4 kg^{-1} of VS excreted

0.67 = conversion factor of m^3 CH_4 to kilograms CH_4, kg m^{-3}

$MCF_{(S,k)}$ = methane conversion factors for each manure management system *S* by climate region *k*, %

$MS_{(T,S,k)}$ = fraction of livestock category *T*'s manure handled using manure management system *S* in climate region *k*, dimensionless

Even when the level of detail presented in the Tier 2 method is not possible in some countries, country-specific data elements such as animal mass, VS excretion, and others can be used to improve emission estimates. If country-specific data are available for only a portion of these variables, countries are encouraged to calculate country-specific emission factors, using the data in Tables 10A-4 through 10A-20 to fill gaps.

Measurement programs can be used to improve the basis for making the estimates. In particular, measurements of emissions from manure management systems under field conditions are useful to verify MCFs. Also, measurements of B_o from livestock in tropical regions and for varying diet regimens are needed to expand the representativeness of the default factors.

As emissions can vary significantly by region and livestock species/category, emission estimates should reflect as much as possible the diversity and range of animal populations and manure management practices between different regions within a country. This may require separate estimates to be developed for each region. Emission factors should be updated periodically to account for changes in manure characteristics and management practices. These revisions should be based on reliable scientifically reviewed data. Frequent monitoring is desirable to verify key model parameters and to track changing trends in the livestock industry.

VS excretion rates

Volatile solids (VS) are the organic material in livestock manure and consist of both biodegradable and non-biodegradable fractions. The value needed for the Equation 10.26 is the total VS (both degradable and non-biodegradable fractions) as excreted by each animal species since the B_o values are based on total VS entering the systems. The best way to obtain average daily VS excretion rates is to use data from nationally published sources. If average daily VS excretion rates are not available, country-specific VS excretion rates can be estimated from feed intake levels. Feed intake for cattle and buffalo can be estimated using the 'Enhanced' characterisation method described in Section 10.2. This will also ensure consistency in the data underlying the emissions estimates. For swine, country-specific swine production data may be required to estimate feed intake.

The VS content of manure equals the fraction of the diet consumed that is not digested and thus excreted as fecal material which, when combined with urinary excretions, constitutes manure. Countries should estimate gross energy (GE) intake (Section 10.2, Equation 10.16) and its fractional digestibility, DC, in the process of estimating enteric methane emissions.

Once these are estimated, the VS excretion rate is estimated as:

EQUATION10. 29

VOLATILE SOLID EXCRETION RATES

$$VS = \left[GE \bullet \left(1 - \frac{DC\%}{100}\right) + \left(UE \bullet GE\right) \right] \bullet \left[\left(\frac{1 - ASH}{18.45} \right) \right]$$

Where:

VS = volatile solid excretion per day on a dry-organic matter basis, kg VS day^{-1}

GE = gross energy intake, MJ day^{-1}

DC% = digestibility of the feed in percent (e.g. 60%)

(UE • GE) = urinary energy expressed as fraction of GE. Typically 0.04GE can be considered urinary energy excretion by most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in the diet or for swine). Use country-specific values where available.

ASH = the ash content of manure calculated as a fraction of the dry matter feed intake (e.g., 0.08 for cattle). Use country-specific values where available.

18.45 = conversion factor for dietary GE per kg of dry matter (MJ kg^{-1}). This value is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock.

Representative DC% values for various livestock categories are provided in Section 10.2, Table 10.2 of this report. The value for ash content fraction can range substantially between livestock types and should reflect national circumstances.

B_o values

The maximum methane-producing capacity of the manure (B_o) varies by species and diet. The preferred method to obtain B_o measurement values is to use data from country-specific published sources, measured with a standardised method. It is important to standardise the B_o measurement. It is important to standardise the B_o measurement, including the method of sampling, and to confirm if the value is based on total as-excreted VS or biodegradable VS, since the Tier 2 calculation is based on total as-excreted VS. If country-specific B_o measurement values are not available, default values are provided in Tables 10A-4 through 10A-20.

MCFs

MCFs are determined for a specific manure management system and represent the degree to which B_o is achieved. Default methane conversion factors (MCFs) are provided in Table 10.21 for different manure management systems. A single MCF value is provided for manure deposited by grazing animals onto pasture, ranges and paddocks, as an analysis of 45 data showed there was no significant difference between temperate and tropical climatic zones (see Annex 10B.6). The amount of methane generated by a specific manure management system is affected by the extent of anaerobic conditions present, the temperature of the system, and the retention time of organic material in the system. Default MCF values for liquid systems and lagoons presented in Table 10.22include the effect of longer retention times.

Liquid-based systems are sensitive to temperature effects, but average annual MCF values for a specific system will largely be determined by the quantity of VS in the storage system during peak temperature periods (Balde et al. 2016). Emissions increase exponentially with increasing temperatures. For this reason monthly temperature variations in combination with timing of storage and application times that largely define annual MCFs rather than average annual temperatures.

Climate zones are used to differentiate variations in MCFs associated with ranges and annual monthly temperature variability. Countries may customize MCF calculations based on their monthly temperature profiles according to the example provided in Annex 10A.6.

These default values may not encompass the potentially wide variation within the defined categories of management systems. Therefore, country-specific MCFs that reflect the specific management systems used in particular countries or regions should be developed if possible. This is particularly important for countries with large animal populations or with multiple climate regions. In such cases, and if possible, field measurements should be conducted for each climate region to replace the default MCF values. Measurements should include the following factors:

- Duration of storage and timing of application;

- Information on manure treatment and VS entering the storage system;
- Feed and animal characteristics at the measurement site (see Section 10.2 for the type of data that would be pertinent);
- Determination of the amount of manure left in the storage facility after emptying (methanogenic inoculum);
- Monthly temperature in the storage..

MCF for CH4 emissions from biogas digesters

The methane emission from the biogas digesters include the unused biogas (including amount of leakage), flared biogas. And emissions from effluents storage of biogas digester.

The MCF calculation from biogas digesters should be based on the following equation which describes emissions from system leakage + flare leakage + digestate storage normalized by the total methane potential of all VS entering the digester:

EQUATION10. 30
METHANE CONVERSION FACTOR FOR MANURE BASED BIOGAS DIGESTER

$$\mathrm{MCF} = \Big[\big[CH_{4\,prod} - CH_{4\,used} - CH_{4\,flared} + \{MCF_{storage,digestate}/100 * \big(F_{Bo,defaut} * Bo * VS_{digestion} * (1 - F_{vs,default}) * 0.67\}\big)\big] / \big(Bo * VS_{digestion} * 0.67\big)\Big] * 100$$

Where:

$CH_{4\,prod}$ = methane production in digester , (kg CH_4) . Note: When a gas tight coverage of the storage for digested manure is used, the gas production of the storage should be included.

$CH_{4\,used}$ = amount of methane gas used for energy, (kg CH_4)

$CH_{4\,flared}$ = amount of methane flared, (kg CH_4), when calculating methane flared, the flare efficiency should be taken into account. The default value for the flare efficiency is 0, 50%, 100% for the flame not detected, workable open flares, and workable enclosed flares, respectively.

$MCF_{storage,digestate}$ = MCF for CH_4 emitted during storage of digestate (%),When a gas tight storage is included: $MCF_{storage,digestate}$ = 0 ; otherwise $MCF_{storage,digestate}$ = MCF value for digestate storage is same to the storage of raw manure.

$F_{Bo,default}$ = Default factor representing the remaining methane production capacity of digestate , unit in fraction. 45% is recommended here to represent the value of $F_{Bo,default}$ based on the study by Rodhe et al., 2015, VanderZaag et al., 2017, and Rico et al., 2011, who compared the Bo of raw manure and its corresponding digestate.

$F_{vs,default}$= Default factor representing degradation rate of VS in biogas digester , unit in fraction. 70% is recommended here to represent the value of $F_{vs,\ default}$ based on the study by XXXXXX

$VS_{digestion}$ = amount of VS that goes to digestion (kg VS)

In the case of co-digestion of animal manures with additional organic residues, it is essential to estimate the additional VS input from these organic residues and the respective CH_4 emissions. The MCF calculation from co-digestion are based on the following equation:

Methane conversion Factor for co- digester should be based on the following equation:

EQUATION10. 31
METHANE CONVERSION FACTOR FOR CO DIGESTION BIOGAS DIGESTER

$$\mathbf{MCF} = \left[\left[\boldsymbol{CH_{4\,prod}} - \boldsymbol{CH_{4\,used}} - \boldsymbol{CH_{4\,flared}} + \left\{\boldsymbol{MCF_{storage,digestate}}/\mathbf{100} * \left(\boldsymbol{F_{Co-Bo,default}} * \left(\sum_{i=1}^{n} \boldsymbol{B_{0,i}} * \boldsymbol{VS_{i,digestion}}\right) * \left(\mathbf{1} - \boldsymbol{F_{Co-vs,default}}\right) * \mathbf{0.67}\right)\right\}\right] / \left(\sum_{i=1}^{n} \boldsymbol{B_{0,i}} * \boldsymbol{VS_{i,digestion}} * \mathbf{0.67}\right)\right] * \mathbf{100}$$

Where:

$CH_{4\,prod}$ = methane production in digester , (kg CH_4) . Note: When a gas tight coverage of the storage for digested manure is used, the gas production of the storage should be included.

$CH_{4\,used}$ = amount of methane gas used for energy, (kg CH_4)

$CH_{4\,flared}$ = amount of methane flared, (kg CH_4), when calculated methane flared, the flare efficiency should be taken into account. The default value for the flare efficiency is 0, 50%, 100% for the flame not detected, workable open flares, and workable enclosed flares, respectively.

$MCF_{storage,digestate}$ = MCF for CH_4 emitted during storage of digestate (%),When a gas tight storage is included: $MCF_{storage,digestate}$ = 0 ; otherwise $MCF_{storage,digestate}$ = MCF value for digestate storage is same to the storage of raw manure.

$F_{Co-Bo,default}$ = Default factor representing the remaining methane production capacity of digestate , unit in fraction. 38% is recommended here to represent the value of $F_{Bo,default}$ based on the study by Baldé et al., 2016, who studied the methane emission from digestate at an agricultural biogas plant with the co-digestion of dairy manure and food industry waste.

$F_{Co-vs,default}$= Default factor representing degradation rate of VS in biogas digester , unit in fraction. 76% is recommended here to represent the value of $F_{vs,\,default}$ based on the study by Baldé et al., 2016, who achieved during the co-digestion of dairy manure and food industry waste.

$B_{0,i}$ =The maximum methane-producing capacity of the material

$VS_{i,digestion}$ = amount of VS that goes to digestion of material (kg VS)

Table 10. 2 1 MCF values for climate zone

System[a]		MCFs by climate zone										Source and comments
		Cool				Temperate		Warm				
		Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry	
Pasture/Range/Paddock		0.43%						0.43%				Based on updated version of Cai et al. (2017) database (see Annex 10B.6)
Daily spread		0.10%				TBD		0.50%				Hashimoto and Steed (1993).
Solid storage		2.00%				4.00%		5.00%				Expert judgement based on IPCC(2006) and update supported by Pardo et al. (2015) . Emissions in temperate climate can be double than in cool climate
Solid storage – Covered/compacted		2.00%				4.00%		5.00%				Expert judgement based on Pardo et al (2015). Emissions in the same range than solid storage.
Solid storage – Bulking agent addition		0.50%				1.00%		1.50%				Expert judgement based on Pardo et al (2015). Estimated reduction of 75% due to bulking agent addition
Solid storage – Additives		1.00%				2.00%		2.50%				Expert judgement based on Pardo et al (2015). Estimated reduction of 50% due to bulking agent addition
Dry lot		1.00%				TBD		1.50%				Judgement of IPCC Expert Group in combination with Hashimoto and Steed (1994).
Liquid/Slurry, and pit ⩾ 1month	1 Month	6%	8%	4%	4%	13%	15%	25%	38%	36%	42%	Judgement of IPCC Expert Group. See Annex X.X for additional details. A reduction of 40% due to crust cover (40%) may be applied only when a thick, dry, crust is present. The tavg C for Cool Temperate Moist, Cool Temperate Dry, Warm Temperate Moist, Warm Temperate Dry, Tropical, Tropical Wet, Tropical Moist, Tropical Dry were 4.6, 5.8, 13.9, 14.0, 21.5, 25.9, 25.2, 25.6 respectively. Solid-liquid separation that removes VS and diverts it to aerobic/solid management should be considered when calculating the VS loading rate into liquid systems.
	3 Month	12%	16%	8%	8%	24%	28%	43%	61%	57%	62%	
	4 Month	15%	19%	9%	9%	29%	32%	50%	67%	64%	68%	
	6 Month	21%	26%	14%	14%	37%	41%	.59%	76%	73%	74%	
	12 Month	31%	42%	21%	20%	55%	64%	73%	80%	80%	80%	
Uncovered anaerobic lagoon		60%	67%	50%	49%	73%	76%	76%	80%	80%	80%	Judgement of IPCC Expert Group utilizing a 12 month retention time and the equations and parameters presented in Mangino et al. (2001). Solid-liquid separation that removes VS and diverts it to aerobic/solid management should be considered when calculating the VS loading rate into liquid systems.
Pit storage below animal confinements	< 1 month	3%	4%	2%	2%	6%	7%	12%	19%	18%	21%	Judgement of IPCC Expert Group in combination with Moller et al. (2004) and Zeeman (1994). Note that the ambient temperature, not the stable temperature is used for determining the climatic conditions.

Anaerobic digester		0-100%				0-100%		0-100%				Should be subdivided in different categories, considering amount of recovery of the biogas, flaring of the biogas and storage after digestion. Calculation with Formula 1.
Burned for fuel		10.00%				10%		10%				Judgement of IPCC Expert Group in combination with Safley et al. (1992).
Cattle and Swine deep bedding	< 1 month	3.0%				3.0%		3%				Judgement of IPCC Expert Group in combination with Moller et al. (2004). Expect emissions to be similar, and possibly greater, than pit storage, depending on organic content and moisture content.
Cattle and Swine deep bedding (cont.)	> 1 month	17%	19%	20%	22%	25%	32%	27%	35%	29%	39%	Judgement of IPCC Expert Group in combination with Mangino et al. (2001).
Composting - In-vessel[b]		0.50%				0.50%		0.50%				Judgement of IPCC Expert Group and Amon et al. (1998). MCFs are less than half of solid storage. Not temperature dependant.
Composting - Static pile (Forced aeration)[b]		1.00%				2.00%		2.50%				Expert judgement update based on (Pardo *et al.* 2015). Estimated reduction of 50% compared to solid storage. Previously it was considered "Not temperature dependent" but now temperature influence has been considered
Composting - Intensive windrow[b]		0.50%				TBD		1%				Judgement of IPCC Expert Group and Amon et al. (1998). MCFs are slightly less than solid storage. Less temperature dependant.
Composting – Passive windrow (Unfrequent turning)[b]		1.00%				2.00%		2.5%				Expert judgement update based on (Pardo *et al.* 2015).. Estimated reduction of 50% compared to solid storage. Previous MCFs have been modified as they could underestimate CH4 emissions
Poultry manure with litter		1.50%				1.50%		1.50%				Judgement of IPCC Expert Group. MCFs are similar to sol id storage but with generally constant warm temperatures.
Poultry manure without litter		1.50%				1.50%		1.5%				Judgement of IPCC Expert Group. MCFs are similar to dry lot at a warm climate.
Aerobic treatment		TBD				0.00%		TBD				MCFs are near zero. Aerobic treatment can result in the accumulation of sludge which may be treated in other systems. Sludge requires removal and has large VS values. It is important to identify the next management process for the sludge and estimate the emissions from that management process if significant.

10.4.3 Choice of activity data

This section is an elaboration

There are two main types of activity data for estimating CH_4 emissions from manure management: (1) animal population data; and (2) manure management system usage data.

The animal population data should be obtained using the approach described in Section 10.2. As noted in Section 10.2, it is *good practice* to conduct a single livestock characterisation that will provide the activity data for all emissions sources relying on livestock population data. It is important to note, however, that the level of disaggregation in the livestock population data required to estimate emissions from manure management, may differ from those used for other sources, such as Enteric Fermentation. For example, for some livestock population species/categories, such as cattle, the enhanced characterisation required for the Tier 2 enteric fermentation estimate could be aggregated to broader categories that are sufficient for this source category. For other livestock species, such as swine, it may be preferable to have more disaggregation of weight categories for manure management calculations than for enteric fermentation. However, consistency in total livestock categories should be retained throughout the inventory.

Inventory agencies in countries with varied climatic conditions are encouraged to obtain population data for each major climatic zone. In addition, where possible, the associated annual average temperature for locations where livestock manure is managed in liquid-based systems (e.g., pits, tanks, and lagoons) should be obtained. This will allow more specific selection of default factors or MCF values for those systems more sensitive to temperature changes. Ideally, the regional population breakdown can be obtained from published national livestock statistics, and the temperature data from national meteorological statistics. If regional data are not available, experts should be consulted regarding regional production (e.g., milk, meat, and wool) patterns or land distribution, which may provide the required information to estimate the regional animal distributions.

To implement the Tier 2 method, the portion of manure managed in each manure management system must also be collected for each representative animal species. Table 10.22 summarizes the main types of manure management systems. Quantitative data should be used to distinguish whether the system is judged to be a solid storage or liquid/slurry. The borderline between dry and liquid can be drawn at 15% dry matter content. Note that in some cases, manure may be managed in several types of manure management systems. For example, manure flushed from a dairy freestall barn to an anaerobic lagoon may first pass through a solids separation unit where some of the manure solids are removed and managed as a solid. Therefore, if manure is managed in multiple systems, it is good practice to report the respective CH_4 emissions in each system.

The best means of obtaining manure management system distribution data is to consult regularly published national statistics. If such statistics are unavailable, the preferred alternative is to conduct an independent survey of manure management system usage. If the resources are not available to conduct a survey, experts should be consulted to obtain an opinion of the system distribution. Volume 1, Chapter 2 *Approaches to Data Collection* describes how to elicit expert judgement. Similar expert elicitation protocols can be used to obtain manure management system distribution data.

Table 10. 2 2 Definitions of manure management systems

System	**Application to Animal Categories**	**Definition**
Pasture/Range/Paddock	All animals	The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.
Daily spread	all animals	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	All animals,	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	All animals with the exception of swine and poultry, intensive systems	A paved or unpaved open confinement area without any significant vegetative cover. Dry lots do not require the addition of bedding to control moisture. Manure may be removed periodically and spread on fields.
Liquid/Slurry [a]	Cattle and swine,	Manure is stored as excreted or with some minimal addition of water or bedding material in tanks or ponds outside the animal housing. Manure is removed and spread on fields once or more in a calendar year. Manure is agitated before removal from the tank/ponds to ensure

			that most of the VS are removed from the tank. Solid-liquid separation that diverts VS from liquid manure to solid management (e.g. composting) should be considered when determining the VS entering the liquid/slurry.
Uncovered anaerobic lagoon		Cattle (mainly dairy) and swine, intensive systems. Dairy cattle in extensive tied stalls	A type of liquid storage system designed and operated to combine waste stabilization and storage. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The supernatant water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.
Pit storage below animal confinements		Cattle (mainly dairy) and swine,. intensive systems. Dairy cattle in extensive tied stalls	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year. Manure may be pumped out of the storage to a secondary storage tank multiple times in one year, or stored and applied directly to fields. It is assumed that VS removal rates on tank emptying are >90%.
Anaerobic digester		All animals,	Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Codigestion with waste or purpose grown crops can occur Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO_2 and CH_4, which is captured and flared or used as a fuel. After anaerobic digestion, digestate is stored in either open or closed storage tanks or open earthen storage basins for periods less than one year prior to being spread on fields. Volatile solid removal rates are typically >80%
Burned for fuel		Mainly cattle, extensive systems	The dung and urine are excreted on fields. The sun dried dung cakes are burned for fuel.
Deep bedding		Cattle, sheep and swine, intensive and extensive systems.	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture. Manure may undergo periods where animals are present and are actively mixing the manure, or periods in which the pack is undisturbed.
Composting	In-vessel[a]	Mainly cattle, sheep intensive systems	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.
	Static pile		Composting in piles with forced aeration but no mixing, with runoff/leaching containment.
			Composting in piles with forced aeration but no mixing, without runoff/leaching containment.
	Intensive windrow[a]		Composting in windrows with regular (at least daily) turning for mixing and aeration, runoff/leaching containment
			Composting in windrows with regular (at least daily) turning for mixing and aeration, no runoff/leaching containment
	Composting - Passive windrow[a]		Composting in windrows with infrequent turning for mixing and aeration, with runoff/leaching.
			Composting in windrows with infrequent turning for mixing and aeration, no runoff/leaching.
Poultry manure with litter		Poultry	Similar to cattle and swine deep bedding except usually not combined with a dry lot or pasture. Typically used for all poultry breeder flocks and for the production of meat type chickens (broilers) and other fowl. Litter and manure are left in place with added bedding during the poultry production cycle and cleaned between poultry cycles, typically 5 to 9 weeks in productive systems and X amount of days in lower productiity systems.

Poultry manure without litter	Poultry	May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as a high-rise manure management system and is a form of passive windrow composting when designed and operated properly. Some intensive poultry farms installed the manure belt under the cage , where the manure was dried inside housing.
Aerobic treatment		The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.
[a] Covers on manure management systems can impact emissions of direct N2O, CH4 and NH3, With N2O and CH4 emission, the effect of the cover depends upon characterical of cover material .		
Modifying this Table, by separating treatment types		

10.4.4 Uncertainty assessment

No refinement in this section

10.4.5 Completeness, Time series, Quality assurance / Quality control and Reporting

No refinement in this section

10.5 N_2O EMISSIONS FROM MANURE MANAGEMENT

The section describes how to estimate the N_2O produced, directly and indirectly, during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes based on updated N excretion, updated emission factors for N_2O emissions, as well as updated NH_3 volatilization and leaching factors. This section also details the principals of N flow and the connection between IPCC N_2O reporting and NH_3 and NOx reporting required for UNECE countries.

The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock. The N_2O emissions generated by manure in the system 'pasture, range, and paddock' occur directly and indirectly from the soil, and are therefore reported under the category '*N_2O Emissions from Managed Soils*' (see Chapter 11, Section 11.2). Direct and indirect N_2O emissions generated by manure managed in other systems and following its application to soils are also reported under the category 'N_2O Emissions from Managed Soils' (see Chapter 11, Section 11.2). The emissions associated with the burning of dung for fuel are to be reported under 'Fuel Combustion' (see Volume 2: Energy), or under 'Waste Combustion' (see Volume 5: Waste) if burned without energy recovery.

Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. Nitrification (the oxidation of ammonia nitrogen to nitrate nitrogen) is a necessary prerequisite for the emission of N_2O from stored animal manures. Nitrification is likely to occur in stored animal manures provided there is a sufficient supply of oxygen. Nitrification does not occur under anaerobic conditions. Nitrites and nitrates are transformed to N_2O and dinitrogen (N_2) during the naturally occurring process of denitrification, an anaerobic process. There is general agreement in the scientific literature that the ratio of N_2O to N_2 increases with increasing acidity, nitrate concentration, and reduced moisture. In summary, the production and emission of N_2O from managed manures requires the presence of either nitrites or nitrates in an anaerobic environment preceded by aerobic conditions necessary for the formation of these oxidized forms of nitrogen. In addition, conditions preventing reduction of N_2O to N_2, such as a low pH or limited moisture, must be present.

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO_x. The fraction of excreted organic nitrogen that is mineralized to ammonium nitrogen during manure collection and storage depends primarily on oxygen supply, time, and on temperature. Simple forms of organic nitrogen such as urea (mammals) and uric acid (poultry) are rapidly mineralized to ammonium nitrogen, which is converted to ammonia under alkaline conditions. Ammonia is highly volatile and easily diffused into the surrounding air (Asman *et al.*, 1998; Monteny and Erisman, 1998). Nitrogen losses begin at the point of excretion in houses and other animal production areas (e.g., milk parlors) and continue through on-site management in storage and treatment systems (i.e., manure management systems). Nitrogen is also lost through runoff and leaching into soils from the solid storage of manure at outdoor areas, in feedlots and where animals are grazing in pastures. Emissions of nitrogen compounds from grazing livestock are considered separately in Chapter 11, Section 11.2, *N_2O Emissions from Managed Soils*, as are.

In the case of co-digestion of animal manures with additional organic residues, energy crops, additional N enters the system. This additional N source also emits N_2O during the storage and land application, and must be considered in the section "N_2O emissions from manure management". The N in co-digestates with manure should be ducted in the sections "Energy" and/or "Waste" to avoid doubling estimation .

Due to significant direct and indirect losses of manure nitrogen in management systems it is important to estimate the remaining amount of animal manure nitrogen available for application to soils or for use in feed, fuel, or construction purposes. This value is used for calculation N_2O emissions from managed soils (see Chapter 11, Section 11.2). The methodology to estimate manure nitrogen that is directly applied to soils, or available for use in feed, fuel, or construction purposes is described in this chapter under Section 10.5.4 "Coordination with reporting for N_2O emissions from managed soils".

10.5.1 Choice of method

This section is an update/elaboration

The level of detail and methods chosen for estimating N_2O emissions from manure management systems will depend upon national circumstances and the decision tree in Figure 10.4 describes *good practice* in choosing a method accordingly. The following sections describe the different tiers referenced in the decision tree for calculating direct and indirect N_2O emissions from manure management systems.

Direct N_2O emissions from Manure Management

Tier 1

The Tier 1 method entails multiplying the total amount of N excretion (from all livestock species/categories) in each type of manure management system by an emission factor for that type of manure management system (see Equation 10.31). Emissions are then summed over all manure management systems. The Tier 1 method is applied using IPCC default N_2O emission factors, default nitrogen excretion data, and default manure management system data (see Annex 10A.2, Tables 10A-4 to 10A-19 for default management system allocations).

Tier 2

A Tier 2 method follows the same calculation equation as Tier 1 but would include the use of country-specific data for some or all of these variables. For example, the use of country-specific nitrogen excretion rates for livestock categories would constitute a Tier 2 methodology.

Tier 3

A Tier 3 method utilizes alternative estimation procedures based on a country-specific methodology. For example, a process-based, mass balance approach which tracks nitrogen throughout the system in detail starting with feed input through final use/disposal could be utilized as a Tier 3 procedure. Tier 3 methods should be well documented to clearly describe estimation procedures.

To estimate emissions from manure management systems, the livestock population must first be divided into categories that reflect the varying amounts of manure produced per animal as well as the manner in which the manure is handled. This division of manure by type of system should be the as that used to characterize methane emissions from manure management (see Section 10.4). For example, if Tier 1 default emission factors are used for calculating CH_4 emissions, then the manure management systems usage data from Tables 10A-4 to 10A-19 should be applied. Detailed information on how to characterise the livestock population for this source is provided in Section 10.2.

In the case of anaerobic digestion of animal manures with additional organic residues it is essential to estimate the additional N input from these organic residues and the respective N_2O emissions.

The following five steps are used to estimate direct N_2O emissions from Manure Management:

Step 1: Collect population data from the Livestock Population Characterisation;

Step 2: Use default values or develop the annual average nitrogen excretion rate per head ($Nex_{(T)}$) for each defined livestock species/category T;

Step 3: Use default values or determine the fraction of total annual nitrogen excretion for each livestock species/category T that is managed in each manure management system S ($MS_{(T,S)}$);

Step 4: Use default values or develop N_2O emission factors for each manure management system S ($EF_{3(S)}$); and

Step 5: For each manure management system type S, multiply its emission factor ($EF_{3(S)}$) by the total amount of nitrogen managed (from all livestock species/categories) in that system, to estimate N_2O emissions from that manure management system. Then sum over all manure management systems.

In some cases, manure nitrogen may be managed in several types of manure management systems. For example, manure flushed from a dairy freestall barn to an anaerobic lagoon may first pass through a solids separation unit where some of the manure nitrogen is removed and managed as a solid. If manure is managed in multiple system, it is good practice to estimate N_2O emissions from all systems.

The calculation of direct N_2O emissions from manure management is based on the following equation:

EQUATION10. 32

DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Where:

$N_2O_{D(mm)}$ = direct N_2O emissions from Manure Management in the country, kg N_2O yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N animal^{-1} yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*

S = manure management system

T = species/category of livestock

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

There may be losses of nitrogen in other forms (e.g., ammonia and NO_x) as manure is managed on site. Nitrogen in the volatilized form of ammonia may be deposited at sites downwind from manure handling areas and contribute to indirect N_2O emissions (see below). Countries are encouraged to consider using a mass balance approach to track the manure nitrogen excreted, managed on site in manure management systems, and ultimately applied to managed soils. The estimation of the amount of manure nitrogen which is directly applied to managed soils or otherwise available for use as feed, fuel or construction purposes is described in the Section 10.5.4, Coordination with reporting for N_2O emissions from managed soils is required. See Chapter 11, Section 11.2 for procedures to calculate N_2O emissions from managed manure nitrogen applied to soils. Additional guidance on ensuring consistency in the mass balance approach and between emissions from manure in the source category *N_2O Emissions from Manure Management* and *N_2O Emissions from Managed Soils* is given in Section 11.5.6 *Consistency of nitrogen flows*.

Indirect N_2O emissions from Manure Management

Tier 1

The Tier 1 calculation of N volatilisation in forms of NH_3 and NO_x from manure management systems is based on multiplication of the amount of nitrogen excreted (from all livestock categories) and managed in each manure management system by a fraction of volatilised nitrogen (see Equation 10.33). N losses are then summed over all manure management systems. The Tier 1 method is applied using default nitrogen excretion data, default manure management system data (see Annex 10A.2, Tables 10A-4 to 10A-19) and default fractions of N losses from manure management systems due to volatilisation (see Table 10.26):

EQUATION10. 33

N LOSSES DUE TO VOLATILISATION FROM MANURE MANAGEMENT

$$N_{volatilization-MMS} = \sum_S \left[\sum_T \left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \bullet \left(\frac{Frac_{GasMS}}{100} \right)_{(T,S)} \right] \right]$$

Where:

$N_{volatilization-MMS}$ = amount of manure nitrogen that is lost due to volatilisation of NH_3 and NO_x, kg N yr^{-1}

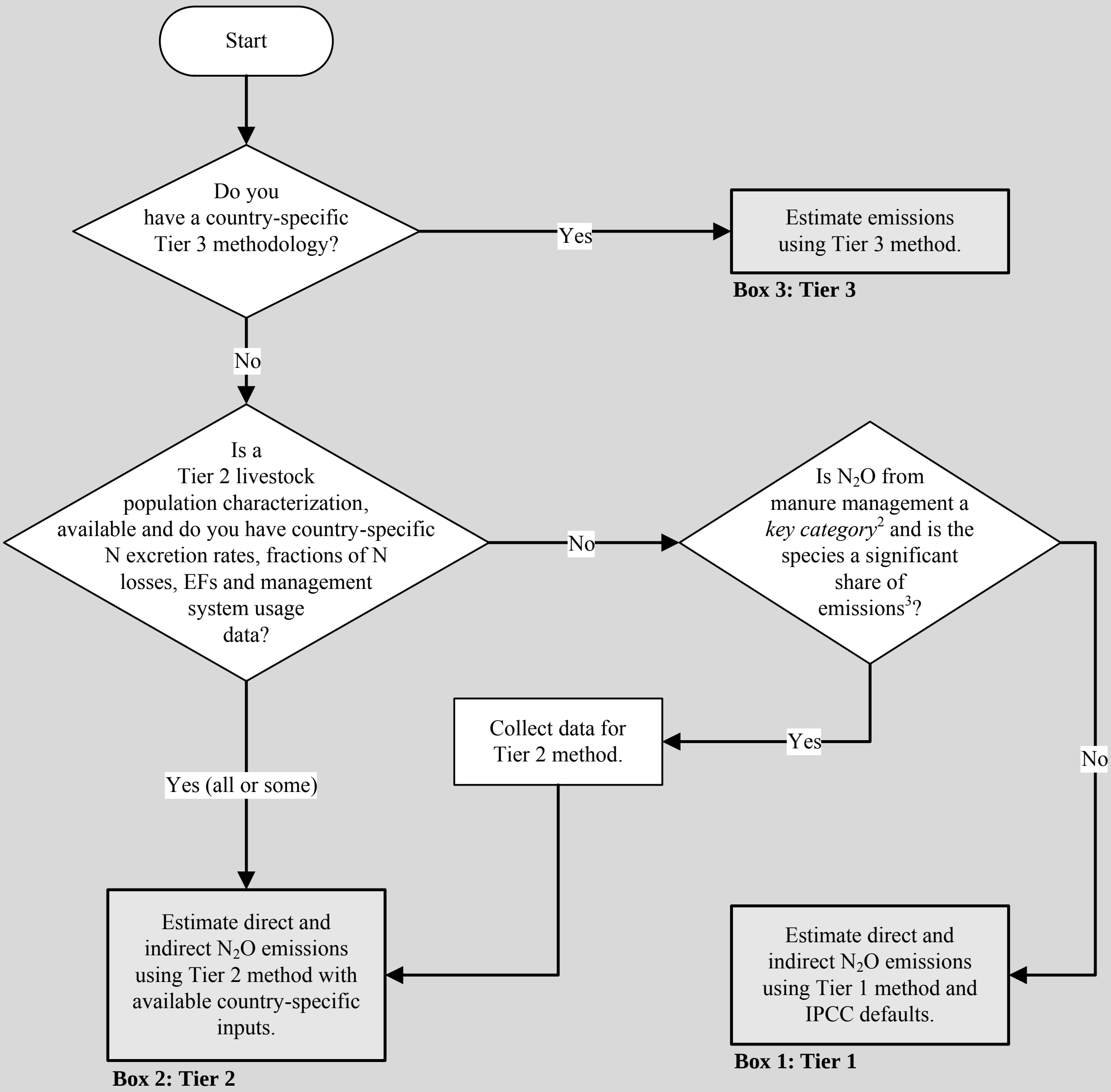
$N_{(T)}$ = number of head of livestock species/category *T* in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N animal^{-1} yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$Frac_{GasMS}$ = percent of managed manure nitrogen for livestock category *T* that volatilises as NH_3 and NO_x in the manure management system *S*, %

Figure 10. 4 Decision tree for N_2O emissions from Manure Management (Note 1)



Note:
1: N_2O emissions from manure management systems include both direct and indirect sources
2: See Volume 1 Chapter 4, "Methodological Choice and Identification of Key Categories" (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.
3: As a rule of thumb, a livestock species would be significant if it accounts for 25-30% or more of emissions from the source category.

The indirect N_2O emissions from volatilisation of N in forms of NH_3 and NO_x ($N_2O_{G(mm)}$) are estimated using Equation 10.34:

EQUATION10. 34

INDIRECT N_2O EMISSIONS DUE TO VOLATILISATION OF N FROM MANURE MANAGEMENT

$$N_2O_{G(mm)} = \left(N_{volatilization-MMS} \bullet EF_4\right) \bullet \frac{44}{28}$$

Where:

$N_2O_{G(mm)}$ = indirect N_2O emissions due to volatilization of N from Manure Management in the country, kg N_2O yr^{-1}

EF_4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N (kg NH_3-N + NO_x-N volatilised)$^{-1}$; default value is 0.01 kg N_2O-N (kg NH_3-N + NO_x-N volatilised)$^{-1}$, given in Chapter 11, Table 11.3

Tier 2

Countries may wish to develop a Tier 2 methodology for better consideration of national circumstances and to reduce uncertainty of estimates as much as possible. As for direct N_2O emission from manure management, a Tier 2 method would follow the same calculation equation as Tier 1 but include the use of country-specific data for some or all of variables. For example, the use of country-specific nitrogen excretion rates for livestock categories would constitute a Tier 2 method. A Tier 2 method would require more detailed characterisation of the flow of nitrogen throughout the animal housing and manure management systems used in the country. It is good practice to check N balance in a Tier 2 approach. Double counting of emissions associated with the application of managed manure should be avoided, as well as manure associated with pasture and grazing operations, which should be calculated and reported under Chapter 11, Section 11.2 (N_2O emissions from managed soils). National NH_3 emission inventories developed by some countries could be used for Tier 2 estimation of NH_3 volatilisation from manure management systems. For countries reporting emissions of NH_3 and NOx to the UN-ECE Convention on Long-Range Transboundary Air Pollution (UN-ECE LRTAP) using a Tier 2 approach as described in the EEA (2016) emission inventory guidebook, it is good practice to report volatilization of NH3 and NOx in consistency to the data reported to the UN-ECE.

There are limited measurement data on leaching and runoff losses from various manure management systems. The greatest N losses due to runoff and leaching typically occur where animals are on a drylot, pens or in over-wintering areas. In drier climates, runoff losses are smaller than in high rainfall areas and have been estimated in the range from 3 to 6% of N excreted (Eghball and Power, 1994). Studies by Bierman *et al.* (1999) found nitrogen lost in runoff was 5 to 19% of N excreted and 10 to 16% leached into soil, while other data show relatively low loss of nitrogen through leaching in solid storage (less than 5% of N excreted); but greater loss could also occur (Rotz, 2004). Further research is needed in this area to improve the estimated losses and the conditions and practices under which such losses occur. Equation 10.34 should only be used where there is country-specific information on the fraction of nitrogen loss due to leaching and runoff from manure management systems available. Therefore, estimation of N losses from leaching and runoff from manure management should be considered part of a Tier 2 or Tier 3 method.

Nitrogen that leaches into soil and/or runs off during solid storage of manure at outdoor areas or in feedlots is derived as follows:

EQUATION10. 35

N LOSSES DUE TO LEACHING FROM MANURE MANAGEMENT SYSTEMS

$$N_{leaching-MMS} = \sum_S \left[\sum_T \left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)}\right) \bullet \left(\frac{Frac_{leachMS}}{100}\right)_{(T,S)} \right] \right]$$

Where:

$N_{leaching\text{-}MMS}$ = amount of manure nitrogen that leached from manure management systems, kg N yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$Frac_{leachMS}$ = percent of managed manure nitrogen losses for livestock category *T* due to runoff and leaching during solid and liquid storage of manure (typical range 1-20%)

The indirect N_2O emissions from leaching and runoff of nitrogen from manure management systems ($N_2O_{L(mm)}$) are estimated using Equation 10.35:

EQUATION10. 36

INDIRECT N_2O EMISSIONS DUE TO LEACHING FROM MANURE MANAGEMENT

$$N_2O_{L(mm)} = \left(N_{leaching-MMS} \bullet EF_5\right) \bullet \frac{44}{28}$$

Where:

$N_2O_{L(mm)}$ = indirect N_2O emissions due to leaching and runoff from Manure Management in the country, kg N_2O yr^{-1}

EF_5 = emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O-N/kg N leached and runoff (default value 0.0075 kg N_2O-N (kg N leaching/runoff)$^{-1}$, given in Chapter 11, Table 11.3

Tier 3

To reduce uncertainty of the estimates, a Tier 3 method could be developed with country-specific emission factors for volatilisation and nitrogen leaching and runoff based on actual measurements.

All losses of N through manure management systems (both direct and indirect) need to be subtracted from the amount of manure N that is available for application to soils and which is reported in Chapter 11, Section 11.2 *N_2O Emissions from Managed Soils*. Refer to Section 10.5.4, Coordination with reporting for N_2O emissions from managed soils, for guidance on calculating total N losses from manure management systems.

10.5.2 Choice of emission factors

This section is an update

Annual average nitrogen excretion rates, $Nex_{(T)}$

Tier 1

Annual nitrogen excretion rates should be determined for each livestock category defined by the livestock population characterization. Country-specific rates may either be taken directly from documents or reports such as agricultural industry and scientific literature, or derived from information on animal nitrogen intake and retention (as explained below). In some situations, it may be appropriate to use excretion rates developed by other countries that have livestock with similar characteristics.

If country-specific data cannot be collected or derived, or appropriate data are not available from another country, the IPCC default nitrogen excretion rates presented in Table 10.24 can be used. These rates are presented in units of nitrogen excreted per 1000 kg of animal per day. These rates can be applied to livestock sub-categories of varying ages and growth stages using a typical average animal mass (TAM) for that population sub-category, as shown in Equation 10.37.

EQUATION10. 37
ANNUAL N EXCRETION RATES

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where:

$Nex_{(T)}$ = annual N excretion for livestock category *T*, kg N animal^{-1} yr^{-1}

$N_{rate(T)}$ = default N excretion rate, kg N (1000 kg animal mass)$^{-1}$ day^{-1} (see Table 10.23)

$TAM_{(T)}$ = typical animal mass for livestock category *T*, kg animal^{-1}

Default TAM values are provided in Tables 10A-4 to 10A-19 in Annex 10A.2. However, it is preferable to collect country-specific TAM values due to the sensitivity of nitrogen excretion rates to different weight categories. For example, market swine may vary from nursery pigs weighing less than 30 kilograms to finished pigs that weigh over 90 kilograms. By constructing animal population groups that reflect the various growth stages of market pigs, countries will be better able to estimate the total nitrogen excreted by their swine population.

When estimating the $Nex_{(T)}$ for animals whose manure is classified in the manure management system *burned for fuel* (Table 10.25, Default emission factors for direct N_2O emissions from Manure Management), it should be kept in mind that the dung is burned and the urine stays in the field. As a rule of thumb, 50% of the nitrogen excreted is in the dung and 50% is in the urine. If the burned dung is used as fuel, then emissions are reported under the IPCC category *Fuel Combustion* (Volume 2: Energy), whereas if the dung is burned without energy recovery the emissions should be reported under the IPCC category *Waste Incineration* (Volume 5: Waste).

Tier 2

The annual amount of N excreted by each livestock species/category depends on the total annual N intake and total annual N retention of the animal. Therefore, N excretion rates can be derived from N intake and N retention data. Annual N intake (i.e., the amount of N consumed by the animal annually) depends on the annual amount of feed digested by the animal, and the protein content of that feed. Total feed intake depends on the production level of the animal (e.g., growth rate, milk production, draft power). Annual N retention (i.e., the fraction of N intake that is retained by the animal for the production of meat, milk, or wool) is a measure of the animal's efficiency of production of animal protein from feed protein. Nitrogen intake and retention data for specific livestock species/categories may be available from national statistics or from animal nutrition specialists. Nitrogen intake can also be calculated from data on feed and crude protein intake developed in Section 10.2. Default N retention values are provided in Table 10.25, Default values for the fraction of nitrogen in feed taken in by animals that is retained by the different animal species/categories. Rates of annual N excretion for each livestock species/category ($Nex_{(T)}$) are derived as follows:

EQUATION10. 38
ANNUAL N EXCRETION RATES (TIER 2)

$$Nex_{(T)} = N_{intake(T)} \bullet \left(1 - N_{retention(T)}\right)$$

Where:

$Nex_{(T)}$ = annual N excretion rates, kg N animal^{-1} yr^{-1}

$N_{intake(T)}$ = the annual N intake per head of animal of species/category *T* , kg N animal^{-1} yr^{-1}

$N_{retention(T)}$ = fraction of annual N intake that is retained by animal of species/category *T*, dimensionless

Example of Tier 2 method for estimating nitrogen excretion for cattle

Nitrogen excretion may be calculated based on the same dietary assumptions used in modelling enteric fermentation emissions (see Section 10.2). The amount of nitrogen excreted by cattle can be estimated as the difference between the total nitrogen taken in by the animal and the total nitrogen retained for growth and milk production. Equations 10.39 and 10.40 can be used to calculate the variables for nitrogen intake and nitrogen retained for use in Equation 10.38. The total nitrogen intake rate is derived as follows:

EQUATION10.39

N INTAKE RATES FOR CATTLE

$$N_{intake(T)} = \frac{GE}{18.45} \bullet \left(\frac{\frac{CP\%}{100}}{6.25} \right)$$

Where:

$N_{intake(T)}$ = daily N consumed per animal of category *T*, kg N animal^{-1} day^{-1}

GE = gross energy intake of the animal, in enteric model, based on digestible energy, milk production, pregnancy, current weight, mature weight, rate of weight gain, and IPCC constants, MJ animal^{-1} day^{-1}

18.45 = conversion factor for dietary GE per kg of dry matter, MJ kg^{-1}. This value is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock.

CP% = percent crude protein in diet, input

6.25 = conversion from kg of dietary protein to kg of dietary N, kg feed protein (kg N)$^{-1}$

Table 10. 2 3 Default values for nitrogen excretion rate [a] (kg N (1000 kg animal mass)$^{-1}$ day^{-1})

Format and inputs of table will be updated to be consistence with enetric and new literatures

Category of animal	Region													
	North America	Western Europe	Eastern Europe	Oceania	Latin America		Africa		Middle East		Asia		Indian Subcontinent	
					high productivity	Low productivity	High productivity	Low productivity	High productivity	Low productivity	High productivity	Low productivity	High productivity	Low productivity
Dairy Cattle	0.56	0.48	0.41	0.42	0.45	0.53	TBD	TBD	0.48	0.52	0.50	0.41	0.55	0.67
Mature cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Other Cattle (Non-dairy Cattle)	0.35	0.40	0.46	0.34	0.40	0.52	0.52	0.52	0.60	0.73	0.43	0.43	TBD	0.53
Mature cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Growing cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Feedlot Cattle	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Swine[b]	0.5	0.68	0.74	0.73	1.64	TBD	1.64	TBD	1.64	TBD	0.5	TBD	TBD	TBD
Market	0.42	0.51	0.55	0.53	1.57	TBD	1.57	TBD	1.57	TBD	0.42	TBD	TBD	TBD
Breeding	0.24	0.42	0.46	0.46	0.55	TBD	0.55	TBD	0.55	TBD	0.24	TBD	TBD	TBD
Poultry	0.83	0.83	0.82	0.82	0.82	TBD	0.82	TBD	0.82	TBD	0.82	TBD	TBD	TBD
Hens >/= 1 yr	0.83	0.96	0.82	0.82	0.82	TBD	0.82	TBD	0.82	TBD	0.82	TBD	TBD	TBD
Pullets	0.62	0.55	0.6	0.6	0.6	TBD	0.6	TBD	0.6	TBD	0.6	TBD	TBD	TBD
Other Chickens	0.83	0.83	0.82	0.82	0.82	TBD	0.82	TBD	0.82	TBD	0.82	TBD	TBD	TBD
Broilers	1.1	1.1	1.1	1.1	1.1	TBD	1.1	TBD	1.1	TBD	1.1	TBD	TBD	TBD
Turkeys	0.74	0.74	0.74	0.74	0.74	TBD	0.74	TBD	0.74	TBD	0.74	TBD	TBD	TBD
Ducks	0.83	0.83	0.83	0.83	0.83	TBD	0.83	TBD	0.83	TBD	0.83	TBD	TBD	TBD
Sheep	0.42	0.85	0.9	1.13	1.17	TBD	1.17	TBD	1.17	TBD	1.17	TBD	TBD	TBD
Goats	0.45	1.28	1.28	1.42	1.37	TBD	1.37	TBD	1.37	TBD	1.37	TBD	TBD	TBD
Horses (and mules, asses)	0.3	0.26	0.3	0.3	0.46	TBD	TBD	TBD	0.46	TBD	0.46	TBD	TBD	TBD
Camels[c]	0.38	0.38	0.38	0.38	0.46	TBD	0.46	TBD	0.46	TBD	0.46	TBD	TBD	TBD
Dairy Buffalo	NA	[0.39]	[0.41]	NA	0.43	TBD	[0.44]	TBD	[0.54]	TBD	TBD	TBD	[0.45]	TBD
Non-dairy Buffalo	NA	[0.51]	[0.39]	NA	0.57	TBD	[0.42]	TBD	[0.69]	TBD	TBD	TBD	[0.56]	TBD

Mink and Polecat (kg N head^{-1} yr^{-1})[d]	4.59	4.59	4.59	4.59	4.59	TBD	4.59	TBD	4.59	TBD	4.59	TBD	TBD	TBD
Rabbits (kg N head^{-1} yr^{-1})	8.1	8.1	8.1	8.1	8.1	TBD	8.1	TBD	8.1	TBD	8.1	TBD	TBD	TBD
Fox and Racoon (kg N head^{-1} yr^{-1})[d]	12.09	12.09	12.09	12.09	12.09	TBD	12.09	TBD	12.09	TBD	12.09	TBD	TBD	TBD

The uncertainty in these estimates is ±50%.

[a] Summarized from *1996 IPCC Guidelines*, 1997; European Environmental Agency, 2002; USA EPA National NH_3 Inventory Draft Report, 2004; and data of GHG inventories of Annex I Parties submitted to the Secretariat UNFCCC in 2004.

[b] Nitrogen excretion for swine are based on an estimated country population of 90% market swine and 10% breeding swine.

[c] Modified from European Environmental Agency, 2002.

[d] Data of Hutchings *et al.*, 2001.

TBD: to be determined.

Table 10. 2 4 Default values for the fraction of nitrogen in feed intake of livestock that is retained by the different livestock species/categories (fraction N-intake retained by the animal)

Format and inputs of table will be updated to be consistent with enteric and new literatures

Category of animal	Region													
	North America	Western Europe	Eastern Europe	Oceania	Latin America		Africa		Middle East		Asia		Indian Subcontinent	
					high productivity	Low productivity	High productivity	Low productivity	High productivity	Low productivity	High productivity	Low productivity	High productivity	Low productivity
Dairy Cattle	0.30	0.24	0.18	0.31	0.26	0.09	TBD	TBD	0.17	0.14	0.29	0.26	0.17	0.07
Other Cattle (Non-dairy Cattle)	0.22	0.05	0.08	0.12	0.10	0.07	0.04	0.04	0.09	0.07	0.03	0.03	TBD	0.04
Dairy Buffalo	NA	[0.08]	[0.10]	NA	TBD	TBD	[0.06]	TBD	[0.09]	TBD	TBD	TBD	[0.12]	TBD
Non-dairy Buffalo	NA	[0.09]	[0.11]	NA	TBD	TBD	[0.09]	TBD	[0.06]	TBD	TBD	TBD	[0.08]	TBD
Sheep	0.1				0.1	TBD	0.1	TBD	0.1	TBD	0.1	TBD	0.1	TBD
Goats	0.1				0.1	TBD	0.1	TBD	0.1	TBD	0.1	TBD	0.1	TBD
Camels	0.07				0.07	TBD	0.07	TBD	0.07	TBD	0.07	TBD	0.07	TBD
Swine	0.3				0.3	TBD	0.3	TBD	0.3	TBD	0.3	TBD	0.3	TBD
Horse	0.07				0.07	TBD	0.07	TBD	0.07	TBD	0.07	TBD	0.07	TBD
Poultry	0.3				0.3	TBD	0.3	TBD	0.3	TBD	0.3	TBD	0.3	TBD

The uncertainty in these estimates is ±50%.

Source: Judgement of IPCC Expert Group (see Co-chairs, Editors and Experts; N_2O emissions from Manure Management).

TBD: to be determined.

The total nitrogen retained is derived as follows:

EQUATION10. 40
N RETAINED RATES FOR CATTLE

$$N_{retention(T)} = \left[\frac{Milk \bullet \left(\frac{Milk\ PR\%}{100} \right)}{6.38} \right] + \left[\frac{WG \bullet \frac{\left[268 - \left(\frac{7.03 \bullet NE_g}{WG} \right) \right]}{1000}}{6.25} \right]$$

Where:

$N_{retention(T)}$ = daily N retained per animal of category *T*, kg N animal^{-1} day^{-1}

Milk = milk production, kg animal^{-1} day^{-1} (applicable to dairy cows only)

Milk PR% = percent of protein in milk, calculated as [1.9 + 0.4 ● %Fat], where %Fat is an input, assumed to be 4% (applicable to dairy cows only)

6.38 = conversion from milk protein to milk N, kg Protein (kg N)$^{-1}$

WG = weight gain, input for each livestock category, kg day^{-1}

268 and 7.03 = constants from Equation 3-8 in NRC (1996)

1000 = conversion from g protein to kg protein

NEg = net energy for growth, calculated in livestock characterisation, based on current weight, mature weight, rate of weight gain, and IPCC constants, MJ day^{-1}

6.25 = conversion from kg dietary protein to kg dietary N, kg Protein (kg N)$^{-1}$

Annual nitrogen excretion data are also used for the calculation of direct and indirect N_2O emissions from managed soils (see Chapter 11, Section 11.2, N_2O emissions from managed soils). The same rates of N excretion, and methods of derivation, that are used to estimate N_2O emissions from Manure Management should be used to estimate N_2O emissions from managed soils.

To be added: N-retention equation for swine and poultry

Emission factors for direct N_2O emissions from Manure Management

The best estimate will be obtained using country-specific emission factors that have been fully documented in peer reviewed publications. It is *good practice* to use country-specific emission factors that reflect the actual duration of storage and type of treatment of animal manure in each management system that is used. *Good practice* in the derivation of country-specific emission factors involves the measurement of emissions (per unit of manure N) from different management systems, taking into account variability in duration of storage and types of treatment. When defining types of treatment, conditions such as aeration and temperature should be taken into account. If inventory agencies use country-specific emission factors, they are encouraged to provide justification for these values via peer-reviewed documentation.

If appropriate country-specific emission factors are unavailable, inventory agencies are encouraged to use the default emission factors presented in Table 10.25, Default emission factors for direct N_2O emissions from Manure Management. This table contains default emission factors by manure management system. Note that emissions from liquid/slurry systems without a natural crust cover, anaerobic lagoons, and anaerobic digesters are considered negligible based on the absence of oxidized forms of nitrogen entering these systems combined with the low potential for nitrification and denitrification to occur in the system.

Emission factors for indirect N_2O emissions from Manure Management

In order to estimate indirect N_2O emissions from Manure Management, two fractions of nitrogen losses (due to volatilization, FracGasMS, and leaching/runoff, FracLeachMS), and two indirect N_2O emissions factors associated with these losses (EF_4 and EF_5) are needed. Default values for volatilization N losses are presented in the Table 10.26 for single manure systems. Values represent the sum of the loss rates for N in the forms of NH_3 and NO_x, with most of the loss in the form of NH_3. Ranges reflect values that appear in the literature. The values represent conditions without any significant nitrogen control measures in place. Countries are encouraged to develop country-specific values, particularly related to ammonia losses where component emissions may be well characterized as part of larger air quality assessments and where emissions may be affected by nitrogen reduction strategies. For example, detailed methodologies for estimating NH_3 and other nitrogen losses using mass balance/mass flow procedures are described in the EMEP/CORINAIR air pollutant emission inventory guidebook, Chapter 3B (current version: European Environmental Agency, 2016).

The fraction of manure nitrogen that leaches from manure management systems ($Frac_{leachMS}$) is highly uncertain and should be developed as a country-specific value applied in Tier 2 method. A Tier 2 method is also required if manure is managed in multiple systems. For example, manure flushed from a dairy freestall barn to an anaerobic lagoon may first pass through a solids separation unit where some of the manure nitrogen is removed and managed as a solid. Therefore, if manure is managed in multiple system, emissions from all systems must be considered. For example, values provided for dairy anaerobic lagoon systems should include nitrogen losses that occur in the dairy barn and milking parlour prior to the collection and treatment of manure, as well as those that occur from the lagoon, if these systems are associated also with all or a share of the manure managed in dairy anaerobic lagoon systems.

Default values for EF_4 (N volatilisation and re-deposition) and EF_5 (N leaching/runoff) are given in Chapter 11, Table 11.3 (Default emission, volatilisation and leaching factors for indirect soil N_2O emissions).

To be updated

Table 10. 2 5 Default emission factors for direct N_2O emissions from manure management

System	Definition	EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
Pasture/Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as is, and is not managed.	Direct and indirect N_2O emissions associated with the manure deposited on agricultural soils and pasture, range, paddock systems are treated in Chapter 11, Section 11.2, N_2O emissions from managed soils.		
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion. N_2O emissions during storage and treatment are assumed to be zero. N_2O emissions from land application are covered under the Agricultural Soils category.	0	Not applicable	Judgement by IPCC Expert Group (see Co-chairs, Editors and Experts; N_2O emissions from Manure Management).
Solid storage[b]	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.	0.010	Factor of 2	Expert judgement based on Pardo et al 2015. Median of N2O emissions from farm-scale collected studies.
Solid storage-Covered/compacted	Similar to solid storage, but the manure pile is a) covered with a plastic sheet to reduce the surface of manure exposed to air and/or b) compacted to increase the density and reduce the free air space within the material.	0.01	Factor of 2	Expert judgement based on Pardo et al 2015. Emissions in the same range than solid storage
Solid storage - Bulking agent addition	Specific materials (bulking agents) are mixed with the manure to provide structural support. This allows the natural aeration of the pile, thus enhancing decomposition. (e.g. sawdust, straw, coffee husks, maize stover)	0.005	Factor of 2	Expert judgement based on Pardo et al 2015. Estimated reduction of 50% N2O emissions due to bulking agent addition
Solid storage - Additives	The addition of specific substances to the pile in order to reduce gaseous	0.005	Factor of 2	Expert judgement based on Pardo et al 2015. Estimated reduction of

Table 10. 2 5 Default emission factors for direct N_2O emissions from manure management

System	Definition		EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
	emissions. Addition of certain compounds such as attapulgite, dicyandiamide or mature compost have shown to reduce N2O emissions; while phosphogypsum reduce CH4 emissions				50% N2O emissions due to additives
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically. Dry lots are most typically found in dry climates but also are used in humid climates.		0.02	Factor of 2	Judgement of IPCC Expert Group in combination with Kulling (2003).
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water to facilitate handling and is stored in either tanks or earthen ponds.	With natural crust cover	0.005	Factor of 2	Judgement of IPCC Expert Group in combination with Sommer *et al.* (2000).
		Without natural crust cover	0	Not applicable	Judgement of IPCC Expert Group in combination with the following studies: Harper *et al.* (2000), Lague *et al.* (2004), Monteny *et al.* (2001), and Wagner-Riddle and Marinier (2003). Emissions are believed negligible based on the absence of oxidized forms of nitrogen entering systems in combination with low potential for nitrification and denitrification in the system.
Liquid/Slurry	cover				
Uncovered anaerobic lagoon	Anaerobic lagoons are designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.		0	Not applicable	Judgement of IPCC Expert Group in combination with the following studies: Harper *et al.* (2000), Lague *et al.* (2004), Monteny *et al.* (2001), and Wagner-Riddle and Marinier (2003). Emissions are believed negligible based on the absence of oxidized forms of nitrogen entering systems in combination with low potential for nitrification and denitrification in the system.
Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility.		0.002	Factor of 2	Judgement of IPCC Expert Group in combination with the following studies: Amon *et al.* (2001), Kulling (2003), and Sneath *et al.* (1997).
Anaerobic digester	Anaerobic digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CH_4 and CO_2, which is captured and flared or used as a fuel.		0.0006	Not applicable	The emission mainly from storage of digestate storage. Judgement of IPCC Expert Group in combination with the following studies: (Wang *et al.* 2016)Wang et al., (2016);Rodhe et al. 2015;Wang et al., (2014a);Wang et al., (2014b);Li, (2016);Amon et al., (2006);Moitzi et al.,(2007);Clemencles et al., (2006).

Table 10. 2 5 Default emission factors for direct N_2O emissions from manure management

System	Definition		EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
Burned for fuel or as waste	The dung is excreted on fields. The sun dried dung cakes are burned for fuel.		The emissions associated with the burning of the dung are to be reported under the IPCC category 'Fuel Combustion' if the dung is used as fuel and under the IPCC category 'Waste Incineration' if the dung is burned without energy recovery.		
	Urine N deposited on pasture and paddock		Direct and indirect N_2O emissions associated with the urine deposited on agricultural soils and pasture, range, paddock systems are treated in Chapter 11, Section 11.2, N_2O emissions from managed soils.		
Cattle and swine deep bedding	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture.	No mixing	0.01	Factor of 2	Average value based on Sommer and Moller (2000), Sommer (2000), Amon *et al.* (1998), and Nicks *et al.* (2003).
		Active mixing	0.07	Factor of 2	Average value based on Nicks *et al.* (2003) and Moller *et al.* (2000). Some literature cites higher values to 20% for well maintained, active mixing, but those systems included treatment for ammonia which is not typical.
Composting - In-Vessel[c]	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.		0.006	Factor of 2	Judgement of IPCC Expert Group. Expected to be similar to static piles.
Composting - Static Pile[c] (Forced aeration)	Composting in piles with forced aeration but no mixing.		0.010	Factor of 2	Expert judgement based on Pardo et al 2015. Emissions in the same range than solid storage
Composting - Intensive Windrow[c] (Frequent turning)	Composting in windrows with regular turning for mixing and aeration.		0.005	Factor of 2	Assuming similar range to passive windrow.
Composting- Passive windrow (infrequent turning)	Composting in windrows with infrequent turning for mixing and aeration.		0.005	Factor of 2	Expert judgement based on Pardo et al 2015. Median of N2O emissions from farm-scale collected studies and estimated reduction of 50% due to bulking agent addition
Poultry manure with litter	Similar to deep bedding systems. Typically used for all poultry breeder flocks and for the production of meat type chickens (broilers) and other fowl.		0.001	Factor of 2	Judgement of IPCC Expert Group based on the high loss of ammonia from these systems, which limits the availability of nitrogen for nitrification/denitrification.
Poultry manure without litter	May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as a high-rise manure management system and is a form of passive windrow composting when designed and operated properly.		0.001	Factor of 2	Judgement of IPCC Expert Group based on the high loss of ammonia from these systems, which limits the availability of nitrogen for nitrification/denitrification.

Table 10. 2 5 Default emission factors for direct N_2O emissions from manure management

System	Definition		EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
Aerobic treatment	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.	Natural aeration systems	0.01	Factor of 2	Judgement of IPCC Expert Group. Nitrification-denitrification is used widely for the removal of nitrogen in the biological treatment of municipal and industrial wastewaters with negligible N_2O emissions. Limited oxidation may increase emissions compared to forced aeration systems.
		Forced aeration systems	0.005	Factor of 2	Judgement of IPCC Expert Group. Nitrification-denitrification is used widely for the removal of nitrogen in the biological treatment of municipal and industrial wastewaters with negligible N_2O emissions.

[a]Also see Dustan (2002), which compiled information from some of the original references cited.

[b] Quantitative data should be used to distinguish whether the system is judged to be a solid storage or liquid/slurry. The borderline between dry and liquid can be drawn at 20% dry matter content.

[c] Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

10.5.3 Choice of activity data

No refinement in this section

we may want to consider that the "activity data" section could be the proper place to account for additional N input via co-digestates?

10.5.4 Coordination with reporting for N_2O emissions from managed soils

This section is an update

Following storage or treatment in any system of manure management, nearly all the manure will be applied to land. The emissions that subsequently arise from the application of the manure to soil are to be reported under the category *N_2O emissions from managed soils*. The methods for estimating these emissions are discussed in Chapter 11, Section 11.2. In estimating N_2O emissions from managed soils, the amount of animal manure nitrogen that is directly applied to soils, or available for use in feed, fuel, or construction purposes, are considered.

A significant proportion of the total nitrogen excreted by animals in managed systems (i.e., all livestock except those in pasture and grazing conditions) is lost prior to final application to managed soils or use as feed, fuel, or for construction purposes. In order to estimate the amount of animal manure nitrogen that is directly applied to soils, or available for use in feed, fuel, or construction purposes (i.e., the value which is used in Chapter 11, Equation 11.1 or 11.2), it is necessary to reduce the total amount of nitrogen excreted by animals in managed systems by the losses of N through volatilisation of reactive nitrogen gases (i.e., NH_3 and NO_x) or through leaching and runoff (both leading to indirect emissions of N2O), direct conversion to N_2O, or losses as inert molecular nitrogen (N2).

Volatilization of NH3 and other forms of gaseous N arise from the mineral fraction of nitrogen in manure, called 'Total Ammoniacal Nitrogen' (TAN). Organic nitrogen (Norg) in manure needs first to be converted to TAN before NH_3 volatilization can happen. The EMEP/EEA air pollutant emission inventory Guidebook 2016 (EEA, 2016, Chapter 3B) therefore distinguishes the flow of TAN and Norg and the transitions between the two forms in agricultural systems. The values for the volatilization fraction FracGASMS listed in Table 10.26 attempt to account for typical TAN contents in manure for the MMS considered. However, different excretion ratios of TAN vs. total N as a consequence of changes in livestock diets are not reflected. Also, information on the TAN content in manure available for application, N_{MMS_Avb}, is not kept if using Equation 10.34. Farming practices that reduce the escape of NH_3 from MMS but not the amount of TAN available are likely to lead to higher NH_3 volatilization rates once the manure is applied to soils or used for feed, fuel, or for construction purposes.

Where organic forms of bedding material (straw, sawdust, chippings, etc.) are used, the additional nitrogen from the bedding material should also be considered as part of the managed manure N applied to soils. The same applies to additional N input from co-digestates during anaerobic digestion. Bedding is typically collected with the remaining manure and applied to soils. It should be noted, however, that since mineralization of nitrogen compounds in beddings occurs more slowly compared to manure and the concentration of ammonia fraction in organic beddings is negligible, both volatilization and leaching losses during storage of bedding are assumed to be zero (European Environmental Agency, 2002).

The estimate of managed manure nitrogen available for application to managed soils, or available for use in feed, fuel, or construction purposes is based on the following equation:

EQUATION10. 41

MANAGED MANURE N AVAILABLE FOR APPLICATION TO MANAGED SOILS, FEED, FUEL OR CONSTRUCTION USES

$$N_{MMS\_Avb} = \sum_{S}\left\{\sum_{(T)}\left[\begin{array}{l}\left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)}\right) \bullet \left(1 - \dfrac{Frac_{GASMS} + Frac_{LEACHMS} + Frac_{N2MS}}{100}\right)\right] + \\ \left[N_{(T)} \bullet MS_{(T,S)} \bullet N_{beddingMS}\right]\end{array}\right]\right\}$$

$$+ N_{codigestates}$$

Where:

N_{MMS_Avb} = amount of managed manure nitrogen available for application to managed soils or for feed, fuel, or construction purposes, kg N yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

$Nex_{(T)}$ = annual average N excretion per animal of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$Frac_{GASMS}$ = amount of managed manure nitrogen for livestock category *T* that is lost in the manure management system *S*, % as NH_3 or NO_X (see Table 10.26)

$Frac_{LEACHSMS}$ = amount of managed manure nitrogen for livestock category *T* that is lost in the manure management system *S*, % by leaching or run-off (if available from Tier 2 calculation).

$Frac_{N2MS}$ = amount of managed manure nitrogen for livestock category *T* that is lost in the manure management system *S*, % as N_2 (see Table 10.27)

$N_{beddingMS}$ = amount of nitrogen from bedding (to be applied for solid storage and deep bedding MMS if known organic bedding usage), kg N $animal^{-1}$ yr^{-1}

$N_{codigestates}$ = amount of nitrogen from co-digestates added to biogas plants

S = manure management system

T = species/category of livestock

Bedding materials vary greatly and inventory compilers should develop values for $N_{beddingMS}$ based on the characteristics of bedding material used in their livestock industries. Limited data from scientific literature indicates the amount of nitrogen contained in organic bedding material applied for dairy cows and heifers is usually around 7 kg N $animal^{-1}$ yr^{-1}, for other cattle is 4 kg N $animal^{-1}$ yr^{-1}, for market and breeding swine is around 0.8

and 5.5 kg N $animal^{-1}$ yr^{-1}, respectively. For deep bedding systems, the amount of N in litter is approximately double these amounts (Webb, 2001; Döhler *et al.*, 2002).

Nitrogen content of co-digestates should be estimated in accordance with the values used in the sections “Energy” and “Waste”.

Table 10.26 presents default values for nitrogen loss due to volatilisation of NH_3 and NO_x from manure management.

Table 10.27 presents default values for total losses of N_2 from manure management systems. These default values include losses that occur from the point of excretion, including animal housing losses, manure storage losses, and losses from leaching and runoff at the manure storage system where applicable.

Countries may wish to develop an alternative approach for better consideration of national circumstances and to reduce the uncertainty of estimates as much as possible. This approach would entail more detailed characterisation of the flow of nitrogen through the components of the animal housing and manure management systems used in the country, accounting for any mitigation activity (e.g., the use of covers over slurry tanks), and consideration of local practices, such as type of bedding material used. For Tier 2 or Tier 3 approaches it is good practice to account for the TAN fraction in total manure N along the different stages of manure management, storage, and application. Additional details are available in the EMEP/EEA air pollutant emission inventory Guidebook 2016 (EEA, 2016, Chapter 3B-3.4 and Annex A1.4).

TABLE 10. 2 6
DEFAULT VALUES FOR NITROGEN LOSS DUE TO VOLATILISATION OF NH_3 AND NO_X FROM MANURE MANAGEMENT
To be updated, and request Expert review to provided data for leaching

System	Applicable System Variation	Swine		Dairy Cow		Poultry		Other Cattle		Other c	
		N loss due to volatilisation of NH3	N leaching	N loss due to volatilisation of NH3	N leaching	N loss due to volatilisation of NH3	N leaching	N loss due to volatilisation of NH3	N leaching	N loss due to volatilisation of NH3	N leaching
Daily spread		TBD	TBD	7% (5 – 60)	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Solid storage		45% (10 – 65) EMEP: 45% for finishing;	2%	30% (10 – 40) EMEP: 16%	2%	TBD	TBD	45% (10 – 65) EMEP: 17%	TBD	12% (5 – 20)	TBD
Solid storage-Covered/compacted		8.4%	2%	4.6%	2 %	8.2%	2%	6.15%	2%	TBD	TBD
Solid storage - Bulking agent addition		22.2 %	TBD	12.2%	TBD	21.7%	TBD	16.3%	TBD	TBD	TBD
Solid storage - Additives		6.8%	TBD	3.8 %	TBD	6.7%	TBD	5 %	TBD	TBD	TBD
Dry lot		TBD	TBD	20% (10 – 35)	TBD	TBD	TBD	30% (20 – 50)	TBD	TBD	TBD
Liquid/Slurry	With natural crust cover	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Liquid/Slurry Uncovered anaerobic lagoon	Without natural crust cover	48% (15 – 60) EMEP: 33% for finishing	TBD	48% (15 – 60) EMEP: 18%	TBD	TBD	TBD	EMEP: 15%	TBD	TBD	TBD
	With cover	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
		40% (25 – 75)	TBD	35% (20 – 80)	TBD	40% (25 – 75)	TBD	TBD	TBD	TBD	TBD
Pit storage below animal confinements		25% (15 – 30)	TBD	28% (10 – 40)	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Anaerobic digester		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Burned for fuel or as waste		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Cattle and swine deep bedding		40% (10 – 60)	TBD	TBD	TBD	TBD	TBD	30% (20 – 40)	TBD	25% (10 – 30)	TBD
Composting - In-Vessel[c]		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Composting - Static Pile[c]		28.9 %	6%	15.9 %	6 %	28.2 %	6%	21.1 %	6%	TBD	TBD
Composting - Intensive Windrow[c]		TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Composting - Passive Windrow[c]		25.7 %	4%	14.1 %	4 %	25.1 %	4%	18.8 %	4%	TBD	TBD
Poultry manure with litter		TBD	TBD	TBD	TBD	40% (10 – 60) EMEP: 41% for layers	TBD	TBD	TBD	TBD	TBD

Poultry manure without litter		TBD	TBD	TBD	TBD	48% (15 – 60) EMEP: 41% for layers	TBD	TBD	TBD	TBD	TBD
Aerobic treatment	Natural aeration systems	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	Forced aeration systems	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

To be updated

Table 10. 2 7 Default values for molecular nitrogen (N_2) loss from manure management

Manure management system	N_2 losses from MMS $Frac_{N2MS}$ (Range of $Frac_{N2MS}$)	Reference
Liquid systems	0.3% x TAN fraction	a
- Cattle, horses, mules and asses, and other animals	0.18%	b
- Swine and poultry	0.21%	b
- buffalo and goats	0.15%	b
Solid systems	30%x TAN fraction	a
- Cattle, horses, mules and asses, and other animals	18%	b
- Swine and poultry	21%	b
- buffalo and goats	15%	b

[a] N2 loss rates as proportion from Total Ammoniacal Nirogen (TAN) from EMEP/EEA air pollutant emission inventory Guidebook 2016 (EEA, 2016, Chapter 3B, Table 3.10), based on Misselbrook et al., 2015.

[b] Typical TAN fractions are given in the EMEP/EEA air pollutant emission inventory Guidebook 2016 (EEA, 2016, Chapter 3B, Table 3.9) as follows: Cattle, horses, mules and asses, and other animals 0.6; Swine and poultry 0.7; buffalo and goats: 0.5.

10.5.5 Uncertainty assessment

No refinement in this section

10.5.6 Completeness, Time series, Quality assurance/Quality control and Reporting

This section doesn't contain a refinement.

It does contain new guidance in a new subsection Consistency of nitrogen flows

A complete inventory should estimate N_2O emissions from all systems of manure management for all livestock species/categories. Additional N input from organic residues and/or energy crops used for co-digestion in biogas plants must also be considered. Countries are encouraged to use manure management system definitions that are consistent with those presented in Table 10.22. Population data should be cross-checked between main reporting mechanisms (such as FAO and national agricultural statistics databases) to ensure that information used in the inventory is complete and consistent. Because of the widespread availability of the FAO database of livestock information, most countries should be able to prepare, at a minimum, Tier 1 estimates for the major livestock categories. For more information regarding the completeness of livestock characterisation, see Section 10.2.

Developing a consistent time series of emission estimates for this source category requires, at a minimum, the collection of an internally consistent time series of livestock population statistics. General guidance on the development of a consistent time series is addressed in Volume 1, Chapter 5 of this report. In most countries, the other two activity data sets required for this source category (i.e., N excretion rates and manure management system usage data), as well as the manure management emission factors, will be kept constant for the entire time series. However, in some cases, there may be reasons to modify these values over time. For example, farmers may alter livestock feeding practices which could affect nitrogen excretion rates. A particular system of manure management may change due to operational practices or new technologies such that a revised emission factor is warranted. These changes in practices may be due to the implementation of explicit greenhouse gas mitigation measures, or may be due to changing agricultural practices without regard to greenhouse gases. Regardless of the driver of change, the parameters and emission factors used to estimate emissions must reflect the change. The inventory text should thoroughly explain how the change in farm practices or implementation of mitigation measures has affected the time series of activity data or emission factors.

It is *good practice* to implement general quality control checks as outlined in Volume 1, Chapter 6, Quality Assurance/Quality Control and Verification, and expert review of the emission estimates. Additional quality control checks and quality assurance procedures may also be applicable, particularly if higher tier methods are used to determine emissions from this source. The general QA/QC related to data processing, handling, and reporting should be supplemented with procedures discussed below:

Activity data check

- The inventory agency should review livestock data collection methods, in particular checking that livestock subspecies data were collected and aggregated correctly with consideration for the duration of production cycles. The data should be cross-checked with previous years to ensure the data are reasonable and consistent with the expected trend. Inventory agencies should document data collection methods, identify potential areas of bias, and evaluate the representativeness of the data.
- Manure management system allocation should be reviewed on a regular basis to determine if changes in the livestock industry are being captured. Conversion from one type of management system to another, and technical modifications to system configuration and performance, should be captured in the system modelling for the affected livestock.
- National agricultural policy and regulations may have an effect on parameters that are used to calculate manure emissions, and should be reviewed regularly to determine what impact they may have. For example, guidelines to reduce manure runoff into water bodies may cause a change in management practices, and thus affect the N distribution for a particular livestock category. Consistency should be maintained between the inventory and ongoing changes in agricultural practices.
- If using country-specific data for $Nex_{(T)}$ and $MS_{(T,S)}$, the inventory agency should compare these values to the IPCC default values. Significant differences, data sources, and methods of data derivation, should be documented.
- The nitrogen excretion rates, whether default or country-specific values, should be consistent with feed intake data as determined through animal nutrition analyses.

Review of emission factors

- The inventory agency should evaluate how well the implied N_2O emission factors and nitrogen excretion rates compare with alternative national data sources and with data from other countries with similar livestock practices. Significant differences should be investigated.
- If using country-specific emission factors, the inventory agency should compare them to the default factors and note differences. The development of country-specific emission factors should be explained and documented, and the results peer-reviewed by independent experts.
- Whenever possible, available measurement data, even if they represent only a small sample of systems, should be reviewed relative to assumptions for N_2O emission estimates. Representative measurement data may provide insights into how well current assumptions predict N_2O production from manure management systems in the inventory area, and how certain factors (e.g., feed intake, system configuration, retention time) are affecting emissions. Because of the relatively small amount of measurement data available for these systems worldwide, any new results can improve the understanding of these emissions and possibly their prediction.

External review

- The inventory agency should utilise experts in manure management and animal nutrition to conduct expert peer review of the methods and data used. While these experts may not be familiar with greenhouse gas emissions, their knowledge of key input parameters to the emission calculation can aid in the overall verification of the emissions. For example, animal nutritionists can evaluate N production rates to see if they are consistent with feed utilization research for certain livestock species. Practicing farmers can provide insights into actual manure management techniques, such as storage times and mixed-system usage. Wherever possible, these experts should be completely independent of the inventory process in order to allow a true external review.

It is *good practice* to document and archive all information required to produce the national emissions inventory estimates as outlined in Volume 1, Chapter 6, Quality Assurance/Quality Control and Verification. When country-specific emission factors, fractions of N losses, N excretion rates, or manure management system usage data have been used, the derivation of or references for these data should be clearly documented and reported along with the inventory results under the appropriate IPCC source category.

N_2O emissions from different types of manure management systems have to be reported according to categories in Table 10.22. N_2O emissions from all types of manure management systems are to be reported under Manure Management, with two exceptions:

- Emissions from the manure management system for *pasture, range, and paddock* are to be reported under the IPCC source category *N_2O emissions from managed soils* because this manure is deposited directly on soils by the livestock.

- Emission from the manure management system *burned for fuel*, are to be reported under the IPCC category *Fuel Combustion* if the dung is used as fuel and under the IPCC category *Waste Incineration* if the dung is burned without energy recovery. It should be noted, however, if the urine nitrogen is not collected for burning it must be reported under N_2O emissions from *pasture, range, and paddock* animals.

New sub-section:

Consistency of nitrogen flows

As discussed in Section 10.5.4, most of the manure excreted by livestock is finally applied to land or deposited to land by grazing animals, causing direct and indirect N_2O emissions from managed soils. On its way from the animal to uptake by crops or the release of N_2O, losses of nitrogen happen at all stages and in different forms. With anaerobic digestion, additional N might enter the system through co-digestates (e.g. organic residues, energy crops). The equations given in Chapters 10 and 11 follow a nitrogen balance approach, but are not capturing all effects on direct and indirect N_2O emissions that might occur as a consequence of 'upstream' changes of nitrogen flow, such as manure covers, changes in animal feeding, or nitrogen application technique, some of which are discussed in Section 10.5.4.

The inventory agency should consult with experts to make sure that any potential effects on N_2O emissions are reflected in the total N_2O emission estimates. Annex 10.A3 lists a set of equations derived from relevant equations in Chapter 10 and 11, allowing the calculation of all direct and indirect N_2O emissions per livestock species/category. These equations can help identifying emissions that might become inaccurate when national methodologies for upstream flows are used. For example, equation 10.40 shows that direct N_2O emissions from soils depend on the amount of manure N available for application, so any application technique that reduces or increase losses of NH_3 and increase or decreases the availability of N that can be transformed to N_2O must be carefully evaluated. Possibly, a correction factor needs to be introduced that is consistent with the national method for NH_3 emissions.

It is also important to consider total N2O emissions (see Equation 10.35) when making a key source assessment.

An illustration of N flows through animal and crop production systems is given in Figure 10.5

According to Equations 11.1, 11.10 and 11.11, direct and indirect emissions of N_2O from managed soils are calculated in the Tier 1 approach on the basis of total N from animal manure applied to soils. The processes of run-off of N, volatilization of NH_3 and NOx, emissions of N_2O, and leaching of N, however, do not occur simultaneously but in a sequence, with the peak of run-off and NH_3+NOx volatilization happening before emissions of N2O and losses of N through leaching. For example, an application technique affecting the volatilization rate of NH3+NOx for example is likely to change the flow rates of subsequent processes. Injecting slurry instead of broadcasting increases the availability of N for N_2O emissions and N-leaching.

It is therefore good practice to carefully assess such 'pollution swapping' effects when implementing higher Tier approaches and adopt the N-flow principle when estimating direct N_2O emissions and indirect N_2O emissions from leaching and runoff. A simple way to account for higher N availability for NH_3 mitigation technologies could be the use of a 'correction factor' $Corr_{practice}$ for the direct N_2O emission factor EF1 and the leaching fraction $Frac_{GASM}$, as given in Equation 10.42.

EQUATION10. 42

CORRECTION FACTOR TO ESTIMATE DIRECT N_2O EMISSIONS AND INDIRECT N_2O EMISSIONS VIA LEACHING AND RUN-OFF FOR SITUATIONS WHERE AMMONIA EMISSIONS FROM MANAGED SOILS HAVE BEEN REDUCED AS A CONSEQUENCE OF MITIGATION TECHNOLOGIES

$$Corr_{practice} = \frac{1 - Frac^{*}_{GASM}}{1 - Frac_{GASM}}$$

$$EF^{*}_{1} = Corr_{practice} \cdot EF_{1}$$

$$Frac^{*}_{GASM} = Corr_{practice} \cdot Frac_{GASM}$$

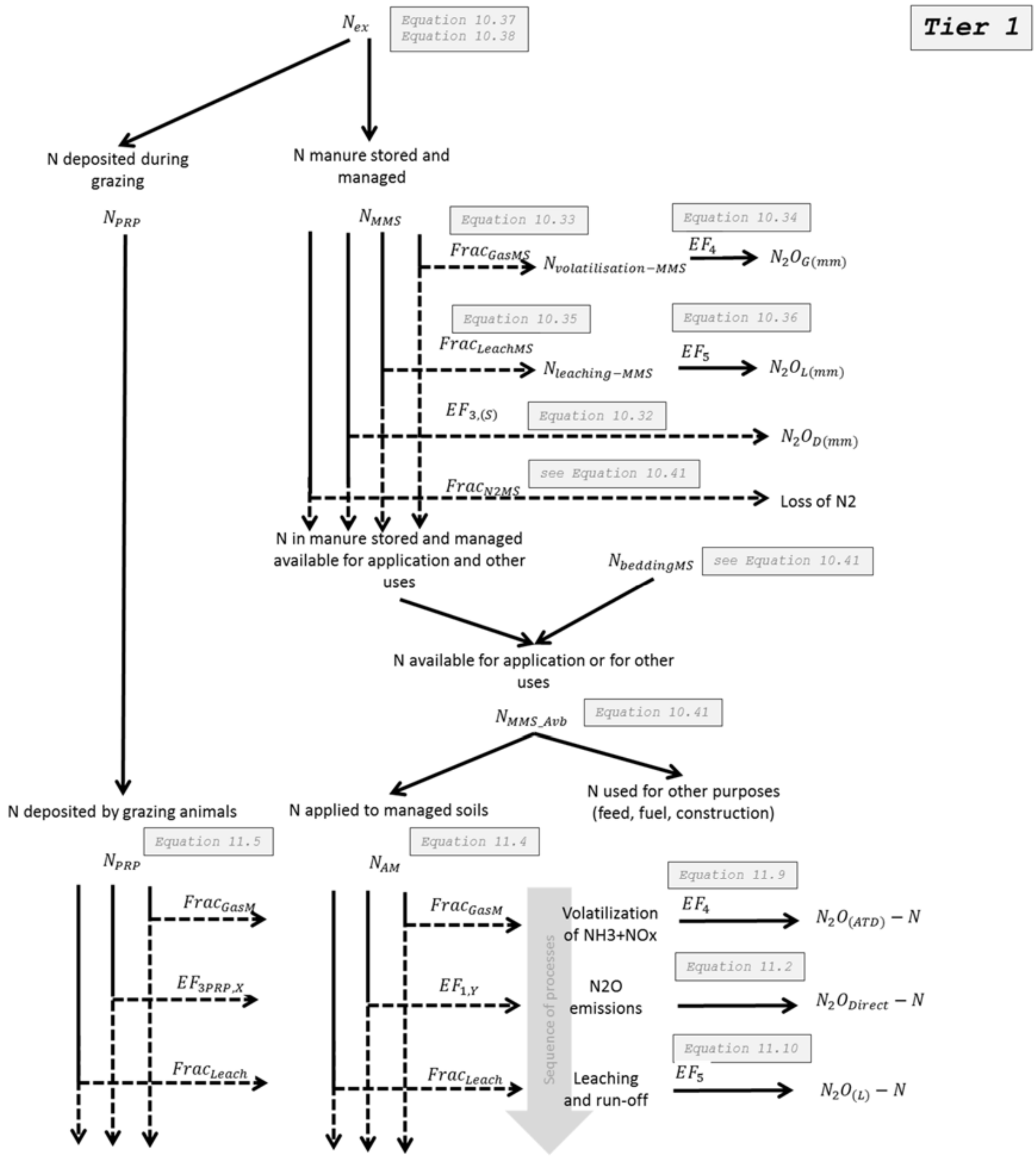
Where:

$Corr_{practice}$ = correction factor for the direct N_2O emission factor EF_1 and the leaching fraction for situations where ammonia emissions from managed soils have been reduced as a consequence of mitigation technologies, dimensionless

$EF^{*}_{1}, Frac^{*}_{GASM}$ = corrected direct N_2O emission factor and leaching fraction taking account higher availability of N if technologies are used that reduce NH_3 losses from N applied to managed soils.

New Figure

Figure 10. 5 Processes leading to the emission of gaseous N species from manure



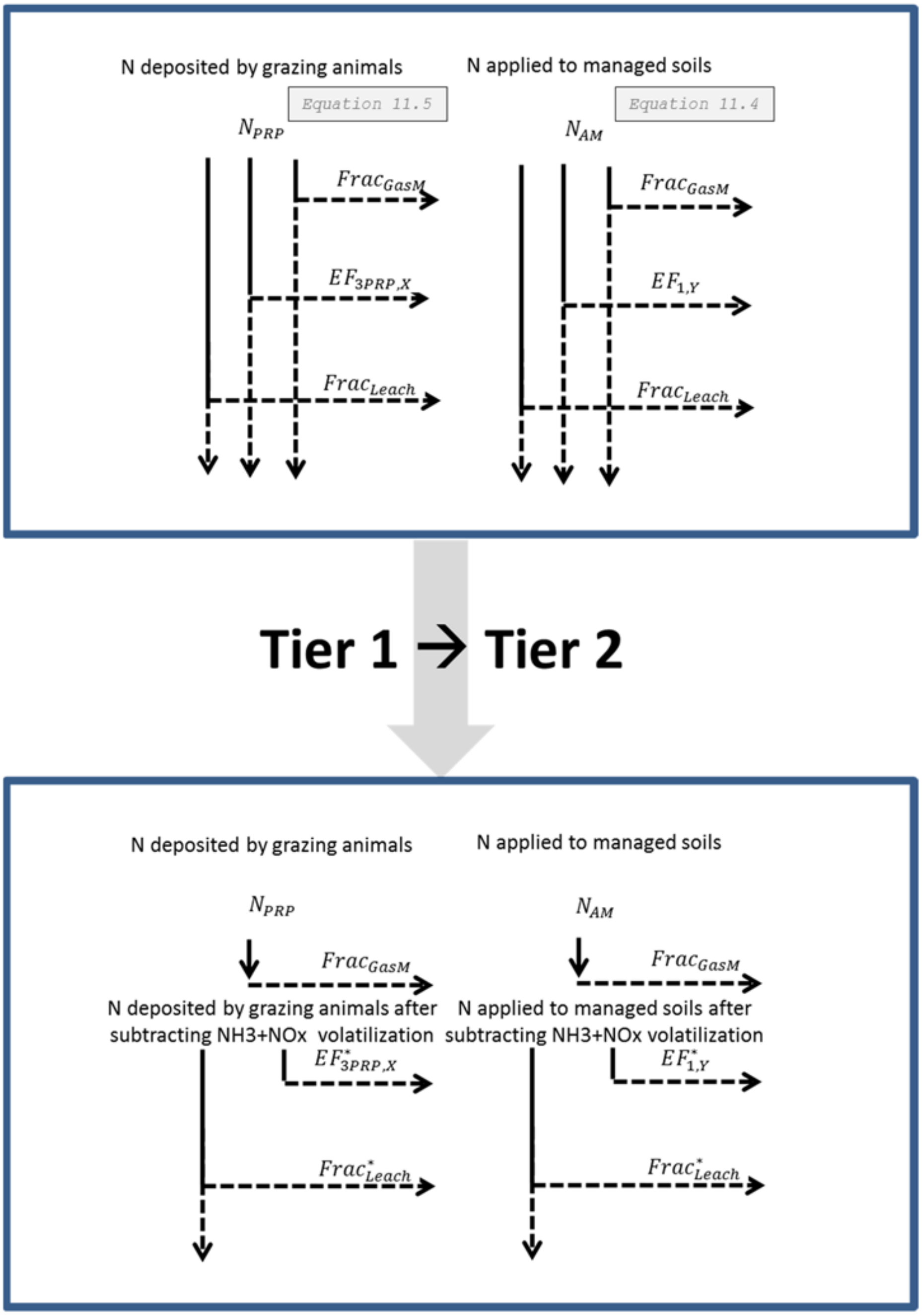
Symbols as defined under the Equations in Chapter 10 and 11 and in Annex 3 of Chapter 10. In this graph all flows denoted with N are averaged annual N flows per head of livestock species/category [kg N aminal^{-1} yr^{-1}]; symbols denoted with Frac are fractions in [kg N (kg N)$^{-1}$]; symbols denoted with EF are N_2O emission factors in [kg N_2O -N (kg N)$^{-1}$].

Broken arrows indicate flows that are split into an emission pathway and a flow of N in the agricultural system.

Note that for N deposited by grazing animals or N applied to managed soils, the flow of N is a sequence of processes with first volatilization of NH_3+NOx and only thereafter emissions of N_2O and N leaching. This is not reflected in the equations proposed for Tier 1 methodology.

New Figure

Figure 10. 6 Accounting for N-flow in estimating direct N2O emissions and indirect N2O emissions from leaching and runoff from managed soils



10.5.7 Use of worksheets

No refinement

ANNEX 10A.1 DATA UNDERLYING METHANE DEFAULT EMISSION FACTORS FOR ENTERIC FERMENTATION

This annex presents the data used to develop the default emission factors for methane emissions from Enteric Fermentation. The Tier 2 method was implemented with these data to estimate the default emission factors for cattle and buffalo.

Table A.10-1a Data for estimating Enteric Fermentation Emission Factors for Dairy Cattle and Nitrogen excretion factor (Tier 1a)

Regions	Weight kg	Weight Gain kg/day	Feeding Situation	Milk kg/day	Fat content %	Protein content %	Work hrs/day	% Pregnant	Digestibility of Feed % (DC)	CP, %	CH4 Conversion %
North America	600	0	Stall Fed	30.0	3.7	3.2	0	90	75	16.6	5.7
Western Europe	600	0	Stall Fed	18.4	4.0	3.2	0	90	73	TBD	6.5
Eastern Europe	550	0	Stall Fed	10.3	3.9	3.2	0	85	70	15.1	6.3
Latin America	560	0	Pasture/range	5.0	4.1	3.2	0	79.8	70.9	14.0	6.3
Middle East	446	0	Stall Fed	8.5	3.7	3.4	0	54	64	14.8	6.3
Indian Subcontinent	285	0	Pasture/Range	3.5	4.1	3.7	0	42	57	15.3	6.5

Source: TBD

450 - updated

[4.0] – assumed values, TBD

Table A-1b Data for estimating Enteric Fermentation Emission Factors for Dairy Cattle and Nitrogen excretion factor (Tier 1b)

Regions	Weight kg	Weight Gain kg/day	Feeding Situation	Milk kg/day	Fat content %	Protein content %	Work hrs/day	% Pregnant	Digestibility of Feed % (DC)	CP, %	CH4 Conversion %	Day weighted population mix	Emission factors, kg CH4 head-1 yr-1
Latin America													

Low productivity systems	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
High productivity systems	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Middle East													
Low productivity systems	250	0	Pasture/Range	3.6	4.5	3.7	0	50	60	12.5	6.3	30	58
High productivity systems	530	0	Stall Fed	10.6	3.4	3.2	0	55	65	15.8	6.3	70	93
Indian Subcontinent													
Low productivity systems	265	0	Pasture/Range	2.4	4.2	3.7	0	40	55	15.0	6.5	77	63
High productivity systems	350	0	Stall Fed	7.1	4.0	3.6	0	50	65	16.4	6.3	23	68

Table 10.A.2a – Data for estimating tier 1a enteric fermentation CH4 emission factors for other cattle in table 10.11

Type	Weight kg	Weight Gain kg/day	Feeding Situation	Milk kg/day	Fat content %	Protein content %	Work hrs/day	Pregnant %	Digestibility of Feed % (DC)	CP %	CH4 Conversion %	Day Weighted Population Mix %	Emission Factors kg/head/yr
North America													
Mature Females	580		Pasture/Range	3.0	4.0	3.5		80	60	12.0	7.0	35	**88**
Mature Males	820		Pasture/Range						60	12.0	7.0	2	103
Calves on milk	125	1.0	Pasture/Range						NA	13.0	0.0	16	0
Calves on forage	215	1.0	Pasture/Range						65	13.0	6.3	8	50
Growing heifers/steers	300	0.9	Pasture/Range						65	13.0	6.3	17	61

Replacement/growing	400	0.5	Pasture/Range						60	12.0	7.0	11	77
Feedlot cattle	500	1.55	Stall Fed						75	14.0	3.0	11	39
Western Europe													
Mature Males	600		Pasture/Range						60	TBD	7.0	22	81
Replacement/growing	400	0.4	Pasture/Range						65	TBD	6.3	54	57
Calves on milk	230	0.3	Stall Fed						95	TBD	0.3	15	1
Calves on forage	230	0.3	Pasture/Range						73	TBD	5.5	8	28
Eastern Europe													
Mature Females	550		Pasture/Range	3.0	3.8	3.04	0	80	70	15.1	6.3	39	61
Mature Males	630		Pasture/Range						65	14.2	6.3	9	67
Replacement/growing	350	0.50	Pasture/Range						65	14.2	6.3	27	50
Calves on forage	190	0.87	Pasture/Range						65	14.3	6.3	25	40
Latin America													
Mature Females	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Mature Males	TBD	TBD	TBD						TBD	TBD	TBD	TBD	TBD
Replacement/growing	TBD	TBD	TBD						TBD	TBD	TBD	TBD	TBD
Calves on forage	TBD	TBD	TBD						TBD	TBD	TBD	TBD	TBD
Middle East													
Mature Females	479		Pasture/Range	2.7	4.0	3.2		54	64	14.3	6.5	10	59
Mature Males	536		Pasture/Range				0.23		60	14.7	6.6	9	63
Replacement/growing	290	0.29	Pasture/Range						61	14.9	6.5	42	46
Calves on forage	155	0.72	Pasture/Range						61	15.0	6.5	40	49
Indian Subcontinent													
Mature Females	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	55	TBD	7.0	22	TBD
Mature Males	291		Pasture/Range				1.6		55		7.0	46	61

Replacement/growing	152	0.21	Pasture/Range						57		6.8	16	37
Calves on forage	81	0.31	Pasture/Range						58		6.7	16	30

31Table 10.A.2b – Data for estimating tier 1b enteric fermentation CH4 emission factors for other cattle in table 10.11

Type	Weight kg	Weight Gain kg/day	Feeding Situation	Milk kg/day	Fat content %	Protein content %	Work hrs/day	Pregnant %	Digestibility of Feed % (DC)	CP %	CH4 Conversion %	Day Weighted Population Mix %	Emission Factors kg/head/yr
Latin America													
Low productivity systems	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Mature Females	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Mature Males	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Replacement/growing	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Calves on forage	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
High productivity systems													
Mature Females	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Mature Males	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Replacement/growing	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Calves on forage	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Middle East													
Low productivity systems													
Mature Females	360		Pasture/Range	2.3	5.0	4.0		50	60	12.5	7.0	10	63
Mature Males	450		Pasture/Range				0.55		55	13.5	7.0	12	79
Replacement/growing	150	0.19	Pasture/Range						55	13.5	7.0	42	40
Calves on forage	80	0.36	Pasture/Range						55	13.5	7.0	36	36

High productivity systems													
Mature Females	530		Pasture/Range	2.8	3.5	3.3		55	65	15.0	6.3	10	64
Mature Males	600		Pasture/Range						63	15.5	6.3	7	68
Replacement/growing	350	0.33	Pasture/Range						63	15.5	6.3	42	53
Calves on forage	150	0.85	Pasture/Range						63	15.5	6.3	41	46
Indian Subcontinent													
Low productivity systems													
Mature Females	250		Pasture/Range	1.7	4.6	3.7		40	55	10.0	6.0	7	46
Mature Males	290		Pasture/Range				1.7		55	TBD	6.0	52	46
Replacement/growing	140	0.15	Pasture/Range						55	TBD	5.5	13	27
Calves on forage	65	0.25	Pasture/Range						55	TBD	5.5	11	21
High productivity systems													
Mature Females	TBD	TBD	Pasture/Range	TBD	TBD	TBD		TBD	62	TBD	6.3	9	TBD
Mature Males	330		Pasture/Range						62	TBD	6.3	11	44
Replacement/growing	180	0.33	Pasture/Range						62	15.0	6.3	35	37
Calves on forage	105	0.41	Pasture/Range						62	15.0	6.3	45	31

Table 10.A.3a Data for estimating Enteric Fermentation Emission Factors for Dairy Buffalo and Nitrogen excretion factor

Regions	Weight kg	Weight Gain kg/day	Feeding Situation	Milk kg/day	Fat content %	Protein content %	Work hrs/day	% Pregnant	Digestibility of Feed % (DC)	CP, %	CH4 Conversion %
Latin America	550		Pasture/Range	3.0	7.1	4.3	0	62	60	12.0	6.5

Table 10.A.3b Data for estimating Enteric Fermentation Emission Factors for non-Dairy Buffalo and Nitrogen excretion factor

Type	Weight kg	Weight Gain kg/day	Feeding Situation	Work hrs/day	Digestibility of Feed % (DC)	CP %	CH_4 Conversion %	Day Weighted Population Mix %	Emission Factors kg/head/yr
Latin America									
Adult Males	650		Pasture/Range	0	60	12.0	6.5	10	81
Growing	275	0.4	Pasture/Range	0	60	12.0	6.5	40	57
Calves	90	0.28	Pasture/Range	0	60	12.0	6.5	50	26

ANNEX 10A. 2 DATA UNDERLYING METHANE DEFAULT EMISSION FACTORS FOR MANURE MANAGEMENT

This annex presents the data used to develop the default emission factors for methane emissions from Manure Management. The Tier 2 method was implemented with these data to estimate the default emission factors for each livestock category.

Need to be updated based on updated manure management system usage (MS %) ,

Table 10A-4 Manure Management Methane Emission Factor Derivation for Dairy Cattle

Table 10A-4 (MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Dairy Cattle

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Daily spread	Digester	Burned for fuel	Other
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%

Region		Dairy Cattle Characterictics			Manure Management System Usage (MS%)									Emission factors, g CH_4/ kg VS									
														Cool				Temperate		Warm			
		Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day										Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	GRASSland based Arid	600	0.24	5.0	47.9	23.6	13.7	0.0	7.4	7.4	0.0	0.0	0.0	59.3	62.8	59.8	60.5	71.3	75.1	80.7	89.4	86.8	88.7
	GRASSland based Humid	600	0.24	5.0	26.4	15.0	11.8	0.0	33.1	13.7	0.0	0.0	0.0	33.6	35.7	33.6	34.1	40.9	43.1	47.0	52.4	50.8	51.9
	GRASSland based Temperate	600	0.24	5.0	12.7	26.0	29.3	0.0	17.3	14.6	0.0	0.0	0.0	23.3	25.8	21.2	21.4	32.4	34.7	42.5	50.2	48.5	49.4
	Mixed Arid	600	0.24	5.0	49.8	24.3	14.9	0.0	2.7	8.3	0.0	0.0	0.0	61.6	65.1	62.1	62.9	73.9	77.9	83.6	92.7	89.9	91.9
	Mixed Humid	600	0.24	5.0	33.4	17.9	12.1	0.0	23.2	13.3	0.0	0.0	0.0	42.1	44.6	42.2	42.7	50.8	53.6	58.1	64.6	62.6	64.0
	Mixed Temperate	600	0.24	5.0	15.2	26.7	34.8	0.0	12.6	10.7	0.0	0.0	0.0	26.3	29.0	24.3	24.5	36.0	38.5	46.4	54.4	52.7	53.6
RUS	GRASSland based Arid	550	0.24	3.6	0.0	0.0	77.5	0.0	22.5	0.0	0.0	0.0	0.0	2.6	2.6	2.6	2.6	5.1	5.1	6.4	6.4	6.4	6.4
	GRASSland based Humid	550	0.24	3.6	0.0	0.0	77.5	0.0	22.5	0.0	0.0	0.0	0.0	2.6	2.6	2.6	2.6	5.1	5.1	6.4	6.4	6.4	6.4
	GRASSland based Temperate	550	0.24	3.6	0.0	0.0	77.5	0.0	22.5	0.0	0.0	0.0	0.0	2.6	2.6	2.6	2.6	5.1	5.1	6.4	6.4	6.4	6.4
	Mixed Arid	550	0.24	3.6	0.0	0.0	77.5	0.0	22.5	0.0	0.0	0.0	0.0	2.6	2.6	2.6	2.6	5.1	5.1	6.4	6.4	6.4	6.4
	Mixed Temperate	550	0.24	3.6	0.0	0.0	77.5	0.0	22.5	0.0	0.0	0.0	0.0	2.6	2.6	2.6	2.6	5.1	5.1	6.4	6.4	6.4	6.4
WE	GRASSland based Arid	600	0.24	4.2	0.1	24.2	46.9	0.0	24.2	4.6	0.0	0.0	0.0	9.9	11.9	7.2	7.2	17.6	19.2	27.1	33.7	32.5	32.9
	GRASSland based Humid	600	0.24	4.2	0.1	32.8	19.7	0.0	40.2	7.1	0.0	0.0	0.0	12.1	14.7	8.4	8.4	21.2	23.3	33.3	42.3	40.7	41.2
	GRASSland based Temperate	600	0.24	4.2	0.0	45.4	26.3	0.0	25.8	2.5	0.0	0.0	0.0	16.4	20.0	11.3	11.3	28.9	31.8	45.5	57.9	55.7	56.4
	Mixed Arid	600	0.24	4.2	0.1	18.3	49.2	0.0	29.2	3.2	0.0	0.0	0.0	8.0	9.4	5.9	5.9	14.3	15.4	21.6	26.6	25.8	26.0
	Mixed Humid	600	0.24	4.2	0.0	20.7	33.3	0.0	44.1	1.8	0.0	0.0	0.0	8.4	10.0	6.0	6.0	14.8	16.1	22.8	28.4	27.4	27.8
	Mixed Temperate	600	0.24	4.2	0.0	50.8	24.4	0.0	23.6	1.1	0.0	0.0	0.0	18.1	22.2	12.4	12.4	32.0	35.2	50.4	64.3	61.8	62.7
EE	GRASSland based Arid	550	0.24	3.6	0.0	18.8	67.2	0.0	13.0	1.0	0.0	0.0	0.0	8.6	10.1	6.5	6.5	15.6	16.8	23.3	28.5	27.6	27.9
	GRASSland based Temperate	550	0.24	3.6	0.0	14.4	67.0	0.0	16.0	2.6	0.0	0.0	0.0	7.1	8.3	5.5	5.5	13.0	13.9	19.2	23.1	22.5	22.7
	Mixed Arid	550	0.24	3.6	0.0	18.8	67.2	0.0	13.0	1.0	0.0	0.0	0.0	8.6	10.1	6.5	6.5	15.6	16.8	23.4	28.6	27.7	28.0
	Mixed Temperate	550	0.24	3.6	0.0	9.3	72.7	0.0	16.8	1.2	0.0	0.0	0.0	5.6	6.3	4.5	4.5	10.3	10.9	14.9	17.4	17.0	17.1

NENA	GRASSland based Arid	446	0.13	4.4	0.0	0.0	0.0	19.8	75.2	0.0	0.0	4.9	0.0	0.8	0.8	0.8	0.8	0.8	0.8	1.1	1.1	1.1	1.1
	GRASSland based Humid	446	0.13	4.4	0.0	0.0	0.0	23.5	75.1	0.0	0.0	1.4	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8
	GRASSland based Temperate	446	0.13	4.4	0.0	0.0	40.3	0.0	39.9	0.0	0.0	19.8	0.0	2.5	2.5	2.5	2.5	3.2	3.2	3.7	3.7	3.7	3.7
	Mixed Arid	446	0.13	4.4	0.0	0.0	0.0	64.1	35.5	0.0	0.0	0.4	0.0	0.7	0.7	0.7	0.7	0.7	0.7	1.1	1.1	1.1	1.1
	Mixed Humid	446	0.13	4.4	0.0	0.0	0.0	67.4	32.6	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	1.0	1.0	1.0	1.0
	Mixed Temperate	446	0.13	4.4	0.0	0.0	70.2	0.0	23.8	0.0	0.0	6.1	0.0	1.8	1.8	1.8	1.8	3.0	3.0	3.7	3.7	3.7	3.7
ESEA	GRASSland based Arid	565	0.13	5.3	0.0	0.1	0.0	4.1	77.7	0.0	0.0	18.2	0.0	1.9	1.9	1.9	1.9	1.9	1.9	2.1	2.1	2.1	2.1
	GRASSland based Humid	565	0.13	5.3	0.0	1.9	0.2	4.1	80.5	0.0	0.0	13.4	0.0	1.8	1.9	1.7	1.7	2.1	2.1	2.6	2.9	2.8	2.8
	GRASSland based Temperate	565	0.13	5.3	0.0	4.0	36.2	0.0	42.2	0.0	0.0	17.6	0.0	3.0	3.2	2.8	2.8	4.2	4.4	5.4	6.0	5.9	5.9
	Mixed Arid	565	0.13	5.3	0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	1.1	1.1	1.1	1.1
	Mixed Humid	565	0.13	5.3	0.0	0.7	0.1	73.7	25.6	0.0	0.0	0.0	0.0	0.8	0.9	0.8	0.8	0.9	1.0	1.4	1.5	1.5	1.5
	Mixed Temperate	565	0.13	5.3	0.0	1.9	71.3	0.0	26.8	0.0	0.0	0.0	0.0	1.7	1.8	1.6	1.6	3.2	3.3	4.2	4.5	4.5	4.5
OCE	GRASSland based Arid	450	0.24	3.1	4.3	0.1	0.0	0.0	93.8	1.8	0.0	0.0	0.0	5.2	5.3	5.4	5.5	5.7	5.9	6.1	6.4	6.2	6.4
	GRASSland based Humid	450	0.24	3.1	4.6	0.1	0.0	0.0	94.4	0.9	0.0	0.0	0.0	5.4	5.6	5.7	5.8	6.0	6.2	6.4	6.6	6.5	6.6
	GRASSland based Temperate	450	0.24	3.1	4.9	0.0	0.0	0.0	94.8	0.3	0.0	0.0	0.0	5.7	5.9	6.0	6.1	6.3	6.5	6.7	6.9	6.8	6.9
	Mixed Arid	450	0.24	3.1	3.9	0.1	0.0	0.0	93.4	2.5	0.0	0.0	0.0	4.8	4.9	5.0	5.1	5.2	5.4	5.7	5.9	5.8	5.9
	Mixed Humid	450	0.24	3.1	4.8	0.0	0.0	0.0	94.7	0.5	0.0	0.0	0.0	5.6	5.8	5.9	6.0	6.1	6.4	6.6	6.8	6.7	6.8
	Mixed Temperate	450	0.24	3.1	4.0	0.1	0.0	0.0	93.3	2.6	0.0	0.0	0.0	4.8	4.9	5.0	5.1	5.3	5.5	5.7	6.0	5.8	6.0
SA	GRASSland based Arid	285	0.13	3.6	0.0	0.0	0.0	4.0	76.0	0.0	0.0	20.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.2	2.2	2.2	2.2
	GRASSland based Humid	285	0.13	3.6	0.0	0.0	0.0	4.0	76.0	0.0	0.0	20.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.2	2.2	2.2	2.2
	GRASSland based Temperate	285	0.13	3.6	0.0	0.0	40.0	0.0	40.0	0.0	0.0	20.0	0.0	2.6	2.6	2.6	2.6	3.3	3.3	3.7	3.7	3.7	3.7
	Mixed Arid	285	0.13	3.6	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	2.3	2.3	2.3	2.3	2.3	2.3	2.6	2.6	2.6	2.6
	Mixed Humid	285	0.13	3.6	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	2.3	2.3	2.3	2.3	2.3	2.3	2.6	2.6	2.6	2.6
	Mixed Temperate	285	0.13	3.6	0.0	0.0	60.0	0.0	20.0	0.0	0.0	20.0	0.0	2.8	2.8	2.8	2.8	3.9	3.9	4.5	4.5	4.5	4.5
LAC	GRASSland based Arid	560	0.13	4.1	0.0	0.0	0.0	24.7	74.1	0.0	0.0	1.3	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8
	GRASSland based Humid	560	0.13	4.1	0.0	0.0	0.0	25.0	74.9	0.0	0.0	0.1	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
	GRASSland based Temperate	560	0.13	4.1	0.0	0.0	64.2	0.0	31.5	0.0	0.0	4.2	0.0	1.6	1.6	1.6	1.6	2.7	2.7	3.3	3.3	3.3	3.3
	Mixed Arid	560	0.13	4.1	0.0	0.0	0.0	49.8	49.8	0.0	0.0	0.3	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Humid	560	0.13	4.1	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Temperate	560	0.13	4.1	0.0	0.0	65.9	0.0	32.4	0.0	0.0	1.7	0.0	1.4	1.4	1.4	1.4	2.5	2.5	3.2	3.2	3.2	3.2
SSA	GRASSland based Arid	275	0.13	2.2	0.0	0.0	0.0	21.6	64.7	0.0	0.0	13.7	0.0	1.6	1.6	1.6	1.6	1.6	1.6	1.8	1.8	1.8	1.8
	GRASSland based Humid	275	0.13	2.2	0.0	0.0	0.0	25.0	75.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	GRASSland based Temperate	275	0.13	2.2	0.0	0.0	67.0	0.0	33.0	0.0	0.0	0.0	0.0	1.3	1.3	1.3	1.3	2.4	2.4	3.1	3.1	3.1	3.1
	Mixed Arid	275	0.13	2.2	0.0	0.0	0.0	53.9	36.0	0.0	0.0	10.1	0.0	1.5	1.5	1.5	1.5	1.5	1.5	1.8	1.8	1.8	1.8
	Mixed Humid	275	0.13	2.2	0.0	0.0	0.0	60.0	40.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	1.0	1.0	1.0	1.0
	Mixed Temperate	275	0.13	2.2	0.0	0.0	75.0	0.0	25.0	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	2.7	2.7	3.4	3.4	3.4	3.4

[a] Average dairy cow mass for each region (default estimates are ±10%)

[b] B_o estimates are ±15%

[c] Average VS production per head per day for the average dairy cow (default estimates are±20%)

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2] Storage period is 6 months.

Sources: For North America, dairy cow mass values are from Safley (2000) and VS values are estimated based on an analysis of feed data from Petersen et.al (2003). North American manure management system usage values are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. B_o values are from Morris (1976) and Bryant, et.al. (1976). For Western and Eastern Europe manure management system usage, mass and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, the detailed information for dairy cows are developed in Gibbs and Johnson (1993), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-5 Manure Management Methane Emission Factor Derivation for Non-dairy Cattle

Table 10A-5(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)
Manure Management Methane Emission Factor Derivation for Non-dairy Cattle

Annual Average Temperature(℃)		Manure Management System MCFs: Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Daily spread	Digester	Burned for fuel	Other
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%

Region		Non-dairy Cattle Characterictics: Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day	Manure Management System Usage (MS%)								
NA	GRASSland based Arid	407.0	0.19	3.3	0.0	0.2	42.7	14.4	42.7	0.0	0.0	0.0	0.0
	GRASSland based Humid	407.0	0.19	3.3	0.0	0.0	42.5	15.0	42.5	0.0	0.0	0.0	0.0
	GRASSland based Temperate	407.0	0.19	3.3	0.0	1.3	43.8	10.7	44.2	0.0	0.0	0.0	0.0
	Mixed Arid	407.0	0.19	3.3	0.0	0.0	42.5	15.0	42.5	0.0	0.0	0.0	0.0
	Mixed Humid	407.0	0.19	3.3	0.0	0.0	42.5	15.0	42.5	0.0	0.0	0.0	0.0
	Mixed Temperate	407.0	0.19	3.3	0.0	0.4	42.9	13.8	43.0	0.0	0.0	0.0	0.0
WE	GRASSland based Arid	405.0	0.18	2.3	0.0	16.3	30.2	0.0	52.5	1.1	0.0	0.0	0.0
	GRASSland based Humid	405.0	0.18	2.3	0.0	13.0	21.2	0.0	63.4	2.5	0.0	0.0	0.0
	GRASSland based Temperate	405.0	0.18	2.3	0.0	19.2	24.9	0.6	46.0	9.2	0.0	0.0	0.0
	Mixed Arid	405.0	0.18	2.3	0.0	22.7	29.1	0.0	48.0	0.2	0.0	0.0	0.0
	Mixed Humid	405.0	0.18	2.3	0.0	26.1	20.0	0.0	51.6	2.3	0.0	0.0	0.0
	Mixed Temperate	405.0	0.18	2.3	0.0	26.1	26.4	0.0	41.1	6.4	0.0	0.0	0.0
EE	GRASSland based Arid	413.0	0.17	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	413.0	0.17	2.6	0.0	63.6	5.3	0.0	31.2	0.0	0.0	0.0	0.0
	Mixed Arid	413.0	0.17	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mixed Temperate	413.0	0.17	2.6	0.0	63.9	4.5	0.0	31.6	0.0	0.0	0.0	0.0

Region		Emission factors, g CH_4/ kg VS: Cool: Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Temperate: Warm Temperate Moist	Warm Temperate Dry	Warm: Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	GRASSland based Arid	1.5	1.5	1.5	1.5	2.6	2.6	3.4	3.5	3.5	3.5
	GRASSland based Humid	1.5	1.5	1.5	1.5	2.5	2.5	3.3	3.3	3.3	3.3
	GRASSland based Temperate	1.8	1.9	1.7	1.7	3.2	3.3	4.3	4.6	4.5	4.6
	Mixed Arid	1.5	1.5	1.5	1.5	2.5	2.5	3.3	3.3	3.3	3.3
	Mixed Humid	1.5	1.5	1.5	1.5	2.5	2.5	3.3	3.3	3.3	3.3
	Mixed Temperate	1.6	1.6	1.5	1.5	2.7	2.7	3.6	3.7	3.6	3.6
WE	GRASSland based Arid	5.1	6.1	3.7	3.7	9.0	9.7	13.8	17.1	16.5	16.7
	GRASSland based Humid	4.1	4.8	3.0	3.0	7.1	7.7	11.0	13.6	13.1	13.3
	GRASSland based Temperate	5.7	6.8	4.1	4.1	10.0	10.9	15.6	19.5	18.8	19.1
	Mixed Arid	6.7	8.0	4.7	4.7	11.7	12.8	18.3	22.9	22.1	22.4
	Mixed Humid	7.3	8.9	5.1	5.1	12.8	14.1	20.2	25.5	24.6	24.9
	Mixed Temperate	7.4	9.0	5.2	5.2	13.1	14.4	20.5	25.9	24.9	25.2
EE	GRASSland based Arid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	15.5	19.1	10.4	10.4	27.2	30.1	43.2	55.6	53.4	54.1
	Mixed Arid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mixed Temperate	15.5	19.2	10.4	10.4	27.3	30.2	43.4	55.8	53.6	54.3

NENA	GRASSland based Arid	277.0	0.10	2.5	0.0	0.0	0.0	4.8	76.0	0.0	0.0	19.2	0.0	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6
	GRASSland based Humid	277.0	0.10	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	277.0	0.10	2.5	0.0	0.0	40.0	0.0	40.0	0.0	0.0	20.0	0.0	2.0	2.0	2.0	2.0	2.5	2.5	2.8	2.8	2.8	2.8
	Mixed Arid	277.0	0.10	2.5	0.0	0.0	0.0	74.8	25.2	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8
	Mixed Humid	277.0	0.10	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mixed Temperate	277.0	0.10	2.5	0.0	0.0	75.0	0.0	25.0	0.0	0.0	0.0	0.0	1.1	1.1	1.1	1.1	2.1	2.1	2.6	2.6	2.6	2.6
ESEA	GRASSland based Arid	319.0	0.10	2.6	0.0	0.0	0.0	4.1	77.4	0.0	0.0	18.5	0.0	1.4	1.4	1.4	1.4	1.4	1.4	1.6	1.6	1.6	1.6
	GRASSland based Humid	319.0	0.10	2.6	0.0	0.0	0.0	4.3	82.2	0.0	0.0	13.5	0.0	1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3	1.3
	GRASSland based Temperate	319.0	0.10	2.6	0.0	0.1	39.1	0.0	41.9	0.0	0.0	18.9	0.0	1.9	1.9	1.9	1.9	2.4	2.4	2.8	2.8	2.8	2.8
	Mixed Arid	319.0	0.10	2.6	0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Humid	319.0	0.10	2.6	0.0	0.0	0.0	74.8	25.2	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Temperate	319.0	0.10	2.6	0.0	0.0	74.3	0.0	25.6	0.0	0.0	0.0	0.0	1.1	1.1	1.1	1.1	2.1	2.1	2.6	2.6	2.6	2.6
OCE	GRASSland based Arid	377.0	0.17	1.8	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	GRASSland based Humid	377.0	0.17	1.8	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	GRASSland based Temperate	377.0	0.17	1.8	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Arid	377.0	0.17	1.8	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Humid	377.0	0.17	1.8	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Temperate	377.0	0.17	1.8	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
SA	GRASSland based Arid	223.0	0.10	2.4	0.0	0.0	0.0	4.0	76.0	0.0	0.0	20.0	0.0	1.5	1.5	1.5	1.5	1.5	1.5	1.7	1.7	1.7	1.7
	GRASSland based Humid	223.0	0.10	2.4	0.0	0.0	0.0	4.0	76.0	0.0	0.0	20.0	0.0	1.5	1.5	1.5	1.5	1.5	1.5	1.7	1.7	1.7	1.7
	GRASSland based Temperate	223.0	0.10	2.4	0.0	0.0	40.0	0.0	40.0	0.0	0.0	20.0	0.0	2.0	2.0	2.0	2.0	2.5	2.5	2.8	2.8	2.8	2.8
	Mixed Arid	223.0	0.10	2.4	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8	2.0	2.0	2.0	2.0
	Mixed Humid	223.0	0.10	2.4	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8	2.0	2.0	2.0	2.0
	Mixed Temperate	223.0	0.10	2.4	0.0	0.0	60.0	0.0	20.0	0.0	0.0	20.0	0.0	2.2	2.2	2.2	2.2	3.0	3.0	3.4	3.4	3.4	3.4
LAC	GRASSland based Arid	365.0	0.10	2.7	0.0	0.0	0.0	5.0	94.4	0.0	0.0	0.6	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	365.0	0.10	2.7	0.0	0.0	0.0	5.0	94.9	0.0	0.0	0.1	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
	GRASSland based Temperate	365.0	0.10	2.7	0.0	0.0	64.4	0.0	31.6	0.0	0.0	4.0	0.0	1.2	1.2	1.2	1.2	2.1	2.1	2.5	2.5	2.5	2.5
	Mixed Arid	365.0	0.10	2.7	0.0	0.0	0.0	5.0	94.8	0.0	0.0	0.2	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
	Mixed Humid	365.0	0.10	2.7	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
	Mixed Temperate	365.0	0.10	2.7	0.0	0.0	65.6	0.0	32.3	0.0	0.0	2.1	0.0	1.1	1.1	1.1	1.1	2.0	2.0	2.5	2.5	2.5	2.5
SSA	GRASSland based Arid	176.0	0.10	1.8	0.0	0.0	0.0	22.8	68.3	0.0	0.0	8.9	0.0	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1.1	1.1	1.1
	GRASSland based Humid	176.0	0.10	1.8	0.0	0.0	0.0	25.0	75.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	176.0	0.10	1.8	0.0	0.0	67.0	0.0	33.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	176.0	0.10	1.8	0.0	0.0	0.0	57.2	38.2	0.0	0.0	4.6	0.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0
	Mixed Humid	176.0	0.10	1.8	0.0	0.0	0.0	60.0	40.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8
	Mixed Temperate	176.0	0.10	1.8	0.0	0.0	75.0	0.0	25.0	0.0	0.0	0.0	0.0	1.1	1.1	1.1	1.1	2.1	2.1	2.6	2.6	2.6	2.6

[a] Average non-dairy mass for each region (default estimates are ±25%)

[b] Bo estimates are ±15%

[c] Average VS production per head per day for the average non-dairy cow (default estimates are ±35%)

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28

[1]Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: For North America, other cattle mass are from Safley (2000) and USDA's Agricultural Waste Management Field Handbook and VS values are estimated based on an analysis of feed data from Petersen, et.al (2003). North American manure management system usage values are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. B_o data are values reported in Hashimoto (1981). For Western and Eastern Europe manure management system usage, average mass, B_o and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, the detailed information for cattle are developed in Gibbs and Johnson (1993), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-6 Manure Management Methane Emission Factor Derivation for Meat-Buffalo

Table 10A-6(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)
Manure Management Methane Emission Factor Derivation for Meat-Buffalo

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Daily spread	Digester	Burned for fuel	Other
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%

Region		Meat-Buffalo Characteristics			Manure Management System Usage (MS%)								
		Mass[a] kg	Bo[b] m³ CH_4/kg VS	VS[c] kg/hd/day									
RUS	GRASSland based Arid	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
	GRASSland based Humid	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
	GRASSland based Temperate	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
	Mixed Arid	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
	Mixed Temperate	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
EE	GRASSland based Arid	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
	GRASSland based Temperate	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
	Mixed Arid	380.0	0.1	3.9	0.0	5.6	66.6	0.0	27.8	0.0	0.0	0.0	0.0
	Mixed Temperate	380.0	0.1	3.9	0.0	11.6	62.8	0.0	25.6	0.0	0.0	0.0	0.0
NENA	GRASSland based Arid	Not applicable			0.0	0.0	17.9	3.0	63.9	0.0	0.0	15.2	0.0
	GRASSland based Humid				0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate				0.0	0.0	40.0	0.0	40.0	0.0	0.0	20.0	0.0
	Mixed Arid				0.0	0.0	0.0	31.0	56.1	0.0	0.0	12.9	0.0
	Mixed Humid				0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0
	Mixed Temperate				0.0	0.0	12.3	55.6	23.2	0.0	0.0	8.8	0.0
ESEA	GRASSland based Arid	380.0	0.1	3.9	0.0	0.0	16.1	3.2	68.5	0.0	0.0	12.1	0.0
	GRASSland based Humid	380.0	0.1	3.9	0.0	0.0	0.0	73.9	26.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	380.0	0.1	3.9	0.0	0.2	38.2	0.0	45.7	0.0	0.0	15.9	0.0
	Mixed Arid	380.0	0.1	3.9	0.0	0.0	0.1	29.2	62.8	0.0	0.0	7.9	0.0
	Mixed Humid	380.0	0.1	3.9	0.0	0.0	0.0	74.7	25.3	0.0	0.0	0.0	0.0
	Mixed Temperate	380.0	0.1	3.9	0.0	0.1	43.3	28.8	27.8	0.0	0.0	0.0	0.0

Region		Emission factors, g CH_4/ kg VS									
		Cool				Temperate		Warm			
		Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
RUS	GRASSland based Arid	1.7	1.9	1.5	1.5	3.2	3.4	4.5	5.2	5.1	5.1
	GRASSland based Humid	1.7	1.9	1.5	1.5	3.2	3.4	4.5	5.2	5.1	5.1
	GRASSland based Temperate	1.7	1.9	1.5	1.5	3.2	3.4	4.5	5.2	5.1	5.1
	Mixed Arid	1.7	1.9	1.5	1.5	3.2	3.4	4.5	5.2	5.1	5.1
	Mixed Temperate	1.7	1.9	1.5	1.5	3.2	3.4	4.5	5.2	5.1	5.1
EE	GRASSland based Arid	1.7	1.9	1.5	1.5	3.2	3.4	4.5	5.2	5.1	5.1
	GRASSland based Temperate	1.7	1.9	1.5	1.5	3.2	3.4	4.6	5.2	5.1	5.1
	Mixed Arid	1.7	1.9	1.5	1.5	3.2	3.4	4.5	5.2	5.1	5.1
	Mixed Temperate	2.5	2.9	2.0	2.0	4.6	4.9	6.8	8.1	7.9	8.0
NENA	GRASSland based Arid	Not applicable									
	GRASSland based Humid										
	GRASSland based Temperate										
	Mixed Arid										
	Mixed Humid										
	Mixed Temperate										
ESEA	GRASSland based Arid	1.2	1.2	1.2	1.2	1.4	1.4	1.7	1.7	1.7	1.7
	GRASSland based Humid	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Temperate	1.7	1.7	1.7	1.7	2.2	2.2	2.6	2.6	2.6	2.6
	Mixed Arid	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1.1	1.1	1.1
	Mixed Humid	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Temperate	0.9	0.9	0.8	0.8	1.4	1.4	1.9	1.9	1.9	1.9

SA	GRASSland based Arid	380.0	0.1	3.9	0.0	0.0	0.6	4.0	75.4	0.0	0.0	20.0	0.0	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7
	GRASSland based Humid	380.0	0.1	3.9	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8	2.0	2.0	2.0	2.0
	GRASSland based Temperate	380.0	0.1	3.9	0.0	0.0	40.0	0.0	40.0	0.0	0.0	20.0	0.0	2.0	2.0	2.0	2.0	2.5	2.5	2.8	2.8	2.8	2.8
	Mixed Arid	380.0	0.1	3.9	0.0	0.0	0.0	42.8	37.2	0.0	0.0	20.0	0.0	1.7	1.7	1.7	1.7	1.7	1.7	1.9	1.9	1.9	1.9
	Mixed Humid	380.0	0.1	3.9	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8	2.0	2.0	2.0	2.0
	Mixed Temperate	380.0	0.1	3.9	0.0	0.0	58.6	1.4	20.0	0.0	0.0	20.0	0.0	2.2	2.2	2.2	2.2	3.0	3.0	3.4	3.4	3.4	3.4
LAC	GRASSland based Arid	380.0	0.1	3.9	0.0	0.0	31.9	2.6	65.4	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	1.0	1.0	1.4	1.4	1.4	1.4
	GRASSland based Humid	380.0	0.1	3.9	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
	GRASSland based Temperate	380.0	0.1	3.9	0.0	0.0	67.0	0.0	33.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	380.0	0.1	3.9	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
	Mixed Humid	380.0	0.1	3.9	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
	Mixed Temperate	380.0	0.1	3.9	0.0	0.0	66.2	0.1	33.7	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.3	2.3	2.3	2.3

[a] Average buffalo mass for each region

[b] Average VS production per head per day for the average buffalo

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2] Storage period is 6 months.

Sources: The detailed information for buffalo are developed in Gibbs and Johnson (1993),and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-7 Manure Management Methane Emission Factor Derivation for Dairy-Buffalo

Table 10A-7(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Dairy-Buffalo

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Daily spread	Digester	Burned for fuel	Other
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%

Region		Dairy-Buffalo Charactericties			Manure Management System Usage (MS%)								
		Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day									
NA	GRASSland based Arid	Not applicable			0.0	42.4	40.2	0.0	17.4	0.0	0.0	0.0	0.0
	GRASSland based Humid				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate				0.0	42.4	40.2	0.0	17.4	0.0	0.0	0.0	0.0
	Mixed Arid				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mixed Humid				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mixed Temperate				0.0	42.4	40.2	0.0	17.4	0.0	0.0	0.0	0.0
WE	GRASSland based Arid	380.0	0.1	3.9	0.0	34.0	63.0	0.0	3.0	0.0	0.0	0.0	0.0
	GRASSland based Humid	380.0	0.1	3.9	0.0	34.0	63.0	0.0	3.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	380.0	0.1	3.9	0.0	34.0	63.0	0.0	3.0	0.0	0.0	0.0	0.0
	Mixed Arid	380.0	0.1	3.9	0.0	34.0	63.0	0.0	3.0	0.0	0.0	0.0	0.0
	Mixed Humid	380.0	0.1	3.9	0.0	34.0	63.0	0.0	3.0	0.0	0.0	0.0	0.0
	Mixed Temperate	380.0	0.1	3.9	0.0	34.0	63.0	0.0	3.0	0.0	0.0	0.0	0.0
EE	GRASSland based Arid	380.0	0.1	3.9	0.0	19.0	67.0	0.0	13.0	1.0	0.0	0.0	0.0
	GRASSland based Temperate	380.0	0.1	3.9	0.0	18.1	67.9	0.0	13.0	1.0	0.0	0.0	0.0
	Mixed Arid	380.0	0.1	3.9	0.0	19.0	67.0	0.0	13.0	1.0	0.0	0.0	0.0
	Mixed Temperate	380.0	0.1	3.9	0.0	18.3	67.7	0.0	13.0	1.0	0.0	0.0	0.0
NENA	GRASSland based Arid	Not applicable			0.0	0.0	47.4	8.3	43.5	0.0	0.0	0.8	0.0
	GRASSland based Humid				0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate				0.0	0.0	40.0	0.0	40.0	0.0	0.0	20.0	0.0
	Mixed Arid				0.0	0.0	0.0	49.3	49.9	0.0	0.0	0.7	0.0
	Mixed Humid				0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0
	Mixed Temperate				0.0	0.0	15.9	59.1	25.0	0.0	0.0	0.0	0.0

Region		Emission factors, g CH_4/ kg VS									
		Cool				Temperate		Warm			
		Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	GRASSland based Arid	Not applicable									
	GRASSland based Humid										
	GRASSland based Temperate										
	Mixed Arid										
	Mixed Humid										
	Mixed Temperate										
WE	GRASSland based Arid	5.6	6.8	4.0	4.0	10.1	11.0	15.6	19.4	18.8	19.0
	GRASSland based Humid	5.6	6.8	4.0	4.0	10.1	11.0	15.6	19.4	18.8	19.0
	GRASSland based Temperate	5.6	6.8	4.0	4.0	10.1	11.0	15.6	19.4	18.8	19.0
	Mixed Arid	5.6	6.8	4.0	4.0	10.1	11.0	15.6	19.4	18.8	19.0
	Mixed Humid	5.6	6.8	4.0	4.0	10.1	11.0	15.6	19.4	18.8	19.0
	Mixed Temperate	5.6	6.8	4.0	4.0	10.1	11.0	15.6	19.4	18.8	19.0
EE	GRASSland based Arid	3.6	4.2	2.7	2.7	6.5	7.0	9.8	12.0	11.6	11.7
	GRASSland based Temperate	3.5	4.1	2.6	2.6	6.3	6.8	9.5	11.5	11.2	11.3
	Mixed Arid	3.6	4.2	2.7	2.7	6.5	7.0	9.8	12.0	11.6	11.7
	Mixed Temperate	3.5	4.1	2.7	2.7	6.4	6.9	9.5	11.6	11.3	11.4
NENA	GRASSland based Arid	Not applicable									
	GRASSland based Humid										
	GRASSland based Temperate										
	Mixed Arid										
	Mixed Humid										
	Mixed Temperate										

ESEA	GRASSland based Arid	380.0	0.1	3.9	0.0	0.0	1.6	4.0	75.8	0.0	0.0	18.6	0.0	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6
	GRASSland based Humid	380.0	0.1	3.9	0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Temperate	380.0	0.1	3.9	0.0	0.0	40.2	0.0	40.2	0.0	0.0	19.6	0.0	1.9	1.9	1.9	1.9	2.5	2.5	2.8	2.8	2.8	2.8
	Mixed Arid	380.0	0.1	3.9	0.0	0.0	0.0	29.1	59.4	0.0	0.0	11.5	0.0	1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3	1.3
	Mixed Humid	380.0	0.1	3.9	0.0	0.0	0.0	75.0	25.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Temperate	380.0	0.1	3.9	0.0	0.0	43.3	31.7	25.0	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.9	1.4	1.4	1.9	1.9	1.9	1.9
SA	GRASSland based Arid	380.0	0.1	3.9	0.0	0.0	0.5	4.0	75.5	0.0	0.0	20.0	0.0	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7
	GRASSland based Humid	380.0	0.1	3.9	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8	2.0	2.0	2.0	2.0
	GRASSland based Temperate	380.0	0.1	3.9	0.0	0.0	40.0	0.0	40.0	0.0	0.0	20.0	0.0	2.0	2.0	2.0	2.0	2.5	2.5	2.8	2.8	2.8	2.8
	Mixed Arid	380.0	0.1	3.9	0.0	0.0	0.0	45.1	34.9	0.0	0.0	20.0	0.0	1.7	1.7	1.7	1.7	1.7	1.7	1.9	1.9	1.9	1.9
	Mixed Humid	380.0	0.1	3.9	0.0	0.0	0.0	60.0	20.0	0.0	0.0	20.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8	2.0	2.0	2.0	2.0
	Mixed Temperate	380.0	0.1	3.9	0.0	0.0	58.7	1.3	20.0	0.0	0.0	20.0	0.0	2.2	2.2	2.2	2.2	3.0	3.0	3.4	3.4	3.4	3.4
LAC	GRASSland based Arid	380.0	0.1	3.9	0.0	0.0	30.2	13.7	56.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	1.0	1.0	1.4	1.4	1.4	1.4
	GRASSland based Humid	380.0	0.1	3.9	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
	GRASSland based Temperate	380.0	0.1	3.9	0.0	0.0	67.0	0.0	33.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	380.0	0.1	3.9	0.0	0.0	0.0	26.0	74.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	380.0	0.1	3.9	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7
	Mixed Temperate	380.0	0.1	3.9	0.0	0.0	66.2	0.6	33.2	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4

[a] Average buffalo mass for each region

[b] Average VS production per head per day for the average buffalo

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: The detailed information for buffalo are developed in Gibbs and Johnson (1993),and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-8 Manure Management Methane Emission Factor Derivation for Market-industrial Swine

Table 10A-8(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Market-industrial Swine

Annual Average Temperature(℃)		Manure Management System MCFs: Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	3.0%	17.0%	0.1%	10.0%	0.35%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	3.0%	19.0%	0.1%	10.0%	0.35%
	Boreal Moist	70%	14%	2.0%	1.0%	3.0%	20.0%	0.1%	10.0%	0.35%
	Boreal Dry	71%	14%	2.0%	1.0%	3.0%	22.0%	0.1%	10.0%	0.35%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	3.0%	25.0%	0.1%	10.0%	0.35%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	3.0%	32.0%	0.1%	10.0%	0.35%
Warm	Tropical	74%	59%	5.0%	1.5%	3.0%	27.0%	0.5%	10.0%	0.58%
	Tropical Wet	77%	76%	5.0%	1.5%	3.0%	35.0%	0.5%	10.0%	0.58%
	Tropical Moist	75%	73%	5.0%	1.5%	3.0%	29.0%	0.5%	10.0%	0.58%
	Tropical Dry	77%	74%	5.0%	1.5%	3.0%	39.0%	0.5%	10.0%	0.58%

Region	Market-industrial Swine Characterictics: Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day	Manure Management System Usage (MS%): Lagoon	Liquid /Slurry	Solid storage	Drylot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
NA	46	0.48	0.27	28.0	31.0	4.0	3.0	0.0	34.0	0.0	0.0	0.0
RUS	50	0.45	0.3	0.0	24.0	76.0	0.0	0.0	0.0	0.0	0.0	0.0
WE	50	0.45	0.3	6.0	52.0	14.0	0.0	2.0	25.0	1.0	0.0	0.0
EE	50	0.45	0.3	6.0	36.0	53.0	1.0	2.0	2.0	0.0	0.0	0.0
NENA	28	0.29	0.3	10.0	29.0	0.0	54.0	0.0	0.0	0.0	7.0	0.0
ESEA	28	0.29	0.3	38.0	22.0	1.0	2.0	30.0	0.0	0.0	7.0	0.0
OCE	45	0.45	0.28	92.0	0.0	1.0	7.0	0.0	0.0	0.0	0.0	0.0
SA	28	0.29	0.3	12.0	28.0	5.0	46.0	1.0	0.0	3.0	7.0	0.0
LAC	28	0.29	0.3	11.0	34.0	12.0	41.0	0.0	0.0	2.0	0.0	0.0
SSA	28	0.29	0.3	0.0	9.0	6.0	84.0	1.0	0.0	0.0	0.0	0.0

Emission factors, g CH_4/ kg VS

Region	Cool: Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Temperate: Warm Temperate Moist	Warm Temperate Dry	Warm: Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	99.3	108	99.2	102.3	131	145	156	184	173	187
RUS	19.8	23.4	14.7	14.7	35.9	38.8	54.1	66.5	64.3	65.0
WE	58.7	68.4	50.7	52.4	91.9	104	129	162	152	162
EE	39.2	45.1	32.5	32.8	61.5	66.8	87.3	107	103	105
NENA	27.1	30.3	23.9	24.1	37.4	40.3	50.6	60.7	58.6	59.6
ESEA	60.9	64.5	60.9	61.6	72.9	76.9	83.1	92.6	89.8	91.7
OCE	183	189	194.4	197.2	203	211	206	214	209	214
SA	29.3	32.5	26.5	26.7	39.9	42.7	52.6	62.6	60.5	61.5
LAC	29.2	33.0	25.5	25.7	41.8	45.1	57.2	69.0	66.6	67.7
SSA	5.6	6.5	4.4	4.4	8.6	9.3	13.4	16.4	15.9	16.0

[a] Average market swine mass for each region (default estimates are ±20%)

[b] B_o estimates are ±15%

[c] Average VS production per head per day for the average market swine (default estimates are ±25%)

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: For North America, mass, VS, and B_o values are from Safley (2000), USDA's Agricultural Waste Management Field Handbook, and Hashimoto (1984), respectively. North American manure management system usage data are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. For Western and Eastern Europe manure management system usage, mass of animals, B_o and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, swine feed intake data are from Crutzen et. al (1986), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-9 Manure Management Methane Emission Factor Derivation for Breeding-industrial Swine

Table 10A-9(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)
Manure Management Methane Emission Factor Derivation for Breeding-industrial Swine

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	3.0%	17.0%	0.1%	10.0%	0.35%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	3.0%	19.0%	0.1%	10.0%	0.35%
	Boreal Moist	70%	14%	2.0%	1.0%	3.0%	20.0%	0.1%	10.0%	0.35%
	Boreal Dry	71%	14%	2.0%	1.0%	3.0%	22.0%	0.1%	10.0%	0.35%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	3.0%	25.0%	0.1%	10.0%	0.35%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	3.0%	32.0%	0.1%	10.0%	0.35%
Warm	Tropical	74%	59%	5.0%	1.5%	3.0%	27.0%	0.5%	10.0%	0.58%
	Tropical Wet	77%	76%	5.0%	1.5%	3.0%	35.0%	0.5%	10.0%	0.58%
	Tropical Moist	75%	73%	5.0%	1.5%	3.0%	29.0%	0.5%	10.0%	0.58%
	Tropical Dry	77%	74%	5.0%	1.5%	3.0%	39.0%	0.5%	10.0%	0.58%

Region	Breeding-industrial Swine Characterictics			Manure Management System Usage (MS%)								
	Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day	Lagoon	Liquid /Slurry	Solid storage	Drylot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
NA	198	0.48	0.5	28.0	31.0	4.0	3.0	0.0	34.0	0.0	0.0	0.0
RUS	180	0.45	0.5	0.0	24.0	76.0	0.0	0.0	0.0	0.0	0.0	0.0
WE	198	0.45	0.46	6.0	52.0	14.0	0.0	2.0	25.0	1.0	0.0	0.0
EE	180	0.45	0.5	6.0	36.0	53.0	1.0	2.0	2.0	0.0	0.0	0.0
NENA	28	0.29	0.3	10.0	29.0	0.0	54.0	0.0	0.0	0.0	7.0	0.0
ESEA	28	0.29	0.3	38.0	22.0	1.0	2.0	30.0	0.0	0.0	7.0	0.0
OCE	180	0.45	0.5	92.0	0.0	1.0	7.0	0.0	0.0	0.0	0.0	0.0
SA	28	0.29	0.3	12.0	28.0	5.0	46.0	1.0	0.0	3.0	7.0	0.0
LAC	28	0.29	0.3	11.0	34.0	12.0	41.0	0.0	0.0	2.0	0.0	0.0
SSA	28	0.29	0.3	0.0	9.0	6.0	84.0	1.0	0.0	0.0	0.0	0.0

Region	Emission factors, g CH_4/ kg VS									
	Cool				Temperate		Warm			
	Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	99.3	108.3	99.2	102.3	130.6	144.9	155.8	184.2	172.8	186.5
RUS	19.8	23.4	14.7	14.7	35.9	38.8	54.1	66.5	64.3	65.0
WE	58.7	68.4	50.7	52.4	91.9	104.0	128.5	161.8	152.2	161.6
EE	39.2	45.1	32.5	32.8	61.5	66.8	87.3	106.7	102.8	104.8
NENA	27.1	30.3	23.9	24.1	37.4	40.3	50.6	60.7	58.6	59.6
ESEA	60.9	64.5	60.9	61.6	72.9	76.9	83.1	92.6	89.8	91.7
OCE	183.3	188.9	194.4	197.2	202.8	211.1	205.7	214.0	208.5	214.0
SA	29.3	32.5	26.5	26.7	39.9	42.7	52.6	62.6	60.5	61.5
LAC	29.2	33.0	25.5	25.7	41.8	45.1	57.2	69.0	66.6	67.7
SSA	5.6	6.5	4.4	4.4	8.6	9.3	13.4	16.4	15.9	16.0

[a] Average breed swine mass for each region (default estimates are ±20%)
[b] B_o estimates are ±15%
[c] Average VS production per head per day for the average market swine (default estimates are ±25%)
Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)
Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: For North America, mass, VS, and B_o values are from Safley (2000), USDA's Agricultural Waste Management Field Handbook, and Hashimoto (1984), respectively. North American manure management system usage data are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. For Western and Eastern Europe manure management system usage, mass of animals, B_o and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, swine feed intake data are from Crutzen et. al (1986), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-10 Manure Management Methane Emission Factor Derivation for Market-intermediate Swine

Table 10A-10(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Market-intermediate Swine

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	3.0%	17.0%	0.1%	10.0%	0.35%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	3.0%	19.0%	0.1%	10.0%	0.35%
	Boreal Moist	70%	14%	2.0%	1.0%	3.0%	20.0%	0.1%	10.0%	0.35%
	Boreal Dry	71%	14%	2.0%	1.0%	3.0%	22.0%	0.1%	10.0%	0.35%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	3.0%	25.0%	0.1%	10.0%	0.35%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	3.0%	32.0%	0.1%	10.0%	0.35%
Warm	Tropical	74%	59%	5.0%	1.5%	3.0%	27.0%	0.5%	10.0%	0.58%
	Tropical Wet	77%	76%	5.0%	1.5%	3.0%	35.0%	0.5%	10.0%	0.58%
	Tropical Moist	75%	73%	5.0%	1.5%	3.0%	29.0%	0.5%	10.0%	0.58%
	Tropical Dry	77%	74%	5.0%	1.5%	3.0%	39.0%	0.5%	10.0%	0.58%

Region	Market-intermediate Swine Characterictics			Manure Management System Usage (MS%)								
	Mass[a] kg	Bo[b] m³ CH_4/kg VS	VS[c] kg/hd/day									
NA	46	0.48	0.27	-	-	-	-	-	-	-	-	-
RUS	50	0.45	0.3	0.0	12.0	76.0	0.0	0.0	0.0	0.0	12.0	0.0
WE	50	0.45	0.3	11.0	3.0	35.0	0.0	19.0	29.0	0.0	3.0	0
EE	50	0.45	0.3	5.0	11.0	59.0	1.0	7.0	7.0	0.0	10.0	0
NENA	28	0.29	0.3	10.0	15.0	0.0	53.0	0.0	0.0	0.0	15.0	7
ESEA	28	0.29	0.3	31.0	10.0	1.0	2.0	38.0	0.0	1.0	10.0	7
OCE	45	0.45	0.28	82.0	0.0	3.0	15.0	0.0	0.0	0.0	0.0	0.0
SA	28	0.29	0.3	12.0	11.0	16.0	30.0	3.0	0.0	9.0	11.0	8
LAC	28	0.29	0.3	12.0	16.0	13.0	41.0	0.0	0.0	2.0	16.0	0
SSA	28	0.29	0.3	0.0	3.0	6.0	87.0	1.0	0.0	0.0	3.0	0

Region	Emission factors, g CH_4/ kg VS									
	Cool				Temperate		Warm			
	Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	-	-	-	-	-	-	-	-	-	-
RUS	15.8	17.6	13.3	13.3	26.2	27.6	36.4	42.6	41.5	41.8
WE	43.4	46.3	46.7	48.8	56.3	63.7	61.4	70.9	64.7	74.2
EE	27.7	30.1	26.7	27.2	39.3	42.6	49.0	56.8	54.2	57.0
NENA	22.9	24.8	21.7	21.9	29.0	30.7	36.1	41.6	40.4	41.1
ESEA	48.1	50.3	49.2	49.8	55.5	58.1	60.4	65.5	63.8	65.2
OCE	163.8	168.7	173.7	176.2	181.3	188.7	184.1	191.5	186.6	191.5
SA	23.5	25.0	22.9	23.1	29.1	30.7	34.8	39.1	38.0	38.7
LAC	26.3	28.4	25.1	25.3	33.4	35.4	41.2	47.2	45.8	46.5
SSA	3.8	4.1	3.4	3.4	5.0	5.2	7.2	8.2	8.0	8.1

[a] Average market swine mass for each region (default estimates are ±20%)

[b] B_o estimates are ±15%

[c] Average VS production per head per day for the average market swine (default estimates are ±25%)

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: For North America, mass, VS, and B_o values are from Safley (2000), USDA's Agricultural Waste Management Field Handbook, and Hashimoto (1984), respectively. North American manure management system usage data are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. For Western and Eastern Europe manure management system usage, mass of animals, B_o and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, swine feed intake data are from Crutzen et. al (1986), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-11 Manure Management Methane Emission Factor Derivation for Breeding-intermediate Swine

Table 10A-11(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Breeding-intermediate Swine

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	3.0%	17.0%	0.1%	10.0%	0.35%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	3.0%	19.0%	0.1%	10.0%	0.35%
	Boreal Moist	70%	14%	2.0%	1.0%	3.0%	20.0%	0.1%	10.0%	0.35%
	Boreal Dry	71%	14%	2.0%	1.0%	3.0%	22.0%	0.1%	10.0%	0.35%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	3.0%	25.0%	0.1%	10.0%	0.35%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	3.0%	32.0%	0.1%	10.0%	0.35%
Warm	Tropical	74%	59%	5.0%	1.5%	3.0%	27.0%	0.5%	10.0%	0.58%
	Tropical Wet	77%	76%	5.0%	1.5%	3.0%	35.0%	0.5%	10.0%	0.58%
	Tropical Moist	75%	73%	5.0%	1.5%	3.0%	29.0%	0.5%	10.0%	0.58%
	Tropical Dry	77%	74%	5.0%	1.5%	3.0%	39.0%	0.5%	10.0%	0.58%

Region	Breeding-intermediate Swine Characterictics			Manure Management System Usage (MS%)								
	Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day									
NA	198	0.48	0.5	-	-	-	-	-	-	-	-	-
RUS	180	0.45	0.5	0.0	12.0	76.0	0.0	0.0	0.0	0.0	12.0	0.0
WE	198	0.45	0.46	11.0	3.0	35.0	0.0	19.0	29.0	0.0	3.0	0
EE	180	0.45	0.5	5.0	11.0	59.0	1.0	7.0	7.0	0.0	10.0	0
NENA	28	0.29	0.3	10.0	15.0	0.0	53.0	0.0	0.0	0.0	15.0	7
ESEA	28	0.29	0.3	31.0	10.0	1.0	2.0	38.0	0.0	1.0	10.0	7
OCE	180	0.45	0.5	82.0	0.0	3.0	15.0	0.0	0.0	0.0	0.0	0.0
SA	28	0.29	0.3	12.0	11.0	16.0	30.0	3.0	0.0	9.0	11.0	8
LAC	28	0.29	0.3	12.0	16.0	13.0	41.0	0.0	0.0	2.0	16.0	0
SSA	28	0.29	0.3	0.0	3.0	6.0	87.0	1.0	0.0	0.0	3.0	0

Emission factors, g CH_4/ kg VS									
Cool				Temperate		Warm			
Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
-	-	-	-	-	-	-	-	-	-
15.8	17.6	13.3	13.3	26.2	27.6	36.4	42.6	41.5	41.8
43.4	46.3	46.7	48.8	56.3	63.7	61.4	70.9	64.7	74.2
27.7	30.1	26.7	27.2	39.3	42.6	49.0	56.8	54.2	57.0
22.9	24.8	21.7	21.9	29.0	30.7	36.1	41.6	40.4	41.1
48.1	50.3	49.2	49.8	55.5	58.1	60.4	65.5	63.8	65.2
163.8	168.7	173.7	176.2	181.3	188.7	184.1	191.5	186.6	191.5
23.5	25.0	22.9	23.1	29.1	30.7	34.8	39.1	38.0	38.7
26.3	28.4	25.1	25.3	33.4	35.4	41.2	47.2	45.8	46.5
3.8	4.1	3.4	3.4	5.0	5.2	7.2	8.2	8.0	8.1

[a] Average breed swine mass for each region (default estimates are ±20%)

[b] B_o estimates are ±15%

[c] Average VS production per head per day for the average market swine (default estimates are ±25%)

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: For North America, mass, VS, and B_o values are from Safley (2000), USDA's Agricultural Waste Management Field Handbook, and Hashimoto (1984), respectively. North American manure management system usage data are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. For Western and Eastern Europe manure management system usage, mass of animals, B_o and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, swine feed intake data are from Crutzen et. al (1986), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-12 Manure Management Methane Emission Factor Derivation for Market-backyard Swine

Table 10A-12(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Market-backyard Swine

Annual Average Temperature(℃)		Manure Management System MCFs: Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	3.0%	17.0%	0.1%	10.0%	0.35%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	3.0%	19.0%	0.1%	10.0%	0.35%
	Boreal Moist	70%	14%	2.0%	1.0%	3.0%	20.0%	0.1%	10.0%	0.35%
	Boreal Dry	71%	14%	2.0%	1.0%	3.0%	22.0%	0.1%	10.0%	0.35%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	3.0%	25.0%	0.1%	10.0%	0.35%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	3.0%	32.0%	0.1%	10.0%	0.35%
Warm	Tropical	74%	59%	5.0%	1.5%	3.0%	27.0%	0.5%	10.0%	0.58%
	Tropical Wet	77%	76%	5.0%	1.5%	3.0%	35.0%	0.5%	10.0%	0.58%
	Tropical Moist	75%	73%	5.0%	1.5%	3.0%	29.0%	0.5%	10.0%	0.58%
	Tropical Dry	77%	74%	5.0%	1.5%	3.0%	39.0%	0.5%	10.0%	0.58%

Region	Market-backyard Swine Characterictics: Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day	Manure Management System Usage (MS%)								
NA	46	0.48	0.27	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
RUS	50	0.45	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
WE	50	0.45	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
EE	50	0.45	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
NENA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
ESEA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
OCE	45	0.45	0.28	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
SA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
LAC	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0
SSA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0

Region	Emission factors, g CH_4/ kg VS: Cool				Temperate		Warm			
	Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	38.2	43.6	32.6	33.0	57.0	62.5	79.5	97.7	93.5	96.4
RUS	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
WE	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
EE	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
NENA	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
ESEA	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
OCE	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
SA	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
LAC	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
SSA	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2

[a] Average market swine mass for each region (default estimates are ±20%)

[b] B_o estimates are ±15%

[c] Average VS production per head per day for the average market swine (default estimates are ±25%)

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: For North America, mass, VS, and B_o values are from Safley (2000), USDA's Agricultural Waste Management Field Handbook, and Hashimoto (1984), respectively. North American manure management system usage data are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. For Western and Eastern Europe manure management system usage, mass of animals, B_o and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, swine feed intake data are from Crutzen et. al (1986), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-13 Manure Management Methane Emission Factor Derivation for Breeding-backyard Swine

Table 10A-13(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)
Manure Management Methane Emission Factor Derivation for Breeding-backyard Swine

Annual Average Temperature(℃)		Manure Management System MCFs: Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Dry lot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/ Range/ Paddock
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	3.0%	17.0%	0.1%	10.0%	0.35%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	3.0%	19.0%	0.1%	10.0%	0.35%
	Boreal Moist	70%	14%	2.0%	1.0%	3.0%	20.0%	0.1%	10.0%	0.35%
	Boreal Dry	71%	14%	2.0%	1.0%	3.0%	22.0%	0.1%	10.0%	0.35%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	3.0%	25.0%	0.1%	10.0%	0.35%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	3.0%	32.0%	0.1%	10.0%	0.35%
Warm	Tropical	74%	59%	5.0%	1.5%	3.0%	27.0%	0.5%	10.0%	0.58%
	Tropical Wet	77%	76%	5.0%	1.5%	3.0%	35.0%	0.5%	10.0%	0.58%
	Tropical Moist	75%	73%	5.0%	1.5%	3.0%	29.0%	0.5%	10.0%	0.58%
	Tropical Dry	77%	74%	5.0%	1.5%	3.0%	39.0%	0.5%	10.0%	0.58%

Region	Breeding-backyard Swine Characterictics: Mass[a] kg	Bo[b] m^3 CH_4/kg VS	VS[c] kg/hd/day	Manure Management System Usage (MS%): Lagoon	Liquid/Slurry	Solid storage	Dry lot	Pit <1 month	Pit >1 month	Daily spread	Digester	Pasture/Range/Paddock	Emission factors, g CH_4/ kg VS: Cool: Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Temperate: Warm Temperate Moist	Warm Temperate Dry	Warm: Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	198	0.48	0.5	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	38.2	43.6	32.6	33.0	57.0	62.5	79.5	97.7	93.5	96.4
RUS	180	0.45	0.5	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
WE	198	0.45	0.46	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
EE	180	0.45	0.5	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
NENA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
ESEA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
OCE	180	0.45	0.5	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	35.8	40.9	30.5	31.0	53.4	58.6	74.6	91.6	87.7	90.4
SA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
LAC	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2
SSA	28	0.29	0.3	5.0	30.0	15.0	15.0	15.0	5.0	5.0	5.0	5.0	23.1	26.4	19.7	20.0	34.4	37.7	48.0	59.0	56.5	58.2

[a] Average breed swine mass for each region (default estimates are ±20%)
[b] B_o estimates are ±15%
[c] Average VS production per head per day for the average market swine (default estimates are ±25%)
Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)
Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2]Storage period is 6 months.

Sources: For North America, mass, VS, and B_o values are from Safley (2000), USDA's Agricultural Waste Management Field Handbook, and Hashimoto (1984), respectively. North American manure management system usage data are estimated using data from the 1992 and 1997 USDA's Census of Agriculture and National Animal Health Monitoring System Reports. For Western and Eastern Europe manure management system usage, mass of animals, B_o and VS values based on the analysis of national GHG inventories of Annex I countires submitted to the secretariat UNFCCC in 2004. For the rest of the world, swine feed intake data are from Crutzen et. al (1986), and manure management system usage and B_o estimates are from Safley et. al (1992). Methane conversion factor data are from Woodbury and Hashimoto (1993). MCFs for lagoons and liquid/slurry systems are based on data obtained from an analysis of these systems in the United States.

Table 10A-14 Manure Management Methane Emission Factor Derivation for Meat Sheep

Table 10A-14(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Meat Sheep

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Daily spread	Digester	Burned for fuel	Other
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%

Region		Meat Sheep Characterictics			Manure Management System Usage (MS%)								
		Mass kg	Bo m^3 CH_4/kg VS	VS kg/hd/day									
NA	GRASSland based Arid	48.5	0.19	0.4	0.0	0.0	53.0	0.0	47.0	0.0	0.0	0.0	0.0
	GRASSland based Humid	48.5	0.19	0.4	0.0	0.0	55.0	0.0	45.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	48.5	0.19	0.4	0.0	0.0	52.1	0.0	47.9	0.0	0.0	0.0	0.0
	Mixed Arid	48.5	0.19	0.4	0.0	0.0	55.0	0.0	45.0	0.0	0.0	0.0	0.0
	Mixed Humid	48.5	0.19	0.4	0.0	0.0	55.0	0.0	45.0	0.0	0.0	0.0	0.0
	Mixed Temperate	48.5	0.19	0.4	0.0	0.0	53.8	0.0	46.2	0.0	0.0	0.0	0.0
RUS	GRASSland based Arid	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	Mixed Arid	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	Mixed Temperate	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
WE	GRASSland based Arid	48.5	0.19	0.4	0.0	0.0	15.4	0.0	84.6	0.0	0.0	0.0	0.0
	GRASSland based Humid	48.5	0.19	0.4	0.0	0.0	8.9	0.0	91.1	0.0	0.0	0.0	0.0
	GRASSland based Temperate	48.5	0.19	0.4	0.0	0.4	12.4	0.0	87.2	0.0	0.0	0.0	0.0
	Mixed Arid	48.5	0.19	0.4	0.0	0.0	17.7	0.0	82.3	0.0	0.0	0.0	0.0
	Mixed Humid	48.5	0.19	0.4	0.0	0.0	10.4	0.0	89.6	0.0	0.0	0.0	0.0
	Mixed Temperate	48.5	0.19	0.4	0.0	0.0	14.1	0.0	85.8	0.0	0.0	0.0	0.0
EE	GRASSland based Arid	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	57.0	0.0	43.0	0.0	0.0	0.0	0.0
	Mixed Arid	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0
	Mixed Temperate	28	0.13	0.32	0.0	0.0	59.1	0.0	40.9	0.0	0.0	0.0	0.0

Region		Emission factors, g CH_4/ kg VS									
		Cool				Temperate		Warm			
		Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	GRASSland based Arid	1.6	1.6	1.6	1.6	2.9	2.9	3.7	3.7	3.7	3.7
	GRASSland based Humid	1.6	1.6	1.6	1.6	3.0	3.0	3.8	3.8	3.8	3.8
	GRASSland based Temperate	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	Mixed Arid	1.6	1.6	1.6	1.6	3.0	3.0	3.8	3.8	3.8	3.8
	Mixed Humid	1.6	1.6	1.6	1.6	3.0	3.0	3.8	3.8	3.8	3.8
	Mixed Temperate	1.6	1.6	1.6	1.6	2.9	2.9	3.8	3.8	3.8	3.8
RUS	GRASSland based Arid	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	GRASSland based Humid	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	GRASSland based Temperate	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	Mixed Arid	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	Mixed Temperate	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
WE	GRASSland based Arid	0.8	0.8	0.8	0.8	1.2	1.2	1.6	1.6	1.6	1.6
	GRASSland based Humid	0.6	0.6	0.6	0.6	0.9	0.9	1.2	1.2	1.2	1.2
	GRASSland based Temperate	0.8	0.8	0.8	0.8	1.2	1.2	1.7	1.8	1.8	1.8
	Mixed Arid	0.8	0.8	0.8	0.8	1.3	1.3	1.7	1.7	1.7	1.7
	Mixed Humid	0.7	0.7	0.7	0.7	0.9	0.9	1.3	1.3	1.3	1.3
	Mixed Temperate	0.7	0.7	0.7	0.7	1.1	1.1	1.5	1.5	1.5	1.5
EE	GRASSland based Arid	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	GRASSland based Temperate	1.1	1.1	1.1	1.1	2.1	2.1	2.7	2.7	2.7	2.7
	Mixed Arid	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Temperate	1.2	1.2	1.2	1.2	2.2	2.2	2.8	2.8	2.8	2.8

NENA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Temperate	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
ESEA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.1	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
OCE	GRASSland based Arid	48.5	0.19	0.4	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	GRASSland based Humid	48.5	0.19	0.4	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	GRASSland based Temperate	48.5	0.19	0.4	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Arid	48.5	0.19	0.4	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Humid	48.5	0.19	0.4	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Temperate	48.5	0.19	0.4	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
SA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
LAC	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
SSA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)
Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]
[2]Storage period is 6 months.

Emission factors, except for poultry, were developed from feed intake values and feed digestibilities used to develop the enteric fermentation emission factors (see Appendix 10A.1). MCFs and B_o values are reported in Woodbury and Hashimoto (1993). All manure except for Layers (wet) is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993). Poultry for developed countries was subdivided into five categories. Layers (dry) represent layers in a "without bedding" waste management system; Layers (wet) represent layers in an anaerobic lagoon waste managemnet system. Estimates of animal mass are ±30%, VS values are ±50% and B_o values are ±15%

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Table 10A-15 Manure Management Methane Emission Factor Derivation for Dairy Sheep

Table 10A-15(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Dairy Sheep

Annual Average Temperature(℃)		Manure Management System MCFs: Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Daily spread	Digester	Burned for fuel	Other
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%

Region		Dairy Sheep Characterictics: Mass kg	Bo m^3 CH_4/kg VS	VS kg/hd/day	Manure Management System Usage (MS%)								
RUS	GRASSland based Arid	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	Mixed Arid	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
	Mixed Temperate	28	0.13	0.32	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0
WE	GRASSland based Arid	48.5	0.19	0.4	0.0	0.0	20.6	0.0	79.3	0.0	0.0	0.0	0.0
	GRASSland based Humid	48.5	0.19	0.4	0.0	0.0	21.0	0.0	79.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	48.5	0.19	0.4	0.0	0.0	21.2	0.0	78.5	0.0	0.0	0.0	0.0
	Mixed Arid	48.5	0.19	0.4	0.0	0.0	19.1	0.0	80.9	0.0	0.0	0.0	0.0
	Mixed Humid	48.5	0.19	0.4	0.0	0.0	22.5	0.0	77.2	0.0	0.0	0.0	0.0
	Mixed Temperate	48.5	0.19	0.4	0.0	0.0	23.7	0.0	75.9	0.0	0.0	0.0	0.0
EE	GRASSland based Arid	28	0.13	0.32	0.0	0.0	53.8	0.0	46.2	0.0	0.0	0.0	0.0
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	30.3	0.0	69.7	0.0	0.0	0.0	0.0
	Mixed Arid	28	0.13	0.32	0.0	0.0	54.0	0.0	46.0	0.0	0.0	0.0	0.0
	Mixed Temperate	28	0.13	0.32	0.0	0.0	30.3	0.0	69.7	0.0	0.0	0.0	0.0
NENA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0
	Mixed Temperate	28	0.13	0.32	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0

Region		Emission factors, g CH_4/ kg VS: Cool: Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Temperate: Warm Temperate Moist	Warm Temperate Dry	Warm: Tropical	Tropical Wet	Tropical Moist	Tropical Dry
RUS	GRASSland based Arid	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	GRASSland based Humid	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	GRASSland based Temperate	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	Mixed Arid	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	Mixed Temperate	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
WE	GRASSland based Arid	0.9	0.9	0.9	0.9	1.4	1.4	1.9	1.9	1.9	1.9
	GRASSland based Humid	0.9	0.9	0.9	0.9	1.4	1.4	1.9	1.9	1.9	1.9
	GRASSland based Temperate	0.9	0.9	0.9	0.9	1.4	1.4	1.9	1.9	1.9	1.9
	Mixed Arid	0.8	0.8	0.8	0.8	1.3	1.3	1.8	1.8	1.8	1.8
	Mixed Humid	0.9	0.9	0.9	0.9	1.5	1.5	2.0	2.0	2.0	2.0
	Mixed Temperate	0.9	0.9	0.9	0.9	1.5	1.5	2.1	2.1	2.1	2.1
EE	GRASSland based Arid	1.1	1.1	1.1	1.1	2.0	2.0	2.6	2.6	2.6	2.6
	GRASSland based Temperate	0.7	0.7	0.7	0.7	1.3	1.3	1.7	1.7	1.7	1.7
	Mixed Arid	1.1	1.1	1.1	1.1	2.0	2.0	2.6	2.6	2.6	2.6
	Mixed Temperate	0.7	0.7	0.7	0.7	1.3	1.3	1.7	1.7	1.7	1.7
NENA	GRASSland based Arid	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Humid	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Temperate	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Arid	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Humid	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Temperate	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9

ESEA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
SA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
LAC	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
SSA	GRASSland based Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	28	0.13	0.32	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	28	0.13	0.32	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)
Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]
[2] Storage period is 6 months.

Emission factors, except for poultry, were developed from feed intake values and feed digestibilities used to develop the enteric fermentation emission factors (see Appendix 10A.1). MCFs and B_o values are reported in Woodbury and Hashimoto (1993). All manure except for Layers (wet) is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993). Poultry for developed countries was subdivided into five categories. Layers (dry) represent layers in a "without bedding" waste management system; Layers (wet) represent layers in an anaerobic lagoon waste managemnet system. Estimates of animal mass are ±30%, VS values are ±50% and B_o values are ±15%

Table 10A-16 Manure Management Methane Emission Factor Derivation for Goat

Table 10A-16(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Goat

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Daily spread	Digester	Burned for fuel	Other
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	0.1%	10.0%	10.0%	1.0%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	0.5%	10.0%	10.0%	1.0%

Region		Goat Characterictics			Manure Management System Usage (MS%)									Emission factors, g CH_4/ kg VS									
														Cool				Temperate		Warm			
		Mass kg	Bo m[3] CH_4/kg VS	VS kg/hd/day										Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	GRASSland based Arid	38.5	0.18	0.3	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	2.6	2.6	3.4	3.4	3.4	3.4
	GRASSland based Humid	38.5	0.18	0.3	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	2.6	2.6	3.4	3.4	3.4	3.4
	GRASSland based Temperate	38.5	0.18	0.3	0.0	0.0	49.8	0.0	50.2	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	2.6	2.6	3.4	3.4	3.4	3.4
	Mixed Arid	38.5	0.18	0.3	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	2.6	2.6	3.4	3.4	3.4	3.4
	Mixed Humid	38.5	0.18	0.3	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	2.6	2.6	3.4	3.4	3.4	3.4
	Mixed Temperate	38.5	0.18	0.3	0.0	0.0	49.8	0.0	50.2	0.0	0.0	0.0	0.0	1.4	1.4	1.4	1.4	2.6	2.6	3.4	3.4	3.4	3.4
RUS	GRASSland based Arid	30	0.13	0.35	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	GRASSland based Humid	30	0.13	0.35	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	GRASSland based Temperate	30	0.13	0.35	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	Mixed Arid	30	0.13	0.35	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
	Mixed Temperate	30	0.13	0.35	0.0	0.0	82.0	0.0	18.0	0.0	0.0	0.0	0.0	1.5	1.5	1.5	1.5	2.9	2.9	3.7	3.7	3.7	3.7
WE	GRASSland based Arid	38.5	0.18	0.3	0.0	0.0	24.9	0.0	75.1	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.9	1.5	1.5	2.0	2.0	2.0	2.0
	GRASSland based Humid	38.5	0.18	0.3	0.0	0.0	22.0	0.0	78.0	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.9	1.4	1.4	1.9	1.9	1.9	1.9
	GRASSland based Temperate	38.5	0.18	0.3	0.0	0.1	35.7	0.0	64.3	0.0	0.0	0.0	0.0	1.1	1.2	1.1	1.1	2.0	2.0	2.6	2.7	2.7	2.7
	Mixed Arid	38.5	0.18	0.3	0.0	0.0	27.0	0.0	73.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.6	1.6	2.1	2.1	2.1	2.1
	Mixed Humid	38.5	0.18	0.3	0.0	0.0	22.6	0.0	77.4	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.9	1.4	1.4	1.9	1.9	1.9	1.9
	Mixed Temperate	38.5	0.18	0.3	0.0	0.0	36.0	0.0	64.0	0.0	0.0	0.0	0.0	1.1	1.1	1.1	1.1	2.0	2.0	2.6	2.6	2.6	2.6
EE	GRASSland based Arid	30	0.13	0.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	GRASSland based Temperate	30	0.13	0.35	0.0	0.0	8.7	0.0	91.3	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.6	0.6	0.8	0.8	0.8	0.8
	Mixed Arid	30	0.13	0.35	0.0	0.0	8.0	0.0	92.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.6	0.6	0.8	0.8	0.8	0.8
	Mixed Temperate	30	0.13	0.35	0.0	0.0	10.0	0.0	90.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.6	0.6	0.9	0.9	0.9	0.9
NENA	GRASSland based Arid	30	0.13	0.35	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Humid	30	0.13	0.35	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	GRASSland based Temperate	30	0.13	0.35	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Arid	30	0.13	0.35	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Humid	30	0.13	0.35	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9
	Mixed Temperate	30	0.13	0.35	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.9	0.9

ESEA	GRASSland based Arid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	GRASSland based Humid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	GRASSland based Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Humid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
OCE	GRASSland based Arid	38.5	0.18	0.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	GRASSland based Humid	38.5	0.18	0.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	GRASSland based Temperate	38.5	0.18	0.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Arid	38.5	0.18	0.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Humid	38.5	0.18	0.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
	Mixed Temperate	38.5	0.18	0.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7
SA	GRASSland based Arid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	GRASSland based Humid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	GRASSland based Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Humid	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
LAC	GRASSland based Arid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
SSA	GRASSland based Arid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Humid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	GRASSland based Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4
	Mixed Arid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Humid	30	0.13	0.35	0.0	0.0	0.0	5.0	95.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
	Mixed Temperate	30	0.13	0.35	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.9	1.9	2.4	2.4	2.4	2.4

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)
Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]
[2] Storage period is 6 months.

Emission factors, except for poultry, were developed from feed intake values and feed digestibilities used to develop the enteric fermentation emission factors (see Appendix 10A.1). B_o values are reported in Woodbury and Hashimoto (1993). All manure except for Layers (wet) is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993). Poultry for developed countries was subdivided into five categories. Layers (dry) represent layers in a "without bedding" waste management system; Layers (wet) represent layers in an anaerobic lagoon waste managemnet system. Estimates of animal mass are ±30%, VS values are ±50% and B_o values are ±15%

Table 10A-17 Manure Management Methane Emission Factor Derivation for Chicken Layer

Table 10A-17(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Chicken Layer

Annual Average Temperature(℃)		Manure Management System MCFs: Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Pit > 1 month	Daily spread	Digester	Poultry manure with litter
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	17.0%	0.1%	10.0%	1.5%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	19.0%	0.1%	10.0%	1.5%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	20.0%	0.1%	10.0%	1.5%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	22.0%	0.1%	10.0%	1.5%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	25.0%	0.1%	10.0%	1.5%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	32.0%	0.1%	10.0%	1.5%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	27.0%	0.5%	10.0%	1.5%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	35.0%	0.5%	10.0%	1.5%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	29.0%	0.5%	10.0%	1.5%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	39.0%	0.5%	10.0%	1.5%

Region	Layer Characterictics: Mass kg	Bo m³ CH_4/kg VS	VS kg/hd/day	Manure Management System Usage (MS%)								
NA	1.8	0.39	0.02	1.0	29.0	70.0	0.0	0.0	0.0	0.0	0.0	0.0
RUS	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
WE	1.8	0.39	0.02	0.0	1.2	20.3	21.1	0.0	43.1	0.6	0.0	13.6
EE	TBD	0.24	0.02	0.0	0.0	0.0	47.3	0.0	33.7	0.0	0.0	19.0
NENA	TBD	0.24	0.02	10.8	6.5	10.9	0.0	0.0	68.2	0.0	0.0	3.5
ESEA	TBD	0.24	0.02	0.0	4.4	0.0	0.0	1.4	93.1	0.9	0.0	0.0
OCE	1.8	0.39	0.02	0.0	0.0	0.0	0.0	23.0	77.0	0.0	0.0	0.0
SA	TBD	0.24	0.02	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
LAC	TBD	0.24	0.02	0.0	58.5	41.5	0.0	0.0	0.0	0.0	0.0	0.0
SSA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	90.0	0.0	0.0	10.0

Emission factors, g CH_4/ kg VS: Cool: Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Temperate: Warm Temperate Moist	Warm Temperate Dry	Warm: Tropical	Tropical Wet	Tropical Moist	Tropical Dry
21.3	25.1	16.1	16.1	37.3	40.4	55.8	68.7	66.4	67.2
27.3	30.6	32.2	35.4	40.2	51.5	43.4	56.3	46.6	62.7
21.9	24.4	25.1	27.4	32.5	40.5	36.3	45.8	38.9	50.2
10.4	11.5	12.0	13.1	14.8	18.5	16.2	20.5	17.3	22.7
32.8	35.8	36.0	38.4	44.8	53.4	49.6	60.7	53.5	64.9
26.9	30.3	30.9	33.9	40.0	50.8	44.6	57.8	48.6	63.6
34.4	38.4	40.5	44.5	50.5	64.6	54.7	70.8	58.7	78.8
3.2	3.2	3.2	3.2	6.4	6.4	8.0	8.0	8.0	8.0
21.1	25.8	14.5	14.5	37.5	41.2	58.8	74.8	72.0	72.9
24.8	27.7	29.2	32.1	36.4	46.6	39.3	50.9	42.2	56.7

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2] Storage period is 6 months.

Emission factors, except for poultry, were developed from feed intake values and feed digestibilities used to develop the enteric fermentation emission factors (see Appendix 10A.1). MCFs and B_o values are reported in Woodbury and Hashimoto (1993). All manure except for Layers (wet) is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993). Poultry for developed countries was subdivided into five categories. Layers (dry) represent layers in a "without bedding" waste management system; Layers (wet) represent layers in an anaerobic lagoon waste managemnet system. Estimates of animal mass are ±30%, VS values are ±50% and B_o values are ±15%

Table 10A-18 Manure Management Methane Emission Factor Derivation for Broiler

Table 10A-18(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Broiler

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Pit > 1 month	Daily spread	Digester	Poultry manure with litter
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	17.0%	0.1%	10.0%	1.5%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	19.0%	0.1%	10.0%	1.5%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	20.0%	0.1%	10.0%	1.5%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	22.0%	0.1%	10.0%	1.5%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	25.0%	0.1%	10.0%	1.5%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	32.0%	0.1%	10.0%	1.5%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	27.0%	0.5%	10.0%	1.5%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	35.0%	0.5%	10.0%	1.5%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	29.0%	0.5%	10.0%	1.5%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	39.0%	0.5%	10.0%	1.5%

Region	Broiler Charactericties			Manure Management System Usage (MS%)								
	Mass kg	Bo m^3 CH_4/kg VS	VS kg/hd/day									
NA	0.9	0.36	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
RUS	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
WE	0.9	0.36	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
EE	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
NENA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
ESEA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
OCE	0.9	0.36	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
SA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
LAC	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
SSA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

Region	Emission factors, g CH_4/ kg VS									
	Cool				Temperate		Warm			
	Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
RUS	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
WE	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
EE	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
NENA	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
ESEA	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
OCE	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
SA	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
LAC	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
SSA	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)
Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]
[2]Storage period is 6 months.

Emission factors, except for poultry, were developed from feed intake values and feed digestibilities used to develop the enteric fermentation emission factors (see Appendix 10A.1). B_o values are reported in Woodbury and Hashimoto (1993). All manure except for Layers (wet) is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993). Poultry for developed countries was subdivided into five categories. Layers (dry) represent layers in a "without bedding" waste management system; Layers (wet) represent layers in an anaerobic lagoon waste managemnet system. Estimates of animal mass are ±30%, VS values are ±50% and B_o values are ±15%

Table 10A-19 Manure Management Methane Emission Factor Derivation for Backyard Chicken

Table 10A-19(MASS AND VS VALUE WILL BE UPDATED TO CONSISTENCE WITH ENTERIC PART)

Manure Management Methane Emission Factor Derivation for Backyard Chicken

Annual Average Temperature(℃)		Manure Management System MCFs								
		Lagoon[1]	Liquid /Slurry[1,2]	Solid storage	Drylot	Pasture/ Range/ Paddock	Pit > 1 month	Daily spread	Digester	Poultry manure with litter
Cool	Cool Temperate Moist	66%	21%	2.0%	1.0%	0.35%	17.0%	0.1%	10.0%	1.5%
	Cool Temperate Dry	68%	26%	2.0%	1.0%	0.35%	19.0%	0.1%	10.0%	1.5%
	Boreal Moist	70%	14%	2.0%	1.0%	0.35%	20.0%	0.1%	10.0%	1.5%
	Boreal Dry	71%	14%	2.0%	1.0%	0.35%	22.0%	0.1%	10.0%	1.5%
Temperate	Warm Temperate Moist	73%	37%	4.0%	1.0%	0.35%	25.0%	0.1%	10.0%	1.5%
	WarmTemperate Dry	76%	41%	4.0%	1.0%	0.35%	32.0%	0.1%	10.0%	1.5%
Warm	Tropical	74%	59%	5.0%	1.5%	0.58%	27.0%	0.5%	10.0%	1.5%
	Tropical Wet	77%	76%	5.0%	1.5%	0.58%	35.0%	0.5%	10.0%	1.5%
	Tropical Moist	75%	73%	5.0%	1.5%	0.58%	29.0%	0.5%	10.0%	1.5%
	Tropical Dry	77%	74%	5.0%	1.5%	0.58%	39.0%	0.5%	10.0%	1.5%

Region	Backyard Chicken Characterictics			Manure Management System Usage (MS%)								
	Mass kg	Bo m^3 CH_4/kg VS	VS kg/hd/day									
NA	TBD	TBD	TBD	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
RUS	TBD	0.24	0.02	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
WE	TBD	TBD	TBD	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
EE	TBD	0.24	0.02	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
NENA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
ESEA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
OCE	TBD	TBD	TBD	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
SA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
LAC	TBD	0.24	0.02	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0
SSA	TBD	0.24	0.02	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0

Region	Emission factors, g CH_4/ kg VS									
	Cool				Temperate		Warm			
	Cool Temperate Moist	Cool Temperate Dry	Boreal Moist	Boreal Dry	Warm Temperate Moist	Warm Temperate Dry	Tropical	Tropical Wet	Tropical Moist	Tropical Dry
NA	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
RUS	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9
WE	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
EE	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9
NENA	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9
ESEA	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9
OCE	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
SA	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9
LAC	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9
SSA	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9

Regions: NA (North America), RUS (Russian Federation), WE (Western Europe), EE (Eastern Europe), NENA (Near East and North Africa), ESEA (East and Southeast Asia), OCE (Oceania), SA (South Asia), LAC (Latin America and the Caribbean) and SSA (Sub-Saharan Africa)

Emission Factors (EF) for each region are calculated based on eq.10.28.

[1] Lagoon and Liquid/Slurry MCFs are calculated based on the van't Hoff-Arrhenius equation relating temperature to biological activity. Lagoon MCFs are also calculated based on longer (up to a year) retention times. [Mangino, et. al (2001)]

[2] Storage period is 6 months.

Emission factors, except for poultry, were developed from feed intake values and feed digestibilities used to develop the enteric fermentation emission factors (see Appendix 10A.1). MCFs and B_o values are reported in Woodbury and Hashimoto (1993). All manure except for Layers (wet) is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993). Poultry for developed countries was subdivided into five categories. Layers (dry) represent layers in a "without bedding" waste management system; Layers (wet) represent layers in an anaerobic lagoon waste managemnet system. Estimates of animal mass are ±30%, VS values are ±50% and B_o values are ±15%

TABLE 10A-20 (CONTINUED) MANURE MANAGEMENT METHANE EMISSION FACTOR DERIVATION FOR OTHER ANIMALS

Animal	Animal Characteristics			Manure management system MCF	Emission factors ($kg\ CH_4\ head^{-1}\ yr^{-1}$)
	Mass (kg)	VS ($kg\ VS\ day^{-1}$)	Bo ($m^3\ kg\ VS$)		
Deer [a]	NR	NR	NR	NR	0.22
Reindeer [b]	NR	0.39	0.19	2.0%	0.36
Rabbits [c]	1.60	0.10	0.32	1.0%	0.08
Fur-bearing animals [b]	NR	0.14	0.25	8.0%	0.68
Ostrich [b]	NR	1.16	0.25	8.0%	5.67

[a] Sneath (1997) cited in the GHG inventory of United Kingdom.

[b] Estimations of Agricultural University of Norway, Institute of Chemistry and Biotechnology, Section for Microbiology.

[c] Data obtained from GHG inventory of Italy, 2004.

NR = not reported

ANNEX 10A.3 DATA UNDERLYING N_2O DEFAULT EMISSION FACTORS FOR MANURE MANAGEMENT

Table 10A-21 Default Tier 1 EF (EF_{NH3}) for calculation of NH_3 emissions from manure management. Figures are annually averaged emissions in kg AAP^{-1} a^{-1} NH_3, as defined in subsection 3.3.1 of EMEP CORINAI emission inventory guidebook

Revised NFR	Livestock	Manure type	Total EF_{NH3} (kg a^{-1} AAP^{-1} NH_3)	EF_{NH3} (kg a^{-1} AAP^{-1} NH_3) for emissions from housing, storage and yards	EF_{NH3} (kg a^{-1} AAP^{-1} NH_3) for emissions following manure application	EF_{NH3} (kg a^{-1} AAP^{-1} NH_3) for emissions from grazed pastures
				Reported under		
				'Manure management'	'Manure applied to soils' (3Da1)	'Excreta deposited by grazing livestock' (3.D.a.3)
3B1a	Dairy cows	Slurry	39.3	19.2	17.2	2.9
3B1a	Dairy cows	Solid	28.7	16.9	8.8	2.9
3B1b	Other cattle (including young cattle, beef cattle and suckling cows)	Slurry	13.4	6.9	5.7	0.8
3B1b	Other cattle	Solid	9.2	6.2	2.2	0.8
3B2	Sheep	Solid	1.4	0.4	0.2	0.8
3B3	'Swine' — Fattening pigs	Slurry	6.7	4.0	2.7	0.0
3B3	'Swine' — Fattening pigs	Solid	6.5	5.4	1.1	0.0
3B3	'Swine' – Sows	Slurry	15.8	9.0	6.0	0.0
3B3	'Swine' – Sows	Solid	18.2	15.0	3.2	0.0
3B3	'Swine' – Sows	Outdoor	7.3	0.0	0.0	7.3
3B4a	Buffalo	Solid	9.0	4.3	0.7	4.0
3B4d	Goats	Solid	1.4	0.4	0.2	0.8
3B4e	Horses	Solid	14.8	7.0	1.7	6.1
3B4f	Mules and asses	Solid	14.8	7.0	1.7	6.1
3B4gi	Laying hens (laying hens and parents)	Solid	0.48	0.32	0.15	0.0
3B4gi	Laying hens (laying hens and parents)	Slurry	0.48	0.32	0.15	0.0
3B4gii	Broilers (broilers and parents)	Litter	0.22	0.15	0.07	0.0
3B4giii	Turkeys	Litter	0.95	0.56	0.39	0.0
3B4giv	Other poultry (ducks)	Litter	0.68	0.45	0.23	0.0
3B4giv	Other poultry (geese)	Litter	0.35	0.30	0.05	0.0
3B4h	Other livestock (fur animals)		0.02	0.02	0.00	0.0
3B4h	Other livestock (camels)	Solid	10.5			

Source: IPCC, 2006; default grazing periods for cattle were taken from Table 10A 4–8, Chapter 10, 'Emissions from livestock and manure management', and default N excretion data for western Europe were taken from Table 10.19, Chapter 10 (these data are also given in Table 3.9, together with the housing period on which these EFs are based).

Table 10A-22 Default Tier 1 EFs for NO from stored manure. According to Annex I of the NFR Reporting Guidelines, NO emissions have to be reported as NO_2

NFR	Livestock	Manure type	EF_{NO} (kg a^{-1} AAP^{-1} NO_2)
3B1a	Dairy cattle	Slurry	0.011
3B1a	Dairy cattle	Solid	0.236
3B1b	Non-dairy cattle (including young cattle, beef cattle and suckling cows)	Slurry	0.003
3B1b	Non-dairy cattle	Solid	0.144
3B2	Sheep	Solid	0.008
3B3	‘Swine’ — Fattening pigs	Slurry	0.002
3B3	‘Swine’ — Fattening pigs	Solid	0.069
3B3	‘Swine’ – Sows	Slurry	0.006
3B3	‘Swine’ – Sows	Solid	0. 204
3B3	‘Swine’ – Sows	Outdoor	0
3B4a	Buffalo	Solid	0.066
3B4d	Goats	Solid	0.008
3B4e	Horses	Solid	0.201
3B4f	Mules and asses	Solid	0.201
3B4gi	Laying hens (laying hens and parents)	Solid	0.005
3B4gi	Laying hens (laying hens and parents)	Slurry	0.0002
3B4gii	Broilers (broilers and parents)	Litter	0.002
3B4giii	Turkeys	Litter	0.008
3B4giv	Other poultry (ducks)	Litter	0.004
3B4giv	Other poultry (geese)	Litter	0.002
3B4h	Other animals	Litter	0.0003

Source: IPCC, 2006; default grazing periods for cattle were taken from Table 10A 4–8, Chapter 10, ‘Emissions from livestock and manure management’, and default N excretion data for western Europe were taken from Table 10.19, Chapter 10 (these data are also given in Table 3.9, together with the housing period on which these EFs are based).

Table 10A-23 Default Tier 2 NH_3-N EFs and associated parameters for the Tier 2 methodology for the calculation of the NH_3-N emissions from manure management

Code	Livestock	Housing period, d a^{-1}	$DeafultN_{ex}$ (a)	Proportion of TAN	Manure type	$EF_{housing}$	EF_{yard}	$EF_{storage}$	$EF_{spreading}$	$EF_{grazing/outdoor}$
3B1a	Dairy cattle	180	105	0.6	Slurry	0.20	0.30 (b)	0.20	0.55	0.10
					Solid	0.19	0.30 (b)	0.27	0.79	0.10
3B1a	Dairy cattle, tied housing	180	105	0.6	Slurry	0.066	0.30 (b)	0.20	0.55	0.10
					Solid	0.066	0.30 (b)	0.27	0.79	0.10
3B1b	Non-dairy cattle (young cattle, beef cattle and suckling cows)	180	41	0.6	Slurry	0.20	0.53 (b)	0.20	0.55	0.06
					Solid	0.19	0.53 (b)	0.27	0.79	0.06
3B2	Sheep	30	15.5	0.5	Solid	0.22	0.75 (b)	0.28	0.90	0.09
3B33	'Swine' (fattening pigs, 8–110 kg)	365	12.1	0.7	Slurry	0.28	0.53 (b)	0.14	0.40	
					Solid	0.27	0.53 (b)	0.45	0.81	
3B3	'Swine' (sows and piglets to 8 kg)	365	34.5	0.7	Slurry	0.22	NA	0.14	0.29	
					Solid	0.25	NA	0.45	0.81	
		0			Outdoor	NA	NA	NA	NA	0.25 (c)
3B4a	Buffalo[c]	140	82.0 (d)	0.5	Solid	0.20	NA	0.17	0.55	0.13
3B4d	Goats)	30	15.5	0.5	Solid	0.22	0.75 (b)	0.28	0.90	0.09
3B4e+3 B4f	Horses (and mules, asses)	180	47.5	0.6	Solid	0.22	NA	0.35	0.90 (d)	0.35
3B4gi	Laying hens (laying hens and parents)	365	0.77	0.7	Solid, can be stacked	0.41	NA	0.14	0.69	
3B4gi	Laying hens (laying hens and parents)	365	0.77	0.7	Slurry, can be pumped	0.41	NA	0.14	0.69	
3B4gii	Broilers (broilers and parents)	365	0.36	0.7	Solid	0.28	NA	0.17	0.66	
3B4giii	Turkeys	365	1.64	0.7	Solid	0.35	NA	0.24	0.54	
3B4giv	Other poultry (ducks)	365	1.26	0.7	Solid	0.24	NA	0.24	0.54	
3B4giv	Other poultry (geese)	365	0.55 (b)	0.7	Solid	0.57	NA	0.16	0.45	
3B4h	Other animals (fur animals)	365	4.60 (c)	0.6	Solid	0.27	NA	0.09	NA	

Notes: EFs are given as a proportion of TAN.

Sources: Default EFs are from the European Agricultural Gaseous Emissions Inventory Researchers (EAGER) network (http://www.eager.ch/)

(a) Default N excretion data were taken from Table 10.19, Chapter 10, of IPCC, 2006.

(b) Taken from Table 10–19 of IPCC (2006).

(c) Taken from NARSES.

(d) From Rösemann et al. (2015).

Nitric oxide

Table 10A-24. Default values for other losses needed in the mass-flow calculation (from Misselbrook et al., 2015, EMEP CORINAI emission inventory guidebook)

Proportion of TAN	
EFstorage_slurryNO	0.0001
EFstorage_slurryN2	0.0030
EFstorage_solidNO	0.0100
EFstorage_solidN2	0.3000

Table 10A-25 Comparison of manure storage type definitions used here and those used by the IPCC

Term	Definition	IPCC equivalent
Lagoons	Storage with a large surface area to depth ratio; normally shallow excavations in the soil	Liquid/slurry Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the livestock building, usually for periods of less than 1 year
Tanks	Storage with a low surface area to depth ratio; normally steel or concrete cylinders	
Heaps	Piles of solid manure	Solid storage The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked because of the presence of a sufficient amount of bedding material or loss of moisture by evaporation
In-house slurry pit	Mixture of excreta and washing water, stored within the livestock building, usually below the confined animals	Pit storage below animal confinements Collection and storage of manure usually with little or no added water, typically below a slatted floor in an enclosed livestock confinement facility, usually for periods of less than 1 year
In-house deep litter	Mixture of excreta and bedding, accumulated on the floor of the livestock building	Cattle and pig deep bedding As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system is also known as a bedded pack manure management system
Crust	Natural or artificial layer on the surface of slurry which reduces the diffusion of gasses to the atmosphere	No definition given
Cover	Rigid or flexible structure that covers the manure and is impermeable to water and gasses	No definition given
Composting, passive windrow	Aerobic decomposition of manure without forced ventilation	Composting, static pile Composting in piles with forced aeration but no mixing
Forced-aeration composting	Aerobic decomposition of manure with forced ventilation	Composting, in-vessel Composting in piles with forced aeration but no mixing
Biogas treatment	Anaerobic fermentation of slurry and/or solid	Anaerobic digester Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilisation by the microbial reduction of complex organic compounds to CO_2 and CH4, which is captured and flared or used as a fuel
Slurry separation	The separation of the solid and liquid components of slurry	No definition given
Acidification	The addition of strong acid to reduce manure pH	No definition given

Source: EMEP CORINAI emission inventory guidebook

ANNEX 10A4. SET OF EQUATIONS RELATING ALL DIRECT AND INDIRECT N2O EMISSIONS FROM MANURE ALONG ALL STAGES IN AGRICULTURAL PRODUCTION FOR LIVESTOCK SPECIES/CATEGORY T.

. EQUATION 10.A4-1. TOTAL N_2O EMISSIONS FOR ANIMAL TYPE T

$$N_2O_{(T)} = N_2O_{mm(T)} + N_2O_{AM(T)} + N_2O_{PRP(T)}$$

EQUATIONS 10.A4-2 AND 10.A4-3. TOTAL N_2O EMISSIONS FROM MANURE MANAGEMENT FOR ANIMAL TYPE T

$$N_2O_{(mm,T)} = N_2O_{D(mm,T)} + N_2O_{G(mm,T)} + N_2O_{L(mm,T)}$$

$$N_2O_{mm(T)} = \left(\sum_S F_{mm(T,S)} \bullet \left[EF_{3(S)} + \left(\frac{Frac_{GasMS}}{100} \right)_{(T,S)} \bullet EF_4 + \left(\frac{Frac_{LeachMS}}{100} \right)_{(T,S)} \bullet EF_5 \right] \right) \bullet \frac{44}{28}$$

EQUATIONS 10.A4-4 THROUGH 10.A4-6. TOTAL, DIRECT AND INDIRECT N_2O EMISSIONS FROM THE APPLICATION OF MANURE TO MANAGED SOILS FOR ANIMAL TYPE T

$$N_2O_{AM(T)} = N_2O_{D,AM(T)} + N_2O_{I,AM(T)}$$

$$N_2O_{D,AM(T)} = F_{AM(T)} \bullet \left[\left(1 - Frac_{AM,Rice} \right) \bullet EF_1 + Frac_{AM,Rice} \bullet EF_{1FR} \right] \bullet \frac{44}{28}$$

$$N_2O_{I,AM(T)} = F_{AM(T)} \bullet \left[Frac_{GASM} \bullet EF_4 + Frac_{LEACH-(H)} \bullet EF_5 \right] \bullet \frac{44}{28}$$

EQUATION 10.A4-7. TOTAL AMOUNT OF ANIMAL MANURE N APPLIED TO SOILS OTHER THAN BY GRAZING ANIMALS FOR ANIMAL TYPE T

$$F_{AM(T)} = \left[\left(\sum_S F_{mm(T,S)} \bullet \left(1 - \frac{Frac_{GasMS} + Frac_{LeachMS} + Frac_{N2MS}}{100} \right)_{(T,S)} \right) + F_{bedding(T,S)} \right] \bullet Frac_{APPL(T)}$$

EQUATION 10.A4-8. FRACTION OF ANIMAL MANURE N AVAILABLE FOR APPLICATION TO MANAGED SOILS, APPLIED TO MANAGED SOILS FOR ANIMAL TYPE T

$$Frac_{APPL(T)} = 1 - \left(Frac_{FEED(T)} + Frac_{FUEL(T)} + Frac_{CNST(T)} \right)$$

EQUATION 10.A4-9 THROUGH EQUATION 10.A4-11. TOTAL, DIRECT AND INDIRECT N_2O EMISSIONS FROM N IN URINE AND DUNG DEPOSITED BY GRAZING ANIMALS ON PASTURE, RANGE AND PADDOCK (TIER 1) FOR ANIMAL TYPE T

$$N_2O_{PRP(T)} = N_2O_{D,PRP(T)} + N_2O_{I,PRP(T)}$$

$$N_2O_{D,PRP(T)} = \left[\left(F_{PRP,CPP(T)} \bullet EF_{3PRP,CPP} \right) + \left(F_{PRP,SO(T)} \bullet EF_{3PRP,SO} \right) \right] \bullet \frac{44}{28}$$

$$N_2O_{I,RPR(T)} = F_{RPR(T)} \bullet \left[Frac_{GASM} \bullet EF_4 + Frac_{LEACH-(H)} \bullet EF_5 \right] \bullet \frac{44}{28}$$

EQUATION 10.A4-12. RELATIONSHIP BETWEEN AVERAGE ANNUAL NITROGEN FLOWS ASSOCIATED WITH AN INDIVIDUAL ANIMAL [KG N ANIMAL^{-1} YR^{-1}] AND THE ANNUAL NITROGEN FLOW FOR THE ANIMAL POPULATION OF LIVESTOCK CATEGORY/SPECIES T IN A COUNTRY [KG N YR^{-1}]

$$F = POP_{(T)} \bullet N$$

EQUATION 10.A4-13. TOTAL MANURE-N EXCRETED

$$N_{(T)} = N_{MMS(T)} + N_{PRP(T)}$$

EQUATION 10.A4-14AND 10.A4.15. NITROGEN EXCRETION CALCULATED EITHER USING A DEFAULT FRACTION OF RETENTION (TIER 1) OR DIRECTLY FROM RETENTION DATA

$$Nex_{(T)} = N_{intake(T)} \bullet \left(1 - Frac_{RET(T)}\right)$$

$$Nex_{(T)} = N_{intake(T)} - N_{RET(T)}$$

EQUATION 10.A4-16. TOTAL MANURE-N IN MANURE MANAGEMENT AND STORAGE SYSTEMS

$$N_{MMS(T)} = \sum_{S} \left(POP_{(T)} \bullet Nex_{(T)} \bullet Frac_{S(T,S)}\right)$$

EQUATION 10.A4-17. MANURE-N MANAGED IN SYSTEM S

$$N_{mm(T,S)} = POP_{(T)} \bullet Nex_{(T)} \bullet Frac_{S(T,S)}$$

EQUATION 10.A4-18. MANURE-N DEPOSITED BY GRAZING ANIMALS, WITH X=CPP,SO

$$N_{PRP(X)} = POP_{(X)} \bullet Nex_{(X)} \bullet Frac_{S(X,G)}$$

EQUATION 10.A4-19. N IN BEDDING MATERIAL ADDED TO MANAGED MANURE

$$N_{bedding(T,S)} = POP_{(T)} \bullet Nex_{(T)} \bullet N_{beddingMS,(T,S)}$$

Where

$POP_{(T)}$ = number of head of livestock species/category *T* in the country

Annual total nitrogen flows F and annual average nitrogen flows per head N:

$F_{(T)}$ and $N_{(T)}$ = animal manure nitrogen excreted for livestock species/category *T* in the country, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{MMS(T)}$ and $N_{MMS(T)}$ = animal manure nitrogen excreted for livestock species/category *T* in manure management and storage systems in the country, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{PRP(T)}$ and $N_{PRP(T)}$ = animal manure nitrogen excreted for livestock species/category *T* on pasture, range and paddock in the country, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{PRP,CPP(T)}$ and $N_{PRP,CPP(T)}$ = animal manure nitrogen excreted for cattle, pig and poultry species/category *T* on pasture, range and paddock in the country, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{PRP,SO(T)}$ and $N_{PRP,SO(T)}$ = total animal manure nitrogen excreted for sheep and other livestock species/category *T* on pasture, range and paddock in the country, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{mm(T,S)}$ and $N_{mm(T,S)}$ = animal manure nitrogen excreted for livestock species/category *T* in manure management and storage system *S* in the country, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{bedding(T,S)}$ and $N_{bedding(T,S)}$ = nitrogen in bedding material added for livestock species/category *T* in manure management and storage system *S* in the country, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{AM(T)}$ and $N_{AM(T)}$ = annual amount of animal manure N applied to soils for each livestock species/category *T*, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{intake(T)}$ and $N_{intake(T)}$ = annual intake of N in feed for each livestock species/category *T*, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{retention(T)}$ and $N_{retention(T)}$ = annual retention of N each livestock species/category *T*, kg N yr^{-1} and kg N $animal^{-1}$ yr^{-1}

$F_{ex(T)}$ and $N_{ex(T)}$ = annual average N excretion of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1}

Annual N_2O emissions for the total population of each livestock species/category T

$N_2O_{(T)}$ = total annual N_2O emissions

$N_2O_{mm(T)}$ = direct annual N2O emissions from Manure Management for each livestock species/category *T* in the country, kg N_2O yr^{-1}

$N_2O_{AM(T)}$ = total annual N_2O emissions from manure nitrogen applied to cultivated soils for each livestock species/category *T*, kg N_2O yr^{-1}

$N_2O_{PRP(T)}$ = total annual N_2O emissions from manure nitrogen deposited on pasture, range and paddock for each livestock species/category *T*, kg N_2O yr^{-1}

$N_2O_{D,AM(T)}$ = direct annual N_2O emissions from Manure Management for each livestock species/category *T* in the country, kg N_2O yr^{-1}

$N_2O_{I,AM(T)}$ = indirect annual N_2O emissions from Manure Management for each livestock species/category *T* in the country, kg N2O yr^{-1}

$N_2O_{D,PRP(T)}$ = direct annual N_2O emissions from pasture, range and paddock for each livestock species/category *T* in the country, kg N_2O yr^{-1}

$N2O_{I,PRP(T)}$ = indirect annual N2O emissions from pasture, range and paddock for each livestock species/category *T* in the country, kg N_2O yr^{-1}

N_2O emission factors

EF_1 = emission factor for direct N_2O emissions from N inputs to cultivated soils, kg N_2O –N (kg N $input)^{-1}$

EF_{1FR} = emission factor for direct N_2O emissions from N inputs to flooded rice, kg N_2O –N (kg N $input)^{-1}$

$EF_{3PRP,X}$ = emission factor for direct N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O –N (kg N input)-1; X=CPP: Cattle, Poultry and Pigs; X=SO: Sheep and Other animals

$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O -N/(kg N in manure management system $S)^{-1}$

EF_4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O -N (kg NH3-N + NOx-N volatilised)$^{-1}$

EF_5 = emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O -N (kg N leached and runoff)$^{-1}$

Fractions

$Frac_{S(T,S)}$ = fraction of manure N excreted that is managed in manure management system *S* for each livestock species/category *T*, dimensionless

$Frac_{S(X,G)}$ = fraction of manure N excreted that is deposited by grazing cattle, poultry or pigs (X=CPP) or sheep or other animals (X=SO), dimensionless

$Frac_{GasMS(T,S)}$ = fraction of managed manure nitrogen for livestock species/category *T* that volatilises as NH3 and NOx in the manure management system *S*, dimensionless

$Frac_{leachMS(T,S)}$ = fraction of managed manure nitrogen losses for livestock species/category *T* due to runoff and leaching during solid and liquid storage of manure (typical range 1-20%) in manure management system *S*, dimensionless

$Frac_{N2MS}$ = fraction of managed manure nitrogen for each livestock species/category *T* that is lost in the manure management system *S*, % as N_2, dimensionless

$Frac_{GASM}$ = fraction of applied organic N fertiliser materials (FON) and of urine and dung N deposited by grazing animals (FPRP) that volatilises as NH3 and NOx, kg N volatilised (kg of N applied or deposited)$^{-1}$

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)-1

$Frac_{APPL(T)}$ = fraction of animal manure N available for application to managed soils which is applied to managed soils for each livestock species/category *T*, dimensionless

$Frac_{FEED(T)}$ = fraction of managed manure used for feed for each livestock species/category *T*, dimensionless

$Frac_{FUEL(T)}$ = fraction of animal manure N available for application to managed soils used for fuel for each livestock species/category *T*, dimensionless

$Frac_{CNST(T)}$ = fraction of animal manure N available for application to managed soils used for construction for each livestock species/category *T*, dimensionless

$Frac_{AM,Rice}$ = fraction of animal manure N applied to managed soils which is applied to flooded rice, dimensionless

$Frac_{RET}$ = fraction of feed intake N that is retained by the animal in body mass or livestock products for each livestock species/category *T*, dimensionless

Note that for internal consistency, the symbol *N* is used for all nitrogen flows in kg N animal^{-1} yr^{-1}; the symbol *F* is used for all animal-independent nitrogen flows or nitrogen flows for the total animal population in kg N yr^{-1}; the symbol *Frac* is used for all fractions in kg N (kg N)$^{-1}$, the symbol *EF* is used for all N_2O emission factors in kg N_2O-N (kg N)$^{-1}$, and the symbol N_2O is used for all N_2O emissions in kg N_2O-N yr^{-1} .

ANNEX 10A.5 DESCRIPTION AND DISCUSSION OF PROPOSED CHANGES TO MCF CALCULATIONS FOR LIQUID/SLURRY.

The following briefly summarizes the 2006 approach and improvements included in the current approach.

.

IPCC 2006 MODEL FOR LIQUID/SLURRY:

The IPCC 2006 MCF for liquid slurry was based on the following relationship:

MCF = *f*

where *f* was calculated with the following temperature-dependent Arrhenius function, derived from Mangino et al., 2001, which is based on Safley and Westerman, 1990:

$f = \mathrm{EXP}[(Ea \times (T_2 - T_1))/(R \times T_2 \times T_1)]$

where,

f is a unitless fraction (0 to 1). Originally, Safley and Westerman 1990 used *f* to design an anaerobic digestion system at a lower temperature (T_2) based on known performance of a digester at a warmer temperature (T_1).

Ea is the activation energy. Originally, Safley and Westerman used Ea = 15175 cal/mol, based on an earlier study. Mangino et al. 2001 continued to use 15175 cal/mol.

T_2 is the variable temperature (K). Defined by Safley and Westerman (1990) as the unknown anaerobic digester temperature. Mangino et al. 2001 defined T2 as the monthly temperature of the anaerobic lagoon (assuming equality with monthly average air temperature). IPCC 2006 defined T2 as the annual average temperature of a region.

T_1 is the reference temperature (K). Defined by Safley and Westerman (1990) as 30 °C (303.16 K). Mangino et al. 2001 and IPCC 2006 use the same value.

R is the gas constant 1.987 cal k^{-1} mol^{-1}.

THE REASONS FOR MODIFICATION OF MCF THOUGH THE METHANE CONVERSION FACTOR (MCF) REMAINS AN UNCERTAIN PARAMETER.

First and foremost, in the IPCC 2006 , the MCF parameter violates a first-principle of inventory development: comparability. The use of an annual average temperature to calculate MCF systematically underestimates the annual MCF due to the mathematical principle known as Jensen's Inequality which applies to non-linear functions such as the Arrhenius equation (VanderZaag, 2018). Using this mathematical principle it can be shown that for a 1-month retention time, the annual average MCF calculated based on monthly temperature will always exceed the MCF calculated from the annual average temperature. Therefore, the IPCC 2006 MCF values are underestimates, and the level of underestimation is greatest for countries with large seasonal temperature extremes..

Secondly, it is well known that the retention time of liquid manure in storage is a critical parameter in determining MCF, and the IPCC 2006 guidelines state "both temperature and retention time play an important role in the calculation of MCF". However, the IPCC 2006 calculations of MCF (Table 1)), give very little focus to retention time. Previous IPCC Good Practice Guide recommended that future MCFs be modeled accounting for the storage period (Zeeman and Gerbens, 2000). Furthermore, the work of Safley and Westerman (1990) showed that the same amount of VS destruction can be achieved by longer retention time at lower temperature compared with shorter retention time at higher temperature. Furthermore the suggestion to use equation 1 for batch-fed storage/digesters that is currently in 2006 guidelines would not result in a value that is comparable to the default annual temperature values, because this equation would inherently require inclusion of retention time.

Recent year-round field studies in climates where the annual average air temperature was <10° C have reported MCFs in the range of 0.61 (Wightman and Woodbury, 2016), ⩾0.57 (Baldé et al. 2016) at liquid dairy manure storages, and greater for anaerobic lagoons (Leytem et al. 2017). Controlled studies at or around 20° C without added inoculum reported MCF of 55% over 165 d (VanderZaag et al. 2010) and 32% over 150-d (Massé et al. 2008). Another study showed the MCF increased non-linearly with the duration of storage (LeRiche et al. 2016). Previous IPCC Guidance reported an MCF of 39%, 45%, and 72% for liquid/slurry for Cool, Temperate, and Warm climates, respectively (Zeeman and Gerbens, 2000). They also stated that liquid/slurry storage tanks were considered to have ⩾6 month retention time. Therefore, the interaction between retention time and temperature has long been recognized, but the calculation of MCFs has not been fully transparent about how this important interaction has been handled (or how it should be handled by practitioners) and therefore has made comparability with measurements challenging.

Thirdly, the single temperature time step given in the IPCC guidelines suggests a level of certainty that is simply not supported by the experimental results, considering the approach being used.

Table 10A-26. IPCC 2006 Table of MCF values for Liquid/Slurry (Table 10.17)

TABLE 10.17
MCF VALUES BY TEMPERATURE FOR MANURE MANAGEMENT SYSTEMS

System[a]		MCFs by average annual temperature (°C)																			Source and comments
		Cool					Temperate											Warm			
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28	
Liquid/Slurry	With natural crust cover	10%	11%	13%	14%	15%	17%	18%	20%	22%	24%	26%	29%	31%	34%	37%	41%	44%	48%	50%	Judgement of IPCC Expert Group in combination with Mangino *et al.* (2001) and Sommer (2000). The estimated reduction due to the crust cover (40%) is an annual average value based on a limited data set and can be highly variable dependent on temperature, rainfall, and composition. When slurry tanks are used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.
	Without natural crust cover	17%	19%	20%	22%	25%	27%	29%	32%	35%	39%	42%	46%	50%	55%	60%	65%	71%	78%	80%	Judgement of IPCC Expert Group in combination with Mangino *et al.* (2001). When slurry tanks are used as fed-batch storage/digesters, MCF should be calculated according to Formula 1.

PROPOSED CHANGES:

The proposed change is to use a spreadsheet model to calculate MCF using monthly temperature in each IPCC climate region, and for a specific liquid manure retention time ((e.g. the Table below). Therefore, this approach produces MCF values that account for both temperature and retention time, while leaving the users to decide which retention time is appropriate for their manure management systems. The spreadsheet model will be made available as well.

Table 10A-27. MCFs calculated for each retention time and climate. (selected IPCC Climate regions shown)

Note that an upper limit MCF of 80% has been imposed for consistency with the Anaerobic Lagoon MCFs at high temperatures and long retention times

	Tropical Montane	Tropical Wet	Tropical Moist	Tropical Dry	Warm Temperate Moist	Warm Temperate Dry	Cool Temperate Moist	Cool Temperate Dry
RETENTION TIME	**N_TM**	**N_TW**	**N_TMst**	**N_TD**	**N_WTM**	**N_WTD**	**N_CTM**	**N_CTD**
1 Month	0.25	0.38	0.36	0.42	0.13	0.15	0.06	0.08
3 Month	0.43	0.61	0.57	0.62	0.24	0.28	0.12	0.16
4 Month	0.50	0.67	0.64	0.68	0.29	0.32	0.15	0.19
6 Month	0.59	0.76	0.73	0.74	0.37	0.41	0.21	0.26
12 Month	0.73	0.80	0.80	0.80	0.55	0.64	0.31	0.42
Tavg C	21.5	25.9	25.2	25.6	13.9	14.0	4.6	5.8

CHANGES IN LIQUID/SLURRY MCF, COMPARED TO THE IPCC 2006 ARE SUMMARIZED BELOW:

#1 – Timestep: Monthly temperature (proposed) instead of annual average temperature (IPCC 2006)

Methane emissions are non-linearly related to temperature, therefore Jensen's inequality states that the use of the average temperature will lead to systematic underestimation. As a result, monthly average air temperature is proposed for the calculation of MCF, rather than annual average temperature. Therefore, it is proposed that MCF for liquid/slurry be calculated using the Mangino et al. 2001 spreadsheet model, with the regional climate data from the IPCC defined climate regions. Additional details below.

#2 – Retention Time:
Several retention times (proposed) instead of 1-month implied retention time (IPCC 2006).

Retention time is a crucial parameter determining the extent of methane emissions and the quantity of VS in storage at any given time, therefore affecting the MCF. The IPCC 2006 used a 1-month retention time for all liquid/slurry systems by using MCF = *f*, based on an annual average temperature. Using a 1-month retention time is unrealistic, since the majority of liquid/slurry storages are meant for storage over several months or more. Therefore, it is proposed to calculate MCF based on five retention times: **1 month, 3 months, 4 months, 6 months, and 12 months.**

Proposed "Good Practice" in the case of countries that do not know have information on retention times is to use the six month retention time.

#3 – Activation Energy (Ea):
Updated Ea value (19347 cal/mol proposed) instead of 15175 cal/mol (IPCC 2006).

Recent research from Petesen et al. (2016), Elsgaard et al. (2016) propose a new Ea value of 81 kJ/mol = 19347 cal/mol. It is proposed to use this updated value.

#4 – Reference Temperature (T_1):
Updated T1 value (308.16 proposed) instead of 303.16 K (IPCC 2006).

The value of T_1 used by IPCC 2006 and Mangino et al. 2001 is directly taken from Safley and Westerman 1990. The original intent of Safley and Westerman was comparing performance of a known and unknown anaerobic digester performance. In Mangino et al. 2001 and IPCC 2006 the value of T1 defines the temperature at which *f* = 1.0, therefore T1 defines the temperature at which the B_0 will be reached in one month. There is considerable literature on laboratory methods for incubating manure to measure methane potential (e.g. BMP, B_0) and it is customary for the temperature of these incubations to be ca. 35°C, rather than 30°C. With a temperature of 35°C it would be reasonable to expect the B_0 to nearly be reached in 30 days (i.e. one month), e.g. Owen et al. 1979; Pham et al. 2012. Therefore, it is proposed to change T1 to 308.16 K (=35 + 273.16).

#5 – Manure Temperature (T_2):
Manure temperature lagging behind T_{air} (proposed) instead of equal T_{air} (IPCC 2006)

Most of the time, manure temperature does not equal air temperature. The temperature of liquid manure tends to lag behind air temperature. While models for manure temperature do exist (Rennie et al. 2017) this is too complex for the general guidelines. As a pragmatic alternative, a 1-month lag is proposed, i.e., set $T_2 = T_{air}$ from the previous month. It has also been shown (Rennie et al. 2018 in prep.) that manure storages which are emptied once per year at the end of the growing season before winter stay cooler than air temperature during the summer. Therefore, only in the case of once per year emptying (i.e. 12 month retention time), a downward temperature shift of 3°C has also been applied.

#6 – VS carryover after emptying:
After manure is removed, 5% remains (proposed), instead of complete emptying (IPCC 2006)

It has been shown in several studies that farms do not completely empty liquid/slurry storages due to the practical challenge of doing so at the farm-scale (Baldé et al. 2016b). Therefore, it is proposed that 5% of VS is retained in storage after emptying, rather than 0% (i.e. completely clean) assumption implied in the IPCC 2006 calculations. It is noteworthy that the IPCC 2000 Good Practice Guide (Zeeman and Gerbens 2000) mention approximately 15% of the manure storage cannot be emptied.

Reference

AAC (Australian Agricultural Council) (1990). Feed Standards for Australian Livestock Ruminants. Commonwealth Scientific and Industrial Research Organization (CSIRO) Publications, East Melbourne, Victoria, Australia.

AFRC Technical Committee on Responses to Nutrients (1990). Nutritive Requirements of Ruminant Animals: Energy. Rep. 5, CAB International, Wallingford, U.K.

Agricultural and Food Research Council (AFRC) Technical Committee on Responses to Nutrients (1993). Energy and Protein Requirements of Ruminants. 24-159, CAB International, Wallingford, U.K.

Amon, B., Amon, Th., Boxberger, J. and Alt, Ch. (2001). Emissions of NH_3, N_2O, and CH_4 from dairy cows housed in a farmyard manure tying stall (Housing, Manure Storage, Manure Spreading). *Nutrient Cycling in Agroecosystems*, **60**: pp. 103-113.

Amon, B., Amon, Th., Boxberger, J. and Alt, Ch. (2001). Emissions of NH_3, N_2O, and CH_4 from dairy cows housed in a farmyard manure tying stall (Housing, Manure Storage, Manure Spreading). *Nutrient Cycling in Agroecosystems*, **60**: pp. 103-113.

Amon, B., Amon, Th., Boxberger, J. and Pollinger, A. (1998). Emissions of NH_3, N_2O, and CH_4 from composted and anaerobically stored farmyard manure. Pages 209-216 in Martinez J, Maudet M-N (eds) Ramiran 98, Proc. 8th Int. Conf. on the FAO ESCORENA Network on Recycling of Agricultural, Municipal and Industrial Residues in Agriculture. Rennes, France.

Amon, B., Amon, Th., Boxberger, J. and Pollinger, A. (1998). Emissions of NH_3, N_2O, and CH_4 from composted and anaerobically stored farmyard manure. Pages 209-216 in Martinez J, Maudet M-N (eds) Ramiran 98, Proc. 8th Int. Conf. on the FAO ESCORENA Network on Recycling of Agricultural, Municipal and Industrial Residues in Agriculture. Rennes, France.

ASAE (1999). ASAE Standards 1999, 46th Edition. American Society of Agricultural Engineers, St. Joseph, MI.

Asman, W.A.H., Sutton, M.A. and Schjoerring, J.K. (1998). Ammonia: emission, atmospheric transport and deposition. *New Phytol.*, **139**, p. 27-48

Baldé, H., VanderZaag, A.C., Burtt, S., Evans, L., Wagner-Riddle, C., Desjardins, R.L., MacDonald, J.D. 2016a. Measured versus modeled methane emissions from separated liquid dairy manure show large model underestimates. Agriculture, Ecosystems and Environment, 230:261-270.

Baldé, H., VanderZaag, A.C., Burtt, S.D., Gordon, R.J., Desjardins, R.L. 2016b. Does fall removal of the dairy manure sludge in a storage tank reduce subsequent methane emissions? Journal of Environmental Quality 45:2038-2043

Bamualim, A. and Kartiarso (1985). 'Nutrition of draught animals with special reference to Indonesia.' In: Draught Animal Power for Production. J.W. Copland (ed.). Australian Centre for International agricultural Research (ACIAR), Proceedings Series No. 10. ACIAR, Canberra, A.C.T., Australia.

Bierman, S., Erickson, G.E., Klopfenstein, T.J., Stock, R.A. and Shain, D.H. (1999). Evaluation of nitrogen and organic matter balance in the feedlot as affected by level and source of dietary fiber. *J. Anim. Sci.* **77**:1645-1653.

Clark, H., Brookes, I. and Walcroft, A. (2003). Enteric methane emissions from New Zealand ruminants 1999-2001 calculated using an IPCC Tier 2 approach. http://www.climatechange.govt.nz/resources/reports/nir-apr03/.

Crutzen, P.J., Aselmann, I. and Seiler, W. (1986). "Methane Production by Domestic Animals, Wild Ruminants, Other Herbivorous Fauna, and Humans," *Tellus* **38B**:271-284.

Diarra, B. (1994). Net energy value of soybean hulls as feed for sheep. Dissertation. Colorado State University, Ft Collins, CO.

Döhler, H., Eurich-Menden, B., Dämmgen, U., Osterburg, B., Lüttich, M., Bergschmidt, A., Berg, W., Brunsch, R. (2002). BMVEL/UBA-Ammoniak-Emissionsinventar der deutschen Landwirtschaft und Minderungsszenarien bis zum Jahre 2010. Texte 05/02. Umweltbundesamt, Berlin.

Donovan, K. and Baldwin, L. (1999). Results of the AAMOLLY model runs for the Enteric Fermentation Model. University of California, Davis.

Dustan, A. (2002). Review of methane and nitrous oxide emission factors in cold climates. Institutet for jordbruks- och miljoteknik, JTI-rapport, Lantbruk & Industri, 299.

Eghball, B. and Power, J.F. (1994). Beef cattle feedlot manure management. *J. Soil Water Cons.* 49:113-122.

Elsgaard, L., Olsen, A.B., Petersen, S.O. 2016. Temperature response of methane production in liquid manures and co-digestates. Science of the Total Environment 539:78-84.

European Environmental Agency (2002). Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, 3rd ed., July 2002, Copenhagen.

Food and Agriculture Organisation (FAO) (1999). Statistical Database.

Gibbs, M.J. and Johnson, D.E. (1993). "Livestock Emissions." In: International Methane Emissions, US Environmental Protection Agency, Climate Change Division, Washington, D.C., U.S.A.

Gibbs, M.J., Conneely, D., Johnson, D., Lassey, K.R. and Ulyatt, M.J. (2002). CH_4 emissions from enteric fermentation. In: Background Papers: IPCC Expert Meetings on Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, p 297–320. IPCC-NGGIP, Institute for Global Environmental Strategies (IGES), Hayama, Kanagawa, Japan.

Groot Koerkamp, P.W.G., Speelman, L. and Metz, J.H.M. (1998). Effect of type of aviary, manure and litter handling on the emission kinetics of ammonia from layer houses. *Br. Poult. Sci.*, **39**, p. 379-392.

Hao, X., Chang, C., Larney, F.J. and Travis, G.R. (2001). Greenhouse gas emissions during cattle feedlot manure composting. *Journal Environmental Quality* **30**: pp. 376-386.

Harper, L.A., Sharpe, R.R. and Parkin, T.B. (2000). Gaseous emissions from anaerobic swine lagoons: Ammonia, Nitrous Oxide, and Dinitrogen Gas. *Journal of Environmental Quality* **29**: pp. 1356-1365.

Hashimoto, A. and Steed, J. (1993). Methane emissions from typical U.S. livestock manure management systems. Draft report prepared for ICF Incorporated under contract to the Global Change Division of the Office of Air and Radiation, US Environmental Protection Agency, Washington, D.C.

Hill, D.T. (1982). Design of digestion systems for maximum methane production. Transactions of the ASAE, 25(1): pp. 226-230.

Hill, D.T. (1984). Methane productivity of the major animal types. Transactions of the ASAE 27(2): pp. 530-540.

Hindrichsen, I., Kreuzer, M., Machmuller, A., Knudsen, K. E., Madsen, J. and Wettstein, H.R. (2003). Methane release and energy expenditure of dairy cows fed concentrates characterized by different carbohydrates. In: Prog. in Res. En. & Prot. Metabol. (Souffrant, W.B, and CC. Metges, eds.) Wageningen Acad. Pub, The Netherlands, EAAP Publ. 109:413-416.

Hutchings, N.J., Sommer, S.G., Andersen, J.M. and Asman, W.A.H. (2001). A detailed ammonia emission inventory for Denmark. *Atmospheric Environment*, **35**, p. 1959-1968.

Ibrahim, M.N.M. (1985). 'Nutritional status of draught animals in Sri Lanka.' In: Draught Animal Power for Production, J.W. Copland (ed.). ACIAR (Australian Centre for International Agricultural Research) Proceedings Series No. 10. ACIAR, Canberra, A.C.T., Australia.

IPCC (1997). Revised 1996 IPCC Guidelines for National Greenhouse Inventories. Houghton J.T., Meira Filho L.G., Lim B., Tréanton K., Mamaty I., Bonduki Y., Griggs D.J. Callander B.A. (Eds). Intergovernmental Panel on Climate Change (IPCC), IPCC/OECD/IEA, Paris, France.

Johnson, K., Huyler, M., Westberg, H., Lamb, B. and Zimmerman, P. (1994). Measurement of methane emissions from ruminant livestock using a SF6 tracer technique. *Environmental. Sci. Tech*., **28**: 359-362.

Johnson, K.A. and Johnson, D.E. (1995). Methane emissions from cattle. *J. Anim. Sci.*, **73**: 2483-2492

Judd, M.J., Kelliher, F.M., Ulyatt, M.J., Lassey, K.R., Tate, K.R., Shelton, I.D., Harvey, M.J. and Walker, C.F. (1999). Net methane emissions from grazing sheep, *Global Change Biol*., **5**, pp. 647–657.

Jurgen, M.H. (1988). Animal Feeding and Nutrition, Sixth Edition, Kendall/Hunt Publishing Company, Dubuque, Iowa, U.S.A.

Kujawa, M. (1994). Energy partitioning in steers fed cottonseed hulls or sugar beet pulp. Dissertation, Colorado State University, Ft Collins, CO.

Külling, D.R., Menzi, H., Sutter, F., Lischer, P. and Kreuzer, M. (2003). Ammonia, nitrous oxide and methane emissions from differently stored dairy manure derived from grass- and hay-based rations. *Nutrient Cycling in Agroecosystems*, **65**: pp. 13-22.

Kurihara, M., Magner, T., Hunter, R.A. and McCrabb, G.J. (1999). Methane production and energy partition of cattle in the tropics. *British Journal of Nutrition*, **81**, pp. 227-234.

Lague, C., Fonstad, T. A., Marquis, A., Lemay, S.P., Godbout, S. and Joncas, R. (2004). Greenhouse Gas Emissions from Swine Operations in Québec and Saskatchewan: Benchmark Assessments. Climate Change Funding Initiative in Agriculture (CCFIA), Canadian Agricultural Research Council, Ottawa, ON.

Lassey, K.R. (2006). Livestock methane emission: from the individual grazing animal through national inventories to the global methane cycle. *Agric. For. Meteorol.* (in press).

Lassey, K.R., Ulyatt, M.J., Martin, R.J., Walker, C.F. and Shelton, I.D. (1997). Methane emissions measured directly from grazing livestock in New Zealand, *Atmos. Environ.*, **31**, pp. 2905-2914.

Lawrence, P.R. (1985). 'A review of nutrient requirements of draught oxen.' In: Draught Animal Power for Production. J.W. Copland (ed.). ACIAR (Australian Centre for International Agricultural Research) Proceedings Series No. 10. ACIAR, Canberra, A.C.T., Australia.

Le Riche, E.L., VanderZaag, A.C., Wood, J.D., Wagner-Riddle, C., Dunfield, K., Ngwabie, N.M., McCabe, J., Gordon, R.J. 2016. Greenhouse gas emissions from stored dairy slurry from multiple farms. Journal of Environmental Quality 45:1822-1828

Leuning, R., Baker, S.K., Jamie, I.M., Hsu, C.H., Klein, L., Denmead, O.T. and Griffith, D.W.T. (1999). Methane emission from free-ranging sheep: a comparison of two measurement methods, *Atmos. Environ*., **33**, pp. 1357–1365.

Leytem, A.B., Bjorneberg, D.L., Koehn, A.C., Moraes, L.E., Kebreab, E., Dugan, R.S. 2017. Methane emissions from dairy lagoons in the western United States. Journal of Dairy Science 100:1-19.

Mangino, J., Bartram, D. and Brazy, A. (2001). Development of a methane conversion factor to estimate emissions from animal waste lagoons. Presented at U.S. EPA's 17th Annual Emission Inventory Conference, Atlanta GA, April 16-18, 2002.

Mangino, J., Bartram, D., Brazy, A. 2001. Development of a Methane Conversion Factor to Estimate Emissions from Animal Waste Lagoons. USEPA Technical Report (Washington, DC: Environmental Protection Agency) pp. 14

Massé, D.I., Masse, L., Claveau, S., Benchaar, C., Thomas, O. 2008. Methane emissions from manure storages. Transactions of the ASABE 51(5):1775-1781

Meisinger, J.J. and Jokela, W.E. (2000). Ammonia Volatilization from Dairy and Poultry Manure. In: Managing Nutrients and Pathogens from Animal Agriculture. Natural Resource, Agriculture, and Engineering Service, Ithaca, NY. March 28-30, 2000. NRAES-130, p.334-354.

Moller, H.B., Sommer, S.G. and Ahring, B. (2004). Biological degradation and greenhouse gas emissions during pre-storage of liquid animal manure. *Journal of Environmental Quality*, **33**: pp. 27-36.

Moller, H.B., Sommer, S.G. and Anderson, B.H. (2000). Nitrogen mass balance in deep litter during the pig fattening cycle and during composting. *Journal of Agricultural Science*, Cambridge **137**:235-250.

Monteny G. J., Groesetein C. M. and Hilhorst M. A. (2001). Interactions and coupling between emissions of methane and nitrous oxide from animal husbandry. *Nutrient Cycling in Agroecosystems*, **60**: pp. 123-132.

Monteny, G.J. and Erisman, J.W. (1998). Ammonia emissions from dairy cow buildings: A review of measurement techniques, influencing factors and possibilities for reduction. *Neth. J. Agric. Sci.*, **46**, p. 225-247.

Moreira, V.R. and Satter, L.D. (2004). Estimating nitrogen loss from dairy farms. *Pedology.*

Murray, B.R., Bryant, A.M. and Leng, R.A. (1978). Methane production in the rumen and lower gut of sheep given lucerne chaff: effect of level of intake, *Br. J. Nutr.*, **39**, pp. 337-345.

National Research Council (NRC) (1984). Nutrient Requirements of Beef Cattle, National Academy Press, Washington, D.C. U.S.A.

National Research Council (NRC) (1989). Nutrient Requirements of Dairy Cattle, 6th Ed., Nat. Acad. Press, Washington, DC.

National Research Council (NRC) (1996). Nutrient Requirements of Beef Cattle, 7th Edit., Nat. Acad. Press, Washington, DC.

National Research Council (NRC) (1996). Nutrient Requirements of Beef Cattle, 7th Revised Ed., Nat. Acad. Press, Washington., DC

National Research Council (NRC) (2001). Nutrient Requirements of Dairy Cattle, 7th Ed., Nat. Acad. Press, Washington, DC.

Nicks, B., Laitat, M., Vandenheede, M., Desiron, A., Verhaege, C. and Canart, B. (2003). Emissions of Ammonia, Nitrous Oxide, Methane, Carbon Dioxide, and Water Vapor in the Raising of Weaned Pigs on Straw-Based and Sawdust-Based Deep Litters. *Animal Research Journal*, **52**: pp. 299-308.

NRC (1989). Nutrient Requirements of Dairy Cattle, 6th, National Academy Press, Washington, D.C. U.S.A.

NRC (1996). Nutrient Requirements of Beef Cattle, National Academy Press, Washington, D.C. U.S.A.

NRC (2001). Nutrient Requirements of Dairy Cattle, 7th Ed., Nat. Acad. Press, Washington, DC.

Owen, W.F., Stuckley, D.C., Healy Jr., J.B., Young, L.Y., McCarty, P.L. 1979. Bioassay for monitoring biochemical methane potential and anaerobic toxicity. Water Research 13:485-492.

Petersen, S.O., Olsen, A.B., Elsgaard, L., Triolo, J.M., Sommer, S.G. 2016. Estimation of methane emissions from slurry pits below pig and cattle confinements. PLoS ONE 11(8):e0160968. doi:10.1371/journal.pone.0160968

Peterson, K. and Jacobs, H. (2003). 1990-2002 Volatile solids and Nitrogen excretion rates deliverable under EPA Contract No. GS-10F-0124J, Task Order 004-02. Memorandum to EPA from ICF Consulting. August 28, 2003.

Pham, C.H., Triolo, J.M., Cu, T.T.T., Pedersen, L., Sommer, S.G. 2012. Validation and recommendation of methods to measure biogas production potential of animal manure. Asian Australasian Journal of Animal Science 26(6):864-873.

Pinares-Patino, C.S., Ulyatt, M.J., Waghorn, G.C., Lassey, K.R., Barry, T.N., Holmes, C.W. and Johnson, D.E. (2003). Methane emission by alpaca and sheep fed on Lucerne hay or grazed on pastures of perennial ryegrass/white clover or birds foot trefoil. *J. Agric. Sci.* **140**:215-226.

Rennie, T.J., Baldé, H., Gordon, R.J., Smith, W.N., VanderZaag, A.C. 2017. A 3-D model to predict the temperature of liquid manure within storage tanks. Biosystems Engineering 163:50-65.

Rennie, T.J., Gordon, R.J., Smith, W.N., VanderZaag, A.C. 2018. Manure storage temperature is affected by storage design and management practices – a modeling assessment. Agriculture, Ecosystems and Environment (*Submitted*)

Rotz, C.A. (2004). Management to reduce nitrogen losses in animal production. *J. Anim. Sci.* **82**(E. Suppl.):E119-E137.

Safley Jr., L.M., Westerman, P.W. 1990. Psychrophilic anaerobic digestion of animal manure: Proposed design methodology. Biological Wastes 34:133-148

Safley, L.M., Casada, M.E., Woodbury, J.W. and Roos, K.F. (1992). Global Methane Emissions from Livestock and Poultry Manure. US Environmental Protection Agency, Global Change Division, Washington, D.C., February 1992, EPA/400/1091/048.

Sneath, R.W., Phillips, V.R., Demmers, G.M., Burgess, L.R. and Short, J.L. (1997). Long Term Measurements of Greenhouse Gas Emissions from UK Livestock Buildings. Bio-Engineering Division, Silsoe Research Institute, Wrest Park, Silsoe, Bedford, MK45 4HS. Livestock Environment: Proceedings of the Fifth International Symposium. Bloomington MN. May 29-31, 1997.

Sneath, R.W., Phillips, V.R., Demmers, G.M., Burgess, L.R. and Short, J.L. (1997). Long Term Measurements of Greenhouse Gas Emissions from UK Livestock Buildings. Bio-Engineering Division, Silsoe Research Institute, Wrest Park, Silsoe, Bedford, MK45 4HS. Livestock Environment: Proceedings of the Fifth International Symposium. Bloomington MN. May 29-31, 1997.

Sommer, S.G. and Moller, H.B. (2000). Emission of greenhouse gases during composting of deep litter from pig production – effect of straw content. *Journal of Agricultural Science*, Cambridge **134**:327-335.

Sommer, S.G., Petersen, S.O. and Sogaard, H.T. (2000). Greenhouse gas emissions from stored livestock slurry. *Journal of Environmental Quality*, **29**: pp. 744-751.

Sommer, S.G., Petersen, S.O. and Søgaard, H.T. (2000). Greenhouse gas emission from stored livestock slurry. *Journal of Environmental Quality* **29**: pp. 744-751.

Steed Jr, J. and Hashimoto, A.G. (1994). Methane emissions from typical manure management systems. *Bioresource Technology* **50**: pp. 123-130.

Ulyatt, M.J., Lassey, K.R., Shelton, I.D. and Walker, C.F. (2002a). "Seasonal variation in methane emission from dairy cows and breeding ewes grazing ryegrass/white clover pasture in New Zealand." *New Zealand Journal of Agricultural Research* **45**:217–226.

Ulyatt, M.J., Lassey, K.R., Shelton, I.D. and Walker, C.F. (2002b). "Methane emission from dairy cows and wether sheep fed subtropical grass-dominant pastures in midsummer in New Zealand." *New Zealand Journal of Agricultural Research* **45**:227–234.

Ulyatt, M.J., Lassey, K.R., Shelton, I.D. and Walker, C.F. (2005). Methane emission from sheep grazing four pastures in late summer in New Zealand. *New Zealand Journal Agricultural Research* 48: 385-390.

US EPA (2004). National Emission Inventory – Ammonia Emissions from Animal Husbandry Operations, Draft Report. January 30, 2004.

USDA (1996). Agricultural Waste Management Field Handbook, National Engineering Handbook (NEH). Part 651, U.S. Department of Agriculture, Natural Resources Conservation Service. July.

VanderZaag, A.C. 2018. On the systematic underestimation of Methane Conversion Factors in IPCC guidance. Waste Management, *WM-17-2301 In Review*

VanderZaag, A.C., Gordon, R.J., Jamieson, R.C., Burton, D.L., Stratton, G.W. 2010. Permeable synthetic covers for controlling emissions from liquid dairy manure. Applied Engineering in Agriculture 26(2):287-297.

Wagner-Riddle, C. and Marinier, M. (2003). Improved Greenhouse Gas Emission Estimates from Manure Storage Systems. Prepared for Climate Change Funding Initiative in Agriculture, Final Project Report, Component 2-3 Projects, Climate Change Science and Technology.

Webb, J. (2001). Estimating the potential for ammonia emissions from livestock excreta and manures. *Environ. Pollut.* **111**, p. 395-406.

Wightman, J.L., Woodbury, P.B. 2016. New York dairy manure management greenhouse gas emissions and mitigation costs (1992-2022). Journal of Environmental Quality 45:266-275.

Woodbury, J.W. and Hashimoto, A. (1993). Methane Emissions from Livestock Manure. In International Methane Emissions, US Environmental Protection Agency, Climate Change Division, Washington, D.C., U.S.A.

Zeeman, G. (1994). Methane production/emission in storages for animal manure. *Fertilizer Research* **37**: 207-211, 1994. Kluwer Academic Publishers, Netherlands.

Zeeman, G., Gerbens, S. 2000. CH_4 emissions from animal manure. IPCC Background Papers—IPCC Expert Meetings on Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, pp. 339–48

Lague, C., Fonstad, T. A., Marquis, A., Lemay, S.P., Godbout, S. and Joncas, R. (2004). Greenhouse Gas Emissions from Swine Operations in Québec and Saskatchewan: Benchmark Assessments. Climate Change Funding Initiative in Agriculture (CCFIA), Canadian Agricultural Research Council, Ottawa, ON.

Lassey, K.R. (2006). Livestock methane emission: from the individual grazing animal through national inventories to the global methane cycle. *Agric. For. Meteorol.* (in press).

Lassey, K.R., Ulyatt, M.J., Martin, R.J., Walker, C.F. and Shelton, I.D. (1997). Methane emissions measured directly from grazing livestock in New Zealand, *Atmos. Environ.*, **31**, pp. 2905-2914.

Lawrence, P.R. (1985). 'A review of nutrient requirements of draught oxen.' In: Draught Animal Power for Production. J.W. Copland (ed.). ACIAR (Australian Centre for International Agricultural Research) Proceedings Series No. 10. ACIAR, Canberra, A.C.T., Australia.

Le Riche, E.L., VanderZaag, A.C., Wood, J.D., Wagner-Riddle, C., Dunfield, K., Ngwabie, N.M., McCabe, J., Gordon, R.J. 2016. Greenhouse gas emissions from stored dairy slurry from multiple farms. Journal of Environmental Quality 45:1822-1828

Leuning, R., Baker, S.K., Jamie, I.M., Hsu, C.H., Klein, L., Denmead, O.T. and Griffith, D.W.T. (1999). Methane emission from free-ranging sheep: a comparison of two measurement methods, *Atmos. Environ.*, **33**, pp. 1357–1365.

Leytem, A.B., Bjorneberg, D.L., Koehn, A.C., Moraes, L.E., Kebreab, E., Dugan, R.S. 2017. Methane emissions from dairy lagoons in the western United States. Journal of Dairy Science 100:1-19.

Mangino, J., Bartram, D. and Brazy, A. (2001). Development of a methane conversion factor to estimate emissions from animal waste lagoons. Presented at U.S. EPA's 17th Annual Emission Inventory Conference, Atlanta GA, April 16-18, 2002.

Mangino, J., Bartram, D., Brazy, A. 2001. Development of a Methane Conversion Factor to Estimate Emissions from Animal Waste Lagoons. USEPA Technical Report (Washington, DC: Environmental Protection Agency) pp. 14

Massé, D.I., Masse, L., Claveau, S., Benchaar, C., Thomas, O. 2008. Methane emissions from manure storages. Transactions of the ASABE 51(5):1775-1781

Meisinger, J.J. and Jokela, W.E. (2000). Ammonia Volatilization from Dairy and Poultry Manure. In: Managing Nutrients and Pathogens from Animal Agriculture. Natural Resource, Agriculture, and Engineering Service, Ithaca, NY. March 28-30, 2000. NRAES-130, p.334-354.

Moller, H.B., Sommer, S.G. and Ahring, B. (2004). Biological degradation and greenhouse gas emissions during pre-storage of liquid animal manure. *Journal of Environmental Quality*, **33**: pp. 27-36.

Moller, H.B., Sommer, S.G. and Anderson, B.H. (2000). Nitrogen mass balance in deep litter during the pig fattening cycle and during composting. *Journal of Agricultural Science*, Cambridge **137**:235-250.

Monteny G. J., Groesetein C. M. and Hilhorst M. A. (2001). Interactions and coupling between emissions of methane and nitrous oxide from animal husbandry. *Nutrient Cycling in Agroecosystems*, **60**: pp. 123-132.

Monteny, G.J. and Erisman, J.W. (1998). Ammonia emissions from dairy cow buildings: A review of measurement techniques, influencing factors and possibilities for reduction. *Neth. J. Agric. Sci.*, **46**, p. 225-247.

Moreira, V.R. and Satter, L.D. (2004). Estimating nitrogen loss from dairy farms. *Pedology.*

Murray, B.R., Bryant, A.M. and Leng, R.A. (1978). Methane production in the rumen and lower gut of sheep given lucerne chaff: effect of level of intake, *Br. J. Nutr.*, **39**, pp. 337-345.

National Research Council (NRC) (1984). Nutrient Requirements of Beef Cattle, National Academy Press, Washington, D.C. U.S.A.

National Research Council (NRC) (1989). Nutrient Requirements of Dairy Cattle, 6th Ed., Nat. Acad. Press, Washington, DC.

National Research Council (NRC) (1996). Nutrient Requirements of Beef Cattle, 7th Edit., Nat. Acad. Press, Washington, DC.

National Research Council (NRC) (1996). Nutrient Requirements of Beef Cattle, 7th Revised Ed., Nat. Acad. Press, Washington., DC

National Research Council (NRC) (2001). Nutrient Requirements of Dairy Cattle, 7th Ed., Nat. Acad. Press, Washington, DC.

Nicks, B., Laitat, M., Vandenheede, M., Desiron, A., Verhaege, C. and Canart, B. (2003). Emissions of Ammonia, Nitrous Oxide, Methane, Carbon Dioxide, and Water Vapor in the Raising of Weaned Pigs on Straw-Based and Sawdust-Based Deep Litters. *Animal Research Journal*, **52**: pp. 299-308.

NRC (1989). Nutrient Requirements of Dairy Cattle, 6th, National Academy Press, Washington, D.C. U.S.A.

NRC (1996). Nutrient Requirements of Beef Cattle, National Academy Press, Washington, D.C. U.S.A.

NRC (2001). Nutrient Requirements of Dairy Cattle, 7th Ed., Nat. Acad. Press, Washington, DC.

Owen, W.F., Stuckley, D.C., Healy Jr., J.B., Young, L.Y., McCarty, P.L. 1979. Bioassay for monitoring biochemical methane potential and anaerobic toxicity. Water Research 13:485-492.

Petersen, S.O., Olsen, A.B., Elsgaard, L., Triolo, J.M., Sommer, S.G. 2016. Estimation of methane emissions from slurry pits below pig and cattle confinements. PLoS ONE 11(8):e0160968. doi:10.1371/journal.pone.0160968

Peterson, K. and Jacobs, H. (2003). 1990-2002 Volatile solids and Nitrogen excretion rates deliverable under EPA Contract No. GS-10F-0124J, Task Order 004-02. Memorandum to EPA from ICF Consulting. August 28, 2003.

Pham, C.H., Triolo, J.M., Cu, T.T.T., Pedersen, L., Sommer, S.G. 2012. Validation and recommendation of methods to measure biogas production potential of animal manure. Asian Australasian Journal of Animal Science 26(6):864-873.

Pinares-Patino, C.S., Ulyatt, M.J., Waghorn, G.C., Lassey, K.R., Barry, T.N., Holmes, C.W. and Johnson, D.E. (2003). Methane emission by alpaca and sheep fed on Lucerne hay or grazed on pastures of perennial ryegrass/white clover or birds foot trefoil. *J. Agric. Sci.* **140**:215-226.

Rennie, T.J., Baldé, H., Gordon, R.J., Smith, W.N., VanderZaag, A.C. 2017. A 3-D model to predict the temperature of liquid manure within storage tanks. Biosystems Engineering 163:50-65.

Rennie, T.J., Gordon, R.J., Smith, W.N., VanderZaag, A.C. 2018. Manure storage temperature is affected by storage design and management practices – a modeling assessment. Agriculture, Ecosystems and Environment (*Submitted*)

Rotz, C.A. (2004). Management to reduce nitrogen losses in animal production. *J. Anim. Sci.* **82**(E. Suppl.):E119-E137.

Safley Jr., L.M., Westerman, P.W. 1990. Psychrophilic anaerobic digestion of animal manure: Proposed design methodology. Biological Wastes 34:133-148

Safley, L.M., Casada, M.E., Woodbury, J.W. and Roos, K.F. (1992). Global Methane Emissions from Livestock and Poultry Manure. US Environmental Protection Agency, Global Change Division, Washington, D.C., February 1992, EPA/400/1091/048.

Sneath, R.W., Phillips, V.R., Demmers, G.M., Burgess, L.R. and Short, J.L. (1997). Long Term Measurements of Greenhouse Gas Emissions from UK Livestock Buildings. Bio-Engineering Division, Silsoe Research Institute, Wrest Park, Silsoe, Bedford, MK45 4HS. Livestock Environment: Proceedings of the Fifth International Symposium. Bloomington MN. May 29-31, 1997.

Sneath, R.W., Phillips, V.R., Demmers, G.M., Burgess, L.R. and Short, J.L. (1997). Long Term Measurements of Greenhouse Gas Emissions from UK Livestock Buildings. Bio-Engineering Division, Silsoe Research Institute, Wrest Park, Silsoe, Bedford, MK45 4HS. Livestock Environment: Proceedings of the Fifth International Symposium. Bloomington MN. May 29-31, 1997.

Sommer, S.G. and Moller, H.B. (2000). Emission of greenhouse gases during composting of deep litter from pig production – effect of straw content. *Journal of Agricultural Science*, Cambridge **134**:327-335.

Sommer, S.G., Petersen, S.O. and Sogaard, H.T. (2000). Greenhouse gas emissions from stored livestock slurry. *Journal of Environmental Quality*, **29**: pp. 744-751.

Sommer, S.G., Petersen, S.O. and Søgaard, H.T. (2000). Greenhouse gas emission from stored livestock slurry. *Journal of Environmental Quality* **29**: pp. 744-751.

Steed Jr, J. and Hashimoto, A.G. (1994). Methane emissions from typical manure management systems. *Bioresource Technology* **50**: pp. 123-130.

Ulyatt, M.J., Lassey, K.R., Shelton, I.D. and Walker, C.F. (2002a). "Seasonal variation in methane emission from dairy cows and breeding ewes grazing ryegrass/white clover pasture in New Zealand." *New Zealand Journal of Agricultural Research* **45**:217–226.

Ulyatt, M.J., Lassey, K.R., Shelton, I.D. and Walker, C.F. (2002b). "Methane emission from dairy cows and wether sheep fed subtropical grass-dominant pastures in midsummer in New Zealand." *New Zealand Journal of Agricultural Research* **45**:227–234.

Ulyatt, M.J., Lassey, K.R., Shelton, I.D. and Walker, C.F. (2005). Methane emission from sheep grazing four pastures in late summer in New Zealand. *New Zealand Journal Agricultural Research* 48: 385-390.

US EPA (2004). National Emission Inventory – Ammonia Emissions from Animal Husbandry Operations, Draft Report. January 30, 2004.

USDA (1996). Agricultural Waste Management Field Handbook, National Engineering Handbook (NEH). Part 651, U.S. Department of Agriculture, Natural Resources Conservation Service. July.

VanderZaag, A.C. 2018. On the systematic underestimation of Methane Conversion Factors in IPCC guidance. Waste Management, *WM-17-2301 In Review*

VanderZaag, A.C., Gordon, R.J., Jamieson, R.C., Burton, D.L., Stratton, G.W. 2010. Permeable synthetic covers for controlling emissions from liquid dairy manure. Applied Engineering in Agriculture 26(2):287-297.

Wagner-Riddle, C. and Marinier, M. (2003). Improved Greenhouse Gas Emission Estimates from Manure Storage Systems. Prepared for Climate Change Funding Initiative in Agriculture, Final Project Report, Component 2-3 Projects, Climate Change Science and Technology.

Webb, J. (2001). Estimating the potential for ammonia emissions from livestock excreta and manures. *Environ. Pollut.* **111**, p. 395-406.

Wightman, J.L., Woodbury, P.B. 2016. New York dairy manure management greenhouse gas emissions and mitigation costs (1992-2022). Journal of Environmental Quality 45:266-275.

Woodbury, J.W. and Hashimoto, A. (1993). Methane Emissions from Livestock Manure. In International Methane Emissions, US Environmental Protection Agency, Climate Change Division, Washington, D.C., U.S.A.

Zeeman, G. (1994). Methane production/emission in storages for animal manure. *Fertilizer Research* **37**: 207-211, 1994. Kluwer Academic Publishers, Netherlands.

Zeeman, G., Gerbens, S. 2000. CH_4 emissions from animal manure. IPCC Background Papers—IPCC Expert Meetings on Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, pp. 339–48

Annex 10A.6 Describe the monthly temperature of each climate zones according to chapter XX of IPCC guideline

TBD

ANNEX10B.2 EXPLANATORY TEXT FOR DEVELOPMENT OF NEW PARAMETERS IN THE 2019 REFINEMENT.

Table 10B.7 North America

Dairy	**2019**		**2006**	**References**
Weight, kg	600			Expert judgement of IPCC panel, with consideration of (Appuhamy *et al.* 2016; Jayasundara *et al.* 2016)
Weight Gain, kg/day	0			Expert judgement of IPCC panel, no change from 2006 guidelines
Feeding Situation	Stall Fed			
Milk, kg/day	30	U	23	Expert judgement of IPCC panel, with consideration of (Appuhamy *et al.* 2016; Jayasundara *et al.* 2016). Milk production was corrected for a 320 day lactation cycle.
Fat, %	3.7	U		
Protein, %	3.2	U		
Work, hrs/day	0			Expert judgement of IPCC panel, no change from 2006 guidelines
% Pregnant	90			
Digestibility of Feed %	75			
CH4 Conversion %	5.7	U	6.5	Expert judgement of IPCC panel, with consideration of (Appuhamy *et al.* 2016; Jayasundara *et al.* 2016)
CP, %	16.6	U		
Day Weighted Population Mix %	100			Expert judgement of IPCC panel, no change from 2006 guidelines

Non Dairy –Mature Males	**2019**		**2006**	**References**
Weight, kg	821	U	800	Expert judgement of IPCC panel, considering consistency with IPCC 2006 and in consideration of (Basarab *et al.* 2005; Ominski *et al.* 2007; Capper 2011; Stackhouse-Lawson *et al.* 2012; Waldrip *et al.* 2013; Dong *et al.* 2014; Sheppard *et al.* 2015; Legesse *et al.* 2016)
Weight Gain, kg/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
Feeding Situation	Pasture/Range		Pasture/Range	
Milk, kg/day	0		0	NA
Fat, %	0		0	
Protein, %	0		0	
Work, hrs/day	0		0	
% Pregnant	0		0	
Digestibility of Feed %	60		60	Expert judgement of IPCC panel, no change from 2006 guidelines

CH4 Conversion %	7.00%	U	6.5	Consistency with Table 10.14
CP, %	12%	U	NA	Expert judgement of IPCC panel, with consideration of (Waldrip *et al.* 2013; Dong *et al.* 2014; Sheppard *et al.* 2015)
Day Weighted Population Mix %	2%		2%	Expert judgement of IPCC panel, no change from 2006 guidelines
Non Dairy –Mature Females	**2019**		**2006**	**References**
Weight, kg	580		500	Expert judgement of IPCC panel, considering consistency with IPCC 2006 and in consideration of (Basarab et al. 2005; Ominski et al. 2007; Capper 2011; Stackhouse-Lawson et al. 2012; Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015; Legesse et al. 2016)
Weight Gain, kg/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
Feeding Situation	Pasture/Range		Pasture/Range	
Milk, kg/day	7	U	23	Expert judgement of IPCC panel, with consideration of (Basarab et al. 2005; Ominski et al. 2007; Mulliniks et al. 2017). Milk production was corrected for a five month lactation cycle. (the value 3 kg day was used in calculations, and is found in Tables A1.
Fat, %	4	U	4	
Protein, %	3.5	U	3.5	
Work, hrs/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
% Pregnant	80%		80%	
Digestibility of Feed %	60		60	
CH4 Conversion %	7.00%	U	6.5	Consistency with Table 10.14
CP, %	12%	U	NA	Expert judgement of IPCC panel, with consideration of (Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015)
Day Weighted Population Mix %	36%		36%	Expert judgement of IPCC panel, no change from 2006 guidelines
Non Dairy –Calves on milk	**2019**		**2006**	**References**
Weight, kg	125	U	100	Expert judgement of IPCC panel, considering consistency with IPCC 2006 and in consideration of (Basarab et al. 2005; Ominski et al. 2007; Capper 2011; Stackhouse-Lawson et al. 2012; Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015; Legesse et al. 2016)
Weight Gain, kg/day	1	U	0.9	
Feeding Situation	Pasture/Range		Pasture/Range	Expert judgement of IPCC panel, no change from 2006 guidelines
Milk, kg/day	0		0	NA
Fat, %	0		0	

Protein, %	0		0	
Work, hrs/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
% Pregnant	0		0	
Digestibility of Feed %	60		60	
CH4 Conversion %	0	U	0	Consistency with Table 10.14
CP, %	12%	U	NA	Expert judgement of IPCC panel, with consideration of (Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015)
Day Weighted Population Mix %	16%		16%	Expert judgement of IPCC panel, no change from 2006 guidelines
Non Dairy –Calves on forage	**2019**		**2006**	**References**
Weight, kg	215	U	185	Expert judgement of IPCC panel, considering consistency with IPCC 2006 and in consideration of (Basarab et al. 2005; Ominski et al. 2007; Capper 2011; Stackhouse-Lawson et al. 2012; Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015; Legesse et al. 2016)
Weight Gain, kg/day	1	U	0.9	
Feeding Situation	Pasture/Range		Pasture/Range	Expert judgement of IPCC panel, no change from 2006 guidelines
Milk, kg/day	0		0	NA
Fat, %	0		0	
Protein, %	0		0	
Work, hrs/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
% Pregnant	0		0	
Digestibility of Feed %	60		60	
CH4 Conversion %	6.3%	U	6.5%	Consistency with Table 10.14
CP, %	13%	U	NA	Expert judgement of IPCC panel, with consideration of (Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015)
Day Weighted Population Mix %	8%		8%	Expert judgement of IPCC panel, no change from 2006 guidelines
Non Dairy –Growing Heifer/Steers	**2019**		**2006**	**References**
Weight, kg	300	U	265	Expert judgement of IPCC panel, considering consistency with IPCC 2006 and in consideration of (Basarab et al. 2005; Ominski et al. 2007; Capper 2011; Stackhouse-Lawson et al. 2012; Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015; Legesse et al. 2016)
Weight Gain, kg/day	0.9	U	0.7	
Feeding Situation	Pasture/Range		Pasture/Range	Expert judgement of IPCC panel, no change from 2006 guidelines

Milk, kg/day	0		0	NA
Fat, %	0		0	
Protein, %	0		0	
Work, hrs/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
% Pregnant	0		0	
Digestibility of Feed %	65		65	
CH4 Conversion %	6.3%	U	6.5%	Consistency with Table 10.14
CP, %	13%	U	NA	Expert judgement of IPCC panel, with consideration of (Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015)
Day Weighted Population Mix %	17%		17%	Expert judgement of IPCC panel, no change from 2006 guidelines
Non Dairy –Replacement/Growing Heifer	**2019**		**2006**	**References**
Weight, kg	400	U	375	Expert judgement of IPCC panel, considering consistency with IPCC 2006 and in consideration of (Basarab et al. 2005; Ominski et al. 2007; Capper 2011; Stackhouse-Lawson et al. 2012; Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015; Legesse et al. 2016)
Weight Gain, kg/day	0.5	U	0.4	
Feeding Situation	Pasture/Range		Pasture/Range	Expert judgement of IPCC panel, no change from 2006 guidelines
Milk, kg/day	0		0	NA
Fat, %	0		0	
Protein, %	0		0	
Work, hrs/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
% Pregnant	0		0	
Digestibility of Feed %	60		60	
CH_4 Conversion %	7%	U	6.5%	Consistency with Table 10.14
CP, %	13%	U	NA	Expert judgement of IPCC panel, with consideration of (Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015)
Day Weighted Population Mix %	11%		11%	Expert judgement of IPCC panel, no change from 2006 guidelines
Non Dairy –Feedlot Cattle	**2019**		**2006**	**References**
Weight, kg	500	U	415	Expert judgement of IPCC panel, considering consistency with IPCC 2006 and in consideration of (Basarab et al. 2005; Ominski et al. 2007; Capper 2011; Stackhouse-Lawson et al. 2012; Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015; Legesse et al. 2016)
Weight Gain, kg/day	1.4	U	1.3	

Feeding Situation	Pasture/Range		Pasture/Range	Expert judgement of IPCC panel, no change from 2006 guidelines
Milk, kg/day	0		0	NA
Fat, %	0		0	
Protein, %	0		0	
Work, hrs/day	0		0	Expert judgement of IPCC panel, no change from 2006 guidelines
% Pregnant	0		0	
Digestibility of Feed %	75		75	
CH_4 Conversion %	3%		3%	Consistency with Table 10.14
CP, %	14%	U	NA	Expert judgement of IPCC panel, with consideration of (Waldrip et al. 2013; Dong et al. 2014; Sheppard et al. 2015)
Day Weighted Population Mix %	11%		11%	Expert judgement of IPCC panel, no change from 2006 guidelines

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References

Appuhamy, J. A., France, J. & Kebreab, E. (2016) Models for predicting enteric methane emissions from dairy cows in North America, Europe, and Australia and New Zealand. *Global Change Biology* **22**(9): 3039-3056.

Basarab, J. A., Okine, E. K., Baron, V. S., Marx, T., Ramsey, P., Ziegler, K. & Lyle, K. (2005) Methane emissions from enteric fermentation in Alberta's beef cattle population. *Canadian Journal of Animal Science* **85**(4): 501-512.

Capper, J. L. (2011) The environmental impact of beef production in the United States: 1977 compared with 2007. *Journal of Animal Science* **89**(12): 4249-4261.

Dong, R. L., Zhao, G. Y., Chai, L. L. & Beauchemin, K. A. (2014) Prediction of urinary and fecal nitrogen excretion by beef cattle. *J Anim Sci* **92**(10): 4669-4681.

Jayasundara, S., Ranga Niroshan Appuhamy, J. A. D., Kebreab, E. & Wagner-Riddle, C. (2016) Methane and nitrous oxide emissions from Canadian dairy farms and mitigation options: An updated review. *Canadian Journal of Animal Science* **96**(3): 306-331.

Legesse, G., Beauchemin, K. A., Ominski, K. H., McGeough, E. J., Kroebel, R., MacDonald, D., Little, S. M. & McAllister, T. A. (2016) Greenhouse gas emissions of Canadian beef production in 1981 as compared with 2011. *Animal Production Science* **56**(2-3): 153-168.

Mulliniks, J. T., Edwards, S. R., Hobbs, J. D., McFarlane, Z. D. & Cope, E. R. (2017) Post-weaning feed efficiency decreased in progeny of higher milk yielding beef cows. *Animal*: 1-5.

Ominski, K. H., Boadi, D. A., Wittenberg, K. M., Fulawka, D. L. & Basarab, J. A. (2007) Estimates of enteric methane emissions from cattle in Canada using the IPCC Tier-2 methodology. *Canadian Journal of Animal Science* **87**(3): 459-467.

Sheppard, S. C., Bittman, S., Donohoe, G., Flaten, D., Wittenberg, K. M., Small, J. A., Berthiaume, R., McAllister, T. A., Beauchemin, K. A., McKinnon, J., Amiro, B. D., MacDonald, D., Mattos, F. & Ominski, K. H. (2015) Beef cattle husbandry practices across Ecoregions of Canada in 2011. *Canadian Journal of Animal Science* **95**(2): 305-321.

Stackhouse-Lawson, K. R., Rotz, C. A., Oltjen, J. W. & Mitloehner, F. M. (2012) Carbon footprint and ammonia emissions of California beef production systems1. *Journal of Animal Science* **90**(12): 4641-4655.

Waldrip, H. M., Todd, R. W. & Cole, N. A. (2013) Prediction of nitrogen excretion by beef cattle: a meta-analysis. *J Anim Sci* **91**(9): 4290-4302.

Table 10B.8 Western Europe

Parameter	Unit	Value	Reference
Milk yield	kg/hd/d	18.4	Eurostat, 2017

DC_Dairy	%	73	Expert judgment based on Gerrits et al., 2014; Bannink et al., 2011; Hammond et al., 2016; Bannink et al., 2016; Spek et al., 2013
DC_Growing	%	65	Expert judgment based on Gerrits et al., 2014; Bannink et al., 2011; Hammond et al., 2016; Bannink et al., 2016; Spek et al., 2013
DC_Calves_forage	%	73	Gerrits et al., 2014
Ym_MM	%	7	Table 10.13 of the 2019 RG
Ym_Calves_milk	%	0.3	Gerrits et al., 2014
Ym_Calves_forage	%	5.5	Gerrits et al., 2014

1. Gerrits, W.J.J., J. Dijkstra, A. Bannink, 2014. *Methaanproductie bij witvleeskalveren.* Wageningen, Wageningen UR (University & Research centre) Livestock Research, Livestock Research Report 813. 15 p.
2. Eurostat, 2017. The statistical office of the European Union. Accessed on 17.11.2017. Available from: http://ec.europa.eu/eurostat
3. Bannink, A., van Schijndel, M.W., Dijkstrac, J., 2011. A model of enteric fermentation in dairy cows to estimate methane emission for the Dutch National Inventory Report using the IPCC Tier 3 approach. Animal Feed Science and Technology, 166: 603– 618 // doi:10.1016/j.anifeedsci.2011.04.043
4. Hammond, K.J., Crompton, L.A., Bannink, A., Dijkstra, J., Yá˜nez-Ruiz, D.R., O'Kiely, P., Kebreab, E., Eugène, M.A., Yuh, Z., Shingfield, K.J., Schwarm, A., Hristov, A.N., Reynolds, C.K., 2016. Review of current in vivo measurement techniques for quantifying enteric methane emission from ruminants. Animal Feed Science and Technology 219: 13–30 // http://dx.doi.org/10.1016/j.anifeedsci.2016.05.018
5. Bannink, A., Warner, D., Hatew, B., Ellis, J. L., Dijkstra, J., 2016. Quantifying effects of grassland management on enteric methane emission. *Animal Production Science,* 56(3): 409-416 // https://doi.org/10.1071/AN15594
6. Spek, J. W., Dijkstra, J., van Duinkerken, G., Hendriks, W.H., Bannink A., 2013. Prediction of urinary nitrogen and urinary urea nitrogen excretion by lactating dairy cattle in northwestern Europe and North America: A meta-analysis. J. Dairy Sci. 96: 4310–4322 // http://dx.doi.org/ 10.3168/jds.2012-6265

Table 10B.8 Eastern Europe

Parameters	**Unit**	**Table of 2019 RG**	**Value**	**Reference**
Dairy cattle		**10.A-1a**		
Weight	kg/hd	550	577	(Kostenko & Pyrozhenko 2012)
Weight	kg/hd	550	562 563	(Sharkaeva 2012)

			571	
Weight	kg/hd	550	543 578	(Zadnepryanskiy & Zakirko 2012)
Weight	kg/hd	550	517 607 505	(Samorukov *et al.* 2013)
Weight	kg/hd	550	517 488 519 541 508 515 494 485	(Furaeva 2013)
Weight	kg/hd	550	545	(Golubkov *et al.* 2015)
Weight	kg/hd	550	520 610 505	(Samorukov *et al.* 2009)
Weight gain	kg/hd/d	0	0	IPCC 2006
Feeding situation		Stall Fed	Stall Fed	IPCC 2006
Milk yield	kg/hd/d	10.24	10.24	FAOSTAT: value of 2006–2014 (Faostat 2017)
Milk fat content	%	3.9	3.93	(Samorukov *et al.* 2009)
Milk fat content	%	3.9	3.85	(Sharkaev & Kochetkov 2012)
Milk protein content	%	3.19	3.19	(Samorukov *et al.* 2009)
Work	hr/day	0	0	IPCC 2006
Pregnancy rate	%	85	85	(Dunin *et al.* 2011)
DC	%	70	66	(Gren 2013)
DC	%	70	72	(Haysanov 2011)
DC	%	70	73	(Nosyreva Yu & Tokareva 2014)
DC	%	70	71	(Azaubaeva 2008)
CP	%	15.1	14.8 15.3	(Kalnickij & Haritonov 2008)
CP	%	15.1	17.0	(Nekrasov *et al.* 2013)
Ym	%	6.3		Table 10.13 of the 2019 RG
Mature Females		**10.A-2a**		
Weight	kg/d	560	500	Dunin et al., 2011
Weight	kg/d	560	535	(Kostenko & Pyrozhenko 2012)

Weight	kg/d	560	630	(Sheveleva & Bakharev 2013)
Weight gain	kg/hd/d	0		2006 IPCC
Feeding situation		Pasture	Pasture	2006 IPCC
Milk yield	kg/hd/d	3.0	Calculated as: milk yield at 1000-1200 kg/hd/yr divided by 365	(Bakharev 2012)
Milk fat content	%	4.16	4.16	(Bakharev 2012)
Milk protein content	%	3.66	3.66	(Bakharev 2012)
Work		0		2006 IPCC
Pregnancy rate	%	80	80 83	(Dunin *et al.* 2011)
Pregnancy rate	%	80	75	(Sharkaeva 2013)Sharkaeva, 2013
DC	%	70	70	DC value of 'Dairy cattle' was applied
CP	%	15.1	15.1	CP value of 'Dairy cattle' was applied
Ym	%	6.3		Table 10.13 of the 2019 RG
Mature Males		**10.A-2a**		
Weight	kg/hd	600	750	(Dunin *et al.* 2011)
Weight	kg/hd	600	570 (1 yr) 700 (2 yr) 750 (4yr)	(Amerkhanov *et al.* 2016)
Weight gain	kg/hd/d	0	0	2006 IPCC
Feeding situation		Pasture	Pasture	2006 IPCC
Work	hr/day	0	0	2006 IPCC
DC	%	65		DC value of 'Growing/Replacement cattle' was applied
CP	%	14.2		CP value of 'Growing/Replacement cattle' was applied
Ym	%	6.3		Table 10.13 of the 2019 RG
Growing / Replacement		**10.A-2a**		
Weight	kg/hd	350	512 (740d)	(Tekeev & Chomaev 2011)
Weight	kg/hd	350	450 (18m)	(Gayirbegov & Mandjiev 2013)
Weight	kg/hd	350	486 (18m) 510 (18m)	Gebaidullin et al., 2011
Weight	kg/hd	350	420 (14m)	(Goncharova & Kibkalo 2011)
Weight	kg/hd	350	440 (18m)	(Levakhin *et al.* 2011)
Weight	kg/hd	350	530 (18m)	(Litovchenko 2012)
Weight	kg/hd	350	420 (18m)	(Samorukov *et al.* 2009)

			370 (18m)	
Weight	kg/hd	350	620 (16m)	(Leontev *et al.* 2013)
Weight gain	kg/hd/d	0.33		A weight-range between 350 kg and 470 kg was employed for Growing/Replacement animals. Hence, the value of weight gain per head per day was evaluated as 0.33 kg/hd/d.
Feeding situation		Pasture	Pasture	2006 IPCC
Work	hr/day	0		2006 IPCC
DC	%	65	62-68	(Gayirbegov & Mandjiev 2013)Gayirbegov and Mandjev, 2013
CP	%	14.2	13.6	(Shevkhuzhev *et al.* 2015)
CP	%	14.2	14.4	(Golubkov *et al.* 2015)
CP	%	14.2	13.9 14.4	(Mamaev *et al.* 2017)
Ym	%	6.3		Table 10.13 of the 2019 RG
Calves on forage		**10.A-2**		
Weight	kg/hd	190	263 (320d)	(Tekeev & Chomaev 2011)
Weight	kg/hd	190	345 (12 m)	(Pracht 2013)
Weight	kg/hd	190	300 (12 m)	(Gayirbegov & Mandjiev 2013)
Weight	kg/hd	190	34 (0d) 340-350 (12m)	(Gubaidullin *et al.* 2011)
Weight	kg/hd	190	300 (12 m)	(Goncharova *et al.* 2009)
Weight	kg/hd	190	350 (12m)	(Goncharova & Kibkalo 2011)
Weight	kg/hd	190	270 (11m)	(Levakhin *et al.* 2011)
Weight	kg/hd	190	340 (12m)	(Litovchenko 2012)
Weight	kg/hd	190	450 (12m)	(Leontev *et al.* 2013)
Weight gain	kg/hd/d	0.87		A weight-range between 34 (birth weight) and 350 (MW) was employed for ‘Calves on forage’ cattle category. The value of mid-point average weight (BW) was selected as 190 kg. The weight gain was calculated as 0.87 kg/hd/d.
Feeding situation		Pasture	Pasture	2006 IPCC
Work	hr/day	0	0	2006 IPCC
DC	%	65	66	(Ilichev *et al.* 2011)
DC	%	65	64	(Gayirbegov & Mandjiev 2013)
CP	%	14.3	14.6	(Shevkhuzhev *et al.* 2015)
CP	%	14.3	14.0	(Golubkov *et al.* 2015)
Ym	%	6.3		Table 10.13 of the 2019 RG

Day weighted population	%	9/39/27/25	Of 100%: 9 – Mature Males 39 – Mature Females 27 – Growing 25 – Calves	RUSSTAT, 2016

1. Amerkhanov, K., Polovinko, L., Kalashnikov, N., Kayumov, F., 2016. Characteristics of the genetic material in breeding high-productive type «Voznesenovsky» of the Kalmyk cattle. Bulletin of meat breeding, 4(96): 15–21
2. Azaubaeva, G.S., 2008. Nitrogen and energy metabolism, milk productivity of cows due to change in diet ration. Agrarian Bulletin of the Urals, 3: 41–43.
3. Bakharev, A.A., 2012. Milk productivity and milk content of beef breed cows. Agricultural policy of the Russian Federation, 9: 57–59.
4. Dunin, I., Sharkaev, V., Kochetkov, A., 2011. Performance results of beef cattle production branch in the Russian federation. Dairy and Beef Cattle Breeding, 5: 2–5.
5. FAOSTAT, 2017. Available from: http://www.fao.org/faostat/en/ Accessed on 7.11.2017
6. Furaeva N.S., 2013. Current state of pedigree base of cattle of the Yaroslavl breed and prospect of its development. Agricultural bulletin of Yaroslavl region, 1(21): 21-30
7. Gayirbegov, D. and Mandjiev, D., 2013. The effect of feeding type on metabolism and growth energy of bulls of kalmyk breed. Dairy and Beef Cattle Breeding, 7: 31–32.
8. Golubkov A.I., Dunin I.M., Adzhibekov K.K., Lazovaya G.S., Chekushkin A.M., 2015. Milk productivity of the red-motley breed cows of different intrabreed types. Bulletin of Krasnoyarsk state agricultural university, 10: 189-196
9. Goncharova, N. and Kibkalo L., 2011. Efficiency of cultivation of bull- calves on meat. Dairy and Beef Cattle Breeding, 3: 20–21.
10. Goncharova, N.A., Kiblalo, L.I., Zerebilov, N.I., 2009. Feedlot efficiency of growing beef cattle. Bulletin of Krasnoyarsk state agricultural university, 3(3): 70–74.
11. Gren, O.V., 2013. The fodder nutrients digestibility when feeding lactation cows with «Biokoretron-forte». Bulletin of Krasnoyarsk state agricultural university, 1: 88–90
12. Gubaidullin N.; Tagirov H.; Iskhakov R., 2011. Productive qualities of thoroughbred and hybrid bulls. Dairy and Beef Cattle Breeding, S1: 25–26.
13. Haysanov, D.P., 2011. The milk yield of cows according to their genotype, feeding level and technology content. Bulletin of Krasnoyarsk state agricultural university, 4: 102–106.
14. Ilichev, E., Nazarova, A., Polishchuk, S., Inozemtsev, V., 2011. Diet digestibility and nutrient balance with the addition of cobalt and copper nanopowders to the calves' rations. Dairy and Beef Cattle Breeding, 5: 27–29.
15. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
16. Kalnickij, B.D. and Haritonov, E.L., 2008. Determination of the dairy cows protein diet standards for the first phase of lactation. Achievements of Science and Technology of AICis, 10: 18–22.
17. Kostenko, V.I. and Pyrozhenko, Y.V., 2012. Methodology for GHG emissions estimation from cattle enteric fermentation in conditions of Ukraine. Scientific Bulletin of UNFU, 179: 183-193.
18. Leontev, V., Burmistrov, V., Linkevich, R., Asaynin, V., Lavrova, A., 2013. Comparative evaluation of limousin bull growth and slaughter quality in the JSC “Zavolzhskoe” farm, in Tver region. Dairy and Beef Cattle Breeding, 2: 18–19.

19. Levakhin, V., Azhmuldinov, E., Ibraev, A., Babicheva, I., Poberukhin, M., 2011. Influence of structure and quality of rations on meat productivity of young animals. Dairy and Beef Cattle Breeding, 6: 31–32

20. Litovchenko V., 2012. Growth and productivity of meat from calves simmental genotypes in Southern Ural. Dairy and Beef Cattle Breeding, 6: 16–18.

21. Mamaev, I.I., Mironova, I.V., Dolzhenkova, G.M., Kosilov, V.I., 2017. Productive qualities of young black-spotted cattle and their double-and-triple cross hybrids. Bulletin of Orenburg State, 1(63): 128–130.

22. Nekrasov, R., Varenikov, M., Chabaev, M., Anisova, N., Anikin, A., Pisarev, V., Turchina, V., 2013. Balancing of the metabolic energy level in the high productive cow rations during the early lactation. Dairy and Beef Cattle Breeding, 3: 9–13.

23. Nosyreva, Y.N., Tokareva, V.F., 2014. Influence of multifunctional supplement “Fungistat gpk” on nutrition digestibility given to lactating cows of black-and-white, Bulletin of Irkutsk state agrarian university, 62: 72–75.

24. Pracht, V., 2013. Effect of growth rate of holsteinized heifers of kholmogorskaya breed on subsequent milk performance. Dairy and Beef Cattle Breeding, 5: 31–32.

25. RUSSTAT, 2016. Preliminary results of All-Russian Agricultural Census of 2016, Federal State Statistics Service of the Russian Federation, 290 p.

26. Samorukov, Y., Bychkov, A., Chernov, V., Andrianov, V., Potepalova, V., Marzanov, N., 2013. About breeds in dairy cattle breeding. Dairy and Beef Cattle Breeding, 1: 21–23.

27. Samorukov Y., Kalyazina T., Marzanov N., 2009. About the breeds in dairy farming. Dairy and Beef Cattle Breeding, 1: 21–23.

28. Sharkaev, V. and Kochetkov, A., 2012. Results of the complex estimation of dairy cattle in the Russian Federation. Dairy and Beef Cattle Breeding, 1: 12–14.

29. Sharkaeva, G., 2012. Use of imported cattle in the territory of the Russian Federation. Dairy and Beef Cattle Breeding, 1: 12–14.

30. Sharkaeva, G., 2013. Monitoring of the cattle imported in the Russian Federation. Dairy and Beef Cattle Breeding, 1: 14–16

31. Sheveleva, O.M. and Bakharev, A.A., 2013. The formation of beef cattle breeding industry with the use of French breeds in the conditions of northern Zauralye Agrarian. Bulletin of the Urals, 8(114): 23–25.

32. Shevkhuzhev, A.F., Dubrovin, A.I., Ulimbasheva, R.A., 2015. The behavioural reactions of bull-calves caused by technology of their growth. Bulletin of Saint-Petersburg State Agrarian University, 41: 100–104.

33. Tekeev, M. and Chomaev, A., 2011. Housing and rearing technology of replacement young cattle stock. Dairy and Beef Cattle Breeding, 5: 18–19.

34. Zadnepryanskiy I. and Zakirko V., 2012. Red-and-white breed milk cattle in Belgorod region. Dairy and Beef Cattle Breeding, 3: 21–23.

Table 10B.9 MIDDLE EAST

Dairy Cattle	Unit	Table 10.A-1b	Value	Reference
Weight_low	kg/hd	270	200–300 (most widespread) 250-350 250-350 310	(Yilmaz *et al.* 2012)
Weight_low	kg/hd	270	200	(Ulas 2016)

			250	
Weight_low	kg/hd	270	150-250 200-300 (most widespread) 250-350	(MFAL 2011)
Weight_low	kg/hd	270	275	(Kamalzadeh 2008)
Weight_high	kg/hd	530	517	(Fatahnia *et al.* 2010)
Weight_high	kg/hd	530	485 (470-500)	(USDA 2015)
Weight_high	kg/hd	530	512 (425-600)	(Tasdemir *et al.* 2011)
Weight_high	kg/hd	530	680 (after 3rd calving)	(Sadeghi-Sefidmazgi *et al.* 2012)
Feeding_low		Pasture	Pasture	(Karakok 2007)
Feeding_high		Stall	Stall	(Kara *et al.* 2015)
Milk yield_low	kg/hd/d	3.60	3.60	TSI, 2017 (Turkish statistical 2017)(Turkish statistical 2017)
Milk yield _high	kg/hd/d	10.62	10.62	TSI, 2017
Fat_low	%	4.5	4 (native black) 3.6 3.6 3.2	(Yilmaz *et al.* 2012)
Fat_low	%	4.5	5.1 (4.71-5.45)	(Ulas 2016)Ula, 2016
Protein_low	%	3.7	Fat: 4.41 - 4.60 Protein: 3.6–3.7	(da Cunha & Pereira 2010)
Fat_high	%	3.4	3.5	***(CBAT 2017)***
Fat_high	%	3.4	3.23 (holstein)	(Fatahnia *et al.* 2010)
Protein_high	%	3.2	3.3	CBAT, 2017
Protein_high	%	3.2	3.10 (holstein)	(Fatahnia *et al.* 2010)
Pregnancy_low	%	50	50	Calculated based on data of TSI, 2017
Pregnancy_high	%	55	55	Calculated based on data of TSI, 2017
Pregnancy_high	%	55	55	(Karakok 2007)
DC_low	%	60		Calculated based on: (Fao & Ifcn 2014) (Gerber *et al.* 2011)
DC_high	%	65		Calculated based on: (Fao & Ifcn 2014) (Gerber *et al.* 2011)
CP_low	%	12.5	12.5	(Özlütürk *et al.* 2006)
CP_high	%	15.8	15.8 (Holstein)	(Fatahnia *et al.* 2010)

Ym_low	%	6.5		Table 10.13 of the 2019 RG
Ym_high	%	6.3		Table 10.13 of the 2019 RG
Day weighted population_DC	%	85/15	High/low	TSI, 2017
Mature Males	Unit	Table 10.A-2b	Value	Reference
Weight_MM_low	kg/hd	450	370	(Kamalzadeh 2008)
Weight_MM-low	kg/hd	450	350-450 550-600 400-600	(Yilmaz *et al.* 2012)
Weight_MM_high	kg/hd	600	615	(Ustuner *et al.* 2017)
Weight_MM_high	kg/hd	600	744 801 743	(Akbaş *et al.* 2006)
Weight_MM-high	kg/hd	600	500 520 490	(Akbaş *et al.* 2006)
Weight_MM_high	k/hd	600	600-700	(Ulas 2016)
Feeding_MM_low		Pasture	Pasture	(Karakok 2007)
Feeding_MM_high		Pasture	paddock	(Ustuner *et al.* 2017)
Work_MM_low	hr/hd/d	0.55		2006 GL
CP_MM_low	%	13.5		The CP,% value of Growing/Replacement animals (low-producing) was applied
CP_MM-high	%	15.5		The CP,% value of Growing/Replacement animals (high-producing) was applied
DC_MM_low	%	55		Calculated based on: FAO, IDF and IFCN. 2014. Pierre Gerber, P., et al., 2011 It was assumed that Data of diet composition of dry dairy cows were taken as input-information.
DC_MM_high	%	62		Calculated based on: FAO, IDF and IFCN. 2014. Pierre Gerber, P., et al., 2011 Data of diet composition of dry dairy cows were taken as input-information.
Mature Females	Unit	Table 10.A-2b	Value	Reference

Weight_MF_low	kg/hd	360	350-450 270-450	(Yilmaz *et al.* 2012)
Milk_yield_MF_low	kg/hd/d	2.3	900 – 1000 600 – 650	(Yilmaz *et al.* 2012)
Fat_MF_low	%	3.8	3.5 3.2 3.5-4.5	(Yilmaz *et al.* 2012)
Protein_MF_low	%	3.2		Judgement of the IPCC panel
MF_low				All other input-parameters, related to low-producing dairy cows and high-producing dairy cows, were applied for Mature Females livestock category
Growing/ Replacement/ Calves on forage	Unit	Table 10.A-2b	Value	Reference
Weight_C_low	kg/hd	80	0m: 18-20 17-22 15-17 23-27 22-24 17-27	(Yilmaz *et al.* 2012)
Weight_G_C_low	kg/hd	80 150	205d: 100 0m: 21	(Özlütürk *et al.* 2006)
Weight_C_high	kg/hd	150	28(0m) 140 (6m)	(Koçyiğit *et al.* 2014)
Weight_G_C_high	kg/hd	150 350	220 (5.5m) 223 (7.5m) 615 (433d) 615 (490d)	(USTUNER *ET AL.* 2017)
Weight_G_C_high	kg/hd	150 350	186 (175d) 1y: 420 390 350	(CHASHNIDEL *ET AL.* 2007)
Weight_G_C_high	kg/hd	150 350	0m: 35 12m: 430 400 460d:	(Akbaş *et al.* 2006)

			500 520 490	
Weight_G_C_high	kg/hd	150 350	205d: 185 (crossbred) 195 (crossbred)	(Özlütürk *et al.* 2006)
Weight_C_G_high	kg/hd	150 350	144 (6m) 507 (18m)	(Yalcin *et al.* 2017)
Weight_gain_C_low	kg/hd/d	0.36		A weight-range between 20 (birth weight) and 150 (MW) was employed for 'Calves on forage' cattle category. The value of mid-point average weight (BW) was selected as 80 kg. The weight gain was calculated as 0.36 kg/hd/d.
Weight_gain_C_high	kg/hd/d	0.85		A weight-range between 35 (birth weight) and 350 (MW) was employed for 'Calves on forage' cattle category. The value of mid-point average weight (BW) was selected as 150 kg. The weight gain was calculated as 0.85 kg/hd/d.
Weight_gain_G_low	kg/hd/d	0.19		A weight-range between 150 kg and 220 kg was employed for Growing/Replacement animals. Hence, the value of weight gain per head per day was evaluated as 0.19 kg/hd/d.
Weight_gain_G_high	kg/hd/d	0.33		A weight-range between 350 kg and 470 kg was employed for Growing/Replacement animals. Hence, the value of weight gain per head per day was evaluated as 0.33 kg/hd/d.
Feeding_low		Pasture	Pasture	(Koçyiğit *et al.* 2014)
Feeding_low		Pasture	Pasture	(Karakok 2007)
Feeding_high		Pasture	Paddock	(Ustuner *et al.* 2017)
CP_C_G_low	%	13.5		The lowest value in CP,%-range reported for high-producing young animals was selected for low-producing young cattle
CP_C_high	%	15.5	17.4	(Özlütürk *et al.* 2006)
CP_G_high	%	15.5	13.5	(Chashnidel *et al.* 2007)
CP_G_high	%	15.5	16.4 = 1.11/6.77 16.4 =1.10/6.69 16.4 =1.07/6.53	(Akbaş *et al.* 2006)

DC_C_G_low	%	55		Calculated based on: FAO, IDF and IFCN. 2014. Pierre Gerber, P., et al., 2011 It was assumed that Data of diet composition of dry dairy cows were taken as input-information.
DC_ C_G_high	%	63		Calculated based on: FAO, IDF and IFCN. 2014. Pierre Gerber, P., et al., 2011 Data of diet composition of dry dairy cows were taken as input-information.
Ym_C_G_low	%	6.3		Table 10.13 of the 2019 RG
Ym_C_G_high	%	6.3		Table 10.13 of the 2019 RG
Day weighted population_low	%	41/42/7/10	Of 100%: 41 – calves on forage 42 – growing animals 7 – mature males 10 – mature females	TSI, 2017
Day weighted population_high	%	36/42/12/10	Of 100%: 36 – calves on forage 42 – growing animals 12 – mature males 10 – mature females	TSI, 2017
Day weighted population	%	70/30	Of 100%: 85 – high-producing cattle 15 – low producing animals	TSI, 2017 (Turkey)
Day weighted population	%	70/30	Of 100%: 42 – high-producing cattle 58 – low producing animals	SCI, 2011 (Iran) (Selected Results of Livestock 2012)

1. Akbaş, Y., Alçiçek, A., Önenç, A., Güngör, M., 2006. Growth curve analysis for body weight and dry matter intake in Friesian, Limousin x Friesian and Piemontese x Friesian cattle. Arch.Tierz., Dummerstorf, 49(4): 329–339.
2. CBAT, 2017. Cattle Breeders' association of Turkey (CBAT)
3. Chashnidel, Y., Pirsaraei, A., Yousef-Elahi, M., 2017. Comparison of daily weight gain and fattening characteristics between buffalo and Holstein male calves with different diets. Italian Journal of Animal Science, 6(S2): 1199-1201.
4. da Cunha, D.N.F.V., Pereira, J.C., de Campos, O.F., Gomes, S.T., Braga, J.L., Martuscello, J.A., 2010. Simulation of Holstein and Jersey profitability by varying milk price payment system R. Bras. Zootec., 39(4): 913-923.
5. FAO, IDF and IFCN. 2014. World mapping of animal feeding systems in the dairy sector. Rome.
6. Fatahnia, F., Rowghani, E., Hosseini, A. R., Darmani Kohi, H., Zamiri, M. J., 2010. Effect of different levels of monensin in diets containing whole cottonseed on milk production and composition of lactating dairy cows. Iranian Journal of Veterinary Research, 11(3): 206–213.
7. Gerber, P., Vellinga, T., Opio, C., Steinfeld, H., 2011. Productivity gains and greenhouse gas emissions intensity in dairy systems Livestock Science 139 , 100–108 // doi:10.1016/j.livsci.2011.03.012
8. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
9. Kamalzadeh, A., Rajabbeygi, M., Kiasat, A., 2008. Livestock production systems and trends in livestock industry in Iran. Journal of Agriculture and Social sciences, 4: 183–188.
10. Kara, N.K., Galic, A., Koyuncu, M., 2015. Comparison of Milk Yield and Animal Health in Turkish Farms with Differing Stall Types and Resting Surfaces Asian Australas. J. Anim. Sci., 28 (2): 268-272 // http://dx.doi.org/10.5713/ajas.14.0366.
11. Karakok, S.G., 2007. Small scale cattle farmers and their sustainability in lowland villages of Adana province, Turkey. *Livestock Research for Rural Development, 19. Accessed on* 12.11.2017, from http://www.lrrd.org/lrrd19/6/kara19087.htm.
12. Koçyiğit, R., Aydin, R., Yanar, M., Güler, O., Diler, A., Avci, M., Özyürek, S., Kabakci, D., Hirik, E.N., 2015. Effects of Weaning Ages on the Growth, Feed Conversion Efficiency and Some Behavioral Traits of Brown Swiss x Eastern Anatolian Red Calves. Journal of Agricultural Sciences, 21: 492–499.
13. MFAL, 2011. Domestic animal genetic resources in Turkey Republic of Turkey, Ministry of Food Agriculture and Livestock, General directorate of agricultural research and policy. Ankara, Turkey.
14. Sadeghi-Sefidmazgi, A., Moradi-Shahrbabak, M., Nejati-Javaremi, A., Miraei-Ashtiani, S.R., Amer, P.R., 2012. Breeding objectives for Holstein dairy cattle in Iran. Journal of Dairy Science, 95(6): 3406-3418 // https://doi.org/10.3168/jds.2011-4573.
15. SCI, 2011. Selected Results of Livestock Survey 1390. Statistical Centre of Iran.
16. Tasdemir, S., Urkmez, A., Inal, S., 2011. Determination of body measurements on the Holstein cows using digital image analysis and estimation of live weight with regression analysis. Computers and Electronics in Agriculture, 76: 189–197 // https://doi.org/10.1016/j.compag.2011.02.001.
17. TSI, 2017. Turkish statistical institute. Accessed on 17.11.2017. Avalaible from http://www.turkstat.gov.tr.
18. Ula, D., 2016. Fat depression in milk obtained from Simmental and native (Yerli Kara) cows in first month of postpartum period. International Journal of Biosciences, 9(6): 125-128.
19. USDA, 2015. Live animals and animal products trade: Turkey. GAIN report, USDA Foreign Agricultural Service.
20. Ustuner, H., Yalcintan, H., Orman, A., Ardicli, S., Ekiz, B., Gencoglu, H., Kandazoglu, O., 2017. Effects of initial fattening age on carcass characteristics and meat quality in Simmental bulls imported from Austria to Turkey. South African Journal of Animal Science, 47(2): 194–201 // http://dx.doi.org/10.4314/sajas.v47i2.11.

21. Özlütürk, A., Yanar, M., Tüzemen, N., Kopuzlu, S., 2006. Calving and preweaning growth performance traits of calves sired by Charolais, Simmental and Eastern Anatolian Red Bulls. Turkish Journal of Veterinary and Animal Sciences, 30(2): 257-263.

22. Yalcin, B., Stepan, V., Cihan, D., 2017. Prediction of liveweight of holstein and brown swiss cattle grown in an 12 month intensive beef production system by using real-time body measurements. Scientific Papers-Animal Science Series, 67: 39–43.

23. Yilmaz, O., Akin, O., Metin Yener, S., Ertugrul M., Wilson, R. T., 2012. The domestic livestock resources of Turkey: cattle local breeds and types and their conservation status. Animal Genetic Resources, 50: 65–73 // doi:10.1017/S207863361200003.

Table 10B.10 Latin America

Dairy (commnercial)	**2019**		**2006**	**References**
Weight, kg	560			Expert judgement of IPCC panel, with consideration of information from FAO
Weight Gain, kg/day	0			Expert judgement of IPCC panel, no change from 2006 guidelines
Feeding Situation	Pasture/Range			
Milk, kg/day	5.02	U		Expert judgement of IPCC panel, with consideration of information from FAO.
Fat, %	4.1	U		
Protein, %	3.2	U		
Work, hrs/day	0			Expert judgement of IPCC panel, with consideration of information from FAO.
% Pregnant	79.8			
Digestibility of Feed %	70.9			
CH4 Conversion %	6.3	U		Consistency with Table 10.14
CP, %	14	U		Expert judgement of IPCC panel, with consideration of information from FAO.
Day Weighted Population Mix %	100			Expert judgement of IPCC panel, no change from 2006 guidelines

Table 10B.10 Indian subcontinent

Dairy cattle	Unit	Table 10.A-1b	Value	Reference
Weight_DC_low	kg/hd	265	200-333	(Singhal *et al.* 2005)
Weight_DC_low	kg/hd	265	255 (200-365)	(Pathak *et al.* 2013)
Weight_DC_low	kg/hd	265	175	(Dhingra *et al.* 2017)
Weight_DC_low	kg/hd		215 278	(Mahakur *et al.* 2017)
Weight_DC_high	kg/hd	350	325 (300-352)	(Singhal *et al.* 2005)
Weight_DC_high		350	393	(Sirohi *et al.* 2012)
Weight_DC_high	kg/hd	350	300 (210-500)	Pathak et al., 2013

Weight_DC_high	kg/hd	350	400	(Sontakke *et al.* 2014a)
Weight_DC_high	kg/hd	350	375	(Saha *et al.* 2004)
Weight_DC_high	kg/hd	350	275	Dhingra et al., 2017
Feeding_DC_low		Pasture	Pasture	(Saha *et al.* 2004)
Feeding_DC_low		Pasture	Stall fed/pasture	Pathak et al., 2013
Feeding_DC_low		Pasture	Pasture	(Khan *et al.* 2009)
Feeding_DC_high		Stall	Stall	(Deshetti *et al.* 2016)
Feeding_DC_high		Stall	Stall fed/pasture	Pathak et al., 2013
Feeding_DC_high		Stall	Stall	(Saha *et al.* 2004)
Milk_DC_low	kg/hd/yr	2.4	2.4	(Landes *et al.* 2017)
Milk_DC_high	kg/hd/yr	7.1	7.1	(Landes *et al.* 2017)
Fat_DC_low	%	4.15	4.37 3.91 4.02 4.23 5.34	(Boro *et al.* 2016)
Protein_DC_low	%	3.73	3.92 4.90 3.58 3.35 3.60 3.04	(Boro *et al.* 2016)
Fat_DC_high	%	4.0	4.2-4.4 (Karan Fries) 3.8-4.0 3.5-4.5	(Landes *et al.* 2017)
Fat_DC_high	%	4.0	3.91 (Karan Fries)	(Sarkar *et al.* 2006)
Protein_DC_high	%	3.6	3.58 (Karan Fries)	(Sarkar *et al.* 2006)
Pregnancy_DC_low	%	40	40	(Patra 2012)
Pregnancy_DC_high	%	40	45-50	Pathak et al., 2013
Pregnancy_DC_high	%	50	50	(Patra 2012)
Pregnancy_DC_high	%	50	45-50	Pathak et al., 2013
DC_DC_low	%	55	55	Calculated based on: FAO, IDF and IFCN. 2014. Gerber et al., 2011
DC_DC_low	%	55	65(53-78)	Pathak et al., 2013
DC_DC_low	%	55	55	Calculated based on: FAO, IDF and IFCN. 2014. Gerber et al., 2011
DC_DC_high	%	65	63	Calculated based on:

				FAO, IDF and IFCN. 2014. Gerber et al., 2011
DC_DC_high	%	65	65(54-80)	Pathak et al., 2013
DC_DC_high	%	65	66-67	(Sontakke *et al.* 2014b)
DC_DC_high	%	65	62.5	Patra, 2012
CP_DC_low	%	15.0		Assumed on: (Garg *et al.* 2013) (Tomar & Sharma 2002)
CP_DC_high	%	16.4	14.5-15.0	(Sontakke *et al.* 2014b)
CP_DC_high	%	16.4	18 (14-22)	(Yasothai 2014)
Ym_DC_low	%	6.5		Table 10.13 of the 2019 RG
Ym_DC_high	%	6.3		Table 10.13 of the 2019 RG
Day weighted population	%	77/23	77/23 (low/high)	(Landes *et al.* 2017)
Day weighted population	%	77/23	77/23	(Patra 2012)

Table 10B.11

Mature Males	Unit	2019	Value	Reference
Weight_MM_low	kg/hd	290	200	Dhingra et al., 2017
Weight_MM_low	kg/hd	290	290 (260-320)	(Singhal *et al.* 2005)
Weight_MM_high	kg/hd	330	300	Dhingra et al., 2017
Weight_MM_high	kg/hd	330	280-355	(Singhal *et al.* 2005)
Work_MM_low	hr/d	1.7	1.7	(Patra 2012)
Feeding_all_low		Pasture	Paddock	Chowdhry, 2007
Feeding_all_high		Stall	Stall	(Saha *et al.* 2004)
CP_MM_low	%	TBD		
CP_MM_high	%	TBD		
DC_MM_low	%	55	55	(Patra 2012)
DC_MM_high	%	62	62.5	(Patra 2012)
Ym_MM_low	%	7.0		Table 10.13 of the 2019 RG
Ym_MM_high	%	6.3		Table 10.13 of the 2019 RG
Mature Females				
Weight_MF_low	kg/hd	250	330	(Chowdhry 2007)
Weight_MF_low	kg/hd	250	175	Dhingra et al., 2017
Weight_MF_low	kg/hd	250	200-330	Singhal et al., 2005
Weight_MF_high	kg/hd	TBD	275	Dhingra et al., 2017
Pregnancy_MF_low	%	40	40	2006 IPCC

Pregnancy_MF_high	%	TBD		
Milk_MF_low	%	1.7	623 –average of 940 600 997 688 572 530 540 384 603 598 400	(Sodhi *et al.* 2007)
Milk_FM_high	%	TBD		
Fat_MF_low		4.6	4.6–average of 4.3 5.5 4.9 4.2 4.3 3.9 4.6 4.9	Sodhi et al., 2007
Fat_MF_high	%	TBD		
Protein_FM_low	%	3.7		(da Cunha & Pereira 2010)
Protein_FM_high	%	TBD		
CP_MF_low	%		10	Chowdhry, 2007
CP_MF_high	%	TBD		
DC_FM_low	%	55	55	(Patra 2012)
DC_FM_high	%	62.5	62.5	Patra, 2012
Ym_FM_low	%	7.0		Table 10.13 of the 2019 RG
Ym_FM_high	%	6.3		Table 10.13 of the 2019 RG
Growing/Replacement Calves on forage				
Weight_C_low	kg/hd	65	40 (below 1yr)	Dhingra et al., 2017
Weight_C_low	kg/hd	65	65-80	Singhal et al., 2005
Weight_C_low	kg/hd	65	0d:14 kg	(Kayastha *et al.* 2008)
Weight_C_low	kg/hd	65	133 (10-18m)	(Sharma *et al.* 2014)
Weight_C_low	kg/hd	65	0d:20 kg 6m: 95 kg	(Manoj 2009)

			12m: 150 kg 18m: 220 kg 30m: 300 kg	
Weight_C_low	kg/hd	65	0d:15kg 12m: 63kg 18m: 83kg 24m: 105kg	(Nahar *et al.* 2016)
Weight_C_low	kg/hd	65	0-3m: 39 4-12m: 82 13-24m:218 25-36m:175	(Thombre *et al.* 2015)
Weight_C_low	kg/hd	65	0-3m: 30kg 4-12m: 115kg 13-24m: 230 kg 25-36m: 234 kg	(Sambhaji 2013)
Weight_C_low	kg/hd	65	6m: 90 kg 12m: 140 kg	(Yadava 2009)
Weight_C_low	kg/hd	65	14m: 96 kg 18m:150 kg	(Roy *et al.* 2016)
Weight gain_C_low	kg/hd/d	0.22		Assumed and calculated value based on weight range from 20 to 100 kg
Weight_G_low	kg/hd	140	140 (1-3yr)	Dhingra et al., 2017
Weight_G_low	kg/hd	140	136-157 (1-3yr)	Singhal et al., 2005
Weight gain_G_low	kg/hd/d	0.15	0.15	Singhal et al., 2005
Weight_C_high	kg/hd	105	60 (below 1yr)	Dhingra et al., 2017
Weight_C_high	kg/hd	105	70-89	Singhal et al., 2005
Weight_C_high	kg/hd	105	0m: 29 kg 3m: 63 kg 6m: 98 kg 12m: 154 kg	(Rahman *et al.* 2015)
Weight_C_high	kg/hd	105	0m: 25kg 6m: 127, 74kg 12m: 202, 183, 151kg 18m: 254, 307 kg	(Yadava 2009)
Weight gain_C_high	kg/hd/d	0.41	0.41	Yadava, 2009
Weight_G_high	kg/hd	180	180 (1-3 yr)	Dhingra et al., 2017
Weight_G_high	kg/hd	180	154-195 (1-3yr) 165-194	Singhal et al., 2005
Weight gain_G_high	kg/hd/d	0.33	0.33	Yadava, 2009

CP_C_G_low	%	TBD		
CP_C_G_high	%	0.15	0.15	Roy et al., 2016
DC_G_C_low	%	TBD		
DC_G_C_high	%	62	60	Roy et al., 2016
DC_G_C_high	%	62	62.5	Patra, 2012
Ym_C_G_low	%	7.0		Table 10.13 of the 2019 RG
Ym_C_G_high	%	6.3		Table 10.13 of the 2019 RG

1. Boro, P., Naha, B.C., Prakash, C., Madkar, A., Kumar, N., Kumari, A., Channa, G.P., 2016. Genetic and non-genetic factors affecting milk composition in dairy cows International journal of advanced biological research, 6(2): 170-174

2. Chowdhry, N.W., 2007. Production system analysis of Tharparkar cattle in its breeding tract. PhD thesis. Division of dairy cattle breeding. National dairy research institute.

3. da Cunha, D.N.F.V., Pereira, J.C., de Campos, O.F., Gomes, S.T., Braga, J.L., Martuscello, J.A., 2010. Simulation of Holstein and Jersey profitability by varying milk price payment system R. Bras. Zootec., 39(4): 913-923.

4. Deshetti, M.B., Teggi, M.Y., Gadd, G.M., Sadashivanagowda, S.N.O., 2016. Economics of dairy enterprise under stall-fed condition in Vijayapura and Bagalakote districts of Karnataka, India. Eco. Env. & Cons., 22 (September Suppl.): S105-S111

5. Dhingra, S. Mehta, R. Krishnaswamy, S., 2017. AFOLU Emissions. Version 2.0 dated September 28, 2017, from GHG platform India: GHG platform - India-2005-2013 National Estimates - 2017 Available from: http://ghgplatform-india.org/data-and-emissions/afolu.html

6. FAO, IDF and IFCN. 2014. World mapping of animal feeding systems in the dairy sector. Rome.

7. Garg, M.R., Sherasia, P.L., Bhanderi, B.M., Phondba, B.T., Shelke, S.K., Makkar, H.P.S., 2013. Effects of feeding nutritionally balanced rations on animal productivity, feed conversion efficiency, feed nitrogen use efficiency, rumen microbial protein supply, parasitic load, immunity and enteric methane emissions of milking animals under field conditions Animal Feed Science and Technology, 179: 24–35 // http://dx.doi.org/10.1016/j.anifeedsci.2012.11.005

8. Gerber, P., Vellinga, T., Opio, C., Steinfeld, H., 2011. Productivity gains and greenhouse gas emissions intensity in dairy systems. Livestock Science, 139: 100–108 // doi:10.1016/j.livsci.2011.03.012

9. IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

10. Kayastha, R.B., Zaman, G., Goswami, R.N. 2008. Studies on the birth weight of indigenous cattle of Assam. Indian J. Anim. Res., 42 (3): 230-231

11. Khan, M. J., Peters, K. J., Uddin, M. M., 2009. Feeding strategy for improving dairy cattle productivity in small holder farm in Bangladesh. Bang. J. Anim. Sci., 38(1&2): 67 – 85

12. Landes, M., Cessna, J., Lindsay Kuberka, L., Jones, K., 2017. India's dairy sector: structure, performance, and prospects. A report from the economic research service, USDA

13. Mahakur, K., Panda, P., Das, B.C., Nayak, G.D., 2017. Study on morphometric traits of different genetic groups of adult cattle in Jajpur district of Odisha. Indian Res. J. Ext. Edu., Special issue on Veterinary Research & Extension: 16–19.

14. Manoj, M., 2009. Evolving multi-trait selection criteria using body weights and first lactation traits in Sahiwal cattle. MSc thesis. National dairy research institute, Karnal (Deemed university), 253 p.

15. Nahar, S., Islam, A.F.M.F., Hoque, M.A., Bhuiyan, A.K.F.H., 2016. Animal performance of indigenous Red Chittagong cattle in Bangladesh. Animal Sciences, 38(2): 177-182.

16. Pathak, H., Upadhyay, R.C., Muralidhar, M., Bhattacharyya, P., Venkateswarlu, B., 2013. Measurement of greenhouse gas emission from crop, livestock and aquaculture. Indian Agricultural Research Institute, New Delhi, 101 p.

17. Patra, A. K., 2012. Estimation of methane and nitrous oxide emissions from Indian livestock. J. Environ. Monit., 14: 2673 – 2684 // DOI: 10.1039/c2em30396e

18. Rahman, S.M.A., Bhuiyan, M.S.A., Bhuiyan, A.K.F.H., 2015. Effects of genetic and non-genetic factors on growth traits of high yielding dairy seed calves and genetic parameter estimates. J. Adv. Vet. Anim. Res., 2(4):450-457 // DOI: 10.5455/javar.2015.b116

19. Roy, D., Kumar, V., Kumar, V., Sirohi, R., Singh, Y., Singh, J.K., 2016. Effect of feeding *Azolla pinnata* on growth performance, feed intake, nutrient digestibility and blood biochemical's of Hariana heifers fed on roughage based diet. Indian J Dairy Sci 69(2): 190 – 196

20. Saha, A., Garcia, O., Hemme, T., 2004. The Economics of milk production in Orissa, India, with particular emphasis on small-scale producers. PPLPI Working Paper No. 16

21. Saha, D., Gupta, R.S., Baghel, R.P.S., Khare, A., 2012. Efficiency of utilization of dietary energy for milk production in lactating crossbred cattle (Bos Indicus). Veterinary Research Forum, 3(3): 213–216

22. Sambhaji, N.M., 2013. Studies on Morphometric Characteristics of Red Kandhari cattle in Parbhani District. MSc thesis. College of agriculture. India, 125 p.

23. Sarkar, U., Gupta, A.K., Sarkar, V., Mohanty, T.K., Raina, V.S., Prasad, S., 2006. Factors affecting test day milk yield and milk composition in dairy animals. J. Dairying Foods and H.S., 25(2):129 – 132

24. Sharma, V.C., Mahesh, M.S., Mohini, M., Datt, C., Nampoothiri, V.M., 2014. Nutrient utilisation and methane emissions in Sahiwal calves differing in residual feed intake. Archives of Animal Nutrition, 68:5, 345-357, DOI:10.1080/1745039X.2014.951193

25. Singhal, K. K., Mohini, M., Jha, A.K., Gupta, P. K., 2005. Methane emission estimates from enteric fermentation in Indian livestock: Dry matter intake approach. Current Science, 88(1): 119 - 127

26. Sirohi A.S., Pandey, H.N., Singla, M., 2012. Effects of milking frequency on feed intake, body weight and haemato-biochemical changes in crossbred cows, Journal of Applied Animal Research, 40:1, 63-68 // DOI:10.1080/09712119.2011.628025

27. Sodhi, M., Mukesh, M., Prakash, B., Mishra, B.P., Sobti, R.C., Singh, K.P., Singh, S., Ahlawat S. P. S., 2007. *Msp*I allelic pattern of bovine growth hormone gene in Indian Zebu cattle (*Bos indicus*) breeds. Biochemical Genetics, 45(1/2): 145-153 / DOI: 10.1007/s10528-006-9068-4

28. Sontakke, U.B., Kaur, H., Tyagi, A.K., Kumar, M., Hossain, S.A., 2014. Effect of feeding rice bran lyso-phospholipids and rumen protected fat on feed intake, nutrient utilization and milk yield in crossbred cows. Indian Journal of Animal Sciences, 84(9):998–1003

29. Thombre, B.M., ShikalgaR, N.S., Bainwad, D. V., 2015. Performance and Colour Pattern of Khillar Cattle on Organized Farm. IOSR Journal of Agriculture and Veterinary Science, 8(4): 04-05 // DOI: 10.9790/2380-08420405

30. Tomar S.K., Sharma, R.L., 2002. Fodder and feeding practices of cattle and sheep in Kasmir (India) Tropical Agricultural research and extension 5(1,2): 48 – 52

31. Yadava, R.K., 2009. Studies on growth pattern for better management of Sahiwal animals. MSc thesis. National dairy research institute (Deemed university) (I.C.A.R.)

32. Yasothai, R., 2014. Importance of protein on reproduction in dairy cattle. International Journal of Science, Environment and Technology, 3(6): 2081 – 2083

Annex 10B.3 Feed intake estimates using a simplified Tier 2 method

***Prediction of DMI for cattle based on body weight and estimated dietary net energy concentration (NE_{ma}) or digestible energy values (DC%)*:**

Several studies have shown that dry matter intake (DMI) is highly and positively related to methane emissions. In some cases it has been reported that up to 92% of the variability in enteric methane emissions could be explained by DMI alone (Charmley et al. 2016). Most models developed to predict enteric methane emissions usually include either DMI or some form of feed intake. There are a number of models already developed with the objective of predicting DMI and these could be used in conjunction with emission factors to estimate enteric methane emissions in a Tier 2 approach. Appuhamy et al. (2016) evaluated 40 prediction equations using data that included measured DMI and feed quality attributes from North America, Europe and Australia/New Zealand. The best performing models in each region were then re-evaluated using calculated DMI and compared with estimates that used measured DMI. They evaluated several DMI prediction equations including the Cornell Net Carbohydrate and Protein System (CNCPS; Fox et al., 1992) as modified by Arnerdal (2005), National Research Council (NRC, 2001) (developed based on North America cows), Lindgren et al. (2001) and Arnerdal (2005) (developed using data from cows in Europe), and Vazquez and Smith (2000) model (developed from Australia/New Zealand data). Appuhamy et al. (2016) reported that models using estimated DMI predicted enteric methane emissions just as good as the measured data and concluded that enteric methane emissions from dairy cows can be predicted successfully with estimated DMI, particularly using the modified CNCPS model. Appuhamy et al. (2017) further evaluated the comprehensive (IPCC-CMP) and simplified (IPCC-SMP) IPCC models (IPCC, 2006) to predict DMI as well as the modified CNCPS and NRC (2001) models to predict DMI using an independent data. The modified CNCPS relying on BW and fat corrected milk yield (Eq. 1) more accurately predicted DMI (RMSPE = 14.1%) than NRC (RMSPE = 19.4%), IPCC-SMP (RMSPE = 16.9%), and IPCC-CMP (RMSPE = 23.4%). Overall, the results demonstrated that DMI of dairy cows can be predicted successfully using information such as milk yield, milk fat content, and BW that are routinely available in dairy farms..

DMI (kg/d) = 0.0185 x BW (kg) + 0.305 x fat corrected milk (kg/d) Eq [1]

A simplified approach can also be used to estimate DMI of beef cattle, as described by NASEM (2017). For growing and finishing cattle, equations are:

<u>Calves</u>

DMI (kg/d) = ($BW^{0.75}$ x (0.2435 x NEm – 0.0466 x NEm^2 – 0.1128)) / NEm Eq. [2]

<u>Yearlings</u>

DMI (kg/d) = ($BW^{0.75}$ x (0.2435 x NEm – 0.0466 x NEm^2 – 0.0869)) / NEm Eq. [3]

<u>Feedlot cattle (high grain diets)</u>

Steers: DMI (kg/d) = 3.830 + 0.0143 x BW x 0.96 Eq. [4]

Heifers: DMI (kg/d) = 3.184 + 0.01536 x BW x 0.96 Eq. [5]

Where: BW = body weight (kg), NEm = Mcal/kg feed DM Eq. [6]

<u>Mature Cows</u>

Forage type	Digestibility	Forage DMI Capacity (kg/day), % of BW (kg)	
		Non-lactating	Lactating
Low quality	<52	1.8	2.2
Average quality	52-59	2.2	2.5
High quality	>59	2.5	2.7

<u>References</u>

Appuhamy, J. A. D. R. N., J. France, and E. Kebreab. 2016. Models for predicting enteric methane emissions from dairy cows in North America, Europe, and Australia and New Zealand. Global Change Biol., 22:3039–3056.

Appuhamy, J. A. D. R. N., L.E. Moraes, C. Wagner-Riddle, D.P. Casper, and E. Kebreab. 2017. Predicting manure volatile solid output of lactating dairy cows. J. Dairy. Sci. in press.

Arnerdal S (2005) Predictions for voluntary dry matter intake in dairy cows. Thesis: Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences.

Fox DG, Sniffen CJ, O'Connor JD, Russell JB, Van Soest PJ (1992) A net carbohydrate and protein system for evaluating cattle diets: III. Cattle requirements and diet adequacy. Journal of Animal Science, 70, 3578–3596.

Lindgren E, Murphy M, Andersson T (2001) Värdering av foder. Lantmännen Foderutveckling AB, Nötfor. Almqvist & Wiksell, Uppsala.

National Research Council (2001) Nutrient Requirements of Dairy Cattle, 7th revised edition. National Academy Press, Washington, DC.

Annex 10B.4 Estimation Cattle/Buffalo CH4 conversion factors (Ym)

Dairy Yms were developed from Appuhamy et al. (2016) according to the methodology outlined in that publication. The cutoff of 7000 kg milk production per year was used to represent the observed differences in that publication between very high production systems such as those observed in North America slightly lower production systems less than 7000 kg year as observed in Europe, for which there was definitive data. A lack of literature was available for very low production systems and as a result, the 2006 default value of 6.5 was proposed for all other production systems.

In the case of beef cattle, a total of 78 measurements were compiled from 27 studies. Studies were divided by their dominant diet type into three categories, high forage diets, mixed diets (mixed forage and concentrate) and feedlot diets. No statistical analysis was carried out, with the exception of the development of group averages. An overall average was developed for the feedlot and non-feedlot diets. Non feedlot diets were differentiated between dominantly forage based diets and mixed concentrate diets. Though there is important variability in the results of scientific studies numerous empirical and biochemical modelling studies demonstrate both statistical significance and the biochemical processes that impact methane production with the introduction of concentrates to ruminant diets(Mills *et al.* 2001; Mills *et al.* 2003; Ellis *et al.* 2006; Ellis *et al.* 2007; Ellis *et al.* 2009; Ellis *et al.* 2010; Alemu *et al.* 2011; Bannink *et al.* 2011; Ellis *et al.* 2014; Escobar-Bahamondes *et al.* 2016; Kebreab *et al.* 2016). At present it was not considered possible to introduce additional categories for differentiation between low and high quality forages, due to a lack of data, particularly for low quality feed conditions.

Author	**Measurement method**	**BW (kg)**	**Category**	**Methane (g/kg DMI)**	**Ym**
Baron et al. 2017	Micro-meteorological	690	High forage	23.73	7.16
Baron et al. 2017	Micro-meteorological	690	High forage	17.72	5.34
Beauchemin and McGinn 2006a	Chambers	260	High forage	25.50	7.93
Beauchemin and McGinn 2006a	Chambers	328	High forage	21.60	6.43
Beauchemin and McGinn 2005	Chambers	306	High forage	24.80	7.55
Beauchemin and McGinn 2005	Chambers	344	High forage	24.30	7.28
Boadi and Wittenberg 2002	SF6	310	High forage	19.40	6.00
Boadi and Wittenberg 2002	SF6	310	High forage	21.45	7.10
Boadi and Wittenberg 2002	SF6	310	High forage	21.12	6.90
Boadi and Wittenberg 2002	SF6	310	High forage	23.17	7.60
Boadi and Wittenberg 2002	SF6	310	High forage	20.86	7.10
Boadi and Wittenberg 2002	SF6	310	High forage	21.12	7.10
Chaves et al. 2006	SF6	380	High forage	23.30	7.30
Chaves et al. 2006	SF6	380	High forage	31.00	9.60
Chaves et al. 2006	SF6	380	High forage	37.40	11.80
Chaves et al. 2006	SF6	380	High forage	18.70	5.80
Chaves et al. 2006	SF6	380	High forage	21.60	6.90
Chaves et al. 2006	SF6	380	High forage	25.70	7.90
Chung et al. 2013	Chambers	630	High forage	26.60	8.60
Chung et al. 2013	Chambers	630	High forage	24.80	8.20
Chung et al. 2013	Chambers	630	High forage	28.20	9.10
Chung et al. 2013	Chambers	630	High forage	24.00	8.00
Chung et al. 2013	Chambers	614	High forage	22.30	7.10
Chung et al. 2013	Chambers	614	High forage	22.50	7.10
Hart et al. 2009	SF6	470	High forage	25.60	9.80
Hart et al. 2009	SF6	470	High forage	25.70	9.90

Kennedy and Charmley 2012	Chambers	326	High forage	18.60	5.80
Kennedy and Charmley 2012	Chambers	326	High forage	21.70	6.93
Kennedy and Charmley 2012	Chambers	326	High forage	20.25	6.40
Kennedy and Charmley 2012	Chambers	326	High forage	18.60	5.50
Kennedy and Charmley 2012	Chambers	326	High forage	19.00	6.00
Kennedy and Charmley 2012	Chambers	326	High forage	15.80	5.00
Kennedy and Charmley 2012	Chambers	326	High forage	18.50	5.40
Kennedy and Charmley 2012	Chambers	326	High forage	21.40	6.50
Mc Geough et al. 2010 b	SF6	531	High forage	29.40	8.40
Mc Geough et al. 2010 b	SF6	531	High forage	25.80	7.70
Mc Geough et al. 2010 b	SF6	531	High forage	27.70	8.10
Mc Geough et al. 2010 b	SF6	531	High forage	26.20	7.30
Mc Geough et al. 2010a	SF6	539	High forage	30.10	8.90
Mc Geough et al. 2010a	SF6	539	High forage	27.50	8.24
Mc Geough et al. 2010a	SF6	538	High forage	28.00	8.52
Mc Geough et al. 2010a	SF6	538	High forage	25.90	6.79
Mc Geough et al. 2010a	SF6	539	High forage	35.60	9.72
Nascimento et al. 2016	SF6	402	High forage	17.38	6.18
Nascimento et al. 2016	SF6	402	High forage	23.41	9.02
Nascimento et al. 2016	SF6	402	High forage	20.02	7.42
Pinares-Patiño et al. 2003	SF6	712	High forage	21.07	5.90
Pinares-Patiño et al. 2003	SF6	712	High forage	22.66	6.70
Pinares-Patiño et al. 2003	SF6	712	High forage	21.84	6.60
Pinares-Patiño et al. 2003	SF6	712	High forage	22.03	6.50
Staerfl et al. 2012	Chambers	310	High forage	16.57	5.28
Staerfl et al. 2012	Chambers	310	High forage	15.53	4.72
Staerfl et al. 2012	Chambers	480	High forage	16.46	5.13
Staerfl et al. 2012	Chambers	493	High forage	18.94	5.73
Staerfl et al. 2012	Chambers	498	High forage	16.87	5.12
Vyas et al. 2014b	Chambers	406	High forage	25.69	7.80
MEAN (±SD)				23.0±4.6	7.2±1.5
Beauchemin and McGinn 2006a	Chambers	328	Intermediate forage	19.90	5.92
Beauchemin and McGinn 2006a	Chambers	328	Intermediate forage	21.10	6.26
Beauchemin and McGinn 2006a	Chambers	328	Intermediate forage	20.50	6.09
Beauchemin et al. 2007	Chambers	324	Intermediate forage	20.00	6.67
Doreau et al. 2011	SF6	417	Intermediate forage	20.20	6.20
Doreau et al. 2011	SF6	417	Intermediate forage	22.60	6.70
Fiorentini et al. 2014	SF6	419	Intermediate forage	16.55	4.81
Hunerberg et al. 2013b	Chambers	388	Intermediate forage	25.30	7.80
Hunerberg et al. 2013b	Chambers	388	Intermediate forage	21.50	6.60

Hunerberg et al. 2013b	Chambers	388	Intermediate forage	23.90	7.30
Jordan et al. 2006b	SF6	474	Intermediate forage	25.46	7.90
Lovett et al. 2003	SF6	462	Intermediate forage	20.40	6.60
McGinn et al. 2009	SF6	381	Intermediate forage	23.80	7.10
McGinn et al. 2009	SF6	381	Intermediate forage	19.90	5.40
Romero-Perez et al. 2014	Chambers	549	Intermediate forage	24.62	6.49
Romero-Perez et al. 2015	Chambers	666	Intermediate forage	22.46	6.46
Staerfl et al. 2012	Chambers	107	Intermediate forage	15.06	4.57
Staerfl et al. 2012	Chambers	107	Intermediate forage	13.73	4.18
Staerfl et al. 2012	Chambers	304	Intermediate forage	15.02	4.59
Staerfl et al. 2012	Chambers	107	Intermediate forage	14.54	4.42
Troy et al. 2015	Chambers	696	Intermediate forage	24.90	7.52
Troy et al. 2015	Chambers	696	Intermediate forage	25.20	7.61
Vyas et al. 2016a	Chambers	602	Intermediate forage	20.00	6.38
Vyas et al. 2016b	Chambers	377	Intermediate forage	26.40	8.18
MEAN (±SD)				21.0±3.8	6.3±1.2
Beauchemin and McGinn 2005	Chambers	439	Feedlot	9.20	2.81
Beauchemin and McGinn 2005	Chambers	427	Feedlot	13.1	4.03
Doreau et al. 2011	SF6	417	Feedlot	10.20	3.00
Hales et al. 2012	Head boxes	223	Feedlot	8.26	2.47
Hales et al. 2012	Head boxes	223	Feedlot	9.94	3.04
Hales et al. 2013	Head boxes	322	Feedlot	7.63	2.40
Hales et al. 2013	Head boxes	322	Feedlot	8.00	2.50
Hales et al. 2013	Head boxes	322	Feedlot	9.43	2.90
Hales et al. 2013	Head boxes	322	Feedlot	12.44	3.70
Hales et al. 2014a	Head boxes	362	Feedlot	10.84	3.07
Hales et al. 2014a	Head boxes	362	Feedlot	11.78	3.35
Hales et al. 2014a	Head boxes	362	Feedlot	13.35	3.80
Hales et al. 2014a	Head boxes	362	Feedlot	14.73	4.18
Hales et al. 2015	Head boxes	503	Feedlot	13.01	3.94
Hales et al. 2015	Head boxes	NA	Feedlot	10.92	3.27
Hales et al. 2015	Head boxes	NA	Feedlot	10.88	3.08
Hales et al. 2015	Head boxes	NA	Feedlot	10.74	3.21
Hales et al. 2015	Head boxes	NA	Feedlot	10.80	3.13
Hales et al. 2017	Head boxes	397	Feedlot	11.05	3.39
Hegarty et al. 2007	SF6	541	Feedlot	16.30	5.09
Hegarty et al. 2007	SF6	541	Feedlot	14.70	4.59

Hunerberg et al. 2013a	Chambers	529	Feedlot	16.60	5.00
Hunerberg et al. 2013a	Chambers	529	Feedlot	13.60	4.00
Hunerberg et al. 2013a	Chambers	529	Feedlot	18.40	5.50
Hunerberg et al. 2013a	Chambers	529	Feedlot	14.50	4.20
Jordan et al. 2006a	SF6	338	Feedlot	11.81	3.90
Lee et al. 2017	Chambers	553	Feedlot	18.30	5.47
Mc Geough et al. 2010 b	SF6	531	Feedlot	22.10	6.30
Mc Geough et al. 2010a	SF6	537	Feedlot	15.30	3.71
Troy et al. 2015	Chambers	696	Feedlot	13.50	4.12
Troy et al. 2015	Chambers	696	Feedlot	15.80	4.79
Vyas et al. 2014a	Chambers	581	Feedlot	15.30	4.40
Vyas et al. 2016b	Chambers	549	Feedlot	16.10	4.45
MEAN (±SD)				12.99±3.3	3.84±1.0

References

Alemu, A. W., Dijkstra, J., Bannink, A., France, J. & Kebreab, E. (2011) Rumen stoichiometric models and their contribution and challenges in predicting enteric methane production. Animal Feed Science and Technology 166-67(June): 761-778.

Appuhamy, J. A., France, J. & Kebreab, E. (2016) Models for predicting enteric methane emissions from dairy cows in North America, Europe, and Australia and New Zealand. Global Change Biology 22(9): 3039-3056.

Arif, M., Sarwar, M., Mehr-un-Nisa, Hayat, Z., Younas, M., 2016. Effect of supplementary sodium nitrate and sulphur on methane production and growth rates in sheep and goats fed forage based diet low in true protein. JAPS, Journal of Animal and Plant Sciences 26, 69–78.

Bannink, A., van Schijndel, M. W. & Dijkstra, J. (2011) A model of enteric fermentation in dairy cows to estimate methane emission for the Dutch National Inventory Report using the IPCC Tier 3 approach. Animal Feed Science and Technology 166-167: 603-618.

Ellis, J. L., Bannink, A., France, J., Kebreab, E. & Dijkstra, J. (2010) Evaluation of enteric methane prediction equations for dairy cows used in whole farm models. Global Change Biology 16(12): 3246-3256.

Ellis, J. L., Dijkstra, J., Bannink, A., Kebreab, E., Archibeque, S., Benchaar, C., Beauchemin, K. A., Nkrumah, J. D. & France, J. (2014) Improving the prediction of methane production and representation of rumen fermentation for finishing beef cattle within a mechanistic model. Canadian Journal of Animal Science 94(3): 509-524.

Ellis, J. L., Kebreab, E., Odongo, N. E., Beauchemin, K., McGinn, S., Nkrumah, J. D., Moore, S. S., Christopherson, R., Murdoch, G. K., McBride, B. W., Okine, E. K. & France, J. (2009) Modeling methane production from beef cattle using linear and nonlinear approaches. Journal of Animal Science 87(4): 1334-1345.

Ellis, J. L., Kebreab, E., Odongo, N. E., McBride, B. W., Okine, E. K. & France, J. (2007) Prediction of methane production from dairy and beef cattle. Journal of Dairy Science 90(7): 3456-3467.

Ellis, J. L., Qiao, F. & Cant, J. P. (2006) Prediction of dry matter intake throughout lactation in a dynamic model of dairy cow performance. Journal of Dairy Science 89(5): 1558-1570.

Escobar-Bahamondes, P., Oba, M. & Beauchemin, K. A. (2016) An evaluation of the accuracy and precision of methane prediction equations for beef cattle fed high-forage and high-grain diets. Animal: 1-10.

Kebreab, E., Tedeschi, L., Dijkstra, J., Ellis, J. L., Bannink, A. & France, J. (2016) Modeling Greenhouse Gas Emissions from Enteric Fermentation. Synthesis and Modeling of Greenhouse Gas Emissions and Carbon Storage in Agricultural and Forest Systems to Guide Mitigation and Adaptation 6(6): 173-195.

Mills, J. A. N., Dijkstra, J., Bannink, A., Cammell, S. B., Kebreab, E. & France, J. (2001) A mechanistic model of whole-tract digestion and methanogenesis in the lactating dairy cow: Model development, evaluation, and application. Journal of Animal Science 79(6): 1584-1597.

Mills, J. A. N., Kebreab, E., Yates, C. M., Crompton, L. A., Cammell, S. B., Dhanoa, M. S., Agnew, R. E. & France, J. (2003) Alternative approaches to predicting methane emissions from dairy cows. Journal of Animal Science 81(12): 3141-3150.

Annex 10B.5 Estimation of Default Emission Factor(s) for Goat Tier 2 parameters

A database was compiled from peer-reviewed articles that studied in-vivo CH4 production from goat enteric fermentation. Overall, 50 publications were obtained from a varied sample of countries and goat breeds. Although there was a total of 290 treatment means, treatments that were using substances with antimethanogenic properties were excluded before analysis. The minimum prerequisite for a study to be included in the data set was that Ym values (or gross energy and CH_4 output energy) were reported.

Information on feed and diet characteristics, feed intake, breed, animal type, digestibility, and rumen

were collected in the final data set. Methane production was expressed as grams per day, liters per day, megajoules per day, or as a proportion of GE or DE; therefore, the following factors were used in converting units: 1 g = 1.40 L =55.5 kJ; 1 L = 0.716 g = 39.54 kJ.

References

Abecia, L., Toral, P.G., Martín-García, A.I., Martínez, G., Tomkins, N.W., Molina-Alcaide, E., Newbold, C.J., Yáñez-Ruiz, D.R., 2012. Effect of bromochloromethane on methane emission, rumen fermentation pattern, milk yield, and fatty acid profile in lactating dairy goats. J. Dairy Sci. 95, 2027–2036. https://doi.org/10.3168/jds.2011-4831

Aguilera, J.F., Prieto, C., 1991. Methane production in goats given diets based on lucerne hay and barley. Arch Tierernahr 41, 77–84.

Aguilera, J.F., Prieto, C., FonollÁ, J., 1990. Protein and energy metabolism of lactating Granadina goats. British Journal of Nutrition 63, 165–175. https://doi.org/10.1079/BJN19900104

Animut, G., Puchala, R., Goetsch, A.L., Patra, A.K., Sahlu, T., Varel, V.H., Wells, J., 2008. Methane emission by goats consuming different sources of condensed tannins. Animal Feed Science and Technology 144, 228–241. https://doi.org/10.1016/j.anifeedsci.2007.10.015

Arif, M., Sarwar, M., Mehr-un-Nisa, Hayat, Z., Younas, M., 2016. Effect of supplementary sodium nitrate and sulphur on methane production and growth rates in sheep and goats fed forage based diet low in true protein. JAPS, Journal of Animal and Plant Sciences 26, 69–78.

Barbosa, A.L., Voltolini, T.V., Menezes, D.R., Moraes, S.A. de, Nascimento, J.C.S., Rodrigues, R.T. de S., 2017. Intake, digestibility, growth performance, and enteric methane emission of Brazilian semiarid non-descript breed goats fed diets with different forage to concentrate ratios. Trop Anim Health Prod 1–7. https://doi.org/10.1007/s11250-017-1427-0

Bhatta, R., Enishi, O., Takusari, N., Higuchi, K., Nonaka, I., Kurihara, M., 2008. Diet effects on methane production by goats and a comparison between measurement methodologies. The Journal of Agricultural Science 146, 705–715. https://doi.org/10.1017/S0021859608007983

Bhatta, R., Enishi, O., Yabumoto, Y., Nonaka, I., Takusari, N., Higuchi, K., Tajima, K., Takenaka, A., Kurihara, M., 2013. Methane reduction and energy partitioning in goats fed two concentrations of tannin from Mimosa spp. The Journal of Agricultural Science 151, 119–128. https://doi.org/10.1017/S0021859612000299

Castro-Lima, A.R., Fernandes, M.H.M. da R., Teixeira, I.A.M. de A., Frighetto, R.T.S., Bompadre, T.F.V., Biagioli, B., Meister, N.C., Resende, K.T. de, Lima, A.R.C., Fernandes, M.H.M. da R., Teixeira, I.A.M. de A., Frighetto, R.T.S., Bompadre, T.F.V., Biagioli, B., Meister, N.C., Resende, K.T. de, 2016. Effects of feed restriction and forage:concentrate ratio on digestibility, methane emission, and energy utilization by goats. Revista Brasileira de Zootecnia 45, 781–787. https://doi.org/10.1590/s1806-92902016001200008

Criscioni, P., Fernández, C., 2016. Effect of rice bran as a replacement for oat grain in energy and nitrogen balance, methane emissions, and milk performance of Murciano-Granadina goats. Journal of Dairy Science 99, 280–290. https://doi.org/10.3168/jds.2015-9472

De Blas, C., García-Rebollar, P., Cambra-López, M., Torres, A.G., 2008. Contribución de los rumiantes a las emisiones de gases con efecto invernadero. XXIV Curso de especialización FEDNA. Editorial FEDNA. Madrid 121–150.

Haque, N., Khan, M.Y., Murarilal, 1997. Effect of level of Leucaena leucocephala in the diets of Jamunapari goats on carbon nitrogen and energy balances. Asian-Australasian Journal of Animal Sciences, Asian-Australasian Journal of Animal Sciences 10, 455–459. https://doi.org/1997.10.5.455

Haque, N., Murarilal, M.Y., Khan, M.Y., Biswas, J.C., Singh, P., 1998. Metabolizable energy requirements for maintenance of pashmina producing Cheghu goats. Small Ruminant Research 27, 41–45. https://doi.org/10.1016/S0921-4488(97)00020-5

Haque, N., Toppo, S., Saraswat, M.L., Khan, M.Y., 2008. Effect of feeding Leucaena leucocephala leaves and twigs on energy utilization by goats. Animal Feed Science and Technology 142, 330–338. https://doi.org/10.1016/j.anifeedsci.2007.09.027

Ibáñez, C., López, M.C., Criscioni, P., Fernández, C., 2015a. Effect of replacing dietary corn with beet pulp on energy partitioning, substrate oxidation and methane production in lactating dairy goats. Anim. Prod. Sci. 55, 56–63. https://doi.org/10.1071/AN13119

Ibáñez, C., Moya, V.J., Arriaga, H., López, D.M., Merino, P., Fernández, C., 2015b. Replacement of cereal with low starch fibrous by-products on nutrients utilization and methane emissions in dairy goats. Open Journal of Animal Sciences 5, 198–209.

Islam, M., Abe, H., Hayashi, Y., Terada, F., 2000. Effects of feeding Italian ryegrass with corn on rumen environment, nutrient digestibility, methane emission, and energy and nitrogen utilization at two intake levels by goats. Small Ruminant Research 38, 165–174. https://doi.org/10.1016/S0921-4488(00)00148-6

Islam, M., Enishi, O., Purnomoadi, A., Higuchi, K., Takusari, N., Terada, F., 2001. Energy and protein utilization by goats fed Italian ryegrass silage treated with molasses, urea, cellulase or cellulase + lactic acid bacteria. Small Ruminant Research 42, 49–60. https://doi.org/10.1016/S0921-4488(01)00235-8

Keli, A., Ribeiro, L.P.S., Gipson, T.A., Puchala, R., Tesfai, K., Tsukahara, Y., Sahlu, T., Goetsch, A.L., 2017. Effects of pasture access regime on performance, grazing behavior, and energy utilization by Alpine goats in early and mid-lactation. Small Ruminant Research 154, 58–69. https://doi.org/10.1016/j.smallrumres.2017.07.004

Li DH, Beob Gyun Kim, Sang Rak Lee, 2010. A respiration-metabolism chamber system for measuring gas emission and nutrient digestibility in small ruminant animals | Lī | Revista Colombiana de Ciencias Pecuarias. Revista Colombiana de Ciencias Pecuarias 23.

Annex 10B.6 Revision of methane from dung deposited onto pasture range and paddocks (Table 10.17)

Summary to date

Cai et al (2017) included 26 data, however some of these were omitted due to incomplete information to allow an estimation of methane conversion factor (MCF) and/or emission factors on the basis of faecal dry matter (FDM) or per unit of volatile solids (VS). Therefore, the number of values retained was 20. Our review of the literature identified a further 25 suitable values (Carran et al. 2003; Kelly et al. 2017; Saggar et al. 2003; Sherlock et al. 2003a, 2003b), resulting in a total of 45 data values spanning six countries (Table 1). Data was assessed for suitability, in terms of length of study, sufficient replication and inclusion of key manure characteristics to allow estimation of the MCF, as reported in Table 10.17. Some of the studies that provided sufficient information for this estimation typically presented their emissions on the basis of mass of CH_4 emitted per unit of either FDM or per unit of VS. Therefore, we have also supplied emission factors using these units (g CH_4/kg VS and g CH_4/kg FDM) for countries with access to total FDM or VS production.

Table 10B.13 Source of data.

Country	**Cattle**	**Sheep**	**Total**
Australia	13		13
Brazil	4		4

China	3	2	5
Japan	5		5
New Zealand	6	6	12
UK	6		6
Total	**37**	**8**	**45**

Emission factors

Methane conversion factors (MCF) and emission factors were estimated for both cattle and sheep (Table 2). For MCF, the 2006 IPCC guidelines assume dung has an ash content of 8%. However, more recent data would suggest this figure is too. Data from UK and New Zealand would suggest, respectively, 15% and 11% for dairy cattle and beef cattle (Defra 2014; Harry Clark, pers. comm.). Therefore, we used these updated values, and, in the absence of suitable data for other livestock classes, assumed sheep and yaks have similar values to cattle beef. The Defra study confirmed that the IPCC Bo values were appropriate for dairy cattle, therefore we assumed the same for beef cattle, sheep and yaks. For yaks, we used the IPCC default Bo value for buffalo (0.100).

There was no significant difference in values for cattle and sheep regardless of the method of representing methane emissions ($P > 0.05$), therefore, for the refinement of the 2006 guidelines we suggest an aggregated value is used. We also explored the possibility of disaggregating MCF and EF values by climatic zones, however the limited size of the dataset did not support this. Therefore, an aggregated value regardless of temperature is suggested for the refinement.

Table 10B.14 Methane conversion factor (MCF) and methane emission factors (per kg faecal dry matter (FDM)) and volatile solids (VS) for cattle and sheep.

N source	Average MCF (%)	Std Dev MCF (%)	Average EF (g CH_4/kg FDM)	Std Dev EF(g CH_4/kg FDM)	Average EF (g CH_4/kg VS)	Std Dev EF (g CH_4/kg VS)
Cattle	0.44	0.36	0.50	0.43	0.58	0.50
Sheep	0.38	0.28	0.53	0.42	0.60	0.47
Average	**0.43**	**0.35**	**0.50**	**0.42**	**0.58**	**0.49**

References

Cai Y, Chang S, Cheng Y. (2017). Greenhouse gas emissions from excreta patches of grazing animals and their mitigation strategies. Earth-Science Reviews, 171: 44-57.

Carran RA, Dewar D, Theobald PW. (2003). Methane and nitrous oxide emission from sheep dung. Client report for Ministry for Agriculture and Forestry. Pp.14.

Defra (2014). Improvements to the National Inventory: Methane. AC0115 Final Report Appendix A – Experimental summaries. April 2014. Pp. 414.

Kelly KB, Ward GN, Hollier JW. (2016). Greenhouse gas emissions from dung, urine and dairy pond sludge applied to pasture. 2. Methane emissions. Animal Production Science. http://dx.doi.org/10.1071/AN15638

Saggar S, Clark H, Hedley C, Tate K, Carran A, Cosgrove G. (2003). Methane emissions from animal dung and waste management systems, and its contribution to the national methane budget. A report prepared for the Ministry for Agriculture and Forestry. Landcare Research. Pp.56.

Sherlock RR, de Klein CAM, Li Z. (2003a). Determination of the N_2O and CH_4 emission factor from animal excreta, following a summer application in 3 regions of New Zealand. A final report of an NzOnet study. Pp.27.

Sherlock RR, de Klein CAM, Li Z. (2003b). Determination of the N_2O and CH_4 emission factor from animal excreta, following a spring application in 3 regions of New Zealand. A final report of an NzOnet study. Pp.28.

Annex 10B.7 WE STILL REQUIRE ALL THE OTHER CHANGES TO MANURE MANAGEMENT EMISSION FACTORS

References

AFRC Technical Committee on Responses to Nutrients (1990). Nutritive Requirements of Ruminant Animals: Energy. Rep. 5, CAB International, Wallingford, U.K.

Akbaş, Y., Alçiçek, A., Önenç, A. & Güngör, M. (2006) Growth curve analysis for body weight and dry matter intake in Friesian, Limousin x Friesian and Piemontese x Friesian cattle. *Arch.Tierz., Dummerstorf.*

Alemu, A. W., Dijkstra, J., Bannink, A., France, J. & Kebreab, E. (2011) Rumen stoichiometric models and their contribution and challenges in predicting enteric methane production. *Animal Feed Science and Technology* **166-67**(June): 761-778.

Amerkhanov, K., Polovinko, L., Kalashnikov, N. & Kayumov, F. (2016) Characteristics of the genetic material in breeding high-productive type «Voznesenovsky» of the Kalmyk cattle. *Bulletin of meat breeding* **4**(96): 15-21.

Animut, G., Puchala, R., Goetsch, A. L., Patra, A. K., Sahlu, T., Varel, V. H. & Wells, J. (2008) Methane emission by goats consuming different sources of condensed tannins. *Animal Feed Science and Technology* **144**(3): 228-241.

Appuhamy, J. A., France, J. & Kebreab, E. (2016) Models for predicting enteric methane emissions from dairy cows in North America, Europe, and Australia and New Zealand. *Global Change Biology* **22**(9): 3039-3056.

Azaubaeva, G. S. (2008) Nitrogen and energy metabolism, milk productivity of cows due to change in diet ration. *Agrarian Bulletin of the Urals* **3**: 41-43.

Bakharev, A. A. (2012) Milk productivity and milk content of beef breed cows. *Agricultural policy of the Russian Federation* **9**: 57-59.

Bannink, A., van Schijndel, M. W. & Dijkstra, J. (2011) A model of enteric fermentation in dairy cows to estimate methane emission for the Dutch National Inventory Report using the IPCC Tier 3 approach. *Animal Feed Science and Technology* **166-167**: 603-618.

Baron, V. S., Flesch, T. K., Doce, R. R., Wilson, J. D. & Basarab, J. A. (2017) Enteric methane emission from winter-grazed beef cows. In: *American Society of Agronomy, Crop Science Society of America, Soil Science Society of America International Annual Meeting*, Long Beach, CA.

Basarab, J. A., Okine, E. K., Baron, V. S., Marx, T., Ramsey, P., Ziegler, K. & Lyle, K. (2005) Methane emissions from enteric fermentation in Alberta's beef cattle population. *Canadian Journal of Animal Science* **85**(4): 501-512.

Beauchemin, K. & McGinn, S. M. (2006a) Enteric methane emissions from growing beef cattle as affected by diet and level of intake. *Canadian Journal of Animal Science* **86**: 401-408.

Beauchemin, K. & McGinn, S. M. (2006b) Methane emissions from beef cattle: Effects of fumaric acid, essential oil, and canola oil. *Journal Animal Science* **84**: 1489-1496.

Beauchemin, K. A. & McGinn, S. M. (2015) Methane emissions from feedlot cattle fed barley or corn diets. *Journal Animal Science* **83**: 653–661.

Beauchemin, K. A., McGinn, S. M. & Martinez, T. F. (2007) Use of condensed tannin extract from quebracho trees to reduce methane emissions from cattle. . *Journal Animal Science* **85**: 1990-1996.

Bhatta, R., Enishi, O., Yabumoto, Y., Nonaka, I., Takusari, N., Higuchi, K., Tajima, K., Takenaka, A. & Kurihara, M. (2013) Methane reduction and energy partitioning in goats fed two concentrations of tannin from Mimosa spp. *The Journal of Agricultural Science* **151**(1): 119-128.

Boadi, D. A. & Wittenberg, K. M. (2002) Methane production from dairy and beef heifers fed forages differing in nutrient density using the sulphur hexafluoride (SF6) tracer gas technique. *Canadian Journal of Animal Science* **82**: 201–206.

Boadi, D. A., Wittenberg, K. M., Scott, S. L., Burton, D., Buckley, K., Small, J. A. & Ominski, K. H. (2004) Effect of low and high forage diet on enteric and manure pack greenhouse gas emissions from a feedlot. *Canadian Journal of Animal Science* **84**(3): 445-453.

Boro, P., Naha, B. C., Prakash, C., Madkar, A., Kumar, N., Kumari, A. & Channa, G. P. (2016) Genetic and non-genetic factors affecting milk composition in dairy cows. *International journal of advanced biological research*.

Capper, J. L. (2011) The environmental impact of beef production in the United States: 1977 compared with 2007. *Journal of Animal Science* **89**(12): 4249-4261.

CBAT. (2017) *Cattle Breeders' association of Turkey (CBAT)*.

Chashnidel, Y., Pirsaraei, A. & Yousef-Elahi, M. (2007) Comparison of daily weight gain and fattening characteristics between buffalo and Holstein male calves with different diets. *Italian Journal of Animal Science*.

Chaves, A. V., Thompson, L. C., Iwaasa, A. D., Scott, S. L., Olson, M. E., Benchaar, C. & Veira, D. M. (2006) Effect of pasture type (alfalfa vs. grass) on methane and carbon dioxide production by yearling beef heifers. *Canadian Journal of Animal Science* **86**: 409-418.

Chowdhry, N. W. (2007) *Production system analysis of Tharparkar cattle in its breeding tract. PhD thesis*. Division of dairy cattle breeding. National dairy research institute.

Chung, Y. H., McGeough, E. J., Acharya, S., McAllister, T. A., McGinn, S. M., Harstad, O. M. & Beauchemin, K. A. (2013) Enteric methane emission, diet digestibility, and nitrogen excretion from beef heifers fed sainfoin or alfalfa. *Journal Animal Science* **91**: 4861-4874.

da Cunha, D. N. F. V. & Pereira, J. C. d. C. O. F. G. S. T. B. J. L. M. J. A. (2010) Simulation of Holstein and Jersey profitability by varying milk price payment system. *R. Bras. Zootec.*

Deshetti, M. B., Teggi, M. Y., Gadd, G. M. & Sadashivanagowda, S. N. O. (2016) Economics of dairy enterprise under stall-fed condition in Vijayapura and Bagalakote Districts of Karnataka, India. *Eco. Env. & Cons.*

Dhingra, S., Mehta, R. & Krishnaswamy, S. (2017) AFOLU Emissions. Version 2.0 dated September 28, 2017, from GHG platform India: GHG platform - India-2005-2013 National Estimates - 2017 URL http://ghgplatform-india.org/data-and-emissions/afolu.html.

Dong, R. L., Zhao, G. Y., Chai, L. L. & Beauchemin, K. A. (2014) Prediction of urinary and fecal nitrogen excretion by beef cattle. *J Anim Sci* **92**(10): 4669-4681.

Doreau, M., Werf, H. M. G. v. d., Micol, D., Dubroeucq, H., Agabriel, J. & Y. (2011) Enteric methane production and greenhouse gases balance of diets differing in concentrate in the fattening phase of a beef production system. *Journal Animal Science* **89**: 2518-2528.

Dunin, I., Sharkaev, V. & Kochetkov, A. (2011) Performance results of beef cattle production branch in the Russian federation. *Dairy and Beef Cattle Breeding* **5**: 2-5.

Ellis, J. L., Bannink, A., France, J., Kebreab, E. & Dijkstra, J. (2010) Evaluation of enteric methane prediction equations for dairy cows used in whole farm models. *Global Change Biology* **16**(12): 3246-3256.

Ellis, J. L., Dijkstra, J., Bannink, A., Kebreab, E., Archibeque, S., Benchaar, C., Beauchemin, K. A., Nkrumah, J. D. & France, J. (2014) Improving the prediction of methane production and representation of rumen fermentation for finishing beef cattle within a mechanistic model. *Canadian Journal of Animal Science* **94**(3): 509-524.

Ellis, J. L., Kebreab, E., Odongo, N. E., Beauchemin, K., McGinn, S., Nkrumah, J. D., Moore, S. S., Christopherson, R., Murdoch, G. K., McBride, B. W., Okine, E. K. & France, J. (2009) Modeling methane production from beef cattle using linear and nonlinear approaches. *Journal of Animal Science* **87**(4): 1334-1345.

Ellis, J. L., Kebreab, E., Odongo, N. E., McBride, B. W., Okine, E. K. & France, J. (2007) Prediction of methane production from dairy and beef cattle. *Journal of Dairy Science* **90**(7): 3456-3467.

Ellis, J. L., Qiao, F. & Cant, J. P. (2006) Prediction of dry matter intake throughout lactation in a dynamic model of dairy cow performance. *Journal of Dairy Science* **89**(5): 1558-1570.

Escobar-Bahamondes, P., Oba, M. & Beauchemin, K. A. (2016) An evaluation of the accuracy and precision of methane prediction equations for beef cattle fed high-forage and high-grain diets. *Animal*: 1-10.

Fao and Idf and, I. (2014) *World Mapping of Animal Feeding Systems in the Dairy Sector*.

Fao, I. D. F. & Ifcn. (2014) *World mapping of animal feeding systems in the dairy sector.* . Rome.

Faostat. (2017) Accessed on 7.11.2017. *http://www.fao.org/faostat/en/*.

Fatahnia, F., Rowghani, E., Hosseini, A. R., Darmani Kohi, H. & Zamiri, M. J. (2010) Effect of different levels of monensin in diets containing whole cottonseed on milk production and composition of lactating dairy cows. *Iranian Journal of Veterinary Research, Shiraz University*.

Fiorentini, G., Carvalho, I. P. C., Messana, J. D., Castagnino, P. S., Berndt, A., Canesin, R. C., Frighetto, R. T. S. & Berchielli, T. T. (2014) Effect of lipid sources with different fatty acid profiles on the intake, performance, and methane emissions of feedlot Nellore steers. *Journal Animal Science* **92**: 1613–1620.

Furaeva, N. S. (2013) Current state of pedigree base of a cattle of the Yaroslavl breed and prospect of its development. *Agricultural bulletin of Yaroslavl region* **21**: 21-30.

Garg, M. R., Sherasia, P. L., Bhanderi, B. M., Phondba, B. T., Shelke, S. K. & Makkar, H. P. S. (2013) Effects of feeding nutritionally balanced rations on animal productivity, feed conversion efficiency, feed nitrogen use efficiency, rumen microbial protein supply, parasitic load, immunity and enteric methane emissions of milking animals under field conditions. *Animal feed science and technology*.

Gayirbegov, D. & Mandjiev, D. (2013) The effect of feeding type on metabolism and growth energy of bulls of kalmyk breed. *Dairy and Beef Cattle Breeding* **7**: 31-32.

Gerber, P., Vellinga, T., Opio, C. & Steinfeld, H. (2011) Productivity gains and greenhouse gas emissions intensity in dairy systems. *Livestock Science*.

Golubkov, A. I., Dunin, I. M., Adzhibekov, K. K., Lazovaya, G. S. & Chekushkin, A. M. (2015) Milk productivity of the red-motley breed cows of different intrabreed types. *Bulletin of Krasnoyarsk state agricultural university* **10**: 189-196.

Goncharova, N. & Kibkalo, L. (2011) Efficiency of cultivation of bull- calves on meat. *Dairy and Beef Cattle Breeding* **3**: 20-21.

Goncharova, N. A., Kiblalo, L. I. & Zerebilov, N. I. (2009) Feedlot efficiency of growing beef cattle. *Bulletin of Krasnoyarsk state agricultural university* **3**(3): 70-74.

Gren, O. V. (2013) The fodder nutrients digestibility wh en feeding lactation cows with «Biokoretron-forte». *Bulletin of Krasnoyarsk state agricultural university* **1**: 88-90.

Gubaidullin, N., Tagirov, H. & Iskhakov, R. (2011) Productive qualities of thoroughbred and hybrid bulls. *Dairy and Beef Cattle Breeding* **S1**: 25-26.

Hales, K, E., Jaderborg, J. P., Crawford, G. I., DiCostanzo, A., Spiehs, M. J., Brown-Brandl, T. M. & Freetly, H. C. (2015) Effects of dry-rolled or high-moisture corn with twenty-five or forty-five percent wet distillers' grains with solubles on energy metabolism, nutrient digestibility, and macromineral balance in finishing beef steers. *Journal Animal Science* **93**: 4995–5005.

Hales, K. E., Brown-Brandl, T. M. & Freetly, H. C. (2014) Effects of decreased dietary roughage concentration on energy metabolism and nutrient balance in finishing beef cattle. *Journal Animal Science* **92**: 264-271.

Hales, K. E., Cole, N. A. & MacDonald, J. C. (2012) Effects of corn processing method and dietary inclusion of wet distillers grains with solubles on energy metabolism, carbon–nitrogen balance, and methane emissions of cattle. *Journal Animal Science* **90**: 3174-3185.

Hales, K. E., Foote, A. P., Brown-Brandl, T. M. & Freetly, H. C. (2017) The effects of feeding increasing concentrations of corn oil on energy metabolism and nutrient balance in finishing beef steers. *Journal Animal Science* **95**: 939–948.

Hammond, K. J., Humphries, D. J., Crompton, L. A., Green, C. & Reynolds, C. K. (2015) Methane emissions from cattle: Estimates from short-term measurements using a Green Feed system compared with measurements obtained using respiration chambers or sulphur hexafluoride tracer. *Animal Feed Science and Technology* **203**: 41-52.

Hart, K. J., Martin, P. G., Foley, P. A., Kenny, D. A. & Boland, T. M. (2009) Effect of sward dry matter digestibility on methane production, ruminal fermentation, and microbial populations of zero–grazed beef cattle. *Journal Animal Science* **87**: 3342-3350.

Haysanov, D. P. (2011) The milk yield of cows according to their genotype, feeding level and technology content. *Bulletin of Krasnoyarsk state agricultural university* **4**: 102-106.

Hegarty, R. S., Goopy, J. P., Herd, R. M. & McCorkell, B. (2007) Cattle selected for lower residual feed intake have reduced daily methane production. *Journal Animal Science* **85**: 1479-1486.

Hünerberg, M., McGinn, S. M., Beauchemin, K. A., Okine, E. K., Harstad, O. M. & McAllister, T. A. (2013) Effect of dried distillers' grains with solubles on enteric methane emissions and nitrogen excretion from finishing beef cattle. *Journal Animal Science* **91**: 2846-2857.

Ilichev, E., Nazarova, A., Polishchuk, S. & Inozemtsev, V. (2011) Diet digestibility and nutrient balance with the addition of cobalt and copper nanopowders to the calves' rations. *Dairy and Beef Cattle Breeding* **5**: 27-29.

Jayasundara, S., Ranga Niroshan Appuhamy, J. A. D., Kebreab, E. & Wagner-Riddle, C. (2016) Methane and nitrous oxide emissions from Canadian dairy farms and mitigation options: An updated review. *Canadian Journal of Animal Science* **96**(3): 306-331.

Johnson, K., Huyler, M., Westberg, H., Lamb, B. & Zimmerman, P. (1994) Measurement of Methane Emissions from Ruminant Livestock Using a SF6 Tracer Technique. *Environmental Science and Technology* **28**(2): 359-362.

Johnson, K. A. & Johnson, D. E. (1995) Methane emissions from cattle. *Journal of Animal Science* **73**(8): 2483-2492.

Jordan, E., Kenny, D., Hawkins, M., Malone, R., Lovett, D. K. & Mara, F. P. O. (2006a) Effect of refined soy oil or whole soybeans on intake, methane output, and performance of young bulls. *Journal Animal Science* **84**: 2418-2425.

Jordan, E., Lovett, D. K., Monahan, F. J., Callan, J., Flynn, B. & Mara, F. P. O. (2006b) Effect of refined coconut oil or copra meal on methane output and on intake and performance of beef heifers. *Journal Animal Science* **84**: 162-170.

Kalnickij, B. D. & Haritonov, E. L. (2008) Determination of the dairy cows protein diet standards for the first phase of lactation. *Achievements of Science and Technology of AICis* **10**: 18-22.

Kamalzadeh, A. R. M. K. A. (2008) Livestock Production Systems and Trends in Livestock Industry in Iran. *Journal of Agriculture & Social sciences*.

Kara, N. K., Galic, A. & Koyuncu, M. (2015) Comparison of Milk Yield and Animal Health in Turkish Farms with Differing Stall Types and Resting Surfaces. *Asian Australas. J. Anim. Sci.*

Karakok, S. G. (2007) Small scale cattle farmers and their sustainability in lowland villages of Adana province, Turkey. *Livestock Research for Rural Development* **19**.

Kayastha, R. B., Zaman, G. & Goswami, R. N. (2008) Studies on the birth weight of indigenous cattle of Assam. *Indian J. Anim. Res.* **42**(3): 230.

Kebreab, E., Johnson, K. A., Archibeque, S. L., Pape, D. & Wirth, T. (2008) Model for estimating enteric methane emissions from United States dairy and feedlot cattle. *J Anim Sci* **86**(10): 2738-2748.

Kebreab, E., Tedeschi, L., Dijkstra, J., Ellis, J. L., Bannink, A. & France, J. (2016) Modeling Greenhouse Gas Emissions from Enteric Fermentation. *Synthesis and Modeling of Greenhouse Gas Emissions and Carbon Storage in Agricultural and Forest Systems to Guide Mitigation and Adaptation* **6**(6): 173-195.

Kennedy, P. M. & Charmley, E. (2012a) Methane yields from Brahman cattle fed tropical grasses and legumes. *Animal Production Science* **52**(4): 225-239.

Kennedy, P. M. & Charmley, E. (2012b) Methane yields from Brahman cattle fed tropical grasses and legumes. Anim. Prod. Sci. 52:225. *Animal Production Science* **52**: 225-239.

Khan, M. J., Peters, K. J. & Uddin, M. M. (2009) Feeding strategy for improving dairy cattle productivity in small holder farm in Bangladesh. *Bang. J. Anim. Sci.*

Koçyiğit, R., Aydin, R., Yanar, M., Güler, O., Diler, A., Avci, M., Özyürek, S., Kabakci, D. & Hirik, E. N. (2014) Effects of Weaning Ages on the Growth, Feed Conversion Efficiency and Some Behavioral Traits of Brown Swiss x Eastern Anatolian Red Calves. *Journal of Agricultural Sciences*.

Kostenko, V. I. & Pyrozhenko, Y. V. (2012) Methodology for GHG emissions estimation from cattle enteric fermentation in conditions of Ukraine. *Scientific journal* **179**: 183-193.

Landes, M., Cessna, J., Lindsay Kuberka, L. & Jones, K. (2017) India's Dairy Sector: Structure, Performance, and Prospects. *USDA report*.

Lassey, K. R. (2007) Livestock methane emission: From the individual grazing animal through national inventories to the global methane cycle. *Agricultural and Forest Meteorology* **142**(2-4): 120-132.

Legesse, G., Beauchemin, K. A., Ominski, K. H., McGeough, E. J., Kroebel, R., MacDonald, D., Little, S. M. & McAllister, T. A. (2016) Greenhouse gas emissions of Canadian beef production in 1981 as compared with 2011. *Animal Production Science* **56**(2-3): 153-168.

Leontev, V., Burmistrov, V., Linkevich, R., Asaynin, V. & Lavrova, A. (2013) Comparative evaluation of limousin bull growth and slaughter quality in the JSC "Zavolzhskoe" farm, in Tver region. *Dairy and Beef Cattle Breeding* **2**: 18-19.

Levakhin, V., Azhmuldinov, E., Ibraev, A., Babicheva, I. & Poberukhin, M. (2011) Influence of structure and quality of rations on meat productivity of young animals. *Dairy and Beef Cattle Breeding* **6**: 31-32.

Litovchenko, V. (2012) Growth and productivity of meat from calves simmental genotypes in Southern Ural. *Dairy and Beef Cattle Breeding* **6**: 16-18.

MacLeod, M. J., Vellinga, T., Opio, C., Falcucci, A., Tempio, G., Henderson, B., Makkar, H., Mottet, A., Robinson, T., Steinfeld, H. & Gerber, P. J. (2017) Invited review: A position on the Global Livestock Environmental Assessment Model (GLEAM). *Animal*: 1-15.

Mahakur, K., Panda, P., Das, B. C. & Nayak, G. D. (2017) Study on morphometric traits of different genetic groups of adult cattle in Jajpur district of Odisha. *Indian Res. J. Ext. Edu., Special issue on Veterinary Research & Extension*: 16–19.

Mamaev, I. I., Mironova, I. V., Dolzhenkova, G. M., Kosilov & V.I. (2017) Productive qualities of young black-spotted cattle and their double-and-triple cross hybrids. *Bulletin of Orenburg State Agrarian University* **1**(63): 128-130.

Manoj, M. (2009) *Evolving multi-trait selection criteria using body weights and first lactation traits in Sahiwal cattle. MSc thesis*. National dairy research institute, Karnal (Deemed university).

Mc Geough, E. J., Kiely, P. O., Foley, P. A., Hart, K. J., Boland, T. M. & Kenny, D. A. (2010a) Methane emissions, feed intake, and performance of finishing beef cattle offered maize silages harvested at 4 different stages of maturity. *Journal Animal Science* **88**: 2703-2716.

Mc Geough, E. J., Kiely, P. O., Hart, K. J., Moloney, A. P., Boland, T. M. & Kenny, D. A. (2010b) Methane emissions, feed intake, performance, digestibility, and rumen fermentation of finishing beef cattle offered whole–crop wheat silages differing in grain content. *Journal Animal Science* **88**: 1479-1491.

McGinn, S. M., Chung, Y. H., Beauchemin, K. A., Iwaasa, A. D. & Grainger, C. (2009) Use of corn distillers' dried grains to reduce enteric methane loss from beef cattle. *Canadian Journal of Animal Science* **89**: 409-413.

MFAL. (2011) *Domestic animal genetic resources in Turkey Republic of Turkey*. Ankara, Turkey: Ministry of Food Agriculture and Livestock, General directorate of agricultural research and policy.

Mills, J. A. N., Dijkstra, J., Bannink, A., Cammell, S. B., Kebreab, E. & France, J. (2001) A mechanistic model of whole-tract digestion and methanogenesis in the lactating dairy cow: Model development, evaluation, and application. *Journal of Animal Science* **79**(6): 1584-1597.

Mills, J. A. N., Kebreab, E., Yates, C. M., Crompton, L. A., Cammell, S. B., Dhanoa, M. S., Agnew, R. E. & France, J. (2003) Alternative approaches to predicting methane emissions from dairy cows. *Journal of Animal Science* **81**(12): 3141-3150.

Mulliniks, J. T., Edwards, S. R., Hobbs, J. D., McFarlane, Z. D. & Cope, E. R. (2017) Post-weaning feed efficiency decreased in progeny of higher milk yielding beef cows. *Animal*: 1-5.

Nahar, S., Islam, A. F. M. F., Hoque, M. A. & Bhuiyan, A. K. F. H. (2016) Animal performance of indigenous Red Chittagong cattle in Bangladesh. *Animal Sciences* **38**(2): 177-182.

Nascimento, C. F. M., Berndt, A., Romero, L. A., Meyer, P. M., Frighetto, R. T. S., Demarchi, J. J. A. A. & Rodrigues, P. H. M. (2016) Methane emission of cattle fed Urochloa brizantha hay harvested at different stages. *Agricultural Science* **8**: 163-174.

National Academies of Sciences, E. & Medicine. (2016) *Nutrient Requirements of Beef Cattle: Eighth Revised Edition*. Washington, DC: The National Academies Press.

Nekrasov, R., Varenikov, M., Chabaev, M., Anisova, N., Anikin, A., Pisarev, V. & Turchina, V. (2013) Balancing of the metabolic energy level in the high productive cow rations during the early lactation. *Dairy and Beef Cattle Breeding* **3**: 9-13.

Nosyreva Yu, N. & Tokareva, V. F. (2014) Influence of multifunctional supplement “Fungistat gpk” on nutrition digestibility given to lactating cows of black-and-white. *Bulletin of Irkutsk state agrarian university* **62**: 72-75.

Ominski, K. H., Boadi, D. A., Wittenberg, K. M., Fulawka, D. L. & Basarab, J. A. (2007) Estimates of enteric methane emissions from cattle in Canada using the IPCC Tier-2 methodology. *Canadian Journal of Animal Science* **87**(3): 459-467.

Özlütürk, A., Yanar, M., Tüzemen, N. & Kopuzlu, S. (2006) Calving and preweaning growth performance traits of calves sired by Charolais, Simmental and Eastern Anatolian Red Bulls. *Turkish Journal of Veterinary and Animal Sciences*.

Pardo, G., Moral, R., Aguilera, E. & del Prado, A. (2015) Gaseous emissions from management of solid waste: a systematic review. *Global change biology* **21**(3): 1313-1327.

Pathak, H., Upadhyay, R. C., Muralidhar, M., Bhattacharyya, P. & Venkateswarlu, B. (2013) *Measurement of greenhouse gas emission from crop, livestock and aquaculture*. New Delhi: Indian Agricultural Research Institute.

Patra, A. K. (2012) Estimation of methane and nitrous oxide emissions from Indian livestock. *J. Environ. Monit.*

Pinares-Patiño, C. S., Baumont, R. & Martin, C. (2003) Methane emissions by Charolais cows grazing a monospecific pasture of timothy at four stages of maturity. *Canadian Journal of Animal Science* **83**: 769-777.

Pracht, V. (2013) Effect of growth rate of holsteinized heifers of kholmogorskaya breed on subsequent milk performance. *Dairy and Beef Cattle Breeding* **5**: 31-32.

Rahman, S. M. A., Bhuiyan, M. S. A. & Bhuiyan, A. K. F. H. (2015) Effects of genetic and non-genetic factors on growth traits of high yielding dairy seed calves and genetic parameter estimates. *J. Adv. Vet. Anim. Res.* **2**(4): 450-457.

Roy, D., Kumar, V., Kumar, V., Sirohi, R., Singh, Y. & Singh, J. K. (2016) Effect of feeding Azolla pinnata on growth performance, feed intake, nutrient digestibility and blood biochemical’s of Hariana heifers fed on roughage based diet. *Indian J Dairy Sci* **69**(2): 190-196.

Sadeghi-Sefidmazgi, A., Moradi-Shahrbabak, M., Nejati-Javaremi, A., Miraei-Ashtiani, S. R. & Amer, P. R. (2012) Breeding objectives for Holstein dairy cattle in Iran. *Journal of Dairy Science*.

Saha, A., Garcia, O. & Hemme, T. (2004) The Economics of Milk Production in Orissa, India, with Particular Emphasis on Small-Scale Producers. *PPLPI Working Paper No. 16*.

Sambhaji, N. M. (2013) *Studies on Morphometric Characteristics of Red Kandhari cattle in Parbhani District. MSc thesis*. College of agriculture. India.

Samorukov, Y., Bychkov, A., Chernov, V., Andrianov, V., Potepalova, V. & Marzanov, N. (2013) About breeds in dairy cattle bree ding. *Dairy and Beef Cattle Breeding* **1**: 21-23.

Samorukov, Y., Kalyazina, T. & Marzanov, N. (2009) About the breeds in dairy farming. *Dairy and Beef Cattle Breeding* **6**: 3-5.

Sarkar, U., Gupta, A. K., Sarkar, V., Mohanty, T. K., Raina, V. S. & Prasad, S. (2006) Factors affecting test day milk yield and milk composition in dairy animals. *J. Dairying Foods and H.S.*

Selected Results of Livestock, S. (2012) *Statistical Centre of Iran*.

Sharkaev, V. & Kochetkov, A. (2012) Results of the complex estimation of dairy cattle in the Russian Federation. *Dairy and Beef Cattle Breeding* **8**: 9-12.

Sharkaeva, G. (2012) Use of imported cattle in the territory of the Russian Rederation. *Dairy and Beef Cattle Breeding* **1**: 12-14.

Sharkaeva, G. (2013) Monitoring of the cattle imported in the Russian Federation. *Dairy and Beef Cattle Breeding* **1**: 14-16.

Sharma, V. C., Mahesh, M. S., Mohini, M., Datt, C. & Nampoothiri, V. M. (2014) Nutrient utilisation and methane emissions in Sahiwal calves differing in residual feed intake. *Archives of Animal Nutrition* **68**: 345-357.

Sheppard, S. C., Bittman, S., Donohoe, G., Flaten, D., Wittenberg, K. M., Small, J. A., Berthiaume, R., McAllister, T. A., Beauchemin, K. A., McKinnon, J., Amiro, B. D., MacDonald, D., Mattos, F. & Ominski, K. H. (2015) Beef cattle husbandry practices across Ecoregions of Canada in 2011. *Canadian Journal of Animal Science* **95**(2): 305-321.

Sheveleva, O. M. & Bakharev, A. A. (2013) The formation of beef cattle breeding industry with the use of French breeds in the conditions of northern Zauralye. *Agrarian Bulletin of the Urals* **114**: 23-25.

Shevkhuzhev, A. F., Dubrovin, A. I. & Ulimbasheva, R. A. (2015) The behavioural reactions of bull-calves caused by technology of their growth. *Bulletin of Saint-Petersburg State Agrarian University* **41**: 100-104.

Singhal, K. K., Mohini, M., Jha, A. K. & Gupta, P. K. (2005) Methane emission estimates from enteric fermentation in Indian livestock: Dry matter intake approach. *Current Science*.

Sirohi, A. S., Pandey, H. N. & Singla, M. (2012) Effects of milking frequency on feed intake, body weight and haemato-biochemical changes in crossbred cows. *Journal of Applied Animal Research* **40**: 63-68.

Sodhi, M., Mukesh, M., Prakash, B., Mishra, B. P., Sobti, R. C., Singh, K. P., Singh, S. & S., A. S. P. (2007) MspI allelic pattern of bovine growth hormone gene in Indian Zebu cattle (Bos indicus) breeds. *Biochemical Genetics* **45**(1/2): 145-153.

Sontakke, U. B., Kaur, H., Tyagi, A. K., Kumar, M. & Hossain, S. A. (2014a) Effect of feeding rice bran lyso-phospholipids and rumen protected fat on feed intake, nutrient utilization and milk yield in crossbred cows. *Indian Journal of Animal Sciences* **84**(9): 998–1003.

Sontakke, U. B., Kaur, H., Tyagi, A. K., Kumar, M. & Hossain, S. A. (2014b) Effect of feeding rice bran lyso-phospholipids and rumen protected fat on feed intake, nutrient utilization and milk yield in crossbred cows. *Indian Journal of Animal Sciences*.

Stackhouse-Lawson, K. R., Rotz, C. A., Oltjen, J. W. & Mitloehner, F. M. (2012) Carbon footprint and ammonia emissions of California beef production systems1. *Journal of Animal Science* **90**(12): 4641-4655.

Staerfl, S. M., Zeitz, J. O., Kreuzer, M. & Soliva, C. R. (2012) Methane conversion rate of bulls fattened on grass or maize silage as compared with the IPCC default values, and the long-term methane mitigation efficiency of adding acacia tannin, garlic, maca and lupine. *Agriculture Ecosystems & Environment* **148**: 111-120.

Swainson, N., Muetzel, S. & Clark, H. (2016) Updated predictions of enteric methane emissions from sheep suitable for use in the New Zealand national greenhouse gas inventory. *Animal Production Science*: [Published online: 8 June 2016].

Tasdemir, S., Urkmez, A. & Inal, S. (2011) Determination of body measurements on the Holstein cows using digital image analysis and estimation of live weight with regression analysis. *Computers and Electronics in Agriculture*.

Tekeev, M. & Chomaev, A. (2011) Housing and rearing technology of replacement young cattle stock. *Dairy and Beef Cattle Breeding* **5**: 18-19.

Thombre, B. M., Shikalga, R. N. S. & Bainwad, D. V. (2015) IOSR Journal of Agriculture and Veterinary Science. *8* **4**(4-5).

Tomar, S. K. & Sharma, R. L. (2002) Fodder and feeding practices of cattle and sheep in Kasmir (India). *Tropical Agricultural research and extension*.

Troy, S. M., Duthie, C. A., Hyslop, J. J., Roehe, R., Ross, D. W., Wallace, R. J., Waterhouse, A. & Rooke, J. A. (2015) Effectiveness of nitrate addition and increased oil content as methane mitigation strategies for beef cattle fed two contrasting basal diets. *Journal Animal Science* **93**: 1815-1823.

Turkish statistical, I. (2017) http://www.turkstat.gov.tr/Start.do. *Access on 07.11.2017*.

Ulas, D. (2016) Fat depression in milk obtained from Simmental and native (Yerli Kara) cows in first month of postpartum period. *International Journal of Biosciences*.

Ulyatt, M. J., Lassey, K. R., Shelton, I. D. & Walker, C. F. (2002a) Methane emission from dairy cows and wether sheep fed subtropical grass-dominant pastures in midsummer in New Zealand. *New Zealand Journal of Agricultural Research* **45**(4): 227-234.

Ulyatt, M. J., Lassey, K. R., Shelton, I. D. & Walker, C. F. (2002b) Seasonal variation in methane emission from dairy cows and breeding ewes grazing ryegrass/white clover pasture in New Zealand. *New Zealand Journal of Agricultural Research* **45**(4): 217-226.

Ulyatt, M. J., Lassey, K. R., Shelton, I. D. & Walker, C. F. (2005) Methane emission from sheep grazing four pastures in late summer in New Zealand. *New Zealand Journal of Agricultural Research* **48**(4): 385-390.

USDA. (2015) *Live animals and animal products trade: Turkey, GAIN report*. USDA Foreign Agricultural Service.

Ustuner, H., Yalcintan, H., Orman, A., Ardicli, S., Ekiz, B., H. Gencoglu, H. & Kandazoglu, O. (2017) Effects of initial fattening age on carcass characteristics and meat quality in Simmental bulls imported from Austria to Turkey. *South African Journal of Animal Science*.

Vyas, D., Alazzeh, A., McGinn, S. M., McAllister, T. A., O, M., Harstad, Holo, H. & Beauchemin, K. A. (2016a) Enteric methane emissions in response to ruminal inoculation of Propionibacterium strains in beef cattle fed a mixed diet. *Animal Production Science* **56**: 1035-1040.

Vyas, D., McGeough, E. J., McGinn, S. M., McAllister, T. A. & Beauchemin, K. A. (2016b) Effect of Propionibacterium spp. on ruminal fermentation, nutrient digestibility, and methane emissions in beef heifers fed a high–forage diet. *Animal Production Science* **56**: 1035-1040.

Waldrip, H. M., Todd, R. W. & Cole, N. A. (2013) Prediction of nitrogen excretion by beef cattle: a meta-analysis. *J Anim Sci* **91**(9): 4290-4302.

Wang, P., Xue, Y., Ma, G. & Luo, J. (2016) 1713 Effects of corn silage levels on methane emissions and blood metabolite concentrations of drying-off Xinong Saanen dairy goats. *Journal of Animal Science* **94**(supplement5): 835-835.

Yadava, R. K. (2009) *Studies on growth pattern for better management of Sahiwal animals. MSc thesis*. National dairy research institute (Deemed university) (I.C.A.R.).

Yalcin, B., Stepan, V. & Cihan, D. (2017) Prediction of liveweight of holstein and brown swiss cattle grown in an 12 month intensive beef production system by using real-time body measurements. *Scientific Papers-Animal Science Series: Lucrări Ştiinţifice - Seria Zootehnie*.

Yasothai, R. (2014) Importance of protein on reproduction in dairy cattle. *International Journal of Science, Environment and Technology*.

Yilmaz, O., Akin, O., Metin Yener, S., Ertugrul, M. & Wilson, R. T. (2012) The domestic livestock resources of Turkey: cattle local breeds and types and their conservation status. *Animal Genetic Resources*.

Zadnepryanskiy, I. & Zakirko, V. (2012) Red-and-white breed milk cattle in Belgorod region. *Dairy and Beef Cattle Breeding* **3**: 21-23.