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METHODS FOR ESTIMATING METHANE EMISSIONS FROM DOMESTICATED ANIMALS

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1

INTRODUCTION

The EIIP guidelines are designed to describe emission estimation techniques for greenhouse gas sources in a clear and unambiguous manner and to facilitate preparation of inventories at the state level. This chapter presents the methodology for estimating methane emissions from domesticated livestock. The methodology presented in this chapter has been revised to reflect new activity data, emission factors, and methods pertaining to this source category. Where possible, the methodology has been updated to be consistent with the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002*.

Section 2 of this chapter contains a general description of this source category. Section 3 provides a listing of the steps involved in estimating methane emissions from domesticated livestock. Section 4 presents the preferred estimation method. Section 5 provides information on an alternative estimation technique for this source category. A summary of uncertainty for this source category is provided in Section 6. References used in developing this chapter are identified in Section 7.

In addition to these guidelines, there are a series of user friendly spreadsheet tools available to assist in the development of emission inventories at the state level. Please consult the Agriculture Module of the State Inventory Tool[1] to calculate emissions from this source category using the preferred emission estimation method.

[1] Note: The spreadsheet tool may have a different order of calculations, and may not show all calculations to the user.

2

SOURCE CATEGORY DESCRIPTION

2.1 EMISSION SOURCES

Methane (CH_4) is a natural by-product of animal digestion. During digestion, CH_4 is produced through a process referred to as enteric fermentation, in which microbes that reside in animal digestive systems break down feed consumed by the animal. Ruminants, which include cattle, sheep, and goats, have higher CH_4 emissions than other types of animals because of their unique digestive system. Ruminants possess a rumen, or large "fore-stomach," in which a significant amount of CH_4-producing fermentation occurs. Non-ruminant domestic animals, such as swine and horses, have much lower CH_4 emissions than ruminants because much less CH_4-producing fermentation takes place in their digestive systems. CH_4 emissions are counted only for domesticated animals; emissions from wild animals are not considered, because such emissions are not the result of human activity.

CH_4 produced as part of the normal digestive processes of animals result in emissions that account for a significant portion of CH_4 emissions in the United States, approximately 5.4 million metric tons annually, or 19 percent of total U.S. CH_4 emissions (U.S. EPA 2004). Approximately 200 species and strains of microorganisms are present in the digestive system of ruminant animals, although only a small portion, about 10 to 20 species, are believed to play an important role in ruminant digestion (Baldwin and Allison 1983). The microbial fermentation that occurs in the rumen enables ruminant animals to digest coarse plant material that non-ruminant animals cannot digest.

CH_4 is produced in the rumen by bacteria as a by-product of the fermentation process. This CH_4 is exhaled or eructated by the animal and accounts for the majority of emissions from ruminants. CH_4 is also produced in the large intestines of ruminants and is excreted. Non-ruminant herbivores have a limited amount of fermentation in the large intestines or ceca. The CH_4 produced in this manner is quite small compared to the amount produced by ruminant animals.

This source category accounts for only some of the many agricultural and forestry activities that emit greenhouse gases. Table 7.2-1 summarizes the agricultural and forestry activities associated with emissions of carbon dioxide, CH_4, and nitrous oxide, and provides a roadmap indicating the chapter in which each activity is addressed.

Table 7.2-1: Greenhouse Gas Emissions and Sinks from the Agricultural and Forest Sectors

A check indicates emissions or sinks may be significant

Activity	Associated Greenhouse Gas Emissions and Sinks and Chapter where these Emissions or Sinks are Addressed					
	CO_2	Chapter	CH_4	Chapter	N_2O	Chapter
Energy (Farm Equipment)	✓	1	✓	3	✓	3
Animal Production: Enteric Fermentation			✓	7		
Animal Production: Manure Management						
Solid Storage			✓	8	✓	8
Drylot			✓	8	✓	8
Deep Pit Stacks			✓	8	✓	8
Litter			✓	8	✓	8
Liquids/Slurry			✓	8	✓	8
Anaerobic Lagoon			✓	8	✓	8
Pit Storage			✓	8	✓	8
Periodic land application of solids from above management practices					✓	10
Pasture/Range (deposited on soil)			✓	8	✓	10
Paddock (deposited on soil)			✓	8	✓	10
Daily Spread (applied to soil)			✓	8	✓	10
Animal Production: Nitrogen Excretion (indirect emissions)					✓	10
Cropping Practices						
Rice Cultivation			✓	9		
Commercial Synthetic Fertilizer Application					✓	10
Commercial Organic Fertilizer Application					✓	10
Incorporation of Crop Residues into the Soil					✓	10
Production of Nitrogen-fixing Crops					✓	10
Liming of Soils	✓	12				
Cultivation of High Organic Content Soils (histosols)	✓	10			✓	10
Cultivation of Mineral Soils	✓	Not included[a]				
Changes in Agricultural Management Practices (e.g., tillage, erosion control)	✓	Not included[a]				
Forest and Land Use Change						
Forest and Grassland Conversion	✓	12				
Abandonment of Managed Lands	✓	12				
Changes in Forests and Woody Biomass Stocks	✓	12				
Agricultural Residue Burning			✓	11	✓	11

[a] Emissions may be significant, but methods for estimating greenhouse gas emissions from these sources are not included in the EIIP chapters.

2.2 FACTORS INFLUENCING METHANE EMISSIONS FROM DOMESTICATED ANIMALS

The amount of CH_4 produced by domesticated animals depends primarily on the type of animal (e.g., ruminant or non-ruminant), the age and weight of the animal, and the quantity and quality of the feed consumed (IPCC/UNEP/OECD/IEA 1997). The quality of the feed depends on the physical and chemical characteristics of the feed, and whether feed additives have been added to promote production efficiency. Other factors that influence CH_4 emissions are the feeding schedule, and the activity level and health of the animal. It has also been suggested that there may be genetic factors that affect CH_4 production.

To describe the CH_4 production by ruminant animals, it is convenient to refer to the portion of feed energy intake that is converted to CH_4. Higher levels of conversion translate into higher emissions, given constant feed energy intake. Similarly, higher levels of intake translate into higher emissions, given constant conversion. However, these values are not independent—there are interactions between the level of intake and the rate of conversion to CH_4. CH_4 emissions can thus be calculated by accounting for the interrelationships among feed characteristics, feed intake, and conversion rates to CH_4.

The rates of conversion of feed energy to CH_4 for the non-ruminant animals are much lower than those for ruminants. Therefore, the global emissions from non-ruminants are much smaller than emissions from ruminant animals. So while there is uncertainty in the estimates of emissions from non-ruminants, the uncertainty in these estimates does not contribute significantly to the uncertainty in the estimates of total CH_4 emissions from livestock.

3

OVERVIEW OF AVAILABLE METHODS

Emissions from this source category are calculated for two basic categories of livestock, cattle and other domesticated animals. For cattle, the preferred and alternative methods described in this chapter are conceptually very similar. The emission factors provided for the preferred method are actually derived from the output from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA 2004), which utilizes the alternative method. The preferred method is recommended for use by states because it is easier to use and the two methods yield similar results in most situations. The preferred method is less complex because it relies on (1) a simplified animal population characterization method, and (2) the emission factors are derived from the detailed data on diet type, feeding situation, and specific animal characteristics used in the alternative method, but the intensive data collection and calculations required for the alternate method are not required. Both are consistent with the Intergovernmental Panel on Climate Change (IPCC) *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000). For other domesticated livestock, there is no alternative method, and the preferred method described in this chapter for other domesticated livestock is the same as the methodology used in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA 2004) and recommended by the IPCC's *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000).

3.1 OVERVIEW OF PREFERRED METHOD

For most (if not all) states, cattle account for the majority of emissions from enteric fermentation. For this reason, the methodology for estimating emissions from cattle is more detailed.

While it is possible to measure methane emissions from cattle directly, it is not practical to do so for an emissions inventory at the state level. Given that direct measurements will not be taken, a model has been developed for estimating emission factors for individual animal types. Emissions are first estimated for each type of animal, by multiplying the factors derived from the model by the applicable animal populations. Then, emissions for each animal type are summed to arrive at total emissions for all animal types.

Cattle are large animals, raised in large numbers, and they account for the majority of methane emissions from this source category in the United States. Cattle characteristics and emissions vary significantly by region. Therefore, it was important to develop a model for cattle that takes into account the diversity of cattle types and cattle feeding systems in the United States. The regional variability in emission factors among other animals is generally believed to be much smaller than the variability in emission factors for cattle, and therefore a single national default factor is considered reasonable for non-cattle species.

The emission factors for cattle presented in the preferred method were developed using the methods developed by the IPCC (2000) in conjunction with a region-specific model (described in U.S. EPA 2004) used for estimating methane emissions from enteric fermentation in the United States. The model utilizes feed characteristics for various regions, as well as predictions of growth, pregnancy, milk production, and other production variables.

For non-cattle animals, emission factors were obtained from the scientific literature (as compiled in IPCC/UNEP/OECD/IEA 1997).

3.2 Harmonizing These Methods with Estimates for Manure Management

Emissions estimates for domesticated livestock (covered in this chapter) and manure management (covered in Chapter 8) rely on the same underlying livestock population data and livestock characteristics data. It is important to use the same underlying data to estimate emissions from these two source categories. One way to ensure consistency is to use USDA National Agriculture Statistics Service (NASS) data to estimate the livestock populations for both source categories. Although the specific sub-categories of livestock types vary between the methods for the two sources, (e.g., total swine populations are used for enteric fermentation, while swine are split into breeding and market, and further divided by weight class in the manure management source category) they rely on the same underlying USDA/NASS population data. Another key difference between the livestock populations needed to estimate emissions from these sources is the omission of calves in the enteric fermentation estimates; this is because emissions are assumed to be zero through six months of age. Emissions from calves are included in the manure management estimates; therefore, the calf populations are required in that chapter. If the alternative method (covered in Section 7.5) for cattle is used to estimate emissions from domesticated animals, an effort should be undertaken to make the estimates from manure management consistent with the cattle populations and characteristics developed for the alternative method. This effort should focus on the sizes of the cattle and their amount of manure production, which are important factors in the emissions estimates for manure management.

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

The preferred method for estimating methane (CH_4) emissions from cattle relies on the results of U.S. EPA's cattle enteric fermentation model. The results of the model are used in conjunction with cattle population data and geographic region. Cattle populations are multiplied by category-specific, regional emission factors and summed across animal types. For non-cattle animals, the animal population data is multiplied by national emission factors (IPCC/UNEP/OECD/IEA 1997). The methodology for estimating these emissions consists of four steps: (1) obtain required data; (2) identify geographic region; (3) estimate CH_4 emissions; and (4) convert units to metric tons of carbon equivalent (MTCE).

Step (1): Obtain Required Data

- *Required Data.* The data required are the average animal populations, over the course of the inventory year, for the following animals: cattle, sheep, goats, swine, and horses. The cattle population data need to be aggregated to the simplified set of categories shown in Table 7.4-1.

- *Data Adjustments for Calculations.* Animal populations fluctuate during the year, in some cases by large amounts. For example, a census done before calving will give a much smaller number than a census done after calving. Thus, the *average* animal population over the course of the inventory year should be used in the estimates (termed here the "annual average population"). For some animals, a specific state's population may only be given for one month, while the national population is given at other points during the year. In this case a state's annual average animal population may be estimated based on (1) the animal population in the state in a given month, (2) the national population of the animal in the same month, and (3) the national population of the animal either six months before or after. Therefore, to obtain an average annual animal population it may be necessary to use animal census data from multiple points throughout each year. See the example below for determining the annual average population from cattle populations.

Example:	According to the January and July USDA *Cattle* reports in 2000, the number of dairy replacement heifers in Ohio in January 2000 was 110,000. The average number of dairy replacement heifers in the United States in 2000 was [4,000,000 (January value) + 3,700,000 (July value)]/2 = 3,850,000 To estimate the annual average number of dairy replacement heifers in Ohio in 2000, scale the January value using a scaling factor of [3,850,000 (national annual average number)] / [4,000,000 (national January value)] = 0.9625 The average number of dairy replacement heifers in Ohio in 2000 was 110,000 x 0.9625 = **105,875**

- *Data Sources.* Much of the required data are available on an annual, twice yearly, or quarterly basis on the Internet from the USDA's National Agricultural Statistics Service (USDA-NASS 2002). Departments within each state responsible for conducting agricultural research are likely to have data on state animal populations, and because states are responsible for providing data to the USDA this information generally is consistent with the USDA-NASS data. Additional detail, such as farm size or county level population estimates on state animal populations may be found in the *Census of Agriculture*, published by the USDA every five years, for 1992 and 1997. See Table 7.4-1 and Table 7.4-2 for suggested data sources for each animal type. Currently, the Agriculture Module of the State Inventory Tool contains annual average populations for most states and animal categories and can be used to simplify data collection efforts.

Table 7.4-1: Relationship Between USDA Cattle Categories and Emission Factor Categories

Animal Type	USDA Category	USDA Source for Data
Dairy Cattle		
Dairy Cows	Milk Cows That Have Calved	*Cattle*-January and July Inventories
Dairy Replacement Heifers	Milk Cow Replacement[a]	*Cattle*-January and July Inventories
Replacements 7-12 months	No data currently available	No data currently available
Replacements 12-24 months	No data currently available	No data currently available
Beef Cattle		
Beef Cows	Beef Cows That Have Calved	*Cattle*-January and July Inventories
Beef Replacement Heifers	Beef Cow Replacement[a]	*Cattle*-January and July Inventories
Replacements 7-12 months	No data currently available	No data currently available
Replacements 12-24 months	No data currently available	No data currently available
Steer Stockers	Steer (500 lbs +) – Feedlot Steer	*Cattle*-January and July Inventories
Heifer Stockers	Other Heifers (500 lbs +) – Feedlot Heifers	*Cattle*-January and July Inventories
Feedlot Steer	Total Cattle on Feed x Steer / (Steer + Other Heifers)	*Cattle*-January and July Inventories
Feedlot Heifers	Total Cattle on Feed x Heifers / (Steer + Other Heifers)	*Cattle*-January and July Inventories
Bulls	Bulls (500 lbs +)	*Cattle*-January and July Inventories

[a] The USDA's reported replacement heifer count does not disaggregate heifer replacements into age categories. Therefore, the total number of replacement heifers is used, unless state specific sources can disaggregate heifer replacements by age.

Table 7.4-2: Inventory Data Sources for Livestock Other than Cattle

Animal Type	Category	Source for Data
Sheep	All Sheep and Lambs	USDA, *Sheep*, not available for all states
Goats	All Goats	USDA, *Census of Agriculture, 1992 and 1997*, scaled between 1993

		and 1996, held constant from 1990-1992 and 1997-2000
Swine	All Hogs and Pigs	USDA, *Hogs and Pigs*, December report has all states, other quarterly reports have top producers and totals for scaling factors
Horses	Horses	FAO reports national data at: http://apps.fao.org/

Step (2): Identify Geographic Region

- For cattle emissions estimates, identify the appropriate geographic region in Table 7.4-3. The emission factors corresponding to the region will be used for Step 3.

Table 7.4-3: Geographic Regions

Region	States
California	CA
West	AK, WA, OR, ID, NV, UT, AZ, HI, NM
Northern Great Plains	MT, WY, ND, SD, NE, KS, CO
South Central	AR, LA, OK, TX
Northeast	PA, NY, MD, DE, NJ, CT, RI, MA, VT, NH, ME, WV, DC
Midwest	MO, IL, IN, OH, MN, WI, MI, IA
Southeast	VA, NC, KY, TN, MS, AL, GA, SC, FL

Step (3): Estimate Methane Emissions

- Multiply each animal population by the appropriate national or regional emission factor. Regional emission factors for cattle are presented in Table 7.4-4. Because emission factors for cattle are dependent on diet characteristics, such as digestible energy and CH_4 yield, which vary by diet and individual animal, there is uncertainty associated with specific local diets and CH_4 yield in the emission factors provided here. If using USDA data please refer back to Table 7.4-1 for the relationship between USDA cattle categories and the emission factor categories presented in this chapter. Note that feedlot animals are split according to the ratio of steer (500 lbs and over) and other heifers (500 lbs and over). Emission factors for all other animals are presented in Table 7.4-5. The calculation used is as follows:

CH_4 Emissions (kg) = Animal Population (head) x Regional Emissions Factor (kg CH_4/head)

Step (4): Convert Units to Metric Tons of Carbon Equivalent

- For each animal, divide the results in kg CH_4 by 1,000 kg/metric ton to obtain metric tons of CH_4.

- Sum across all animal types to obtain total CH_4 emissions from domesticated animals, in metric tons.

- Multiply by the Global Warming Potential of CH_4 (21) and the ratio of the atomic weight of carbon to the molecular weight of carbon dioxide (12/44) to obtain the amount of CH_4 in MTCE.

Example:	CH_4 emissions from dairy replacement heifers in Ohio for 2000 are calculated as follows:
	105,875 head x 53.4 (kg CH_4/head) = 5,653,061 kg CH_4
	5,653,061 kg CH_4 ÷ 1,000 (kg/MT) = 5,653 MT CH_4
	5,653 MT x 21 x 12/44 = **32,376 MTCE**

Table 7.4-4: Emission Factors for U.S. Cattle by Region (kg CH_4/head/year)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Dairy Cows													
California	128.7	129.1	129.9	114.5	119.6	128.7	100.5	102.7	101.5	105.9	107.1	106.3	107.2
West	124.6	126.0	128.0	126.9	129.2	124.6	128.5	130.4	131.6	134.5	135.7	135.7	137.0
Northern Great Plains	102.0	102.4	104.3	103.1	105.5	102.0	105.5	106.9	109.0	110.8	114.5	114.6	117.4
Southcentral	121.1	120.2	122.3	112.3	113.9	121.1	102.9	102.6	104.2	105.2	106.5	104.6	108.4
Northeast	114.5	116.4	119.5	113.3	113.9	114.5	110.4	111.4	112.8	114.4	115.2	115.7	117.2
Midwest	105.2	106.2	108.4	107.2	107.9	105.2	107.9	109.8	112.0	113.2	115.0	114.2	115.4
Southeast	125.4	126.4	128.4	115.5	117.1	125.4	103.5	104.6	104.2	106.0	107.3	107.7	108.4
National Average[a]	114.0	115.2	117.5	112.0	113.8	114.0	108.7	110.3	111.6	113.7	115.2	114.9	116.5
Dairy Replacements 7-12 Months[b]													
California	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3
West	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3
Northern Great Plains	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1
Southcentral	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5
Northeast	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7
Midwest	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1
Southeast	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
National Average[a]	40.2	40.1	40.1	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.1	40.2	40.1
Dairy Replacements 12-24 Months[b]													
California	63.4	63.3	63.3	63.3	63.3	63.4	63.3	63.4	63.3	63.4	63.3	63.3	63.3
West	63.4	63.3	63.3	63.3	63.3	63.4	63.3	63.4	63.3	63.4	63.3	63.3	63.3
Northern Great Plains	60.0	59.9	59.9	59.9	59.9	60.0	59.9	59.9	59.9	59.9	59.9	59.9	59.9
Southcentral	71.7	71.6	71.6	71.6	71.6	71.7	71.6	71.6	71.6	71.6	71.6	71.6	71.6
Northeast	64.0	63.9	63.9	63.9	63.9	64.0	63.9	64.0	63.9	64.0	63.9	63.9	63.9
Midwest	60.0	59.9	59.9	59.9	59.9	60.0	59.9	59.9	59.9	59.9	59.9	59.9	59.9
Southeast	73.7	73.7	73.7	73.7	73.7	73.7	73.7	73.7	73.7	73.7	73.7	73.7	73.7
National Average[a]	63.3	63.1	63.0	63.2	63.2	63.3	63.2	63.2	63.2	63.2	63.1	63.1	63.0
Total Dairy Replacements[b]													
California	56.6	56.5	56.5	56.5	56.5	56.5	56.5	56.6	56.4	56.6	56.4	56.5	56.5
West	56.6	56.5	56.5	56.5	56.5	56.5	56.5	56.6	56.4	56.6	56.4	56.5	56.5
Northern Great Plains	53.5	53.4	53.4	53.5	53.4	53.4	53.5	53.5	53.4	53.5	53.4	53.4	53.4
Southcentral	64.0	63.8	63.8	63.9	63.8	63.9	63.9	64.0	63.8	63.9	63.8	63.9	63.8
Northeast	57.1	57.0	57.0	57.1	57.0	57.0	57.1	57.1	57.0	57.1	57.0	57.0	57.0
Midwest	53.5	53.4	53.4	53.5	53.4	53.4	53.5	53.5	53.4	53.5	53.4	53.4	53.4
Southeast	65.8	65.7	65.7	65.8	65.7	65.7	65.8	65.8	65.7	65.8	65.7	65.7	65.7
National Average[a]	56.5	56.2	56.2	56.4	56.4	56.5	56.4	56.4	56.3	56.4	56.2	56.3	56.2

Table 7.4-4: Emission Factors for U.S. Cattle by Region (kg CH_4/head/year)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Beef Cows													
California	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8
West	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3
Northern Great Plains	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8
Southcentral	74.6	74.6	74.6	74.6	74.6	74.6	74.6	74.6	74.6	74.6	74.6	74.6	74.6
Northeast	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1
Midwest	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1
Southeast	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7
National Average[a]	74.8	74.8	74.8	74.8	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.6	74.6
Beef Replacements 7-12 Months[b]													
California	40.2	40.2	40.1	40.1	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2
West	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8
Northern Great Plains	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0
Southcentral	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6
Northeast	40.3	40.3	40.3	40.3	40.3	40.4	40.4	40.4	40.3	40.3	40.3	40.3	40.3
Midwest	40.3	40.3	40.3	40.3	40.3	40.4	40.4	40.4	40.4	40.3	40.3	40.3	40.3
Southeast	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7
National Average[a]	40.8	40.8	40.7	40.7	40.7	40.8	40.8	40.8	40.8	40.7	40.7	40.7	40.7
Beef Replacements 12-24 Months[b]													
California	62.9	62.8	62.8	62.9	62.8	62.8	62.8	62.9	62.9	62.9	62.8	62.9	62.9
West	73.8	73.8	73.7	73.8	73.7	73.8	73.7	73.8	73.9	73.8	73.8	73.8	73.8
Northern Great Plains	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.1	61.0	61.0	61.0	61.0
Southcentral	63.6	63.6	63.6	63.6	63.6	63.6	63.6	63.6	63.7	63.6	63.6	63.6	63.6
Northeast	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.2	63.2	63.1	63.1	63.1	63.1
Midwest	63.2	63.1	63.1	63.1	63.1	63.1	63.1	63.2	63.2	63.2	63.1	63.2	63.2
Southeast	63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.8	63.7	63.7	63.7	63.7
National Averagea	64.0	63.9	63.7	63.8	63.7	63.8	63.8	63.9	63.9	63.8	63.8	63.8	63.8
Total Beef Replacements[b]													
California	56.1	56.0	55.9	56.0	56.1	56.2	56.2	56.3	56.3	56.2	56.1	56.2	56.1
West	65.7	65.7	65.5	65.6	65.7	65.9	65.9	66.0	66.0	65.8	65.7	65.8	65.8
Northern Great Plains	54.4	54.4	54.2	54.4	54.4	54.6	54.5	54.7	54.7	54.5	54.4	54.5	54.5
Southcentral	56.7	56.7	56.5	56.7	56.7	56.9	56.9	57.0	57.0	56.8	56.8	56.8	56.8
Northeast	56.3	56.3	56.1	56.3	56.3	56.5	56.4	56.6	56.6	56.4	56.3	56.4	56.4
Midwest	56.3	56.3	56.1	56.3	56.3	56.5	56.5	56.6	56.6	56.4	56.4	56.4	56.4
Southeast	56.8	56.8	56.6	56.8	56.8	57.0	56.9	57.1	57.1	56.9	56.8	56.9	56.9
National Average[a]	57.0	56.9	56.7	56.8	56.9	57.1	57.1	57.2	57.2	57.0	56.9	57.0	56.9
Steer Stockers													
California	54.2	54.1	54.4	54.5	54.4	54.6	54.4	54.5	54.4	54.2	54.0	54.0	54.1
West	63.8	63.7	64.1	64.2	64.0	64.2	64.0	64.1	64.0	63.8	63.6	63.6	63.7
Northern Great Plains	52.6	52.5	52.8	52.9	52.7	53.0	52.8	52.8	52.7	52.5	52.4	52.4	52.5
Southcentral	54.9	54.7	55.1	55.2	55.0	55.3	55.1	55.1	55.0	54.8	54.7	54.6	54.8
Northeast	54.4	54.3	54.7	54.8	54.6	54.9	54.7	54.7	54.6	54.4	54.3	54.2	54.4
Midwest	54.5	54.3	54.7	54.8	54.6	54.9	54.7	54.7	54.6	54.4	54.3	54.3	54.4
Southeast	54.9	54.8	55.2	55.3	55.1	55.4	55.2	55.2	55.1	54.9	54.8	54.7	54.9
National Average[a]	54.7	54.6	54.9	55.0	54.8	55.0	54.8	54.8	54.7	54.5	54.3	54.3	54.5

Table 7.4-4: Emission Factors for U.S. Cattle by Region (kg CH_4/head/year)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Heifer Stockers													
California	48.0	48.0	48.4	48.6	48.6	48.7	48.6	48.6	48.6	48.4	48.3	48.2	48.5
West	56.3	56.2	56.7	56.9	56.9	57.1	57.0	56.9	56.9	56.7	56.6	56.6	56.8
Northern Great Plains	46.6	46.5	47.0	47.1	47.1	47.3	47.2	47.1	47.1	47.0	46.9	46.8	47.0
Southcentral	48.6	48.5	48.9	49.1	49.1	49.3	49.2	49.1	49.1	48.9	48.9	48.8	49.0
Northeast	48.2	48.2	48.6	48.8	48.8	49.0	48.8	48.8	48.8	48.6	48.5	48.4	48.7
Midwest	48.2	48.2	48.6	48.8	48.8	49.0	48.8	48.8	48.8	48.6	48.5	48.5	48.7
Southeast	48.6	48.6	49.0	49.2	49.2	49.4	49.2	49.2	49.2	49.0	48.9	48.9	49.1
National Average[a]	48.1	48.1	48.5	48.7	48.7	48.9	48.7	48.7	48.7	48.5	48.4	48.3	48.5
Steer Feedlot													
California	39.9	40.0	37.8	36.0	36.1	33.9	34.1	33.0	33.3	33.2	33.3	32.9	33.2
West	40.5	38.7	37.5	36.4	35.4	34.4	33.6	33.2	33.4	33.4	33.0	33.0	33.5
Northern Great Plains	39.8	38.7	37.6	36.3	35.4	34.3	33.3	33.1	33.4	33.4	33.2	33.1	33.5
Southcentral	39.9	38.8	37.6	36.2	35.1	34.7	33.1	33.3	33.3	33.4	33.2	33.3	33.6
Northeast	39.9	38.6	37.4	36.3	36.0	34.0	33.6	33.4	33.5	33.3	33.5	33.6	33.5
Midwest	39.8	38.8	37.8	36.6	35.3	34.5	33.4	33.2	33.7	33.2	33.4	33.5	33.7
Southeast	40.8	39.1	37.1	37.0	35.7	34.3	34.8	33.9	33.7	34.1	34.2	32.9	33.9
National Average[a]	39.9	38.8	37.6	36.3	35.4	34.4	33.3	33.2	33.4	33.3	33.2	33.2	33.5
Heifer Feedlot													
California	37.4	37.9	35.7	34.1	34.2	32.1	32.4	31.3	31.5	31.4	31.5	31.0	31.3
West	38.2	36.3	35.4	34.5	33.6	32.6	31.8	31.5	31.6	31.6	31.2	31.1	31.6
Northern Great Plains	37.3	36.4	35.4	34.4	33.6	32.4	31.5	31.4	31.6	31.5	31.3	31.3	31.6
Southcentral	37.4	36.5	35.4	34.3	33.2	32.9	31.3	31.5	31.5	31.6	31.4	31.4	31.7
Northeast	37.4	36.2	35.2	34.4	34.2	32.1	31.8	31.7	31.7	31.5	31.7	31.7	31.6
Midwest	37.4	36.5	35.7	34.7	33.5	32.6	31.7	31.5	31.9	31.4	31.5	31.7	31.8
Southeast	38.5	36.9	34.9	35.1	33.8	32.4	33.0	32.2	31.9	32.3	32.3	31.1	32.0
National Average[a]	37.4	36.5	35.5	34.4	33.5	32.6	31.6	31.5	31.6	31.5	31.4	31.4	31.6
Bulls	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] National averages are weighted by regional animal populations.

[b] A portion of the offspring are retained to replace mature cows that die or are removed from the herd (culled) each year. Those that are retained are called "replacements." If specific age data is not available for replacements, use the total replacements emission factors.

Source: U.S. EPA 2004.

Table 7.4-5 Emission Factors for Animals Other than Cattle (All Regions)

Animal Type	Emission Factor (kg CH_4/head/yr)
Sheep	8
Goats	5
Swine	1.5
Horses	18

Source: IPCC/UNEP/OECD/IEA 1997.

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ALTERNATIVE METHOD FOR ESTIMATING EMISSIONS

The IPCC has developed an alternative method for emissions from cattle and sheep. The alternative method for estimating methane emissions from cattle and sheep requires four steps: (1) characterize the populations using an 'enhanced' livestock characterization method; (2) estimate emission factors based on specific variables, such as the feeding situation, weight, weight gain, hours worked, milk production, and diet characteristics; (3) multiply the population of each type of cattle by the appropriate emission factor; and (4) sum the results across all types of cattle. To use the alternative method, please refer to the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 4 (IPCC 2000).

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UNCERTAINTY SUMMARY

The quantity of methane (CH_4) emitted from enteric fermentation from livestock is dependent on the estimates of animal populations and the emission factors used for each animal type. Therefore, the uncertainty associated with the emission estimates stems from those two variables. Animal populations fluctuate throughout the year, and thus using a single point estimate (e.g., horses and sheep), multiple point estimates (e.g., cattle and swine), or periodic estimates (e.g., goats) introduces uncertainty into the average annual estimates of these populations. In addition, there is uncertainty associated with the original population survey methods employed by USDA.

Emission factors vary in each animal, depending on its production and diet characteristics, as well as genetics. This makes determining an exact emission factor for each state and all possible animal sub-groupings impossible. However, for cattle, these variables were simulated when estimating emissions for the United States. (EPA 2004), thus providing a reasonable average for the regions defined in this analysis. While some of the characteristics used for cattle differ from the IPCC default values, a review of the U.S. situation determined that these factors are justified. For other (non-cattle) animal populations there is also uncertainty associated with the emission factors, but it is believed not to vary as drastically within each species.

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