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Global Methane Emissions From Livestock And Poultry Manure

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GLOBAL METHANE EMISSIONS FROM LIVESTOCK AND POULTRY MANURE

by

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ABBREVIATIONS

AWMS = animal waste management system
B_o = maximum methane production capacity
CAF = climate adjustment factor
CH_4 = methane
CO_2 = carbon dioxide
f of B_o = fraction of B_o that is achieved (f of B_o = MCF • CAF).
g = grams
h = head
kg = kilograms
lb = pounds
m^3 = cubic meters
MCF = methane conversion factor
MJ = megajoules = 10^6 joules
mo = month
mt = metric ton = 10^6 grams = 10^3 kilograms
Pop = population
ppmv = part per million by volume
TAM = typical animal mass
Tg = teragram = 10^{12} grams = 10^9 kilograms = 10^6 metric tons
TM = annual mass methane production
Tot = total
TS = total solids
VMP = daily volumetric methane production
VS = volatile solids
WS% = percentage of waste handled by a waste system
wb = weight basis

EXECUTIVE SUMMARY

This report estimates that global methane emissions from animal waste are about 28 Tg/yr[1] with a range of about 20 to 35 Tg/yr, or about 6 to 10 percent of total annual anthropogenic emissions. These estimates were made by collecting information on the methane producing potential of animal waste management systems around the world and the quantity of animal waste managed by each system. Information was collected from government statistics, literature reviews, and animal waste experts worldwide. This report is one of a series of reports being prepared by the U.S. Environmental Protection Agency to estimate global methane emissions and to identify options for stabilizing global methane concentrations.

BACKGROUND

The atmospheric concentration of methane (CH_4), currently about 1.7 ppmv,[2] is increasing at a rate of about 1 percent per year and has more than doubled over the last two centuries. Prior to this doubling, the atmospheric concentration of methane remained fairly constant, at least as far back as 160,000 years before present. The increased abundance of methane will have important impacts on global climate change, tropospheric (ground-based) ozone, and the stratospheric ozone layer. Estimates are that methane contributes about 20 percent of the expected global warming from the greenhouse effect, second only to carbon dioxide (EPA 1989).

As part of the overall strategy to identify options for stabilizing global methane concentrations, emissions inventories are being prepared and opportunities for reducing methane emissions are being identified and evaluated by the U.S. Environmental Protection Agency and others. Methane emission estimates from the decomposition of animal wastes are necessary both to improve understanding of the emissions sources and to help identify opportunities for controlling emissions. The estimates presented in this report do not include methane emissions from the digestive processes of ruminant animals (i.e., due to enteric fermentation) and do not include emissions resulting from the decomposition of the waste of wild animals.

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1 Tg = 1 teragram = 10^{12} grams = 10^{9} kilograms = 10^{6} metric tons

2 ppmv is parts per million by volume.

METHANE PRODUCTION

Methane is produced during the anaerobic decomposition[3] of the organic material in livestock waste. Because the quantity of livestock waste is large and because the waste is primarily composed of organic material, the potential for methane emissions is large. However, only a portion of this emissions potential is realized because when waste is kept in contact with oxygen (e.g., spread on fields) methane production is minimal.

The principal determinants of methane production from animal waste are the following:

- **Quantity and Characteristics of the Waste.** Potential methane production is directly related to the quantity of waste and the fraction of the waste available for decomposition. These factors vary by animal species and their diet.

- **Waste Management System.** The waste management system strongly influences methane production from animal waste. Waste management systems that promote anaerobic (oxygen free) decomposition will produce methane.

- **Temperature and Moisture.** Temperature and moisture affect both the rate and total amount of methane production in animal waste. A warm and moist environment promotes methane production.

METHODOLOGY

The steps used to estimate emissions are:

1. Identify waste management systems in use throughout the world and estimate their methane producing potential.

2. Estimate the amount of waste managed in each system.

3. Estimate methane emissions by multiplying the amount of waste managed in each waste system by the estimated emissions rate per unit of waste in the system.

Information was obtained from a variety of sources, including: FAO Production Yearbook; the U.S. Census of Agriculture and USDA agriculture statistics; animal science experts throughout the world; and literature reviews.

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[3] Anaerobic decomposition (fermentation) of animal waste is a micro-biological process that occurs in an oxygen free environment.

RESULTS

This report estimates that global methane emissions from animal waste are about 28 Tg/yr with a range of about 20 to 35 Tg/yr, or about 6 to 10 percent of total annual anthropogenic emissions. Exhibit 1 illustrates the global distribution of these emissions by region and animal type. Exhibit 2 presents the global distribution of emissions by region and animal waste management system. The major findings of this report are that:

- Of the 28 Tg/yr, liquid animal waste management systems (liquid/slurry storage and anaerobic lagoons) account for over 10 Tg/yr, or about 35 percent of total emissions from animal waste. These systems are used at confined, energy intensive livestock operations and may provide profitable opportunities to recover methane for use as a fuel.

- Of the 28 Tg/yr, three regions account for 78 percent of the total: Europe (Eastern and Western) with 11.4 Tg/yr (40 percent); Asia and the Far East with 6.4 Tg/yr (23 percent); and North America with 4.2 Tg/yr (15 percent).

- Of the 28 Tg/yr, over 20 Tg are from three animal groups: cattle (beef and draft animals), dairy cows, and swine.

These methane emission estimates are uncertain for various reasons, including:

- The estimates of the methane produced by pasture and range waste is very uncertain. Assumptions regarding methane emission from waste in pasture have a large influence on the overall emissions estimate because a large portion of animal waste is found in pastures.

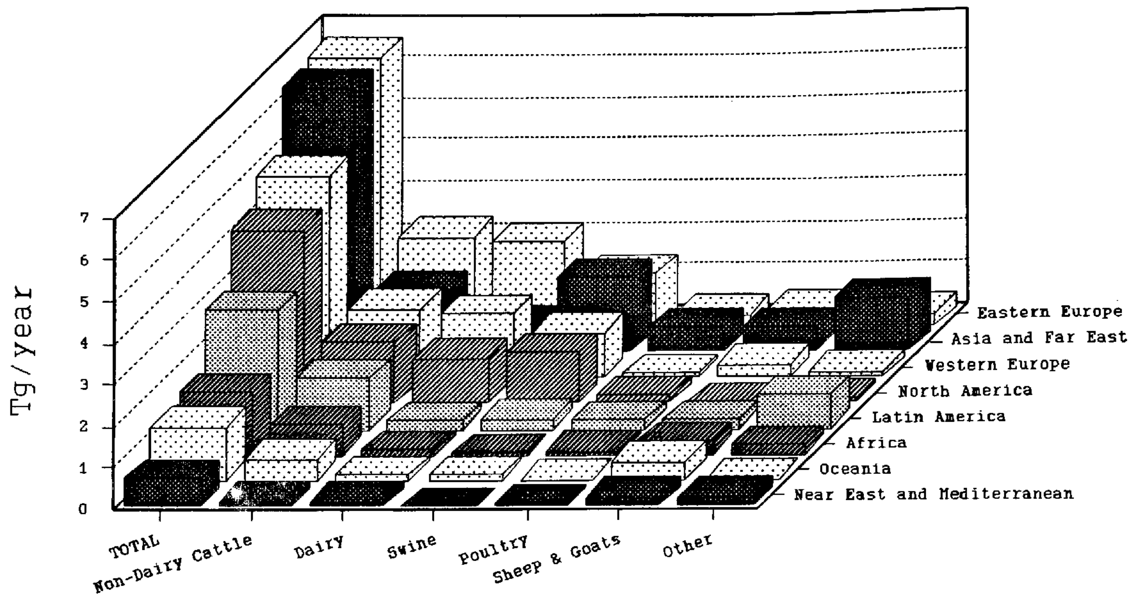
- Data on animal numbers, size, and feed are uncertain for many developing countries.

- Limited data are available to assess the methane producing potential of animal waste in developing countries.

- Limited data exist on the types and numbers of animal waste systems in developing countries.

While many of the assumptions used to estimate emissions may be uncertain, this report provides a framework for estimating emissions. As additional data become available, the estimates can be improved. The report will focus research by indicating the regions and animal waste systems that likely produce the greatest emissions. In addition, the report will help identify regions where profitable opportunities for reducing emissions exist.

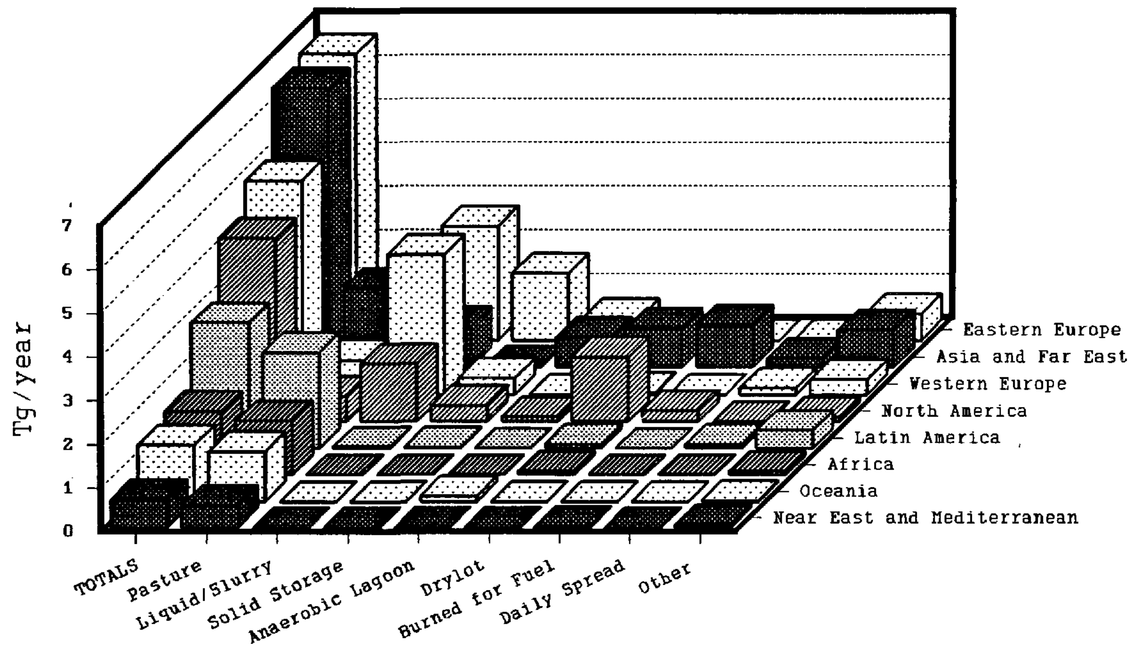
EXHIBIT 1: GLOBAL ANIMAL WASTE METHANE EMISSIONS BY ANIMAL TYPE AND REGION (TG/YR)



Animal Type	North America	West Europe	East Europe	Oceania	Latin America	Africa	Near East & Med	Asia & Far East	Total[A]
Cattle	1.5	1.7	2.2	0.5	1.2	0.7	0.1	1.5	9.4
Dairy	1.1	1.5	2.0	0.2	0.2	0.1	0.1	0.6	5.9
Swine	1.2	1.1	1.3	0.1	0.2	<0.1	<0.1	1.8	5.8
Sheep and Goats	<0.1	0.3	0.4	0.4	0.2	0.3	0.2	0.6	2.5
Poultry	0.2	0.1	0.3	<0.1	0.2	0.1	0.1	0.6	1.7
Other Animals	0.1	0.1	0.3	<0.1	0.8	0.2	0.2	1.3	2.9
Total[A]	4.2	4.9	6.5	1.3	2.9	1.5	0.7	6.4	28.3

[A] Totals may not add due to rounding.

EXHIBIT 2: GLOBAL WASTE METHANE EMISSIONS BY REGION AND SYSTEM (TG/YR)



Waste Management System	North America	West Europe	East Europe	Oceania	Latin America	Africa	Near East & Med	Asia & Far East	Total[A]
Pasture/Range	1.3	0.8	1.2	1.2	2.2	1.3	0.5	1.8	10.2
Liquid/Slurry	0.4	3.2	2.6	0.0	0.0	0.0	0.0	0.9	7.2
Solid Storage	0.1	0.4	1.6	0.0	0.0	0.0	0.0	0.0	2.1
Anaerobic Lagoon	1.5	0.0	0.5	0.1	0.0	0.0	0.0	0.7	2.8
Drylot	0.3	0.0	0.1	0.0	0.1	0.1	0.0	0.9	1.5
Burned for Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
Daily Spread	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.6
Other Systems	0.6	0.3	0.6	0.0	0.4	0.1	0.1	0.9	3.0
Total[A]	4.2	4.9	6.5	1.3	2.9	1.5	0.7	6.4	28.3

[A] Totals may not add due to rounding.

CHAPTER 1. INTRODUCTION

BACKGROUND

Comprehensive global measurements since the late 1970s indicate that the global average methane concentration is about 1.7 ppmv[4] and is increasing at the rate of about one percent per year or about 0.017 ppmv per year (Blake and Rowland 1988). Atmospheric methane concentrations are determined by natural and anthropogenic emissions (sources) and by destruction mechanisms (sinks).

To explain the observed increases in atmospheric methane, it is believed that methane emissions related to human activities are increasing. These anthropogenic sources include: animals (primarily ruminant livestock); animal waste; rice cultivation; biomass burning; oil and gas production and distribution; coal mining; and landfills. Exhibit 3 summarizes the major anthropogenic and natural sources of methane.

The observed increased abundance of methane, when coupled with methane's chemical and radiative properties, will have adverse impacts on environmental quality and human health. These impacts include:

Global Climate Change: Methane is very effective at absorbing infrared radiation (IR). Comparatively, a gram of methane will initially absorb about 70 times as much IR as will a gram of carbon dioxide. Methane's contribution to global warming is believed to be second only to CO_2 (EPA 1989).

Tropospheric Ozone: Methane is primarily destroyed through reaction with the hydroxyl (OH) radical in the atmosphere. In the presence of NO_x (NO and NO_2) these reactions result in the formation of tropospheric ozone (Lashof 1989) which will also contribute to the greenhouse effect. In addition, increasing concentrations of tropospheric ozone, a primary component of urban "smog," are considered to be a threat to human health, crops, ecosystems and polymer-based materials (EPA 1987).

Stratospheric Ozone: Increasing methane concentrations will tend to suppress tropospheric OH through atmospheric reactions which, unopposed, will deplete the oxidizing potential of the atmosphere, including its capacity for removing hydrogenated chlorofluorocarbons (HCFCs) (Thompson and Cicerone 1986; Thompson et al. 1989). The resulting slower removal of the HCFCs from the atmosphere will exacerbate stratospheric ozone depletion. In addition, the water vapor that is added to the stratosphere when methane is oxidized may enhance the destruction of stratospheric ozone (Blake and Rowland 1988).

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[4] ppmv is parts per million by volume.

METHANE EMISSIONS FROM ANIMAL WASTE

The amount of methane produced by animal waste depends on how the waste is managed. If the waste is managed aerobically, in contact with oxygen (e.g., spread on fields), then methane production is minimal. If the waste is managed anaerobically, kept out of contact with oxygen (e.g., placed in lagoons or liquid/slurry storage) then methane production may be substantial.

Anaerobic conditions are most likely to occur in locations where large numbers of animals are managed in a confined location (e.g., dairies in the United States and Europe, feedlots in the United States; swine farms in the United States). Typically, a large amount of waste accumulates until it is hauled away or washed into a waste treatment lagoon, thereby producing anaerobic conditions that lead to methane production.

Until recently, methane emissions from animal waste have not been considered explicitly as a major source of methane emissions. Bingemer and Crutzen (1987) state that the large amount of organic matter produced in agricultural wastes may contribute a very significant part of the world's annual methane budget, but they found no information on how much animal waste is anaerobically decomposed to produce methane. Verma et al. (1988) estimated that if all of the world's livestock and poultry manure were anaerobically decomposed then up to 152 Tg/yr of methane would be produced. However, Verma et al. (1988) estimated that less than 10 percent of this manure actually undergoes anaerobic decomposition.

THIS REPORT

As part of an overall strategy to identify options for stabilizing global methane concentrations, emissions inventories are being prepared and opportunities for reducing methane emissions are being identified and evaluated by the U.S. Environmental Protection Agency and others. By estimating methane emissions from the management of animal wastes throughout the world, this report provides a next step toward improving emissions estimates and identifying regions with emission levels and management systems suitable for control.

This report is organized as follows:

- Chapter 2 describes the process of methane production in animal waste and the factors that influence it.
- Chapter 3 describes the methodology and data used to estimate emissions in the U.S. and rest of the world.
- Chapter 4 presents emission estimates by region, animal type, and waste system.

The appendices at the end of this report detail the emission estimates and list the data and assumptions used to make the estimates.

EXHIBIT 3: SOURCES OF METHANE EMISSIONS (TG/YR)

	Annual Emissions	Range	Comments	Source
Animal Wastes	28	20-35	Livestock in developed and developing countries	This report
Animals	80	65-100		Cicerone and Oremland
Wastewater	NR[a]	20-25	Anaerobic decomposition of organic matter in waste water	IPCC
Rice paddies	110	60-170	Principally in developing countries	Cicerone and Oremland
Coal Mining	NR[a]	30-50	Surface and (mostly) sub-surface mining	IPCC
Oil/Gas Systems	45	25-50	Production, transmission, and distribution	Cicerone and Oremland
Landfills	NR	25-40	Decay of organic wastes	IPCC
Biomass Burning	55	50-100	Forest clearing and waste burning	Cicerone and Oremland
Natural Wetlands	115	100-200	Tundra, bogs, swamps, and alluvial formations	Cicerone and Oremland
Termites	40	10-100	Bacteria within termites	Cicerone and Oremland
Oceans and Freshwaters	15	6-45		Cicerone and Oremland
Hydrates	5?	0-100	Potentially important future source	Cicerone and Oremland
Total[b]	540	440-640	Well constrained	Cicerone and Oremland

Sources: Cicerone and Oremland (1988), "Biogeochemical Aspects of Atmospheric Methane," Global Biogeochemical Cycles, December 1988. Japan Environment Agency and United States Environmental Protection Agency (1990), "Methane Emissions and Opportunities for Control. Workshop Results of Intergovernmental Panel on Climate Change Response Strategies Working Group," September 1990.

[a] NR = not reported at the IPCC workshops

[b] Total annual emissions of 540 Tg ± 100 Tg is well constrained based on observational data. The point estimates of the individual source estimates presented here do not sum to 540 Tg.

CHAPTER 2. FUNDAMENTALS OF METHANE PRODUCTION FROM ANIMAL WASTES

Waste decomposition is a process in which microorganisms derive energy and material for cellular growth by metabolizing organic material in the waste. Under certain conditions, methane is an end-product of the decomposition process. The factors that determine the amount of methane produced are: the types of microorganisms present; the environmental conditions such as temperature and moisture; and the characteristics of the waste.

ANIMAL WASTE DECOMPOSITION

Animal wastes are primarily composed of organic material and water. The portion of this organic material that can be decomposed by microorganisms is the volatile portion, referred to as volatile solids.[5] Under certain conditions, a portion of the volatile solids is converted to methane.

A variety of microorganisms are responsible for the decomposition of animal wastes. These microorganisms are found in the environment in decaying vegetation, marshlands, stagnant waters, and the digestive tracts of herbivorous animals (Chawla 1986). Like all organisms, microorganisms require energy and carbon to function and reproduce. One source of carbon is carbon dioxide in the atmosphere; another source is carbon found in organic material, including animal waste. The two basic types of microorganisms are:

- <u>Autotrophs</u>. Autotrophic microorganisms derive carbon from atmospheric carbon dioxide and use either light (photosynthesis) or an inorganic chemical process (chemosynthesis) as a source of energy. Algae are a common type of autotrophic microorganism.

- <u>Heterotrophs</u>. Heterotrophic microorganisms derive carbon from organic material such as animal waste and obtain energy through the oxidation of this organic material (Metcalf & Eddy 1972). Heterotrophic microorganisms include fungi and many bacteria.

The primary microorganisms responsible for the decomposition of animal waste are heterotrophic bacteria. While thousands of species of heterotrophic bacteria can be found under a broad range of environmental conditions, an individual species may only thrive under a narrow range of conditions. Heterotrophic bacteria can be broadly classified as aerobic, anaerobic, or facultative, depending on their need for oxygen. Aerobic bacteria require molecular oxygen (O_2) to live; whereas oxygen is fatal to anaerobic bacteria. Facultative bacteria live in either the presence or absence of oxygen.

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[5] Volatile solids (VS) are defined as the organic fraction of the total solids (TS) in waste that will oxidize and be driven off as gas at a temperature of 600° C. Total solids (TS) are defined as the material that remains after evaporation of waste at a temperature between 103° and 105° C.

The decomposition of animal waste can occur in either an aerobic or anaerobic environment. Under aerobic conditions, the organic material is decomposed by aerobic and facultative bacteria using molecular oxygen. The end products of aerobic decomposition are carbon dioxide and stabilized organic material.[6] Under anaerobic conditions, the organic material is decomposed by anaerobic and facultative bacteria. The end products of anaerobic decomposition are methane, carbon dioxide, and stabilized organic material. The bacteria responsible for methane production in animal waste are strictly anaerobic.[7]

THE ANAEROBIC DIGESTION PROCESS

The anaerobic digestion process can be described in terms of three stages:[8] hydrolytic; acid forming; and methanogenic. Carbohydrates in animal wastes are decomposed in these three stages as follows:[9]

- Stage 1: Hydrolytic. In the first stage, complex organic materials in the waste substrate are broken down through the hydrolytic action of enzymes. Enzymes are proteins formed by living cells that act as catalysts in metabolic reactions.[10] The enzyme cellulase is responsible for breaking down carbohydrates such as cellulose and starch into simple sugars (e.g., glucose and maltose). Simple organic acids are produced when the enzyme lipase breaks down fats (lipids) into smaller chained fatty acids and the enzyme protease breaks down proteins into amino acids. The amount and rate of breakdown can vary substantially and depend on the enzymes present, the characteristics of the waste, and environmental factors such as pH and temperature.

- Stage 2: Acid Forming. Anaerobic and facultative bacteria reduce (ferment) the simple sugars produced in Stage 1 to simple organic acids. Acetic acid is the primary product of the breakdown of carbohydrates, though other organic acids such as propionic acid and butyric acid can be formed. In addition, hydrogen and carbon dioxide are produced. The organic acids, along with hydrogen and

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6 Stabilized organic material cannot be broken-down or decomposed further.

7 Aerobic and facultative bacteria, however, can also play a role by providing precursors for methane production.

8 Some authors describe the anaerobic digestion process as a two stage process with the first two stages as described below being considered as a single stage.

9 This discussion focuses on the decomposition of carbohydrates because carbohydrate digestion accounts for the majority of the methane produced from animal wastes and because the process of methane production from the decomposition of carbohydrates is best understood. By weight, the volatile solids portion of cattle and swine wastes is approximately 40 percent carbohydrate, 15 to 20 percent protein, 10 to 20 percent fat and 20 to 35 percent other (Hrubant, Rhodes, and Sloneker 1978).

10 A catalyst is a chemical substance that modifies (generally increases) the rate of a chemical reaction without being consumed or modified in the process.

carbon dioxide form a substrate[11] for the methane forming bacteria in Stage 3. Unlike the methane forming bacteria, the acid formers are fast growing and thrive at a broad range of temperature and pH. With acetic acid as an end product, the breakdown of a simple sugar molecule (glucose) in Stage 2 can be represented as:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{water}}{2H_2O} \longrightarrow \underset{\text{acetic acid}}{2CH_3COOH} + \underset{\text{carbon dioxide}}{2CO_2} + \underset{\text{hydrogen}}{4H_2}$$

- <u>Stage 3: Methanogenic</u>. Methane producing bacteria (methanogenes) convert the simple organic acids, hydrogen, and carbon dioxide from Stage 2 into methane and carbon dioxide. Methanogenes are strict anaerobes and cannot tolerate the presence of molecular oxygen. Methanogenes multiply slowly and are very sensitive to temperature, pH, and substrate composition. With acetic acid, hydrogen and carbon dioxide as substrate, the reactions producing methane can be expressed as:

$$\underset{\text{acetic acid}}{2CH_3COOH} \longrightarrow \underset{\text{methane}}{2CH_4} + \underset{\text{carbon dioxide}}{2CO_2}$$

$$\underset{\text{hydrogen}}{4H_2} + \underset{\text{carbon dioxide}}{CO_2} \longrightarrow \underset{\text{methane}}{CH_4} + \underset{\text{water}}{2H_2O}$$

METHANE PRODUCING CAPACITY OF ANIMAL WASTE

The specific composition of animal waste determines its maximum methane producing capacity. The composition of the waste is primarily determined by the animal diet. The composition and digestibility of the animal diet influences the methane capacity of the waste. The greater the energy content and digestibility of the feed, the greater the methane producing capacity of the waste. For example, cattle fed a high energy grain diet produce a highly biodegradable waste which contains a large fraction of readily available organic material. Cattle fed a roughage diet will produce a less biodegradable waste containing more complex organics such as cellulose, hemicellulose, and lignin. Under similar conditions, the waste of cattle fed the high energy corn-based diet will produce about twice as much methane as the waste of the cattle fed a roughage diet.

In principal, the ultimate methane producing capacity of a quantity of waste can be predicted from the gross elemental composition of the manure. In practice, however, insufficient information exists to implement this approach and the methane producing capacity is determined through direct laboratory measurement. The methane producing capacity of animal waste is generally expressed in terms of the quantity of methane that can be produced per kilogram of volatile solids (VS) in the waste. This quantity is commonly referred to as B_o with units of cubic meters of methane (CH_4) per kilogram VS (m^3 CH_4 / kg VS). Representative B_o values for a number of animal waste types are discussed in Chapter 3.

[11] Substrate refers to the material that the bacteria use for growth and metabolism.

FACTORS INFLUENCING METHANE PRODUCTION

The characteristics of the animal waste management system and the climate influence the amount of methane produced during waste decomposition. Realized methane production can be defined as the quantity of methane produced per kilogram of volatile solids (VS) in the waste for a given set of waste management practices and climatic conditions:

$$\text{Realized Emissions} = B_o \bullet MCF_{(AWMS)} \bullet CAF \qquad (2.1)$$

where B_o = the maximum methane producing capacity of the waste determined by animal type and diet (m^3 CH_4 / kg VS).

$MCF_{(AWMS)}$ = Methane Conversion Factor (MCF) that represents the extent to which the B_o is realized for a given animal waste management system (*AWMS*). Note: $0 \leq MCF \leq 1$.

CAF = Climate Adjustment Factor (CAF) that represents the extent to which the B_o is realized under a given set of climatic conditions (e.g., temperature and rainfall). Note: $0 \leq CAF \leq 1$.

Animal Waste Management System Factors, MCF

The characteristics of the waste management systems determine the MCF of that system. As defined in Equation 2.1, waste systems that promote methane production will have an MCF near 1 and systems that do not promote methane production will have an MCF near 0. The primary characteristics determining the MCF of a waste system are:

- Contact with Oxygen. Under aerobic conditions where oxygen is in contact with the waste, there is no potential for methane production in the waste.

- Moisture Content. Liquid based systems promote an oxygen-free environment and anaerobic decomposition. In addition, water is required for bacterial cell production and metabolism and acts as a buffer to stabilize pH. Moist conditions increase the potential for methane production.

- pH. Methane producing bacteria are sensitive to changes in pH. The optimal pH is near 7.0 but methane will be produced in a range between 6.6 and 7.6. Deviation in pH from 7.0 will decrease the rate of methane production.

- Nutrients. Bacterial growth depends on the availability of nutrients such as nitrogen, phosphorus, and sulfur. Deficiency in one or more of these nutrients will inhibit bacterial growth and methane formation. Animal diets typically contain sufficient nutrients to sustain bacterial growth. Therefore, nutrient availability is not a limiting factor in methane production under most circumstances.

Climate Factors, CAF

The climatic conditions in which the waste decomposes have a strong influence on methane production by the waste. As defined in Equation 2.1, climatic conditions that promote methane production will have a CAF near 1 and conditions that inhibit methane production will have a CAF near 0. These climate conditions include:

- Temperature. Methanogenesis in animal waste has been observed between 4° C and 75° C. Temperature is one of the major factors affecting the growth of the bacteria responsible for methane formation (Chawla 1986). Methane production generally increases with rising temperature.

- Moisture. For non-liquid based waste systems, the moisture content of the waste is determined by rainfall and humidity. The moisture content of the waste will determine the rate of bacterial growth and waste decomposition. Moist conditions promote methane production.

CHAPTER 3. METHODOLOGY AND DATA

Methane emissions from animal waste depend on the type of waste, the characteristics of the waste management system, and the climatic conditions in which the waste decomposes. Emission estimates were developed by identifying the waste management systems in use throughout the world and their methane producing potential; estimating the amount and type of waste managed by each system; and estimating emissions by multiplying the amount of waste managed in each system by the estimated emission rate per unit of waste in the system. Information was obtained from a variety of sources, including: FAO Production Yearbook; the U.S. Census of Agriculture; USDA agriculture statistics; animal science experts throughout the world; and the animal science literature.

METHODOLOGY

The methane emissions per kilogram of volatile solids (VS) depend on: the characteristics of the waste (B_o); the characteristics of the waste management system (MCF); and the climatic conditions such as temperature and moisture (CAF). Total emissions will equal the quantity of volatile solids managed in each system times emissions per kilogram of volatile solids (VS). The following procedure was performed to estimate total emissions:

- Estimate the amount of waste produced by collecting data on: (1) the populations of the major animal types throughout the world; and (2) the sizes of the animals (i.e., in kilograms per head). These data were obtained from published statistics.

- Collect information on the characteristics of the waste produced by each of the animal populations, including: (1) the amount of volatile solids (VS) produced; and (2) the methane producing capacity (B_o) of the waste. These data were available from published sources for most developed countries but were estimated for the developing countries.

- Identify the animal waste management systems employed in each part of the world and the amount of waste managed by each. This information is not readily available and was estimated based on interviews with animal waste experts. In cases where no data were available, waste management system usage was estimated using economic measures (e.g., per capita GNP) and regional averages.

- Estimate the methane producing potential (MCF) of each waste management system. Direct measurements of methane emissions were used where available. If no measurements were available, the MCFs were estimated by extrapolating from similar systems based on the characteristics of the waste management system, including: contact with oxygen, moisture content, and pH.

- Assess climatic conditions (CAF) for each waste system in each region using temperature and precipitation data for each region of the world.

- Estimate methane emissions for each animal and waste system by multiplying the amount of volatile solids (VS) produced by the methane producing capacity of the waste (B_o) times the methane producing potential (MCF) of the waste system times the climate adjustment factor (CAF). Total methane emissions will be the sum over all animal types and all waste systems.

Using this approach, total annual methane emissions (TM_i) for animal type *i* in a particular climate region is the sum of annual emissions over all applicable waste management systems *j*:

$$TM_i = \sum_j VS_i \cdot B_{oi} \cdot MCF_j \cdot CAF_j \cdot WS\%_{ij} \tag{3.1}$$

where:

VS_i	=	total volatile solids produced annually (in kilograms) for animal *i*;
$B_{o\,i}$	=	maximum methane producing capacity per kilogram of VS for animal *i*;
MCF_j	=	methane conversion factor for each waste system *j*;
CAF_j	=	climate adjustment factor for each waste system *j* in the region; and
$WS\%_{i\,j}$	=	percentage of the animal *i*'s waste handled using waste system *j*.

The amount of volatile solids produced depends on the number of animals and their mass:

$$VS_i = N_i \cdot TAM_i \cdot vs_i \tag{3.2}$$

where:

N_i	=	number of animals;
TAM_i	=	typical animal mass in kilograms; and
vs_i	=	the average annual volatile solids production per unit of animal mass (kilograms per kilogram).

In many cases either the typical animal mass (TAM_i) or volatile solids production per unit of animal mass (vs_i), or both, are not known. In these cases, total annual VS production per head was estimated directly, so that the total annual VS production for the population of animals can be estimated by:

$$VS_i = N_i \cdot \overline{vs}_i \tag{3.3}$$

where:

N_i	=	number of animals;
$\overline{vs}_i$	=	average volatile solids production per head.

Total annual methane emissions from all animals (TM) is estimated as the sum over all *i* animal types as follows:

$$TM = \sum_{i} TM_i \qquad (3.4)$$

These equations show that methane emissions are driven by five main factors: the quantity of VS produced; the B_0 values for the wastes; the MCFs for the waste management systems; the climatic conditions (CAFs); and the portion of the waste handled by each waste management system (WS%). The following sections describe the data collected to implement this method:

- Volatile solids production (VS). Data were collected on the number of animals by type and the volatile solids production per animal.
- Maximum methane producing capacity (B_0). Data were obtained from the literature for B_0 for various animal types by region. In many cases estimates were made based on diet information.
- Waste management system definitions. The waste systems used to manage animal wastes in the United States and the rest of the world were defined.
- Methane conversion factors (MCFs). The methane producing potential of each animal waste management system was estimated using published data or extrapolated from similar systems based on the characteristics of the system.
- Climate adjustment factors (CAFs). The climate adjustment factor for each animal waste management system was estimated using published temperature and precipitation data.
- Animal waste management system usage (WS%). Data were obtained for estimating the portion of waste handled using each animal waste management system.

VOLATILE SOLIDS PRODUCTION (VS)

Methane emissions from animal waste are directly related to the amount of volatile solids (VS) produced. The data required to estimate total VS production are shown in Equation 3.2: the number of animals (N_i), their average size (TAM_i), and their average VS production per unit of animal size (vs_i). For developed countries, these data are generally available and Equation 3.2 can be implemented. For most developing countries, however, only animal population data are available and total VS production must be estimated using Equation 3.3.

Developed Countries

For the United States, considerable data were available that allowed the populations of animals to be analyzed by: species, production system, and (for cattle) age. Six main categories of animals were defined: feedlot beef cattle;[12] other beef cattle; dairy cattle; swine; poultry; and other. These main categories were further divided into 20 subcategories. For each subcategory, VS production was estimated using data on: the animal population; the typical animal mass (TAM); and the VS production per unit of animal mass. Exhibit 4 lists the data obtained for the 20 subcategories.

For Canada, the animal populations were divided into the same categories used for the United States analysis, with the exception that the feedlot beef cattle category was not used due to a lack of data. Estimates of animal populations, TAMs, and VS production rates were obtained from Agriculture Canada (1989). The TAM and VS production rates for Canada are very similar to the rates shown in Exhibit 4 for the United States. Appendix D presents the estimates for Canada.

For other developed countries, including Eastern Europe,[13] the animal populations were divided into the following 11 categories: beef cattle; dairy cattle; swine; sheep; goats; chickens; ducks; turkeys; horses; donkeys; and camels. Population statistics were obtained for each category for each country from FAO (1989). For 13 countries, data for estimating the TAMs for each category were available from **Meat and Dairy Products** (1988) and Taiganides and Stroshine (1971).[14] For developed countries without country-specific TAM data, the average of the values for the 13 countries was used.

The United States total manure and VS production rates per unit of animal mass were used as the basis for estimating waste production per TAM for the other developed countries. Small adjustments were made to several of the rates to reflect differences in diets. Exhibit 5 presents average statistics for the TAM, manure, and VS estimates for the other developed countries. Detailed estimates by country are reported in Appendices C and E.

Developing Countries

The animal populations in developing countries were divided into the same 11 categories used to analyze the animal populations in the other developed countries. Population data for each category for each country were obtained from FAO (1989).

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[12] Feedlot cattle are animals fed a ration of grain, silage, hay and protein supplements for the slaughter market (ASB 1991).

[13] For purposes of this analysis the other developed countries include: Albania, Australia, Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, the Netherlands, New Caledonia, New Zealand, Norway, Poland, Portugal, Romania, South Africa, Soviet Union, Spain, Sweden, Switzerland, United Kingdom, and Yugoslavia.

[14] The 13 countries for which TAM data were obtained are: Australia; Austria; Belgium; Denmark; France; Western Germany; Ireland; Italy; Holland; South Africa; United Kingdom; Soviet Union; and Yugoslavia.

EXHIBIT 4: U.S. ANIMAL POPULATIONS, AVERAGE SIZE, AND VS PRODUCTION					
				Waste per day[D] (kg/day per 1000 kg mass)	
Animal Type		Population[A,B] N_i	TAM_i[C] Kg	Total Manure	Volatile Solids vs_i
Feedlot Beef Cattle	Steers	7,367,000	383	58	7.2
	Heifers	3,785,000	391	58	7.2
	Cows/Other	87,000	500	58	7.2
	Total	11,239,000			
Other Beef Cattle	Calves	20,248,000	181	58	7.2
	Heifers	13,547,000	391	58	7.2
	Steers	8,430,000	383	58	7.2
	Cows	33,583,000	680	58	7.2
	Bulls	2,221,000	680	58	7.2
	Total	78,029,000			
Dairy Cattle	Heifers	4,199,000	476	86	10
	Cows	10,217,000	680	86	10
	Total	14,416,000			
Swine	Market	48,259,000	46	84	8.5
	Breeding	7,040,000	181	84	8.5
	Total	55,299,000			
Poultry[C]	Layers	355,469,000	1.6	64	12
	Broilers	951,914,000	0.7	85	17
	Ducks	7,000,000	1.4	107	18.5
	Turkeys	53,783,000	3.4	47	9.1
Other	Sheep	10,639,000	70	40	9.2
	Goats	2,396,000	64	41	9.5
	Donkeys	4,000	300	51	10
	Horses and Mules	2,405,000	450	51	10

A Population data for all animals except goats and horses from ASB (1988). Goat and horse population data from Bureau of Census (1987). Population data as of January 1, 1988 for cattle, poultry, and sheep and as of December 1, 1987 for swine, goats, and horses.

B Broiler and turkey populations are estimated yearly average averages based on the average number of flocks per year (North 1978; Carter 1989).

C Source: Taiganides and Stroshine 1971 (See also Appendix A).

D Source: ASAE (1988).

EXHIBIT 5: AVERAGE ANIMAL STATISTICS FOR DEVELOPED COUNTRIES[A] (EXCEPT U.S. AND CANADA).					
Animal Type	Typical Animal Mass (TAM) (kg)	Total Manure Production		VS Production	
		KG/Day/TAM	Kg/Day/ 1000 Kg Mass	Percent of Total Manure Production	Kg/Day/ 1000 Kg Mass
Beef Cattle[B]	361	20.9	58	12.4	7.2
Dairy Cattle	640	55.0	86	11.6	10
Swine	59	5.0	85	10.1	8.6
Sheep	67	2.7	40	23.0	9.3
Goats	64	2.6	41	26.6	10.8
Chickens	1.1	0.10	91	19.4	17.6
Ducks	1.4	0.15	107	17.3	18.5
Turkeys	6.8	0.30	44	19.4	8.6
Horses[C]	450	23.0	51	19.6	10
Donkeys	300	15.3	51	19.6	10
Camels	450	23.0	51	16.0	8.2

A Average values estimated across the developed countries. Individual country data are used when available. See Appendices C and E.
B Includes buffaloes.
C Includes Mules.

Estimates of the TAM for each category were not made for the developing countries. Instead, manure and VS production per head were estimated directly. The following data were identified regarding manure and VS production by cattle in developing countries:

- Odend'hal (1972) measured an average daily manure production of 8.3 kg for adult cattle in India and assumed 20 percent total solids (TS).

- Jain et al. (1981) measured 18.9 percent TS and Pathak et al. (1985) measured 15.2 percent TS for cattle in India.

- Ramen et al. (1989) measured 12.5 to 13.7 kg/day total manure and 16 to 18 percent TS for Indian cattle.

- Singh et al. (1985) measured 17 percent TS and 14 percent VS for Indian cattle, while Gunaseelan (1987) measured 21 percent TS.

Of these measurements only Odend'hal (1972) and Ramen et al. (1989) used cattle from working Indian farms. The others were cattle on research farms. Additional data on cattle include:

- Lichtman (1983) estimated (with the support of data) that Indian cattle produce 8 kg/day of "collectible" manure (produced at night while the animals are tied up) at 20 percent total solids content.

- Gorkhali (1984) estimated that cattle in Nepal produce 10 kg/day total manure.

- Chen et al. (1988) analyzed manure from dairy cattle fed on low quality roughage diets (simulating the diet of African cattle) and found 20.1 percent TS and 17.4 percent VS.

Based on these values from the literature, cattle in developing countries were assumed to produce 12.5 kg/day/head of total manure (about 60 percent of typical U.S. cattle) with 18 percent TS and 15 percent VS (wet basis).

There are rarely any specialized dairy cattle in developing countries. The vast majority of "dairy" cattle are exactly the same as other cattle in those countries, except that they are lactating. Comparatively, dairy cattle in the United States produce 78 percent more manure per unit of live animal mass than do beef cattle in the United States (ASAE 1988). Because the lactating cattle in developing countries are also generally better fed than the rest of the cattle (Preston and Leng 1987), but not at the extreme level of specialized dairy breeds, their manure production was assumed to be 25 percent greater than non-lactating cattle, or 15.6 kg/day per head.

For horses, goats, and sheep (except for feedlot sheep), U.S. animals are not fed as much above maintenance levels as are cattle; thus, the daily manure production for these animals in developing countries is assumed to be 70 percent of that for U.S. animals. For sheep waste Jain et al. (1981) reported 25.8 percent TS and 20.1 percent VS. These values are slightly below the the U.S values. In the absence of data for horses and goats, the solids concentrations were assumed to be the same as those for U.S. animals: horses, 29 percent TS and 20 percent VS; and goats, 32 percent TS and 27 percent VS. Mules, donkeys, and camels were again assumed to have the same manure characteristics as horses (except for camel VS which was assumed to be between cattle and horses), and buffaloes the same characteristics as cattle.

Because the swine diets in developing countries are very similar to swine diets in the U.S., total manure production from swine was assumed to be 80 percent of that for typical swine in the U.S. (ASAE 1988), with the same percentage of volatile solids as in the U.S. Exhibit 6 summarizes the manure and VS production estimates of all these animals for developing countries.

MAXIMUM METHANE PRODUCING CAPACITY (B_o)

The maximum amount of methane that can be produced per kilogram of VS (B_o) varies by animal type and diet. This section presents the B_o values developed for animal waste in the U.S. and the rest of the world.

EXHIBIT 6: ANIMAL WASTE PRODUCTION DATA FOR DEVELOPING COUNTRIES			
Animal Type	Total Manure Production Kg/head/day	Volatile Solids (VS) Production	
		Percent of Total Manure Production	Kg/head/day
Cattle (non-dairy)	12.5	15%	1.9
Dairy Cattle	15.6	15%	2.3
Swine	4.1	10%	0.41
Sheep	1.6	23%	0.37
Goats	1.8	27%	0.49
Chickens	0.12	19%	0.02
Ducks	0.12	17%	0.02
Turkeys	0.26	19%	0.05
Horses and Mules	18.4	20%	3.7
Donkeys	12.2	20%	2.4
Camels	18.4	16%	2.9

United States

The various B_o values for U.S. animals identified from the literature are listed in Exhibit 7. As shown in the exhibit, values for beef animals range from 0.17 cubic meters of methane per kilogram of VS (m^3/kg-VS) for a corn silage diet to 0.33 m^3/kg-VS for a corn-based high energy diet that is typical of feedlots. Ranges are also shown for the other animal types.

Appropriate B_o values were selected depending on the typical diet of each animal type and category. For animal types without B_o measurements, the B_o was estimated based on similarities with other animals and the authors' experience. Ruminants for which there were no literature values were assumed generally to have the same values as cattle, except for sheep, which were assumed to have B_o values 10 percent higher than cattle (Jain et al. 1981). Exhibit 8 lists the values selected for the analysis.

World

Unlike the U.S., virtually no data are available describing the B_o values for wastes produced in other countries. Consequently, these values were estimated. In making these estimates, the major impact of the variation in livestock diets around the world on the methane-producing potential had to be considered. This effect was incorporated into the calculations of methane emissions for the world by using B_o values that account for the estimated energy content of the feed consumed by the animals. This approach required characterizing the animal diets for different regions of the world.

EXHIBIT 7: MAXIMUM METHANE PRODUCING CAPACITY FOR U.S. ANIMAL WASTE

Animal Type	Diet	B_o (m^3 CH_4/kg-VS)	Reference
Beef	7% corn silage, 87.6% corn	0.29	Hashimoto et al. (1981)
Beef	Corn-based high energy	0.33	Hashimoto et al. (1981)
Beef	91.5% corn silage, 0% corn	0.17	Hashimoto et al. (1981)
Beef		0.23	Hill (1984)
Beef		0.33	Chen, et al. (1980)
Dairy	58-68% silage	0.24	Morris (1976)
Dairy	72% roughage	0.17	Bryant et al. (1976)
Dairy		0.14	Hill (1984)
Dairy	Roughage, poor quality	0.10	Chen, et al. (1988)
Horse		0.33	Ghosh (1984)
Poultry	Grain-based ration	0.39	Hill (1982)
Poultry		0.36	Hill (1984)
Poultry		0.24	Webb & Hawkes (1985)
Poultry		0.24	Hawkes & Young (1980)
Swine	Barley-based ration	0.36	Summers & Bousfield (1980)
Swine	Corn-based high energy	0.48	Hashimoto (1984)
Swine		0.32	Hill (1984)
Swine	Corn-based high energy	0.52	Kroeker et al. (1984)
Swine	Corn-based high energy	0.48	Stevens & Schulte (1979)
Swine	Corn-based high energy	0.47	Chen (1983)
Swine	Corn-based high energy	0.44	Iannotti et al. (1979)
Swine	Corn-based high energy	0.45	Fischer et al. (1975)

Exhibit 9 shows the typical diets determined for each region of the world. Because animal diets in other developed countries are similar to the U.S, the B_o values adopted for the U.S. were used for other developed countries. These values are shown in Exhibit 10.

The diets of animals in developing countries are known to be very different from the diets typically found in the U.S. and other developed countries. The following data were obtained for purposes of estimating B_o values for non-dairy cattle in developing countries:

- Odend'hal (1972) reported that cattle in India consume 60.3 MJ of gross energy per day. This is 61 percent of the 99.3 MJ/day consumed by U.S. beef cattle not in feedlots (USDA 1987).

- Harvey (1990) estimated that beef cattle in Latin America consume no more than 60 percent of the digestible energy per day that U.S. beef cattle consume (lifetime average). This gives 64 MJ/day for Latin American beef cattle.

EXHIBIT 8: MAXIMUM METHANE PRODUCING CAPACITY ADOPTED FOR U.S. ESTIMATES			
Animal Type, Category		Maximum Potential Emissions (B_o)	Reference
Cattle:	Beef in Feedlots	0.33	Hashimoto et al. (1981)
	Beef Not in Feedlots	0.17	Hashimoto et al. (1981)
	Dairy	0.24	Morris (1976)
Swine:	Breeder	0.36	Summers & Bousfield (1980)
	Market	0.47	Chen (1983)
Poultry:	Layers	0.34	Hill (1982 & 1984)[A]
	Broilers	0.30	Authors' estimate[B]
	Turkeys	0.30	Authors' estimate[B]
Sheep:	In Feedlots	0.36	Authors' estimate[C]
	Not in Feedlots	0.19	Authors' estimate[C]
Goats:		0.17	Authors' estimate[D]
Horses and Mules:		0.33	Ghosh (1984)

A Adjusted value.
B Based on Hill (1984).
C Based on Jain et al. (1981) and Hashimoto et al. (1981).
D Based on Hashimoto et al. (1981).

- Chen et al. (1988) reported that the B_o for African cattle is 0.10, which is 59 percent of the value for U.S. cattle not in feedlots.

Because these values consistently show that cattle in these developing regions consume and/or excrete energy (B_o taken as a measure of excreted energy) at about 60 percent of the rate for U.S. cattle, the B_o for non-dairy cattle in developing regions was taken to be 0.10 m^3 CH_4/kg-VS.

Using the diets in Exhibit 9 (D+ versus D rated diets), the B_o for dairy cattle was assumed to be 0.13 m^3 CH_4/kg-VS, or 30 percent higher than the B_o for non-dairy cattle. Based on the work of Jain et al. (1981), sheep waste was assumed to have a B_o of 0.13 $m^3 CH_4$/kg-VS (about 30 percent higher than cattle). Goats were assumed to have the same B_o as sheep.

Because swine and poultry diets cannot be substantially reduced while still maintaining growth, the digestible energy intake in Exhibit 9 is 80 percent of the energy intake for U.S. animals not on high energy feeding; thus, B_o values for these animals were taken to be 80 percent of the value for U.S. animals. The same factor of 80 percent was used for horses, mules, donkeys, and camels based on the B_o values for the U.S. (with mule and donkey waste B_o values assumed equal to B_o for horses; buffalo B_o assumed equal to cattle; and camel B_o assumed between cattle and horses). Exhibit 10 summarizes the B_o values adopted.

EXHIBIT 9: TYPICAL LIVESTOCK DIETS FOR THE WORLD

Region	Cattle[1]	Dairy	Swine	Sheep	Goats	Poultry	Horses[2]
Western Europe	B	A	E	B	C	F/G	C
Eastern Europe	B	A	E	B	C	F/G	C
Oceania (Developed)	C	A	E	C	C	F/G	C
Oceania (Developing)	D	D+	E	D	D	-	D
Latin America	D	D+	H	D	D	I/J	D
Africa	D	D+	H	D	D	I/J	D
South Africa	B/C	A	E	C	C	F/G	C
Near East and Mediterranean	D	D+	H	D	D	I/J	D
Israel	B	A	E	B	C	F/G	C
Asia & Far East	D	D+	H	D	D	I/J	D
Japan	B	A	E	B	C	F/G	C

Diets:

A - Dairy, very high energy, 230 MJ/day
B - Corn-based, high energy, 160 MJ/day
C - Pasture, medium energy, 100 MJ/day
D - Roughage, low energy, 60 MJ/day
D+-Modified during lactation, 80 MJ/day
E - Grain, high energy, swine, 42 MJ/day
F - Grain, high energy, poultry, 0.30 MJ/day
G - Grain, high energy, turkey, 1.5 MJ/day
H - Roughage, medium energy, swine, 34 MJ/day
I - Roughage, medium energy, poultry, 0.24 MJ/day
J - Roughage, medium energy, turkey, 1.4 MJ/day

1 Including buffaloes and camels; excluding dairy.
2 Including mules and donkeys.

Notes: Energy values are for gross energy. Diets F and I do not include turkeys. For diets A, B, C, and D: MJ/day per typical cattle live animal mass.

EXHIBIT 10: B_o VALUES ADOPTED FOR DEVELOPED AND DEVELOPING COUNTRIES

Animal Type	Developed Countries (Non-U.S.) (m^3 CH_4 / kg VS)	Developing Countries (m^3 CH_4 / kg VS)
Cattle (non-dairy) and buffalo	0.17/0.33[A]	0.10
Dairy Cattle	0.24	0.13
Swine	0.45	0.29
Sheep	0.19	0.13
Goats	0.17	0.13
Chickens	0.32	0.24
Ducks	0.32	0.24
Turkeys	0.30	0.24
Horses and Mules	0.33	0.26
Donkeys	0.33	0.26
Camels	0.26	0.21

A The lower value is for cattle not in feedlots. The higher value is for feedlot cattle.

WASTE MANAGEMENT SYSTEMS DEFINITIONS

A variety of waste management practices are in use throughout the world. In many parts of the world, manure is spread on fields as a fertilizer. In other cases, manure is used as an energy source. The following is a brief description of the major animal waste management systems in use.

PASTURE/RANGE	Animals that are grazing on pasture are not on any true waste handling system. The manure from these animals is allowed to lie as is, and is not handled at all.
DAILY SPREAD	With the daily spread system the manure is collected in solid form, with or without bedding, by some means such as scraping. The collected manure is applied to fields on a regular basis (usually daily).
SOLID STORAGE	In a solid storage system the solid manure is collected as in the daily spread system, but this collected manure is stored in bulk for a long period of time (months) before any disposal.
DRYLOT	In dry climates animals may be kept on unpaved feedlots where the manure is allowed to dry until it is periodically removed. Upon removal the waste may be spread on fields.
DEEP PIT STACKS	With caged layers the manure may be allowed to collect in solid form in deep pits (several feet deep) below the cages. The manure in the pits may only be removed once a year. This manure generally stays dry.
LITTER	Broilers and young turkeys may be grown on beds of litter -- shavings, sawdust, or peanut hulls -- and the manure/litter pack is removed periodically between flocks. This manure will not generally be as dry as with deep pits, but will still be in solid form.
PADDOCK	Horses are frequently kept in paddocks where they are confined to a limited area, but not entirely confined to their stalls. This manure will be essentially the same as manure on pasture or a drylot. The manure left in the stalls will be essentially in a solid storage.
LIQUID/SLURRY	These systems are generally characterized by large concrete lined tanks built into the ground. Waste is stored in the tank for six or more months until it can be applied to fields. To facilitate handling as a liquid, water usually must be added to the manure, reducing its total solids concentration to less than 12 percent. Slurry systems may or may not require addition of water.
ANAEROBIC LAGOON	Anaerobic lagoon systems are generally characterized by automated flush systems that use water to transport the waste to treatment lagoons that are usually greater than six feet deep. The waste resides in the lagoon for periods ranging from 30 days to over 200 days depending on the lagoon

design and other local conditions. The water from the lagoon is often recycled as flush water. Periodically the lagoon water may be used for irrigation on fields with the treated waste providing fertilizer value.

PIT STORAGE Liquid swine manure may be stored in a pit while awaiting final disposal. The pits are often constructed beneath the swine building. The length of storage time varies, and for this analysis is divided into two categories: less than one month or greater than one month.

ANAEROBIC DIGESTER The manure, in liquid or slurry form, may be placed in an anaerobic digester for treatment. Although digester designs vary, all have the objective of producing methane for energy and reducing the volume of the waste. The amount of usable methane produced depends on the operating characteristics of the digester and the characteristics of the waste. The digester effluent is often used as a fertilizer.

BURNED FOR FUEL Manure is collected and dried in cakes and burned for heating or cooking. This system is common in Asia and the Far East; in India it is estimated that two-thirds of cattle manure is burned for fuel (NCAER 1965).

METHANE CONVERSION FACTORS (MCFs)

The extent to which the maximum methane producing capacity (B_o) is realized for a given animal waste management system must be known to determine the amount of methane that can be emitted. This fraction is defined as the Methane Conversion Factor (MCF) for the waste system. For example, a waste system that produces no methane emissions would have an MCF of 0. A waste system that achieves the full potential methane emissions would have an MCF of 1.

To assess the MCF values for the wide range of animal waste management systems defined in the previous section, three broad classifications of animal waste handling systems can be defined based on the total solids content of the waste:

- Solid systems have a total solids content greater than about 20 percent.
- Slurry systems have a total solids content between 10 to 20 percent.
- Liquid systems have a total solids content less than about 10 percent.

Waste as excreted may have a total solids content from 9 to 30 percent (Taiganides 1987). This solids content may be modified by adding an absorbent bedding material to increase the total solids content for easier handling. Alternately, water may be added to lower the total solids to allow for liquid transport and handling.

These classifications of systems are particularly important to the potential for methane production from the manure. Liquid and slurry systems will typically cause anaerobic conditions to develop, which result in methane production. The solid systems limit the development of anaerobic conditions and, thus, limit the amount of methane that is produced from the manure.

EXHIBIT 11: METHANE POTENTIAL BY WASTE MANAGEMENT SYSTEM TYPE

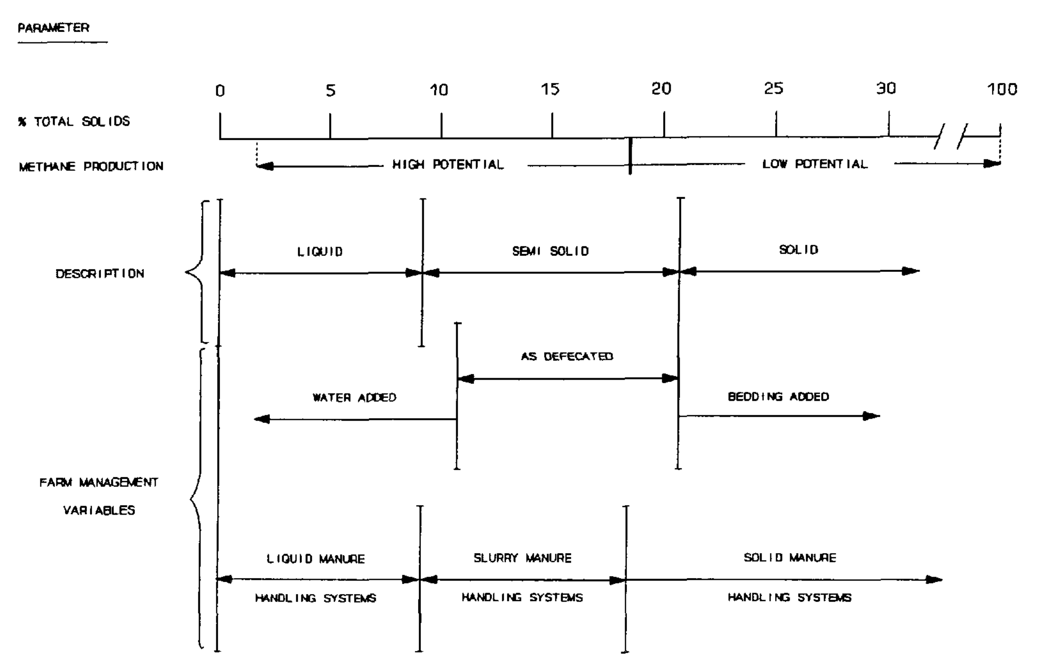

Exhibit 11 illustrates the methane producing potential by waste management system classification.

With this general framework as the background, literature was reviewed to investigate the appropriate range of MCF values for the waste management systems in use throughout the world. Although some data were available, MCF values were estimated for most systems as shown in Exhibit 12. As anticipated, the solid waste management systems were assigned relatively low MCF values, while the liquid systems received higher values. The highest value, 90 percent, was adopted for lagoons based on the authors' extensive experience with methane production by lagoons. The most uncertain value is for pasture and range systems. The following is a summary of the key factors affecting the choice of the MCFs:

PASTURE/RANGE — The manure will typically dry out and only a minimum amount of anaerobic activity can be expected. Chen et al. (1988) indicate that about 11 percent of the methane producing potential of the manure is lost during the drying process. An MCF of 10 percent is adopted.

DAILY SPREAD — The daily spreading process speeds up the drying of the manure, as compared to drying on pasture, and drastically limits the methane

EXHIBIT 12: METHANE CONVERSION FACTORS (MCF) FOR WASTE SYSTEMS	
Animal Waste System	MCF
Pasture/Range[B]	10%
Daily spread[A]	5%
Solid storage[B]	10%
Drylot[B]	10%
Deep pit stacking[A]	5%
Litter[A]	10%
Paddock[A]	10%
Liquid/slurry storage[A]	20%
Anaerobic lagoon[A]	90%
Pit storage, less than one month[A]	10%
Pit storage, more than one month[A]	20%
Anaerobic Digester (Chinese)	14%
Anaerobic Digester (Indian)	5%
Burned for Fuel	5% to 10%

[A] Authors' estimate; no data available in the literature.
[B] Based on Chen et al. (1988).

producing potential of the manure.[15] An MCF of 5 percent is adopted.

SOLID STORAGE

Large bulk storage of waste may lead to the formation of anaerobic conditions. The moisture content of the waste will affect methane production. The manure in this system is assumed to have the same methane producing potential as manure lying on pasture, 10 percent.

DRYLOT

This manure is subject to about the same limited conditions for methane production as waste on pasture. Therefore, an MCF of 10 percent is assumed.

DEEP PIT STACKS

Although this manure may only be removed once a year, it is generally very dry. Therefore, an MCF of 5 percent is assumed.

LITTER

This manure will not generally be as dry as with deep pits, but will still be in solid form with a limited methane production potential. An MCF of 10 percent is assumed.

[15] It has been suggested that excessive application of manure on land can induce anaerobic conditions in the soil which may lead to methane emissions. In this case, the MCF for daily spread and possibly for pasture/range systems may be considerably higher than the values assumed in this analysis.

PADDOCK — This manure will be essentially the same as on pasture or a drylot and, thus, will have the same potential for methane production as those systems. The manure left in the stalls will be essentially the same as in a solid storage. An MCF value of 10 percent is therefore adopted.

LIQUID/SLURRY — When waste is managed as a liquid or slurry, the methane producing potential is enhanced because anaerobic conditions will likely form. When the storage facility is sufficiently deep the conditions may be almost entirely anaerobic, thereby maximizing the methane production potential of the manure. For these systems temperature may be an important process limiting factor, along with residence time in storage. An MCF value of 20 percent is assumed, although higher values may be observed in some cases.

ANAEROBIC LAGOON — Anaerobic lagoons are specifically designed to create anaerobic conditions as the means of treating the waste. Typically, almost all of the methane production potential of the waste will be realized in the anaerobic lagoon, assuming proper design and operation.[16] An MCF of 90 percent is used.

PIT STORAGE — The amount of methane production from pits will depend on the residence time of the waste in the pit. Because the waste is generally handled as a liquid, anaerobic conditions form, causing methane production to be enhanced. Short storage times, less than one month, are assumed to have an MCF of 10 percent. When storage times exceed one month, an MCF of 20 percent is assumed.

ANAEROBIC DIGESTER — Theoretically, all of the methane produced in a digester will be used as fuel (combusted). In practice, typical digesters used in developing countries are subject to numerous problems particularly from leakage (Smil 1984). Yancun et al. (1985) showed that typical Chinese digesters leaked at least 14 percent of the methane they produced. An MCF of 14 percent is used for Chinese digesters. No data were found in the literature on leakage from Indian digesters; but, the typical floating cover digester used in India (Stuckey 1984 and Lichtman 1983) do not appear to be as leak prone as the Chinese digesters. An MCF of 5 percent was assumed for Indian digesters.

BURNED FOR FUEL — When manure is collected and dried in cakes for use as a fuel, methane may be released during the drying process. The MCF value will depend on the rate of drying and is assumed to range from 5 to 10 percent depending on the climate. Methane emissions associated with the combustion of the waste itself are not considered in this analysis.

[16] It is possible to cover these lagoons and harvest methane gas that is evolved for its energy potential (Chandler et al. 1983 and Safley and Westerman 1988).

The assumed MCF values strongly influence estimated emissions. The MCF values, however, are based on limited data, especially for developing countries. The U.S. Environmental Protection Agency is sponsoring research to improve the MCF estimates for several key animal waste systems for which limited emissions data exist. This research will validate many of the MCF estimates used in this report.

CLIMATE ADJUSTMENT FACTORS (CAFs)

Despite similarities in the waste management systems, the methane producing potential for areas outside the United States may vary due to differences in climate conditions. In this analysis, climate conditions were considered using a climate adjustment factor (CAF) based on the temperature and precipitation prevailing in a country. Significant effects from precipitation are limited to dry waste handling systems where the manure will dry much slower or much faster than normal due to moisture extremes. Temperature extremes could potentially affect most systems by enhancing anaerobic digestion at high temperatures or by inhibiting anaerobic digestion at low temperatures. Stevens and Schulte (1977) found reports of methanogenesis in the literature at temperatures as low as 4°C. Apparently anaerobic digestion is inhibited below 4°C. Stevens and Schulte (1977) also found that the rate of methanogenesis dramatically increases as the temperature increases from 4°C to 25°C.

The following climate adjustment factors (CAF) were defined to adjust the realized methane producing potential to reflect the impact of climate conditions:

- No adjustments were made to the methane potential of the waste in warm or tropical countries. The CAF for these countries equals 1.

- The dryness and low rainfall of arid and semiarid regions were assumed to reduce by 50 percent the emission potential for pasture and related systems such as drylot, solid storage, and paddock. The CAF for these systems in arid/semiarid regions was assumed to be 0.5.

- The areas with very cold winter temperatures were considered to reduce the methane producing potential of the waste for all systems by 20 percent when averaged over the whole year. The CAF for these systems was assumed to be 0.8.

Exhibit 13 summarizes the climate adjust factors used. Any country not listed in Exhibit 13 has a CAF of 1. The countries listed in Exhibit 13 have either very dry or very cold climates. The countries designated as arid or semiarid or with very cold winter were defined according to climatic region maps in **Goode's World Atlas** (1986). Animal population maps in **Goode's World Atlas** (1986) were also used to distinguish the few countries where the sheep population is largely in arid regions while the cattle population is largely in moist parts of the country. For the countries where this disparity exists between the sheep and cattle populations, all other animal types were taken to be largely in the arid region.

Countries in Exhibit 13 with very cold winters were designated based on January normal temperature maps in **Goode's World Atlas** (1986). A country was defined as very cold if the

EXHIBIT 13: COUNTRIES CONSIDERED CLIMATIC EXCEPTIONS (ARID/SEMIARID AND COLD) FOR CLIMATE ADJUSTMENT FACTOR ESTIMATES

Country	Climate	CAF[A]	Country	Climate	CAF[A]
Afghanistan	Arid/Semiarid	0.5	Mongolia	Arid/Semiarid	0.5
Algeria[B]	Arid/Semiarid	0.5	Namibia	Arid/Semiarid	0.5
Australia[B]	Arid/Semiarid	0.5	Niger	Arid/Semiarid	0.5
Botswana	Arid/Semiarid	0.5	Norway	Very Cold Winter	0.8
Burkina Faso	Arid/Semiarid	0.5	Oman	Arid/Semiarid	0.5
Canada	Very Cold Winter	0.8	Pakistan	Arid/Semiarid	0.5
Chad	Arid/Semiarid	0.5	Poland	Very Cold Winter	0.8
Czechoslovakia	Very Cold Winter	0.8	Romania	Very Cold Winter	0.8
Egypt[C]	Arid/Semiarid	0.5	Saudi Arabia	Arid/Semiarid	0.5
Ethiopia	Arid/Semiarid	0.5	Somalia	Arid/Semiarid	0.5
Finland	Very Cold Winter	0.8	South Africa[B]	Arid/Semiarid	0.5
Hungary	Very Cold Winter	0.8	Soviet Union	Very Cold Winter	0.8
Iran	Arid/Semiarid	0.5	Sudan	Arid/Semiarid	0.5
Iraq[C]	Arid/Semiarid	0.5	Sweden	Very Cold Winter	0.8
Jordan	Arid/Semiarid	0.5	Syria	Arid/Semiarid	0.5
Kenya	Arid/Semiarid	0.5	Tunisia	Arid/Semiarid	0.5
Lybia	Arid/Semiarid	0.5	UAE	Arid/Semiarid	0.5
Mali	Arid/Semiarid	0.5	Yemen Arab Rep	Arid/Semiarid	0.5
Mauritania	Arid/Semiarid	0.5			

A Climate Adjustment Factor: $0 \leq CAF \leq 1$.
B Sheep are largely in the arid/semiarid region; cattle are not.
C Major river valleys alter the arid climate effects.

majority of the country's land area is in a region where the January normal temperature is less than 0°C. Only January was considered because there were no southern hemisphere countries in very cold winter regions.

ANIMAL WASTE MANAGEMENT SYSTEM USAGE (WS%)

To estimate the use of the waste management systems the world was divided into eight primary regions shown in Exhibit 14. The definitions of these regions are generally along well recognized geographic and economic lines and are based on the classification of countries by the Food and Agriculture Organization of the United Nations (FAO 1989).

Not all countries recognized by the Food and Agriculture Organization of the United Nations were included in this study; rather, in order to keep the number of countries being

EXHIBIT 14: REGIONS OF THE WORLD FOR ANIMAL WASTE MANAGEMENT STUDY

NORTH AMERICA:	*Canada, *United States
WESTERN EUROPE:	Austria, *Belgium/Luxembourg, *Denmark, *Finland, France, Germany (Western), Greece, *Ireland, *Italy, *Netherlands, *Norway, Portugal, Spain, *Sweden, *Switzerland, United Kingdom.
EASTERN EUROPE:	Albania, Bulgaria, *Czech and Slovak Federal Republics, Germany (Eastern), *Hungary, Poland, Romania, Soviet Union (B), Yugoslavia.
OCEANIA:	*Australia, Fiji(A), New Caledonia, New Zealand, Papua New Guinea(A), Vanuatu(A).
LATIN AMERICA:	Argentina, Bolivia, Brazil, *Chile, Columbia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, *Guatemala, *Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico (C), Uruguay, Venezuela.
AFRICA:	
East & Subsaharan Africa:	Burundi, Central African Republic, Chad, *Ethiopia, Kenya, *Mali, Mauritania, Niger, Rwanda, Somalia, Tanzania, Uganda, Zaire.
West & Southern Africa:	Angola, Benin, Botswana, Burkina Faso, Cameroon, Côte d'Ivoire, The Gambia, Ghana, *Guinea, Guinea-Bissau, Lesotho, Madagascar, *Malawi, Mozambique, *Namibia, Nigeria, Senegal, Sierra Leone, *South Africa, Swaziland, Togo, Zambia, Zimbabwe.
NEAR EAST & MEDITERRANEAN:	Afghanistan, Algeria, Egypt(A), Iran, Iraq(A), Israel, Jordan, Kuwait, Libya, Morocco, Oman, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, Yemen Arab Republic.
ASIA & FAR EAST:	Bangladesh, Bhutan, China, *India, *Indonesia, *Japan(A), Kampuchea, Myanmar(Burma), North Korea, South Korea, Laos, Malaysia, Mongolia, Nepal, *Pakistan, *Philippines, Sri Lanka, Thailand, Viet Nam.

(A) Major exception to the region. (B) As defined before August 1991.
(C) Considered separately from the U.S. for this analysis.

* Supplied estimate of AWMS usage.

studied to a manageable size, cattle populations were used as a criterion to select those countries with sufficiently large livestock populations to make significant contributions to the world total. Only those countries with 100,000 or more head of cattle (according to FAO 1989) were retained in the study. Exhibit 14 lists 128 countries that meet this criterion out of approximately 212 countries listed in the **1988 FAO Production Yearbook** (FAO 1989).

Detailed data on waste management system usage were collected for the United States and selected other countries. Animal waste management system usage in the United States was determined by obtaining information from Extension Service personnel in each state. For the other countries listed in Exhibit 14 animal waste system usage was determined by contacting the Ministry of Agriculture in each country. In addition, individual researchers in many countries were contacted to provide information. U.S. states or countries that did not supply estimates were assumed to have waste systems similar to other countries in their region (see below). Appendix F lists the information requested from each U.S. state and from each country of the world.

As discussed above, for countries that did not supply waste system usage estimates, a regional average system usage was assumed. These regional averages were then adjusted based on per capita gross national product (GNP) of the country.[17] Exhibit 15 lists the countries that were analyzed in this manner and their GNP. Adjustments were made by weighting poorer countries toward more traditional labor intensive waste systems than those used by the affluent countries. Only relatively small differences in system usage were assumed between the adjacent per capita GNP levels for countries in the same region. In general, each level of income was assumed to make about a 10 to 15 percent difference in the amount of solid handled manure as compared to liquid handled manure.

The following sections describe the estimated waste management system usage by region. Appendix H presents detailed estimates of waste system for the U.S. by state and animal, and Appendix I presents the same information for the rest of the world.

North America

The U.S. was divided into eleven geographic regions based on similarities of climate and livestock production as shown in Exhibit 16. For states that did not provide information, the regional average waste system usage was assumed. Some states did not give data for all animal types and the regional average was used in these cases. A similar process was followed for Canada. Waste system usage information was obtained for each province except Newfoundland, Prince Edward Island, and Saskatchewan. The system usage for these provinces is based on Patni (1989).

Exhibit 17 lists the percentage of waste managed by the major systems in North America. The important waste management characteristics of this region are:

- Approximately one-third of dairy waste is managed as a liquid and approximately one-third is spread directly to cropland.

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[17] Miner (1989) and Ward (1989) observed that animal waste management practices around the world are correlated with personal income.

EXHIBIT 16: PER CAPITAL GROSS NATIONAL PRODUCTS (U.S. DOLLARS)				
Region	< $1,600	$1,600 - $3,200	$3,200 - $6,400	>$6,400
Western Europe		Portugal	Ireland Spain	All Other Countries[A]
Eastern Europe	Albania	Hungary Yugoslavia	Bulgaria Poland Romania Soviet Union[B]	Czechoslovakia Eastern Germany
Oceania	Fiji Papua New Guinea Vanuatu			Australia New Caledonia New Zealand
Latin America	All Other Countries[A]	Argentina Brazil Chile Ecuador Mexico	Uruguay Venezuela Panama	Puerto Rico[C]
Near East & Mediterranean	Afghanistan Egypt Morocco Sudan Tunisia Turkey Yemen Arab Republic	Algeria Iran Iraq Jordan Kuwait Syria	Isreal Oman	Libya Saudi Arabia
Asia and Far East	All Other Countries[A]	South Korea Malaysia		Japan

A See Exhibit 14 B As defined before August 1991. C Considered separately from the U.S. for this analysis.

Source: **Goode's World Atlas** (1986).

- Seventy-five percent of swine waste is managed as a liquid.
- Poultry waste is primarily managed by deep pit stacking or litter and is included in "other systems" in Exhibit 17.

Western Europe

Western Europe is a developed region with slightly fewer cattle than in North America, but with more than twice as many swine. There is no specialization of either dairy of beef production; cattle are used first for milking and then slaughtered for beef. Swine and poultry generally are raised in confinement.

In many parts of Europe, environmental concerns over ground and surface water pollution and odor emission have affected the management of animal wastes. Odor emissions from animal

EXHIBIT 16: REGIONS OF THE U.S. FOR WASTE MANAGEMENT CHARACTERIZATION.

North East	*Connecticut, Maine, Massachusetts, *New Hampshire, New Jersey, *New York, Pennsylvania, Rhode Island, Vermont.
South East	*Delaware, *Florida, *Georgia, Maryland, *North Carolina, *South Carolina, *Virginia, *West Virginia.
Plains	*Colorado, *Kansas, *Montana, *Nebraska, *North Dakota, *South Dakota, Wyoming.
South	*Alabama, *Arkansas, Kentucky, *Louisiana, *Mississippi, *Tennessee
South West	*New Mexico, *Oklahoma, *Texas.
Mid West	*Illinois, *Indiana, Michigan, *Ohio, *Wisconsin, *Iowa, *Minnesota, *Missouri.
North West	*Idaho, *Oregon, *Washington
Far West	*Arizona, Nevada, *Utah
Pacific West	*California
North Pacific	*Alaska
Pacific Islands	*Hawaii

* States that have supplied estimates of their percent use of waste management systems.

confinement facilities and from the spreading of manure on cropland have become a major problem in the last two decades, especially in the north (Hartung 1984). Mandatory storage covers are being considered in northern Europe to control odor (Manneback 1986).

These problems are compounded in many areas because there is not enough cropland available for spreading the manure. Manure spreading is prohibited during the winter to avoid ground and surface water contamination. During the winter manure must be stored for three to six months until it can be spread on fields during the summer (Csoma 1981; O'Rourke 1989).

Exhibit 18 lists the percentage of waste managed by the major systems in Western Europe. The key characteristics are:

EXHIBIT 17: ANIMAL WASTE SYSTEM USAGE FOR NORTH AMERICA							
Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	0%	1%	0%	14%	84%	0%	1%
Dairy	10%	23%	37%	23%	0%	0%	7%
Poultry[E]	5%	4%	0%	0%	1%	0%	90%
Sheep	0%	0%	0%	2%	88%	0%	10%
Swine	25%	50%	0%	18%	0%	0%	6%
Other Animals[F]	0%	0%	0%	0%	92%	0%	8%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

- Over seventy-five percent of swine manure is managed in lagoons and liquid systems.

- Most non-dairy cattle waste is deposited in pastures.

- One-third of dairy waste is handled as a liquid with most of the remainder spread directly on fields or stored as a solid.

<u>Eastern Europe</u>

Eastern Europe is classified as a developed region, with livestock grown in confinement in most of the region. A large portion of manure is handled as a solid. In some areas, municipal type waste treatment facilities are used to treat manure from confinement facilities. Manure managed in this manner requires liquid handling. As in other parts of the world, the less affluent countries utilize more labor intensive solid waste handling systems and the more affluent countries utilize liquid systems. For example, Czechoslovakia is a relatively affluent country where all swine and most poultry manure is handled as a liquid.

Exhibit 19 lists the percentage of waste handled by the major waste systems in Eastern Europe. The key waste management characteristics are:

- About 25 to 45 percent of non-dairy cattle, poultry, and swine wastes are managed in lagoons or other liquid systems.

- Most dairy waste is managed as a solid and only about 20 percent is managed as a liquid.

- Very little waste is spread directly to crops.

EXHIBIT 18: ANIMAL WASTE SYSTEM USAGE FOR WESTERN EUROPE							
Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	0%	55%	0%	2%	33%	0%	9%
Dairy	0%	46%	24%	21%	8%	0%	1%
Poultry[E]	0%	13%	0%	1%	2%	0%	84%
Sheep	0%	0%	0%	2%	87%	0%	11%
Swine	0%	77%	0%	23%	0%	0%	0%
Other Animals[F]	0%	0%	0%	0%	96%	0%	4%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

Oceania

The majority of livestock in Oceania are in the developed countries of Australia and New Zealand. Overall the region does not contain significant numbers of animals except for sheep, which in Australia and New Zealand account for about 20 percent of the world total. Although the region is largely developed, there is little confinement of livestock (Ward 1989). Swine operations are an exception where a large fraction of the waste is managed in anaerobic lagoons.

Exhibit 20 lists the percentage of waste managed by each of the major waste systems in Oceania. The primary characteristics are:

- Almost all waste is managed on pastures and range.
- Over half of the swine waste is managed in anaerobic lagoons.
- Animal waste is not spread directly to cropland.

Latin America

Latin America is a developing region with approximately one-third of the world cattle population and one-fifth of the swine population. Cattle are not specialized and supply draft power, milk, and meat. The only exception are the large beef herds in Argentina and Brazil. Most cattle waste in the region is deposited on pasture or range (Ward 1989; Getz 1989). Swine production is largely limited to small family holdings without any concentrated manure

EXHIBIT 19: ANIMAL WASTE SYSTEM USAGE FOR EASTERN EUROPE

Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	8%	39%	0%	52%	0%	0%	1%
Dairy	0%	18%	1%	67%	13%	0%	0%
Poultry[E]	0%	28%	0%	0%	1%	0%	71%
Sheep	0%	0%	0%	0%	73%	0%	27%
Swine	0%	29%	0%	0%	27%	0%	45%
Other Animals[F]	0%	0%	0%	0%	92%	0%	8%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

management. Brazil and Mexico are exceptions with some swine waste managed as a liquid. Unlike cattle and swine, poultry are raised in confinement (Grove 1989) and Western style waste treatment systems are found, including anaerobic lagoons (Getz 1989).

Exhibit 21 lists the percentage of waste managed by the major systems in Latin America. The key characteristics are:

- Except for poultry and swine, almost all animal waste is deposited on pastures or range.
- Almost 50 percent of poultry waste is managed as litter or in deep pit stacks and about 10 percent is managed as a liquid.
- Half of swine waste is managed as a solid and 10 percent is managed as a liquid.
- Animal manure is generally not used for fuel.

Africa

Africa is a developing region with little livestock confinement (Peters 1989). Most cattle are multi-purpose and there are few specialized dairies. Most livestock graze on communal pastures and with little waste management. In part this results from an aversion to direct handling of manure in many parts of Africa. In some areas, however, manure is spread on cropland for its fertilizer value. South Africa is a major exception to the region with a large number of specialized feedlot beef and dairy cattle and confined swine production. Most cattle and swine waste in South Africa is stored as a solid or spread directly to cropland (Cloete 1989).

EXHIBIT 20: ANIMAL WASTE SYSTEM USAGE FOR OCEANIA							
Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	0%	0%	0%	0%	100%	0%	0%
Dairy	0%	0%	0%	0%	100%	0%	0%
Poultry[E]	0%	0%	0%	0%	3%	0%	98%
Sheep	0%	0%	0%	0%	100%	0%	0%
Swine	55%	0%	0%	17%	0%	0%	28%
Other Animals[F]	0%	0%	0%	0%	100%	0%	0%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

Exhibit 22 lists the percentage of waste managed by the major systems in Africa. The key characteristics are:

- Except for swine, almost all waste is deposited on pastures and range.
- Between 5 and 10 percent of swine waste is managed as a liquid.
- Manure is not used for fuel.

Near East and Mediterranean

The Near East and Mediterranean is a largely developing arid region with about 5 percent of the world cattle population and virtually no swine population. The cattle are mostly on range throughout the region; although, there is some drying and burning of the manure for fuel (Getz 1990). The few swine in the region are usually on drylot and a few on liquid/slurry storage systems. Three-quarters of the poultry are on range while most the remainder are on litter systems (Getz 1990).

The major exceptions in this region are the fertile valleys of the Nile, Tigris, and Euphrates rivers. The land is generally irrigated in these areas and about half of the cattle manure is collected and burned for fuel (Getz 1990). The other half is either kept in solid storage or hauled and spread on fields (Getz 1990 and Johnson 1989). Most of the cattle and sheep populations of Egypt are in the Nile river valley, while the majority of Iraq's cattle and sheep populations are in the valleys of the Tigris and Euphrates rivers (**Goode's World Atlas** 1986).

Exhibit 23 lists the percentage of waste managed by the major systems in the Near East and Mediterranean region. The key characteristics are:

EXHIBIT 21: ANIMAL WASTE SYSTEM USAGE FOR LATIN AMERICA							
Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	0%	0%	0%	0%	99%	0%	1%
Dairy	0%	1%	62%	1%	36%	0%	0%
Poultry[E]	0%	9%	0%	0%	42%	0%	49%
Sheep	0%	0%	0%	0%	100%	0%	0%
Swine	0%	8%	2%	51%	0%	0%	40%
Other Animals[F]	0%	0%	0%	0%	99%	0%	1%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

- Except for swine, almost all animal waste is managed on pastures or range.
- One-third of swine waste is managed as a liquid with the remainder managed as a solid.
- Almost twenty percent of the cattle waste is used for fuel.

Asia and the Far East

Asia and the Far East is a developing region with few livestock confinement facilities and little concentrated manure production. Cattle and most other livestock are generally graze in the region. However, there is a measure of confinement when the animals are tethered near the house in family farming operations with one to five animals. Approximately 80 percent of the livestock in the region are in small mixed farming operations (Getz 1989). When these animals are confined, the manure is removed occasionally using baskets, often along with earth or some not too absorptive bedding such as feed residue, and spread in solid form. Numerous countries in the region use animal manures as their primary source of fertilizer for a variety of crops, including rice (RAPA 1988). Because commercial fertilizers are very costly throughout the region, in many instances the fertilizer value of the manure is the major reason for keeping the animals when they would otherwise be past a useful age (McDowell 1977)

A second important use for collected manure in Asia and the Far East is burning for fuel. In these cases the manure is dried in cakes and used for heating or cooking. In India, it is estimated that 66 percent of the cattle manure is burned for fuel (NCAER 1965). In Bangladesh, acute fuel shortages throughout the country also lead to most cattle manure being burned for fuel (RAPA 1988).

EXHIBIT 22: ANIMAL WASTE SYSTEM USAGE FOR AFRICA							
Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	0%	0%	1%	3%	96%	0%	0%
Dairy	0%	0%	12%	0%	83%	0%	5%
Poultry[E]	0%	0%	0%	0%	81%	0%	19%
Sheep	0%	0%	0%	1%	99%	0%	1%
Swine	0%	7%	0%	93%	0%	0%	0%
Other Animals[F]	0%	0%	0%	0%	99%	0%	1%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

In an effort to make this use cleaner and more efficient, and to retain the fertilizer value of the manure, many countries in the region are turning to biogas production as shown in Exhibit 24. Small family-size anaerobic digesters are often used, primarily in rural areas of China and India. Seven million small biogas digesters have been constructed in China (Smil 1984) with about 4.5 million of them still in operation in 1986 (RAPA 1987). Between one-half and one-third of these work as reasonably reliable energy generators (Smil 1984), with gas leaks being the major cause of poor operation.

Japan is a major exception to the region, although its cattle population accounts for only about one percent of the region's cattle population. Japan is a developed country with intensive livestock production and waste management. With farm land scarce, most livestock are grown in confinement and land area is not adequate for spreading the manure. The waste systems utilized are similar to those in the U.S. and Western Europe (Minagawa 1989). About one-third of the dairy cattle waste in Japan is handled by daily spread. Most of the remaining dairy waste is kept in solid storage with only a fraction handled in liquid form. Almost 90 percent of beef cattle are in confinement with about one-third of the animals on anaerobic lagoons and most of the rest on drylot. About half of the swine waste is in solid storage, one-third is handled with anaerobic lagoons, and the rest is usually spread on fields. Most of the poultry waste from layers is in deep pit stacking while most broiler waste is treated with anaerobic lagoons.

Exhibit 25 lists the percentage of waste managed by the major systems in Asia and the Far East: The key characteristics are:

- Between 40 and 50 percent of cattle waste is used for fuel.
- Forty percent of swine waste is managed in liquid systems.
- Six percent of dairy waste is managed in anaerobic lagoons, almost entirely in Japan.

EXHIBIT 23: ANIMAL WASTE SYSTEM USAGE FOR NEAR EAST AND MEDITERRANEAN							
Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	0%	0%	2%	0%	77%	18%	2%
Dairy	0%	0%	3%	3%	77%	18%	0%
Poultry[E]	0%	1%	0%	0%	71%	0%	28%
Sheep	0%	0%	0%	0%	100%	0%	0%
Swine	0%	32%	0%	68%	0%	0%	0%
Other Animals[F]	0%	0%	0%	0%	100%	0%	0%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

EXHIBIT 24: USE OF BIOGAS DIGESTERS IN DEVELOPING COUNTRIES			
Country	Number Built	Number in Use	References
China[A,C]	7,000,000	4,500,000	Smil (1984), Stuckey (1984),RAPA (1987)
India[A,C]	700,000	525,000	Moulik et al. (1984), RAPA (1987)
North Korea[A]	50,000	37,500	RAPA (1987)
South Korea[A]	31,405	11,470	Stuckey (1984), RAPA (1987)
Thailand[A,C]	7,500	5,625	Chantavorapap (1984), RAPA (1987)
Pakistan[A,C]	4,000	3,000	RAPA (1987)
Brazil[B]	3,033	1,820	Caceres & Chiliquinga (1984)
Nepal[B,C]	1,600	1,200	Gorkhali (1984)
Taiwan[B]	>1,000	Not Available	Stuckey (1984)

A As of 1986
B As of 1984
C Assuming that 75 percent of built digesters are still in use.

EXHIBIT 25: ANIMAL WASTE SYSTEM USAGE FOR ASIA AND FAR EAST							
Animal	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Non-Dairy Cattle[D]	0%	0%	16%	14%	29%	40%	0%
Dairy	6%	4%	21%	0%	24%	46%	0%
Poultry[E]	1%	2%	0%	0%	44%	1%	52%
Sheep	0%	0%	0%	0%	83%	0%	17%
Swine	1%	38%	1%	53%	0%	7%	0%
Other Animals[F]	0%	0%	0%	0%	95%	0%	5%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.
[E] Includes chickens, turkeys, and ducks.
[F] Includes goats, horses, mules, donkeys, and camels.

CHAPTER 4. ANIMAL WASTE EMISSIONS ESTIMATES

This chapter presents estimates of global methane emissions from the anaerobic decomposition of animal waste. Emission estimates are presented for the U.S. and world by animal and waste system using the previously described data on volatile solids (VS) production, maximum methane producing capacity (B_0), waste system definitions, methane conversion factors (MCFs), climate adjustment factors (CAFs), and waste system usage (WS%). In addition, "high" and "low" case emissions estimates are presented to indicate the uncertainty of the point estimates.

This report estimates that global methane emissions from animal waste are about 28 Tg/yr with a range of about 20 to 35 Tg/yr, or about 6 to 10 percent of total annual anthropogenic emissions. The major findings of this report are that:

- Of the 28 Tg/yr, liquid animal waste management systems (liquid/slurry storage and anaerobic lagoons) account for over 10 Tg/yr, or about 35 percent of total emissions from animal waste. These systems are used at confined, energy intensive livestock operations and may provide profitable opportunities to recover methane for use as a fuel.

- Of the 28 Tg/yr, three regions account for about 22 Tg/yr, or about 75 percent of the total: Europe (East and West); Asia and the Far East; and North America.

- Of the 28 Tg/yr, over 20 Tg are from three animal groups: cattle (beef and draft animals), dairy cows, and swine.

UNITED STATES EMISSION ESTIMATE

Livestock and poultry wastes in the United States emit 3.9 Tg/yr of methane to the atmosphere, or about 14 percent of the world's total emissions of about 28 Tg/yr. Exhibit 26 summarizes the contribution of the major animal groups. Of the 3.9 Tg/yr, three animal groups account for 3.5 Tg/yr or about 90 percent of the total:

- Beef cattle wastes produce 1.4 Tg/yr or about 35 percent of the U.S. total emissions;

- Swine wastes produce 1.1 Tg/yr or about 30 percent of the U.S. total emissions; and

- Dairy cattle wastes produce 1.0 Tg/yr or about 25 percent of the U.S. total emissions.

The contributions of each state are summarized in Exhibits 27 and 28 and full details of the U.S. emission estimate are in Appendix B.

EXHIBIT 26: U.S. METHANE EMISSIONS FROM ANIMAL WASTE		
Animal Type	Population	Methane (Tg/yr)
Cattle in Feedlots	11,200,000	0.26
Other Beef Cattle	78,000,000	1.11
Dairy Cattle	14,400,000	1.01
Swine	55,300,000	1.12
Caged Layers	355,500,000	0.11
Broilers	951,900,000	0.09
Turkeys and Ducks	60,800,000	0.01
Sheep	10,600,000	0.03
Goats	2,400,000	< 0.01
Horses, Mules, and Donkeys	2,409,000	0.09
Total		3.86

The portions of the U.S. methane emissions from the different animal waste management systems are shown in Exhibit 29. Of the total 3.9 Tg/yr emissions:

- Liquid based systems (anaerobic lagoons plus liquid/slurry storage) account for 1.8 Tg/yr or over 40 percent of total emissions. Because liquid based systems are often used for confined and energy intensive livestock operations, they provide an opportunity for emissions reduction by capturing the methane for use as an on-farm energy source. The U.S. EPA is currently assessing the economic and technical feasibility of these opportunities in several key U.S. states, including: Texas, California, Iowa, Illinois, and North Carolina.

- Solid based systems (pasture/range, drylots, solid storage, daily spread, and other) account for 2.1 Tg/yr or about 60 percent of total emissions. Solid based systems make a large contribution to overall emissions in spite of their low methane conversion factors (MCFs) because a very large number of animals are on solid based systems.

The details of the contributions of different systems in the United States are in Appendix G and Appendix H.

EXHIBIT 27: INDIVIDUAL U.S. STATE AND SYSTEM METHANE EMISSIONS (METRIC TONS/YEAR)

State	Anaerobic Lagoons	Slurry Storage	Solid Storage	Drylot	Pasture/ Range	Litter	Pit Storage (<1 month)	Pit Storage (>1 month)	Daily Spread	Deep Pit Stacking	Paddock	Other	Total
AK	123	130	2	0	262	0	0	0	1	0	7	103	629
AL	41,109	463	0	416	26,104	10,649	0	379	481	116	622	0	80,340
AR	637,693	4,035	0	709	26,762	14,436	0	571	1,265	0	144	0	85,616
AZ	10,161	0	0	3,944	12,526	0	0	0	0	30	886	3,788	31,336
CA	203,398	391	0	6,143	50,988	4,436	0	0	0	1,465	1,068	35,699	303,588
CO	4,630	862	0	11,906	36,259	0	262	598	1,610	287	481	11,742	68,635
CT	49	1,873	9	0	556	0	0	0	411	453	124	54	3,529
DE	506	287	0	18	294	3,295	0	250	123	75	54	0	4,902
FL	7,276	285	0	583	30,443	1,867	8	0	414	831	328	8,676	50,711
GA	56,452	954	0	1,449	21,035	11,769	0	1,303	130	572	404	7,832	101,900
HI	3,738	670	0	300	2,643	34	59	166	18	2	57	234	7,922
IA	25,805	6,519	10,103	30,940	58,049	432	8,376	59,391	622	766	170	26,592	227,765
ID	9,318	15,031	0	3,003	20,977	0	22	314	86	40	705	458	49,953
IL	79,966	3,926	1,010	8,306	23,025	72	3,147	28,326	2,272	286	597	4,717	155,652
IN	64,206	11,920	931	5,163	14,915	607	1,210	29,043	931	2,105	945	41	132,018
KS	35,245	4,188	0	23,669	69,610	11	0	4,902	1,570	175	200	0	139,571
KY	62,493	1,957	0	990	34,603	41	410	117	1,604	6	968	4,614	107,802
LA	8,170	0	0	121	16,506	0	0	0	83	0	347	4,136	29,363
MA	48	866	186	93	798	6	4	148	415	80	150	34	2,827
MD	5,319	5,324	274	200	3,391	3,830	0	759	1,235	366	333	37	21,067
ME	13	1,472	289	26	856	0	1	41	644	413	79	118	3,953
MI	38,313	11,194	2,153	3,467	10,664	150	300	5,843	4,038	513	734	1,802	79,171
MN	0	27,046	12,651	8,763	25,452	2,410	5,213	20,852	8,434	716	975	10,501	123,011
MO	184,807	519	0	3,837	63,100	1,644	0	0	2,280	519	267	42	257,015

(continued on next page)

EXHIBIT 27: INDIVIDUAL U.S. STATE AND SYSTEM METHANE EMISSIONS (METRIC TONS/YEAR)													
State	Anaerobic Lagoons	Slurry Storage	Solid Storage	Drylot	Pasture/ Range	Litter	Pit Storage (<1 month)	Pit Storage (>1 month)	Daily Spread	Deep Pit Stacking	Paddock	Other	Total
(continued from previous page)													
MS	20,377	212	68	324	20,387	5,469	69	249	34	0	405	3,621	51,215
MT	1,328	472	271	1,582	41,568	0	334	668	230	66	26	253	46,799
NC	101,841	4,193	524	2,190	11,392	9,714	0	4,327	1,311	232	107	2,049	137,882
ND	3,940	68	849	793	24,609	24	572	1,144	38	22	349	28	32,434
NE	74,086	489	0	29,371	64,619	105	12,029	2,187	856	354	92	3,562	187,750
NH	24	884	442	48	425	1	0	5	110	24	131	0	2,094
NJ	62	938	197	156	1,178	4	5	192	439	133	291	69	3,663
NM	24,247	45	0	1,708	20,699	0	15	30	146	50	1,396	56	48,393
NV	221	1,622	2,836	395	7,733	0	0	0	203	1	127	6	13,145
NY	336	16,606	4,017	412	8,938	55	37	896	14,058	259	959	660	47,233
OH	50,978	11,856	2,321	3,270	17,748	360	124	11,365	4,351	1,822	2,570	2,570	109,334
OK	13,846	308	0	4,059	71,247	1,832	127	0	130	308	692	16,600	109,149
OR	21,067	3,582	49	1,040	20,738	344	212	145	123	205	947	2,061	50,512
PA	0	1,876	1,091	2,939	14,951	2,275	53	6,335	17,277	1,312	1,170	2,630	51,910
RI	8	80	16	16	66	0	1	26	36	16	13	4	282
SC	38,567	203	102	356	8,630	1,336	0	246	102	280	301	112	50,233
SD	38,997	3,682	1,346	5,324	50,993	117	2,454	4,908	1,010	106	325	0	109,262
TN	46,913	8,784	0	1,106	31,719	1,318	0	585	1,018	5	560	7,124	99,133
TX	59,583	20,782	0	27,075	196,350	4,035	478	637	1,299	147	0	9,534	319,920
UT	777	80	3,597	712	12,996	0	0	0	160	98	284	281	18,984
VA	18,801	11,810	0	419	23,257	3,422	0	464	976	118	17	549	59,834
VT	9	4,745	1,062	17	1,499	0	1	28	2,369	14	95	21	9,859
WA	41,822	11,599	0	2,439	15,582	427	30	359	570	464	1,036	0	74,329
WI	0	27,361	13,589	1,814	23,811	198	1,442	10,093	31,708	186	257	1,751	112,211
WV	777	1,041	260	176	7,745	635	60	121	195	0	406	495	11,912
WY	707	324	97	1,255	23,554	0	24	56	82	2	292	152	26,545
OTHER	0	0	0	0	296	3,013	0	0	0	0	0	609	3,919
TOTAL	1,438,149	233,554	60,342	203,044	1,272,548	90,375	37,077	198,070	107,497	16,042	23,498	176,017	3,857,141

EXHIBIT 28: INDIVIDUAL U.S. STATE AND ANIMAL METHANE EMISSIONS (MT/YR)							
State	Beef	Dairy	Swine	Sheep & Goats	Poultry	Horses & Other	Total
AK	103	318	40	99	2	67	629
AL	26,288	9,144	15,743	26	27,893	1,245	80,340
AR	25,521	8,854	19,143	34	30,620	1,444	85,616
AZ	13,492	7,527	6,398	1,357	30	2,532	31,336
CA	49,770	226,078	5,584	3,404	13,413	5,339	303,588
CO	55,699	4,071	3,937	1,472	627	2,830	68,635
CT	403	2,293	79	50	455	248	3,529
DE	238	595	589	1	3,370	109	4,902
FL	29,965	9,196	2,955	33	5,832	2,731	50,711
GA	20,388	22,209	42,614	51	15,415	1,223	101,900
HI	2,855	2,347	906	2	1,684	127	7,922
IA	63,736	21,760	137,057	1,373	1,709	2,130	227,765
ID	22,096	22,589	2,044	933	278	2,014	49,953
IL	30,304	13,381	108,584	448	943	1,991	155,652
IN	17,965	21,413	87,128	433	3,188	1,891	132,018
KS	100,827	5,758	30,230	573	186	1,996	139,571
KY	32,508	26,192	43,388	129	2,359	3,227	107,802
LA	15,501	6,451	3,182	65	2,775	1,390	29,363
MA	481	1,432	292	51	142	429	2,827
MD	2,916	7,765	5,122	116	4,197	952	21,068
ME	674	2,221	82	51	699	227	3,953
MI	13,554	26,469	35,580	401	1,126	2,040	79,171
MN	28,125	46,388	41,703	766	4,079	1,949	123,011
MO	65,792	63,844	121,562	463	2,682	2,672	257,015
MS	19,912	6,410	8,033	13	15,835	1,012	51,215
MT	38,261	2,306	1,671	1,818	143	2,599	46,799
NC	11,047	7,864	97,364	118	20,414	1,075	137,882
ND	24,086	990	5,529	558	108	1,163	32,434
NE	95,972	4,867	84,202	409	459	1,840	187,749
NH	372	1,436	78	38	25	145	2,094
NJ	594	1,515	379	113	230	831	3,663
NM	19,910	23,856	282	1,928	555	1,862	48,393
NV	7,289	4,659	274	285	2	636	13,145
NY	8,500	34,142	1,493	262	918	1,918	47,233
OH	20,583	28,523	54,599	741	2,182	2,706	109,334
OK	71,590	23,733	7,350	567	2,449	3,461	109,149
OR	20,019	23,902	2,019	1,320	1,148	2,103	50,512
PA	14,409	19,823	8,446	440	6,452	2,341	51,910
RI	41	125	51	1	27	37	282
SC	8,533	15,034	20,279	16	5,769	602	50,233
SD	56,028	20,863	27,978	2,069	699	1,626	109,262
TN	30,115	20,865	43,570	153	2,190	2,240	99,133
TX	209,880	61,046	13,061	9,858	17,704	8,371	319,920
UT	10,626	4,196	557	1,700	488	1,418	18,984
VA	21,602	12,693	19,265	406	4,138	1,730	59,834
VT	1,286	8,170	54	54	23	272	9,859
WA	16,722	52,977	1,197	263	1,098	2,072	74,329
WI	23,899	72,476	12,256	271	994	2,315	112,211
WV	57,259	1,836	784	507	986	542	11,914
WY	21,308	825	365	2,323	3	1,720	26,545
OTHER	0	0	0	182	4,533	132	4,258
Total	1,379,044	1,013,428	1,125,080	38,741	213,276	87,572	3,857,141

EXHIBIT 29: U.S. METHANE EMISSIONS FROM WASTE MANAGEMENT SYSTEMS		
System Type	MCF	Emissions (Tg/Yr)
Pasture/Range	0.1	1.3
Anaerobic Lagoon	0.9	1.4
Liquid/Slurry Storage	0.2	0.2
Drylot	0.1	0.2
Solid Storage	0.1	<0.1
Daily Spread	0.05	0.1
Other		0.6
Total		3.9

WORLD EMISSION ESTIMATE

A summary of worldwide methane emissions from animal waste is shown in Exhibit 30. Of the total 28 Tg/yr emissions:

- Three animal groups account for 21.2 Tg/yr (75 percent) of the world total: non-dairy cattle wastes account for 9.5 Tg/yr (33 percent); dairy cattle wastes account for 5.9 Tg/yr (20 percent); and swine wastes account for 5.8 Tg/yr (20 percent).

- Three regions of the world account for 22 Tg/yr (75 percent) of emissions: Europe (East and West) contributes 11.4 Tg/yr (40 percent); Asia and the Far East contributes 6.4 Tg/yr (22 percent); and North America contributes 4.2 Tg/yr (14 percent).

The contribution of each country is summarized in Exhibit 31 and listed in detail in Appendix E.

The worldwide contribution of different types of waste management systems is shown in Exhibit 32. Of the total 28.3 Tg/yr emissions:

- Liquid based systems (anaerobic lagoons and liquid/slurry storage) account for 10 Tg/yr or about 35 percent of total worldwide emissions. Other than the U.S., these emissions are concentrated in Europe. Like the U.S., opportunities may exist to reduce emissions by capturing this methane for use as an on-farm energy source.

- Solid based systems (Pasture/Range, solid storage, drylots, daily spread, and other) account for 17.4 Tg/yr or about 60 percent of total worldwide emissions. As in the U.S., solid based systems make a large contribution despite their low MCFs because such a large number of animals are on solid based systems (primarily pasture/range).

EXHIBIT 30: WORLDWIDE METHANE EMISSIONS BY REGIONS (TG/YR)									
Animal Type	North America	West Europe	East Europe	Oceania	Latin America	Africa	Near East & Med.	Asia & Far East	Total
Cattle	1.50	1.70	2.14	0.54	1.23	0.72	0.12	1.49	9.45
Dairy	1.09	1.55	2.03	0.16	0.21	0.12	0.10	0.64	5.91
Swine	1.23	1.08	1.29	0.14	0.24	0.04	<0.01	1.80	5.84
Sheep	0.03	0.27	0.44	0.44	0.14	0.18	0.14	0.22	1.85
Goats	<0.01	0.03	0.02	<0.01	0.05	0.12	0.06	0.37	0.66
Chicken	0.21	0.12	0.29	<0.01	0.20	0.08	0.07	0.62	1.59
Ducks	<0.01	<0.01	<0.01	0.00	<0.01	<0.01	<0.01	0.06	0.07
Turkeys	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.07
Buffalo	0.00	<0.01	<0.01	0.00	<0.01	0.00	0.01	0.52	0.55
Horses	0.10	0.06	0.25	0.01	0.51	0.05	0.04	0.34	1.37
Mules	<0.01	0.01	<0.01	0.00	0.16	0.02	0.02	0.12	0.33
Donkeys	<0.01	0.01	0.02	0.00	0.11	0.07	0.09	0.21	0.51
Camels	0.00	0.00	<0.01	0.00	0.00	0.08	0.03	0.04	0.16
Total	4.19	4.87	6.51	1.31	2.86	1.47	0.70	6.45	28.3

RANGE OF ESTIMATES

The estimates presented above should be regarded with caution. Some of the data used to make these estimates are uncertain, in particular:

- Little information is available to assess the methane produced by pasture and range waste. Because a large fraction of animal waste is managed on pastures and range, this creates uncertainty in the overall emissions estimate.

- The methane producing potential of liquid/slurry and pit storage waste systems may be much greater than assumed in this report. Because of the widespread use of these systems, total emission may be underestimated.

- Limited data exist on the numbers and characteristics of animal waste systems in use in some parts of the world.

At this time, insufficient information exists to provide a statistical confidence limit for the emission estimates presented above. The greatest uncertainty in the emission estimates results from the methane conversion factor assumptions for the various waste management systems.

EXHIBIT 31: GLOBAL METHANE EMISSIONS SUMMARY

Country	Non-Dairy Cattle	Dairy	Swine	Sheep & Goats	Poultry[A]	Other[B]	Methane mt/yr
NORTH AMERICA							
Canada	116,029	81,332	102,998	1,605	15,796	12,406	330,166
USA	1,379,044	1,013,428	1,125,080	38,741	213,276	87,572	3,857,141
Total	1,495,073	1,094,760	1,228,078	40,346	229,072	99,978	4,187,307
WESTERN EUROPE							
Austria	46,213	49,900	34,396	157	2,245	1,618	134,529
Belgium	60,825	40,351	59,135	548	7,669	863	169,390
Denmark	25,733	48,388	76,435	365	2,446	1,043	154,411
Finland	17,841	19,010	9,779	151	942	1,036	48,758
France	396,733	478,638	124,357	32,816	38,945	11,482	1,082,970
Germany (Western)	276,150	255,978	234,040	4,404	12,247	12,586	795,405
Greece	15,067	17,877	11,766	40,761	4,641	9,345	99,458
Ireland	103,325	76,578	4,916	13,208	1,448	2,528	202,003
Italy	191,188	145,311	100,638	36,104	23,564	14,174	510,978
Netherlands	83,645	93,345	133,668	2,625	18,179	2,301	333,764
Norway	17,336	17,591	6,579	7,591	628	734	50,459
Portugal	22,058	16,978	21,533	17,005	2,452	8,465	88,491
Spain	80,202	72,743	148,895	59,277	8,063	16,079	385,259
Sweden	33,716	22,585	19,485	459	1,762	1,669	79,676
Switzerland	37,014	28,324	21,111	1,233	797	1,810	90,288
United Kingdom	297,421	162,348	75,608	78,325	23,214	6,592	643,508
Total	1,704,467	1,545,944	1,082,342	295,028	149,242	92,325	4,869,348
EASTERN EUROPE							
Albania	9,269	9,105	1,411	6,866	755	3,568	30,974
Bulgaria	25,139	27,582	26,591	26,560	7,739	13,594	127,205
Czechoslovakia	107,697	59,296	92,839	2,566	9,042	949	272,389
Germany (Eastern)	138,350	85,256	200,547	7,629	9,651	3,740	445,173
Hungary	18,286	18,032	313,393	5,359	12,766	2,627	370,465
Poland	102,360	160,901	94,770	10,010	12,491	30,235	410,765
Romania	108,081	71,064	80,282	45,130	25,783	22,861	353,201
Soviet Union	1,574,132	1,492,342	408,177	335,770	220,771	183,378	4,214,571
Yugoslavia	55,444	105,652	71,601	23,339	11,190	13,885	281,112
Total	2,138,758	2,029,230	1,289,612	463,230	310,188	274,838	6,505,855
OCEANIA							
Australia	418,177	81,798	116,188	252,176	6,466	8,652	883,457
Fiji	589	230	84	90	293	952	2,238
New Caledonia	2,439	222	1,911	68	115	360	5,115
New Zealand	121,308	81,205	17,398	189,042	1,039	3,596	413,588
Papua New Guinea	449	16	4,935	28	439	23	5,889
Vanuatu	476	0	229	18	0	68	791
Total	543,438	163,470	140,744	441,423	8,353	13,650	1,311,079

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EXHIBIT 31: GLOBAL METHANE EMISSIONS SUMMARY

(continued from previous page)

Country	Non-Dairy Cattle	Dairy	Swine	Sheep & Goats	Poultry[A]	Other[B]	Methane mt/yr
LATIN AMERICA							
Argentina	217,332	14,006	13,092	38,584	9,991	75,355	368,359
Bolivia	24,361	579	5,080	14,637	1,843	18,270	64,771
Brazil	525,895	89,582	104,414	39,678	90,763	202,142	1,052,474
Chile	12,378	2,787	2,112	8,466	3,380	11,476	40,598
Colombia	94,756	26,251	7,507	4,469	5,991	67,565	206,539
Costa Rica	8,521	2,393	647	22	768	2,802	15,154
Cuba	19,947	4,501	7,257	607	4,148	16,719	53,179
Dominican Republic	8,629	1,737	1,187	919	4,148	12,462	29,082
Ecuador	14,531	3,964	13,283	2,427	7,725	16,885	58,816
El Salvador	4,016	1,992	1,283	28	461	2,659	10,439
Guatemala	7,728	3,215	2,540	856	2,250	3,472	20,060
Guyana	716	455	518	255	2,085	60	4,089
Haiti	6,572	733	2,613	1,914	1,997	14,919	28,748
Honduras	11,290	2,637	1,742	46	1,170	5,725	22,610
Jamaica	1,092	378	726	665	922	663	4,446
Mexico	112,401	31,675	52,686	22,736	40,475	258,396	518,370
Nicaragua	6,889	1,390	2,163	12	768	6,807	18,029
Panama	6,313	647	766	11	1,075	3,989	12,802
Paraguay	34,785	811	6,119	705	2,458	8,217	53,095
Peru	14,490	5,428	6,967	17,961	7,988	27,196	80,030
Puerto Rico	2,207	546	623	29	1,811	574	5,790
Uruguay	44,679	3,267	687	30,144	1,317	10,826	90,920
Venezuela	52,058	7,543	8,644	2,598	9,382	19,464	99,688
Total	1,231,586	206,519	242,654	187,769	202,917	786,644	2,858,089
EAST & SUBSAHARAN AFRICA							
Burundi	1,269	475	244	1,533	571	0	4,092
Central African Rep.	10,279	356	1,164	1,883	428	0	14,110
Chad	8,280	1,688	20	2,987	322	7,419	20,717
Ethiopia	61,469	16,110	32	26,695	4,587	72,695	181,588
Kenya	17,098	9,375	170	10,615	1,851	5,926	45,035
Mali	9,663	1,971	174	8,781	1,390	7,339	29,318
Mauritania	2,216	1,131	0	4,778	322	7,365	15,812
Niger	6,730	2,203	62	7,703	1,368	10,318	28,385
Rwanda	2,266	1,267	280	2,222	143	0	6,178
Somalia	9,065	4,157	17	22,851	241	50,374	86,705
Tanzania	48,495	22,173	561	64,743	4,671	2,585	143,228
Uganda	12,826	8,552	1,341	6,225	2,140	255	31,340
Zaire	6,309	63	2,438	5,592	2,710	0	17,113
Total	195,967	69,522	6,503	166,609	20,743	164,275	623,619

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EXHIBIT 31: GLOBAL METHANE EMISSIONS SUMMARY

(continued from previous page)

Country	Non-Dairy Cattle	Dairy	Swine	Sheep & Goats	Poultry[A]	Other[B]	Methane mt/yr
WEST & SOUTHERN AFRICA							
Angola	14,073	2,336	1,463	1,773	856	98	20,599
Benin	3,617	919	1,975	2,439	3,281	151	12,381
Botswana	4,668	1,206	15	955	80	1,418	8,342
Burkina Faso	5,321	1,917	835	5,629	1,690	2,333	17,724
Cameroon	19,824	768	3,590	7,722	2,282	1,153	35,340
Côte d'Ivoire	3,653	1,219	1,372	3,991	2,282	23	12,541
The Gambia	1,224	238	40	532	0	60	2,093
Ghana	5,008	1,544	2,286	7,405	1,712	466	18,421
Guinea	6,781	1,782	152	1,224	1,854	68	11,862
Guinea-Bissau	1,274	467	884	553	143	68	3,388
Lesotho	2,017	634	219	3,215	143	4,613	10,841
Madagascar	47,775	467	4,267	2,331	4,819	23	59,682
Malawi	2,871	752	1,219	1,672	995	15	7,525
Mozambique	4,396	3,088	488	702	3,126	301	12,101
Namibia	4,263	669	70	5,581	80	1,146	11,809
Nigeria	49,764	9,661	3,962	15,264	27,104	16,455	122,211
Senegal	10,642	2,059	1,433	6,115	1,569	7,990	29,808
Sierra Leone	1,269	396	152	652	856	0	3,326
South Africa	299,611	16,961	6,015	50,794	4,272	8,966	386,621
Swaziland	2,253	1,212	58	522	143	256	4,442
Togo	1,142	301	914	1,470	428	68	4,323
Zambia	10,941	2,138	549	724	2,140	30	16,522
Zimbabwe	25,186	1,132	579	3,153	1,427	2,062	33,539
Total	527,573	51,865	32,537	124,421	61,282	47,762	845,440
NEAR EAST & MEDITERRANEAN							
Afghanistan	5,507	4,633	0	11,936	640	20,344	43,059
Algeria	4,319	4,514	17	10,968	2,103	10,274	32,196
Egypt	1,331	7,176	38	1,892	3,282	22,761	36,482
Iran	13,597	9,305	0	30,194	10,059	22,267	85,422
Iraq	3,179	1,730	0	6,485	6,950	5,317	23,662
Israel	4,445	4,414	1,107	1,162	6,804	567	18,498
Jordan	25	71	0	1,051	5,487	344	6,979
Kuwait	45	127	0	377	4,097	188	4,833
Libya	376	194	0	4,051	3,383	3,015	11,019
Morocco	7,886	12,353	30	26,882	5,413	28,287	80,852
Oman	213	166	0	662	183	793	2,017
Saudi Arabia	453	495	0	7,025	6,310	4,073	18,356
Sudan	43,170	13,660	0	20,853	2,652	26,610	106,945
Syria	952	1,148	2	8,503	1,097	2,444	14,147
Tunisia	820	990	8	4,250	1,555	5,063	12,687
Turkey	31,726	39,594	33	65,966	9,364	39,338	186,021
Yemen Arab Rep.	1,598	1,378	0	2,358	2,103	4,441	11,877
Total	119,643	101,948	1,236	204,616	71,481	196,128	695,051

(continued on following page)

EXHIBIT 31: GLOBAL METHANE EMISSIONS SUMMARY

Country	Non-Dairy Cattle	Dairy	Swine	Sheep & Goats	Poultry[A]	Other[B]	Methane mt/yr
			(continued from previous page)				
ASIA & FAR EAST							
Bangladesh	78,518	26,631	0	16,261	16,619	8,974	147,002
Bhutan	1,220	828	247	79	0	866	3,239
China	325,305	30,356	1,388,076	235,907	316,468	626,042	2,922,154
India	681,973	210,700	29,899	217,747	45,649	364,792	1,550,760
Indonesia	22,661	3,365	26,416	50,740	91,664	43,606	238,453
Japan	232,070	320,002	212,554	199	116,990	791	882,605
Kampuchea	1,175	737	5,878	3	1,467	3,195	12,455
Myanmar (Burma)	31,082	17,904	11,756	1,996	5,223	12,328	80,291
North Korea	4,956	263	12,148	859	3,072	1,065	22,364
South Korea	8,644	2,114	18,640	253	9,626	68	39,345
Laos	2,252	286	5,957	114	1,383	5,031	15,022
Malaysia	2,572	366	8,286	625	9,178	1,086	22,112
Mongolia	4,376	2,709	238	13,031	0	27,285	47,639
Nepal	23,247	5,078	1,877	8,674	1,536	11,829	52,241
Pakistan	30,169	15,097	0	40,727	17,984	67,463	171,441
Philippines	5,728	232	28,604	3,131	9,561	16,623	63,879
Sri Lanka	4,772	4,890	396	789	1,383	4,306	16,536
Thailand	20,118	512	16,694	230	15,146	24,905	77,604
Viet Nam	11,740	339	47,225	649	14,123	14,541	88,616
Total	1,492,576	642,408	1,814,892	592,017	677,071	1,234,797	6,453,761
WORLD TOTAL	9,449,080	5,905,665	5,838,598	2,515,459	1,730,348	2,910,397	28,349,549

[A] Includes chickens, turkeys and ducks.
[B] Includes buffalo, horses, mules, donkeys and camels.

While assumptions concerning other factors are somewhat uncertain (i.e., methane producing capacity of the waste (B_o), animal populations and waste quantities, waste system usage), their contribution to the overall uncertainty is likely to be less.

To capture the uncertainty in these estimates, "high" and "low" case emission estimates have been defined as follows:

- High Case. The MCF for anaerobic lagoons was assumed to be 1 and the MCFs for all other liquid systems were assumed to be double that of the base case.

- Low Case. The MCFs for each of the major solid systems (pasture/range, solid storage, and drylots) were assumed to be half that of the base case.

Exhibit 33 lists the MCF values used to estimate the low and high cases.

EXHIBIT 32: WORLDWIDE METHANE EMISSIONS BY WASTE SYSTEM (TG/YR)									
Waste System	North America	West Europe	East Europe	Oceania	Latin America	Africa	Near East & Med	Asia & Far East	Total
Pasture/Range	1.31	0.78	1.17	1.16	2.18	1.25	0.53	1.82	10.19
Liquid/Slurry	0.36	3.21	2.62	0.00	0.04	0.01	0.00	0.94	7.18
Solid Storage	0.11	0.37	1.55	0.00	0.03	0.00	0.00	0.03	2.09
An. Lagoon	1.47	0.00	0.49	0.13	0.00	0.00	0.00	0.68	2.77
Drylot	0.25	0.04	0.10	0.00	0.10	0.09	0.00	0.90	1.48
Burned for Fuel	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.96	1.0
Daily Spread	0.11	0.14	0.01	0.00	0.10	0.02	0.00	0.21	0.59
Other	0.58	0.34	0.62	0.02	0.42	0.09	0.09	0.86	3.02
Total	4.18	4.86	6.55	1.31	2.86	1.47	0.67	6.41	28.3

As shown in Exhibit 34, the range of emissions implied by these cases is about 20 Tg/yr to 35 Tg/yr. The high estimate assumptions have the greatest influence on the estimates for Europe, where a large number of liquid/slurry based systems are used. Emissions from Eastern and Western Europe combined increase by almost 6 Tg/yr or by about 50 percent. Because of the widespread use of solid based waste systems, the high case has only a small effect on estimated emissions for North America and Asia, and no effect on the emissions estimate for Latin America, Oceania, Africa, and the Near East and Mediterranean.

On the other hand, the low case estimates are 1.7 Tg/yr or about 40 percent lower for Latin America, Oceania, Africa, and the Near East and Mediterranean; 0.9 Tg/yr or 20 percent lower for North America; and 1.9 Tg/yr or about 15 percent lower for Eastern and Western Europe combined.

The U.S. EPA is currently sponsoring research to verify the estimated MCFs for several key animal waste systems, including: liquid/slurry storage, drylots, and pasture/range. In addition, research is necessary to measure the methane capacity (B_0) of animal waste in developing countries and to improve the characterization of animal waste management systems throughout the world.

While many of the assumptions used to estimate emissions are uncertain, this report provides a framework for estimating emissions and for identifying regions where opportunities are available for reducing emissions. As additional data become available, the estimates presented in this report will be improved.

EXHIBIT 33: BASE, HIGH, AND LOW CASE EMISSION ESTIMATE ASSUMPTIONS			
	Methane Conversion Factors (MCFs)		
Management System	Base Case	High Case	Low Case
Solid Systems			
Pasture/Range	0.10	0.10	0.05
Drylot	0.10	0.10	0.05
Solid Storage	0.10	0.10	0.05
Liquid Systems			
Liquid/Slurry Storage	0.20	0.40	0.20
Pit Storage, less than 1 month	0.10	0.20	0.10
Pit Storage, greater than 1 month	0.20	0.40	0.20
Anaerobic Lagoon	0.90	1.00	0.90

EXHIBIT 34: BASE, HIGH, AND LOW CASE EMISSION ESTIMATES (TG/YR)			
Region	Base Case	High Case	Low Case
North America	4.2	4.7	3.3
Western Europe	4.8	8.1	4.3
Eastern Europe	6.6	9.2	5.2
Oceania	1.3	1.3	0.7
Latin America	2.9	2.9	1.7
Africa	1.5	1.5	0.8
Near East and Mediterranean	0.7	0.7	0.4
Asia & Far East	6.4	7.4	5.0
Total	28.4	35.8	21.4

5. REFERENCES

Agriculture Canada. 1989. **Handbook of Selected Agricultural Statistics - 1988.** January, 1989. Policy Branch, Agriculture Canada, Central Experimental Farm. Ottawa, Ontario K1A-0C5 Canada.

ASAE. 1988. **Manure Production and Characteristics.** ASAE Data: ASAE D384.1. American Society of Agricultural Engineers. St. Joseph, MI 49085-9659.

ASB. 1989a. **Cattle.** Released: February 8, 1989. Agricultural Statistics Board. ERS-NASS, USDA, P.O. Box 1608, Rockville, MD 20850. 15 pp.

ASB. 1989b. **Cattle on Feed.** Released: January 26, 1989. Agricultural Statistics Board. ERS-NASS, USDA, P.O. Box 1608, Rockville, MD 20850. 14 pp.

ASB. 1989c. **Hogs and Pigs.** Released: January 6, 1989. Agricultural Statistics Board. ERS-NASS, USDA, P.O. Box 1608, Rockville, MD 20850. 20 pp.

ASB. 1989d. **Layers and Egg Production, 1988 Summary.** January, 1989. Agricultural Statistics Board. ERS-NASS, USDA, P.O. Box 1608, Rockville, MD 20850. 40 pp.

ASB. 1989e. **Poultry, Production and Value, 1988 Summary.** April, 1989. Agricultural Statistics Board. ERS-NASS, USDA, P.O. Box 1608, Rockville, MD 20850.

ASB. 1989f. **Sheep and Goats.** Released: February 8, 1989. Agricultural Statistics Board. ERS-NASS, USDA, P.O. Box 1608, Rockville, MD 20850. 11 pp.

ASB. 1991. **Cattle on Feed.** Released: October 22, 1991. Agricultural Statistics Board. ERS-NASS, USDA, P.O. Box 1608, Rockville, MD 20850. 16 pp.

Berge, E. 1989. Professor. Agricultural University of Norway. P.O. Box 15, N 1432 AAS NLH. Norway. Completed request for data. November 21, 1989.

Bingemer, H. G. and P. J. Crutzen. 1987. The production of methane from solid wastes. **Journal of Geophysical Research.** 92:2181-2187.

Blake, D. R. and F. S. Rowland. 1986. World-wide increase in tropospheric methane, 1978-1983. **Journal of Atmospheric Chemistry.** 4:43-62.

Blake, D. R. and F. S. Rowland, "Continuing Worldwide Increase in Troposhperhic Methane, 1978 to 1987," Science, March 4, 1988.

Bryant, M. P., V. H. Varel, R. A. Frobish, and H. R. Isaacson. 1976. 347 pp. In: H. G. Schlegel (ed.). **Seminar on Microbial Energy Conversion.** E. Goltz KG. Gottingen, Germany.

Bureau of Census. 1987. **Census of Agriculture.** United States Department of Commerce. U.S. Government Printing Office. Washington, DC 20402.

Caceres, R. and B. Chiliquinga. 1984. Experiences with rural biogas in Latin America. pp. 150-155. In: M. M. El-Halwagi (ed.). **Biogas Technology, Transfer and Diffusion.** Elsevier. New York.

Carter, T. A. 1989. Personal communication with Dr. Thomas A. Carter. Extension Professor of Poultry Science. Poultry Science Department. North Carolina State University. Box 7608. Raleigh, NC 27695-7608.

Chandler, J. A., S. K. Hermes, and K. D. Smith. 1983. A low cost 75-kW covered lagoon biogas system. Presented at the conference on "Energy from Biomass and Wastes VII", Lake Buena Vista, FL. 23 pp.

Chantavorapap, S. 1984. Biogas program of Thailand. pp. 691-694. In: M. M. El-Halwagi (ed.). **Biogas Technology, Transfer and Diffusion.** Elsevier. New York.

Chawla, O.P. 1986. **Advances in Biogas Technology**. Indian Council of Agricultural Research: New Delhi.

Chen, T. H., D. L. Day, and M. P. Steinberg. 1988. Methane production from fresh versus dry dairy manure. **Biological Wastes.** 24:297-306.

Chen, Y. R. 1983. Kinetic analysis of anaerobic digestion of pig manure and its implications. **Agricultural Wastes.** 8:65-81.

Chen, Y. R., V. H. Varel, and A. G. Hashimoto. 1980. Effect of temperature on methane fermentation kinetics of beef-cattle manure. **Biotechnology and Bioengineering Symposium.** 10:325-339.

Cicerone, R. J. and R. S. Oremland. 1988. "Biogeochemical Aspects of Atmospheric Methane," Global Biogeochemical Cycles, December 1988.

Cloete, J. G. 1989. Director: Animal and Dairy Science Research Institute. Private Bag X2. Irene, South Africa 1675. Letter to author (Casada), and completed request for data. December 12, 1989.

Coffey, M. T. 1989. Personal communication with Dr. M. Terry Coffey. Professor of Animal Science. North Carolina State University. Box 7621. Raleigh, NC 27695-7621. October 9, 1989.

Crutzen, P. J. 1983. Atmospheric interactions -- homogeneous gas reactions of C, N, and S containing compounds. pp. 69-112. In: B. Bolin and R. B. Cook (eds.). **The Major Biogeochemical Cycles and Their Interactions.** Wiley. Chichester.

Crutzen, P. J., I. Aselmann, and W. Seiler. 1986. Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. **Tellus.** 38B:271-284.

Crutzen, P. J. and L. T. Gidel. 1983. A two-dimensional photochemical model of the atmosphere. 2: The tropospheric budgets of the anthropogenic chlorocarbons, CO, CH_4, CH_3Cl and the effect of various NO_x sources on tropospheric ozone. **Journal of Geophysical Research** 88:6641- 6661.

Csoma, M. 1981. Different manure handling methods and their inter-action with the building construction and environmental hazards. **Information Bulletin from The FAO European network on Animal Waste Utilization.** Food and Agriculture Organization of the United Nations. Via delle Terme di Caracalla, 00100 Rome, Italy.

Ehhalt, D. H. 1974. The atmospheric cycle of methane. **Tellus.** 26:58-69.

EPA 1987. "Assessing the Risks of Trace Gases That Can Modify the Stratosphere," United States Environmental Protection Agency. Washington, D.C. 1987.

EPA 1989. "Policy Options for Stabilizing Global Climate. Draft Report to Congress," United States Environmental Protection Agency. Washington, D.C. February 1989.

FAO. 1989. **FAO Production Yearbook.** v. 42. Food and Agriculture Organization of the United Nations. Via delle Terme di Caracalla, 00100 Rome, Italy.

Fee, S. 1989. Personal communication with Ms. Sharon Fee, Animal Scientist. U.S. Agency for International Development. Project Development Office. Washington, DC 20523. September 15, 1989.

Fischer, J. R., D. M. Seivers, and D. C. Fulhage. 1975. Anaerobic digestion in swine wastes. pp. 307-316. In: W. J. Jewell (ed.). **Energy, Agriculture and Waste Management.** Ann Arbor Science. Ann Arbor, MI.

Foster, M. P. 1990. Engineer. Department of Agriculture and Rural Affairs. Agricultural Engineering Center. Princes Highway. Werribee, Victoria, 3030 Australia. Completed request for data. January 3, 1990.

Getz, W. R. 1989. Personal communication with William. R. Getz, Animal Scientist. Winrock International Livestock Research and Training Center. Petit Jean Mountain. Morrilton, AK 72110. September 22, 1989.

Getz, W. R. 1990. Correspondence from William. R. Getz, Animal Scientist. Winrock International Livestock Research and Training Center. Petit Jean Mountain. Morrilton, AK 72110. January 17, 1990.

Ghosh, S. 1984. Methane production from farm waste. pp. 372-380. In: M. M. El-Halwagi (ed.). **Biogas Technology, Transfer and Diffusion.** Elsevier. New York.

Goode's World Atlas. 1986. Ed. Edward B. Espenshade, Jr. Rand McNally. Chicago. pp. 10, 39-40.

Gorkhali, H. G. 1984. Summary of the Nepal biogas program. pp. 665-668. In: M. M. El-Halwagi (ed.). **Biogas Technology, Transfer and Diffusion.** Elsevier. New York.

Grove, T. L. 1989. Personal communication with Dr. Thurman L. Grove. U.S. Agency for International Development, Office of Agriculture, Bureau for Science and Technology. Washington, DC 20523. October 16, 1989.

Gunaseelan, V. N. 1987. Parthenium as an additive with cattle manure in biogas production. **Biological Wastes.** 21:195-202.

Hartung, J. 1984. Odour problems in intensive animal husbandry. **Second Information Bulletin from The FAO European network on Animal Waste Utilization.** Food and Agriculture Organization of the United Nations. Via delle Terme di Caracalla, 00100 Rome, Italy.

Harvey, R. W. 1990. Personal communication with Dr. Raymond W. Harvey. Professor of beef cattle nutrition. Animal Science Department, North Carolina State University. Raleigh, NC 27695-7621.

Hashimoto, A. G. 1984. Methane from swine manure: effect of temperature and influent substrate composition on kinetic parameter (k). **Agricultural Wastes.** 9:299-308.

Hashimoto, A. G., V. H. Varel, and Y. R. Chen. 1981. Ultimate methane yield from beef cattle manure; effect of temperature, ration constituents, antibiotics and manure age. **Agricultural Wastes.** 3:241-256.

Hawkes, F. R. and B. V. Young. 1980. Design and operation of laboratory- scale anaerobic digesters: operating experience with poultry litter. **Agricultural Wastes.** 2:119-133.

Hill, D. T. 1982. Design of digestion systems for maximum methane production. **Transactions of the ASAE.** 25(1):226-230.

Hill, D. T. 1984. Methane productivity of the major animal types. **Transactions of the ASAE.** 27(2):530-540.

Hrubant, G.R., R.A. Rhodes, and J.H. Sloneker, "Specific Composition of Representative Feedlot Wastes: A Chemical and Microbial Profile," SEA-NC-59. Northern Regional Research Center, U.S. Department of Agriculture, Peoria, Illinois, 1978.

Iannotti, E. L., J. H. Porter, J. R. Fischer, and D. M. Sievers. 1979. **Developments in Industrial Microbiology.** 20(49):519-520.

Jain, M. K., R. Singh, and P. Tauro. 1981. Anaerobic digestion of cattle and sheep waste. **Agricultural Wastes.** 3:65-73.

Lashof, D. 1989. "The dynamic greenhouse: feedback processes that may influence future concentrations of atmospheric trace gases and climate change. **Climatic Change.** 14:213-242.

JEA and EPA (Japan Environment Agency and United States Environmental Protection Agency) 1990. "Methane Emissions and Opportunities for Control. Workshop Results of Intergovernmental Panel on Climate Change Response Strategies Working Group," September 1990.

Johnson, D. 1989. Personal communication with Dr. Don Johnson. Professor of Animal Science. Colorado State University. Department of Animal Science. Fort Collins, CO 80523. September 11, 1989.

Khalil, M. A. K. and R. Rasmussen. 1983. Sources, Sinks, and seasonal cycles of atmospheric methane. **Journal of Geophysical Research.** 88:5131-5144.

Kroeker, E. J., D. D. Schulte, A. B. Sparling, and J. T. Chieng. 1984. Anaerobic treatment process stability. **Journal WPCF.** 51:718-727.

Lerner, J., E. Matthews, and I Fung. 1988. Methane emission from animals: a global high-resolution data base. **Global Biogeochemical Cycles.** 2(2):139-156. June 1988.

Lichtman, R. J. 1983. **Biogas Systems in India.** VITA. 1815 N. Lynn St, Suite 200, Arlington, VA 22209-2079. p. 2.

Lu, D. 1987. Management and use of organic wastes of rural and urban origin in China. pp. 431-442. In: E. Welte and I. Szabolcs (eds.). **4th International CIEC Symposium, Agricultural Waste Management and Environmental Protection. 1987, 11-14 May, Braunschweig, Fed. Rep. of Germany. Proceedings, Volume 1.**

Mannebeck, H. 1986. Covering manure storing tanks to control odour. pp. 188-193. In: V. C. Nielsen, J. H. Voorburg, and P. L'Hermite (eds.). **Odour Prevention and Control of Organic Sludge and Livestock Farming.** Elsevier. London.

McDowell, R. E. 1977. **Ruminant Products: More than Meat and Milk.** Winrock Report. September, 1977. Winrock International Livestock Research and Training Center. Petit Jean Mountain. Morrilton, AR 72110.

Meat and Dairy Products. May 1988. Commonwealth Secretariat Publications. Marlborough House. London SW4Y 5HX, United Kingdom. 83 pp.

Metcalf & Eddy, Inc. 1972. **Wastewater Engineering: Collection, Treatment, Disposal.** McGraw-Hill Book Company: New York.

Minagawa, H. 1989. Professor. Kitasato University. Sanbongi, Towada, Japan. Completed request for data. December, 1989.

Miner, J. R. 1989. Personal communication with Dr. J. Ronald Miner. Professor. International Research and Development. Oregon State University. Corvallis, OR 97331. October 10, 1989.

Morris, G. R. 1976. Anaerobic fermentation of animal wastes: a kinetic and empirical design fermentation. M. S. Thesis. Cornell University.

Moulik, T. K., J. B. Singh, and S. K. Vyas. 1984. The biogas program in India. pp. 661-664. In: M. M. El-Halwagi (ed.). **Biogas Technology, Transfer and Diffusion.** Elsevier. New York.

NCAER. 1965. **Domestic Fuels in Rural India.** National Council of Applied Economic Research. New Deli, India. As cited in Odend'hal (1972).

Nielsen, V. C. 1989. New European codes and recommendations for farm waste management. **Farm Buildings & Engineering.** 6(1):21-23.

North, M. O. 1978. **Commercial Chicken Production Manual.** AVI. Westport, Connecticut. pp. 344-368.

Odend'hal, S. 1972. Energetics of Indian cattle and their environment. **Human Ecology.** 1(1):3-22.

Oldrich, Dolezal 1989. Federal Ministry of Agriculture and Food. 110 01 Prahal, Tesnov 17, Prague, Czechoslovakia. Completed request for data. December 14, 1989.

O'Rourke, J. 1989. Inspector Gr. III. Department of Agriculture and Food. Agriculture House. Dublin 2, Ireland. Completed request for data. November 29, 1989.

Pathak, B. S., A. k. Jain, and D. S. Dev. 1985. Biogasification of cattle dung and cattle dung-rice straw mixture at different solid concentrations. **Agricultural Wastes.** 13:251-259.

Patni, N. K. 1989. Personal communication with Dr. N. K. Patni. Research Scientist. Agriculture Canada. Animal Research Center, Ottawa, Ontario K1A 0C6. December 29, 1989.

Peters, K. J. 1989. Deputy Director General (Research), International Livestock Center for Africa. P.O. Box 5689. Addis Ababa, Ethiopia. Letter to author (Casada). December 19, 1989.

Preston, T. R. and R. A. Leng. 1987. **Matching Ruminant Production Systems with Available Resources in the Tropics and Sub-tropics.** Penambul Books. Armidale. New South Wales, Australia.

Ramen, P., V. V. Ranga Rao, and V. V. N. Kishore. 1989. A static scum- breaking net for fixed-dome biogas plants. **Biological Wastes.** 30:261- 273.

RAPA. 1987. **Biogas in Asia and the Pacific.** Report of the Regional Expert Consultation on Biogas - Network. Bangkok, Thailand, 28 October - 1 November 1986. RAPA REPORT: 1987/1. Regional Office for Asia and the Pacific (RAPA). Food and Agriculture Organization of the United Nations.

RAPA. 1988. **Bio and Organic Fertilizers: Prospects and Progress in Asia.** Report of the Regional Expert Consultation of the Asian Network on Bio and Organic Fertilizers. Bangkok, Thailand, 6-9 September 1988. RAPA PUBLICATION: 1988/10. Regional Office for Asia and the Pacific (RAPA). Food and Agriculture Organization of the United Nations.

Rasmussen, R. A. and M. A. K. Khalil. 1984. Atmospheric methane in the recent and ancient atmospheres: concentrations, trends, and interhemispheric gradient. **Journal of Geophysical Research.** 89:177- 183.

Safley, L. M., Jr. 1989. Methane production from animal waste management systems. ICF/USEPA Workshop "Methane Emissions from Ruminants." Palm Springs, CA. February 27-28, 1989.

Safley, L. M., Jr. and P. W. Westerman. 1988. Anaerobic lagoon biogas recovery systems. ASAE Paper No. 88-6603. Presented at the 1988 International Winter Meeting of the American Society of Agricultural Engineers, Chicago, IL, December 13-16, 1988. ASAE. St. Joseph, MI 49085-9659.

Schneider, S. H. 1989. The greenhouse effect: science and policy. **Science.** 243:771-781.

Seiler, W. 1984. Contribution of biological processes to the global budget of CH_4 in the atmosphere. pp. 468-477. In: M. J. Klug and C. A. Reddy (eds.). **Current Perspectives in Microbial Ecology.** American Society for Microbiology. Washington.

Sheppard, J. C., H. Westburg, J. F. Hooper, K. Ganesan, and P. Zimmerman. 1982. Inventory of global methane sources and their production rates. **Journal of Geophysical Research.** 87:1305-1312.

Simpson, K. 1986. **Fertilizers and Manures.** Longman Press. London and New York. pp. 2,3.

Singh, R., R. K. Malik, and P. Tauro. 1985. Anaerobic digestion of cattle waste at various retention times: a pilot plant study. **Agricultural Wastes.** 12:313-316.

Smil, V. 1984. The realistic potential of biogas. pp. 45-50. In: M. M. El-Halwagi (ed.). **Biogas Technology, Transfer and Diffusion.** Elsevier. New York.

Sprool, D. 1989. Personal communication with Dr. David Sprool. Professor of Animal Science. University of Georgia. Animal Science Department. Athens, GA. September 19, 1989.

Steele, L. P., P. J. Fraser, R. A. Rasmussen, M. A. K. Khalil, T. J. Conway, A. J. Crawford, R. H. Gammon, K. A. Masarie, and K. W. Thoning. 1987. The global distribution of methane in the troposphere. **Journal of Atmospheric Chemistry.** 5:125-171.

Stevens, M. A. and D. D. Schulte. 1977. Low temperature anaerobic digestion of swine manure. ASAE-NCR Paper 77-1013. Presented at the North Central Region ASAE Meeting. ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659.

Stevens, M. A. and D. D. Schulte. 1979. Low temperature digestion of swine manure. **Journal of the Environmental Engineering Division, ASCE.** 105(EE1): 33-42.

Stuckey, D. C. 1984. Biogas: a global perspective. pp. 18-44. In: M. M. El-Halwagi (ed.). **Biogas Technology, Transfer and Diffusion.** Elsevier. New York.

Summers, R. and S. Bousfield. 1980. A detailed study of piggery-waste anaerobic digestion. **Agricultural Wastes.** 2:61-78.

Taiganides, E. P. 1987. Animal waste management and wastewater treatment. pp. 91-153, In: D. Strauch (ed.). **Animal Production and Environmental Health.** Elsevier. New York.

Taiganides, E. P. and R. L. Stroshine. 1971. Impacts of farm animal production and processing on the total environment. pp. 95-98. In: **Live stock Waste Management and Pollution Abatement. The Proceedings of the International Symposium on Livestock Wastes, April 19-22, 1971, Columbus, Ohio.** ASAE. St. Joseph, MI.

Thompson, A.M. and R.J. Cicerone. 1986. Possible perturbations to atmospheric CO, CH_4, and OH. **Journal of Geophysical Research.** Vol. 91, No. D10, pp. 10853-10864.

Thompson, A.M., M.A. Owens, and R.W. Stewart (1989), "Sensitivity of Tropospheric Hydrogen Peroxide to Global Chemical and Climate Change," Geophysical Research Letters, Vol. 16, p. 53-56.

USDA. 1987. **Agricultural Statistics 1987.** United States Department of Agriculture. U.S. Government Printing Office. Washington, DC 20402.

Verma, S. B., R. A. Britton, M. D. Janson, T. J. Klopfenstein, S. M. Lauda, J. M. Norman, D. D. Schulte, J. M. Skopp, and F. G. Ullman. 1988. Center for Bio-Atmospheric Studies of Trace Gas Dynamics. University of Nebraska. Lincoln, NE 68583. Proposal submitted to the National Science Foundation.

Ward, G. 1989. Personal communication with Dr. Gerald Ward. Professor of Animal Science. Colorado State University. Department of Animal Science. Fort Collins, CO 80523. September 22, 1989.

Webb, A. R. and F. R. Hawkes. 1985. Laboratory scale anaerobic digestion of poultry litter: gas yield-loading rate relationships. **Agricultural Wastes.** 13:31-49.

Yancun, C., H. Cong and Liang Pusen. 1985. Development of a new energy village - Xinbu, China. In Integrated Rural Energy Plannings edited by Y. El Mahgary and A. K. Biswas. Butterworths Publishing, Guildsford, England. pp. 99-108.

APPENDICES

TABLE OF CONTENTS

APPENDIX A: U.S. ANIMAL POPULATIONS

APPENDIX A: U.S. ANIMAL POPULATIONS

The age and weight classifications in the ASB population statistics were as follows:

Beef Cattle: For beef cattle not in feedlots, two weight classes for all states are defined: under 500 lb. and over 500 lb. For feedlot cattle five weight classes for 13 major cattle producing states[1] are defined: under 500 lb.; 500 to 699 lb.; 700 to 899 lb.; 900 to 1099 lb.; and 1100 lb. over. and over.

Dairy Cattle: For dairy cattle, two weight classes for all states: under 500 lb. and over 500 lb.

Swine:[2] For breeding animals, a single weight class is defined for data for all states. For market animals, four weight classes are defined for all states: under 60 lb.; 60 to 119 lb.; 120 to 179 lb.; 180 lb. and over.

Chickens: For layers, five classes are defined for all states:[2] hens one year and older; pullets of laying age; pullets three months old and older, not of laying age; pullets under three months of age; and other chickens (excluding broilers). For broilers, annual production data (1988) for the 34 major producing states was collected and converted to average populations. For other chickens, annual production data (1988) was collected for all states and converted to average populations.

Turkeys Annual production data (1988) for the 32 major producing states were collected and converted to average populations.

Sheep For stock sheep, four weight classes are defined for all states: ewes, one year and older; ewes, lambs less than one year old; rams and wethers, one year and older; rams and wethers, lambs less than one year old. For sheep on feed, data are for most states and for the U.S. total.

Goats Populations are for 50 states from census data (USDA 1987).

The animal populations for all 50 states are summarized in Table A1 for the nine major animal types. The weight class data for cattle on feed in the 13 major producing states[1] can be found in Table A2. All other age class population data are listed by animal type in Tables B1 to B11.

ASSUMED ANIMAL MASS

Many of the animal populations in the ASB (1989a, 1989b, 1989c, 1989d, 1989e, and 1989f) releases were divided into several categories that were not ascribed specific weights. Since livestock produce manure in proportion to their live mass, it was necessary to determine the proper live animal mass for each category in the animal population data. Table A2 shows the average animal weights that were assigned to each of these categories, including the weight classes.

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[1] Arizona, California, Colorado, Idaho, Illinois, Iowa, Kansas, Minnesota, Nebraska, Oklahoma, South Dakota, Texas, and Washington.

[2] December 1, 1988 data.

TABLE A1: U.S. LIVESTOCK AND POULTRY POPULATIONS (1000 HEAD)									
	Beef	Dairy	Swine	Layers	Broilers	Turkeys	Sheep	Goats	Horses
AK	7	3	1	5	0	0	48	0	2
AL	1,761	53	345	14,650	127,779	0	0	11	35
AR	1,682	93	540	21,435	163,060	4,000	0	14	40
AZ	788	112	130	310	0	0	399	100	71
CA	3,675	1,510	120	36,800	38,567	5,889	1,160	29	149
CO	2,675	105	220	3,986	0	0	445	7	79
CT	38	49	7	5,600	0	7	18	1	7
DE	21	11	33	986	39,537	0	0	0	3
FL	1,843	222	140	13,890	22,400	0	0	12	61
GA	1,396	144	1,210	23,587	140,514	533	0	20	34
HI	196	16	43	1,217	411	0	0	1	4
IA	4,440	430	13,900	10,100	545	1,733	448	7	59
ID	1,450	237	80	1,280	0	0	291	3	56
IL	1,750	280	5,600	3,760	0	378	135	8	55
IN	1,110	260	4,300	27,800	0	2,867	151	7	53
KS	5,796	145	1,500	2,250	0	50	164	9	56
KY	2,285	295	1,090	2,250	492	0	32	10	90
LA	987	113	60	2,100	0	0	17	4	39
MA	40	39	31	1,202	0	33	14	3	12
MD	219	152	170	4,821	45,891	30	35	3	27
ME	62	62	8	6,425	0	0	15	1	6
MI	880	502	1,250	7,400	136	667	115	21	57
MN	2,130	1,180	4,690	11,700	6,018	8,556	241	7	54
MO	4,274	316	2,850	7,900	9,909	3,667	139	17	74
MS	1,322	94	237	8,103	65,631	0	0	5	28
MT	2,325	32	245	910	0	0	588	2	72
NC	743	144	2,700	19,755	90,927	10,644	34	9	30
ND	1,501	26	340	255	0	267	189	2	32
NE	5,297	133	4,050	4,150	205	394	121	4	51
NH	34	31	9	309	0	6	11	1	4
NJ	45	42	38	1,850	0	22	46	3	23
NM	1,287	79	26	1,320	0	0	485	135	52
NV	482	109	15	17	0	0	85	1	18
NY	773	1,107	151	5,050	455	76	81	9	53
OH	1,393	543	2,210	23,000	2,182	800	216	17	75
OK	5,093	142	240	4,650	21,982	0	120	70	96
OR	1,296	138	100	3,050	3,145	367	420	11	59
PA	1,201	1,009	970	24,400	23,073	1,756	134	9	65
RI	4	4	6	242	0	0	0	0	1
SC	569	56	450	7,050	12,879	1,238	0	6	17
SD	3,336	182	1,760	1,500	0	527	690	2	45
TN	2,098	282	1,050	2,070	15,818	0	33	29	62
TX	13,345	475	560	18,200	48,418	0	1,730	1,750	233
UT	696	113	33	2,260	0	867	523	2	40
VA	1,528	222	400	4,771	31,954	3,622	115	8	48
VT	127	223	6	209	0	0	17	1	8
WA	1,084	320	53	6,085	5,127	0	82	7	58
WI	2,390	2,535	1,275	4,060	2,382	0	76	9	48
WV	474	36	37	730	6,394	511	199	4	15
WY	1,320	11	21	19	0	0	720	4	48
OTHER	0	0	0	0	26,082	4,278	57	0	0
U.S	89,268	14,416	55,299	355,469	951,914	53,783	10,639	2,396	2,404

TABLE A2: U.S. AVERAGE LIVE ANIMAL MASS

	Mass (kg)
Layers:	
Hens 1 year and older[A]	2.0
Pullets of laying age[A]	1.6
Pullets, 3 months and older, not of laying age[A]	0.9
Pullets under 3 months of age[A]	0.6
Other Poultry:	
Broilers[B]	0.676
Turkeys[B]	3.38
Other chickens, lost[B]	0.37
Other chickens, sold[B]	0.74
Sheep:	
Ewes 1 year and older[A]	86.
Rams and Wethers 1 year and older[A]	82.
Ewe lambs[A]	36.
Ram and wether lambs[A]	39.
Sheep and lambs on feed[A]	25.
Swine:	
Breeding[A]	181.
Market: under 60 lb[A]	14.
60 - 119 lb[A]	41.
120 - 179 lb[A]	68.
180 lb & over[C]	95.
Cattle & Calves:	
Beef cows and heifers that have calved[A]	680.
Milk cows and heifers that have calved[A]	680.
Heifers 500 lb and over for beef cow replacement[A]	391.
Heifers 500 lb and over for milk cow replacement[A]	476.
Steers 500 lb and over[A]	383.
Bulls 500 lb and over[C]	680.
Calves under 500 lb[A]	181.
Steers and steer calves on feed (except 13 major states)[A]	383.
Heifers and heifer calves on feed (except 13 major states)[A]	391.
Cows and others on feed[C]	500.
Goats:	64.
Horses:	450.

[A] Taiganides and Stroshine, 1971.
[B] Calculated from total ASB weight data for type.
[C] Estimated from related data in this table or in ASB data.

APPENDIX B: U.S. ANIMAL WASTE METHANE PRODUCTION

APPENDIX B: U.S. ANIMAL WASTE METHANE PRODUCTION

Tables B1 to B10 list the methane emissions for each major animal type for each state of the U.S. Table B11 lists the total U.S. emissions for donkeys, mules, and ducks. Methane emissions were calculated using Equations 3.1, 3.2, and 3.4 in Chapter 3. The following data were used:

- Volatile Solids (VS) production is calculated with the following data:
  - Number of animals (N) listed in Tables B1 to B10;
  - Typical Animal Mass (TAM) listed in Exhibit 4; and
  - Volatile solids production per unit of animal mass listed in Exhibit 4.
- Maximum Methane Producing Capacity for each animal waste type is shown in Exhibit 8.
- Methane Conversion Factors (MCFs) for each animal waste management system are listed in Exhibit 12.
- Climate Adjustment Factors (CAFs) for each animal waste system in each state are assigned a value of 1.
- Waste System Usage (WS%) for each state and animal are listed in Appendix I.

The following abbreviations are used in tables B1 through B10.

1000 h	=	1000 head
VS	=	volatile solids production (mt/day)
f of B_o	=	Fraction of B_o that is achieved (f of B_o = MCF • CAF). Note: $0 \leq f$ of $B_o \leq 1$.
Rams/Weth.	=	rams and wethers
>3mo.	=	over 3 months of age
<3mo.	=	under 3 months of age
Other chick	=	other chickens for laying purposes
mt	=	Metric ton
Tot	=	Total
Oth	=	Other
Pop.	=	Population

Note: the density of methane is assumed to be 0.662 kg/m^3 (72°F, 1 atm).

TABLE B1: METHANE EMISSIONS FOR U.S. BEEF CATTLE IN FEEDLOTS.

State	1000 head Tot	Steers	Heifers	Oth	Tot Mass (mt)	VS (mt/day)	f of B_0	Methane (mt/year)
AL	40	29	10	1	15,501	112	0.18	903
AR	12	9	3	0	4,650	33	0.10	267
AZ	275	262	13	0	90,064	759	0.10	6,055
CA	485	365	118	2	134,636	1,346	0.10	10,736
CO	885	458	420	7	292,934	2,471	0.18	24,182
FL	15	11	4	0	5,813	42	0.50	342
GA	15	11	4	0	5,813	42	0.12	334
HI	23	17	6	1	8,913	64	0.10	512
IA	640	416	218	6	236,996	1,782	0.11	14,386
ID	238	160	68	10	99,178	669	0.10	5,364
IL	340	179	161	0	130,623	947	0.19	8,712
IN	230	165	60	5	89,134	642	0.15	5,542
KS	1,546	1,050	496	0	584,800	4,291	0.15	38,731
KY	25	18	7	1	9,688	70	0.10	556
LA	9	7	2	0	3,488	25	0.10	200
MD	12	9	3	0	4,650	33	0.16	275
MI	210	151	55	4	81,383	586	0.16	5,322
MN	310	217	90	3	112,864	863	0.11	6,978
MO	95	68	25	2	36,816	265	0.50	2,267
MS	12	9	3	0	4,650	33	0.11	267
MT	90	65	23	2	34,878	251	0.10	2,003
NC	23	17	6	1	8,913	64	0.26	532
ND	40	29	10	1	15,501	112	0.19	645
NE	1,950	1,170	770	10	782,620	5,430	0.12	45,504
NJ	3	2	1	0	1,163	8	0.10	67
NM	130	94	34	3	50,380	363	0.10	2,893
NV	29	21	8	1	11,239	81	0.10	905
NY	19	14	5	0	7,363	53	0.11	423
OH	200	144	52	4	77,507	558	0.15	4,713
OK	305	202	103	0	125,673	847	0.10	6,756
OR	91	65	24	2	35,266	254	0.15	2,082
PA	75	54	20	2	29,065	209	0.10	1,670
SC	20	14	5	0	7,751	56	0.10	445
SD	260	141	109	10	105,798	732	0.27	6,438
TN	20	14	5	0	7,751	56	0.10	445
TX	2,070	1,366	702	2	813,117	5,750	0.10	45,870
UT	48	35	13	1	18,602	134	0.10	1,068
VA	40	29	10	1	15,501	112	0.11	892
WA	190	127	63	0	78,339	528	0.10	4,208
WI	100	72	26	2	38,754	279	0.11	2,231
WV	10	7	3	0	3,875	28	0.10	223
WY	109	78	28	2	42,242	304	0.11	2,435
US	11,239	7,367	3,785	87	4,263,894	31,283		264,384

TABLE B2: METHANE EMISSIONS FOR U.S. BEEF CATTLE NOT IN FEEDLOTS									
	1000 head					Mass	VS		Methane
State	Bulls	Calves	Heifers	Steers	Cows	(mt)	(mt/dy)	f of B_o	(mt/year)
AK	1	2	1	1	3	3,492	25	0.10	103
AL	60	495	200	66	900	845,917	6,091	0.10	25,385
AR	55	400	212	71	932	853,569	6,146	0.10	25,254
AZ	26	156	68	0	263	251,344	1,810	0.10	7,436
CA	70	1,005	702	490	923	1,319,297	9,499	0.10	39,034
CO	45	305	340	332	768	868,141	6,251	0.10	31,517
CT	1	14	16	2	5	13,636	98	0.10	403
DE	1	6	5	6	3	8,059	58	0.10	238
FL	72	423	176	9	148	978,333	7,044	0.10	29,623
GA	50	377	191	63	700	676,954	4,874	0.10	20,054
HI	5	57	30	4	77	79,196	570	0.10	2,343
IA	80	1,040	687	734	1,259	1,648,499	11,869	0.10	49,349
ID	32	320	229	121	510	562,362	4,049	0.10	16,732
IL	35	370	314	171	520	632,637	4,555	0.10	21,591
IN	25	300	180	30	345	387,822	2,792	0.10	12,423
KS	73	1,142	664	921	1,450	1,854,809	13,355	0.10	62,096
KY	73	617	329	182	1,059	1,079,919	7,775	0.10	31,951
LA	34	205	138	20	582	517,161	3,724	0.10	15,301
MA	1	12	13	4	10	16,267	117	0.10	481
MD	7	64	64	12	60	86,688	624	0.10	2,641
ME	2	22	25	4	9	22,769	164	0.10	674
MI	17	270	175	87	121	244,337	1,759	0.10	8,232
MN	42	615	558	218	387	704,707	5,074	0.10	21,147
MO	110	1,135	560	372	2,002	2,003,035	14,422	0.10	63,525
MS	50	325	177	46	712	663,734	4,779	0.10	19,645
MT	75	242	428	168	1,322	1,225,483	8,823	0.10	36,258
NC	26	220	113	18	343	341,674	2,460	0.10	10,514
ND	45	230	238	128	831	779,436	5,612	0.10	23,441
NE	85	930	425	220	1,687	1,623,725	11,691	0.10	50,468
NH	1	13	12	2	6	12,571	91	0.10	372
NJ	2	11	15	3	11	17,828	128	0.10	527
NM	35	250	156	141	575	575,131	4,141	0.10	17,016
NV	13	130	59	9	230	215,789	1,554	0.10	6,384
NY	17	268	348	19	102	272,655	1,963	0.10	8,077
OH	40	384	291	97	381	506,657	3,648	0.10	15,870
OK	105	1,195	687	908	1,893	2,191,316	15,777	0.10	64,834
OR	35	265	214	120	571	589,708	4,246	0.10	17,936
PA	31	380	361	140	214	430,273	3,098	0.10	12,738
RI	0	1	1	0	1	1,396	10	0.10	41
SC	22	143	77	22	286	273,347	1,968	0.10	8,087
SD	73	637	517	353	1,496	1,519,563	10,941	0.10	49,590
TN	60	600	270	111	1,038	1,002,814	7,220	0.10	29,670
TX	410	2,600	1,488	1,334	5,443	5,543,370	39,912	0.10	164,010
UT	21	127	127	59	314	323,035	2,326	0.10	9,558
VA	40	405	230	151	662	698,472	5,029	0.10	20,710
VT	3	50	58	4	12	43,460	313	0.10	1,286
WA	25	175	229	106	359	422,932	3,045	0.10	12,513
WI	33	1,025	856	228	148	730,595	5,260	0.10	21,668
WV	17	90	67	45	245	237,823	1,712	0.10	7,036
WY	40	200	227	77	668	635,416	4,575	0.10	18,872
US	2,221	20,248	13,547	8,430	33,583	36,537,154	263,068		1,114,660

TABLE B3: METHANE EMISSIONS FOR U.S. DAIRY CATTLE							
	1000 head			Mass	VS		Methane
State	Total	Cows	Heifers	(mt)	(mt/day)	f of B_o	(mt/year)
AK	3	2	1	1,578	16	0.35	318
AL	53	39	14	33,184	332	0.48	9,144
AR	93	68	25	58,140	581	0.26	8,854
AZ	112	92	20	72,080	721	0.18	7,527
CA	1,510	1,025	485	927,860	9,279	0.48	226,078
CO	105	75	30	65,280	653	0.11	4,071
CT	49	35	14	30,464	305	0.13	2,293
DE	11	9	2	7,072	71	0.15	595
FL	222	182	40	142,800	1,428	0.11	9,196
GA	144	104	40	89,760	898	0.43	22,209
HI	16	12	4	10,064	101	0.40	2,347
IA	430	310	120	267,920	2,679	0.14	21,760
ID	237	170	67	147,492	1,475	0.26	22,589
IL	280	200	80	174,080	1,741	0.13	13,381
IN	260	180	80	160,480	1,605	0.23	21,413
KS	145	104	41	90,236	902	0.11	5,758
KY	295	215	80	184,280	1,843	0.25	26,192
LA	113	88	25	71,740	717	0.16	6,451
MA	39	30	9	24,684	247	0.10	1,432
MD	152	109	43	94,588	946	0.14	7,765
ME	62	43	19	38,284	383	0.10	2,221
MI	502	345	157	309,332	3,093	0.15	26,469
MN	1,180	810	370	726,920	7,269	0.11	46,388
MO	316	226	90	196,520	1,965	0.56	63,844
MS	94	68	26	58,616	586	0.19	6,410
MT	32	25	7	20,332	203	0.20	2,306
NC	144	107	37	90,372	904	0.15	7,864
ND	109	88	21	69,836	698	0.12	990
NE	133	103	30	84,320	843	0.10	4,867
NH	31	21	10	19,040	190	0.13	1,436
NJ	42	30	12	26,112	261	0.10	1,515
NM	79	63	16	50,456	505	0.82	23,856
NV	26	19	7	16,252	163	0.11	4,659
NY	1,107	811	296	692,376	6,924	0.09	34,142
OH	543	367	176	333,336	3,333	0.15	28,523
OK	142	107	35	89,420	894	0.46	23,733
OR	138	94	44	84,864	849	0.49	23,902
PA	1,009	719	290	626,960	6,270	0.06	19,823
RI	4	2	1	2,156	22	0.10	125
SC	56	41	15	35,020	350	0.74	15,034
SD	182	144	38	116,008	1,160	0.31	20,863
TN	282	202	80	175,440	1,754	0.21	20,865
TX	475	355	120	298,520	2,985	0.35	61,046
UT	113	74	39	68,884	689	0.11	4,196
VA	222	142	80	134,640	1,346	0.16	12,693
VT	223	170	53	140,828	1,408	0.10	8,170
WA	320	216	104	196,384	1,964	0.47	52,977
WI	2,535	1,740	795	1,561,620	15,616	0.08	72,476
WV	36	26	10	22,440	224	0.14	1,836
WY	11	10	1	7,276	73	0.20	825
US	14,416	10,217	4,199	8,946,345	89,463		1,013,428

TABLE B4: METHANE EMISSIONS FOR U.S. SWINE									
	Breeding Pigs	Market Pigs Weight (lb)				Mass	VS		Methane
St.		<60	60-119	120-179	>180	(mt)	(mt/dy)	f of B_o	(mt/yr)
AK	0	0	0	0	0	54	1	0.90	40
AL	48	109	86	65	37	21,675	184	0.83	15,743
AR	76	212	102	87	63	32,807	279	0.67	19,143
AZ	15	44	27	23	21	7,997	68	0.90	6,398
CA	21	42	26	17	14	7,941	68	0.82	5,584
CT	1	2	2	1	1	407	4	0.10	3,937
CO	32	70	48	42	28	14,256	121	0.32	79
DE	7	15	5	4	2	2,144	18	0.33	589
FL	27	52	31	20	10	9,196	78	0.38	2,955
GA	165	420	280	205	140	74,465	633	0.65	42,614
HI	7	15	11	7	3	2,689	23	0.39	906
IA	1,600	4,390	3,260	2,600	2,050	856,270	7,278	0.17	137,057
ID	11	26	18	13	12	5,117	44	0.46	2,044
IL	710	1,760	1,240	1,020	870	356,000	3,026	0.35	108,584
IN	540	1,260	1,060	820	620	273,500	2,325	0.36	87,128
KS	175	500	317	293	215	92,021	782	0.37	30,230
KY	155	410	215	180	130	67,200	571	0.74	43,388
LA	11	15	16	10	8	4,297	37	0.86	3,182
MA	4	9	8	5	5	1,993	17	0.17	292
MD	27	55	40	33	15	10,966	93	0.54	5,122
ME	2	3	1	1	1	585	5	0.17	82
MI	170	350	260	230	240	84,770	721	0.48	35,580
MN	600	1,500	1,060	855	675	295,325	2,510	0.16	41,703
MO	410	895	585	535	425	187,480	1,594	0.74	121,562
MS	38	77	48	38	36	15,928	135	0.64	8,033
MT	32	82	54	47	30	15,200	129	0.13	1,671
NC	320	970	555	465	390	162,925	1,385	0.68	97,364
ND	42	107	75	62	54	21,521	183	0.29	5,529
NE	500	1,380	910	710	550	247,660	2,105	0.43	84,202
NH	2	3	2	1	2	618	5	0.15	78
NJ	3	7	11	8	9	2,491	21	0.17	379
NM	4	9	5	4	4	1,707	15	0.19	282
NV	2	4	3	3	3	1,030	9	0.30	274
NY	21	67	31	16	16	8,618	73	0.20	1,493
OH	295	720	480	395	320	140,415	1,194	0.44	54,599
OK	35	95	50	30	30	14,605	124	0.58	7,350
OR	13	25	23	20	19	6,811	58	0.33	2,019
PA	105	305	229	185	146	59,114	503	0.16	8,446
RI	1	2	2	1	0	357	3	0.17	51
SC	64	153	104	77	52	28,166	239	0.83	20,279
SD	241	562	410	311	236	111,867	951	0.38	27,978
TN	160	380	210	150	150	67,340	572	0.75	43,570
TX	90	188	118	94	70	36,802	313	0.41	13,061
UT	5	12	6	5	5	2,134	18	0.30	557
VA	50	120	80	78	72	26,154	222	0.83	19,265
VT	1	2	2	1	1	377	3	0.17	54
WA	7	18	8	13	7	3,396	29	0.40	1,197
WI	185	415	273	229	173	82,495	701	0.17	12,256
WV	7	10	7	5	8	2,794	24	0.33	784
WY	4	8	5	2	2	1,367	12	0.32	365
US	7,040	17,875	12,399	10,016	7,969	3,471,048	29,504		1,125,080

TABLE B5: METHANE EMISSIONS FOR U.S. CAGED LAYERS.

St.	Pullets >1 yr	Pullets laying	Pullets >3 mo	Pullets <3 mo	Other chick	Mass (mt)	VS (mt/day)	f of B_0	Methane (mt/yr)
AK	3	1	1	0	0	9	0	0.20	2
AL	4,270	5,695	1,855	2,075	755	21,246	255	0.75	15,610
AR	6,138	7,955	3,113	3,198	1,031	30,652	368	0.48	14,510
AZ	200	100	3	1	6	569	7	0.05	28
CA	18,400	13,400	2,200	2,600	200	61,960	744	0.14	8,341
CO	1,570	1,605	310	498	3	6,289	76	0.10	595
CT	2,598	1,590	754	650	8	8,816	106	0.05	435
DE	193	415	235	76	67	1,367	16	0.05	67
FL	7,510	3,830	1,260	1,160	130	23,095	277	0.17	3,804
GA	5,947	12,240	1,981	2,606	813	35,556	427	0.09	3,296
HI	633	372	135	77	0	2,029	24	0.14	1,641
IA	3,620	4,900	740	800	40	16,262	195	0.08	1,203
ID	465	405	245	156	9	1,900	23	0.14	262
IL	1,190	2,000	340	200	30	6,033	72	0.14	803
IN	6,300	15,650	2,450	3,350	50	41,900	503	0.06	2,376
KS	550	1,120	250	320	10	3,318	40	0.05	164
KY	850	960	70	330	40	3,533	42	0.62	2,159
LA	740	640	330	295	95	3,064	37	0.86	2,598
MA	417	541	38	182	24	1,865	22	0.07	126
MD	1,054	2,484	241	970	72	6,946	83	0.05	343
ME	2,737	1,973	874	835	6	9,924	119	0.07	670
MI	2,200	3,600	570	1,000	30	11,300	136	0.08	892
MN	4,500	4,500	1,000	1,645	55	18,137	218	0.09	1,565
MO	3,100	2,800	830	1,100	70	12,150	146	0.08	959
MS	2,918	2,387	1,050	1,332	416	11,774	141	0.80	9,231
MT	285	405	84	131	5	1,377	17	0.10	130
NC	4,710	9,700	2,535	2,050	760	29,136	350	0.34	9,698
ND	132	108	7	4	4	449	5	0.10	44
NE	1,740	1,840	185	370	15	6,826	82	0.05	337
NH	102	10	50	46	3	452	5	0.05	22
NJ	735	965	25	120	5	3,113	37	0.07	21
NM	605	477	123	112	3	2,154	26	0.25	526
NV	9	4	2	1	1	28	0	0.06	2
NY	1,600	2,550	410	470	20	7,949	95	0.10	784
OH	7,000	10,450	2,740	2,780	30	34,881	419	0.05	1,720
OK	1,445	2,310	350	400	145	7,272	87	0.08	574
OR	1,460	1,040	60	470	20	4,938	59	0.16	765
PA	6,700	13,300	1,560	2,710	130	37,827	454	0.10	3,824
RI	128	53	39	21	1	389	5	0.07	26
SC	2,030	3,145	740	1,055	80	10,463	126	0.40	4,076
SD	640	630	95	131	4	2,456	30	0.22	533
TN	730	1,000	150	130	60	3,327	40	0.25	802
TX	7,100	6,600	1,490	2,500	510	28,060	337	0.47	12,868
UT	1,237	631	202	186	4	3,781	45	0.08	280
VA	1,748	1,919	504	433	167	7,430	89	0.09	623
VT	42	116	34	16	1	311	4	0.07	21
WA	2,768	2,106	609	590	12	9,819	118	0.07	629
WI	1,450	1,750	345	490	25	6,327	76	0.12	733
WV	271	196	112	116	35	1,058	13	0.30	313
WY	9	7	1	1	1	32	0	0.10	3
US	122,779	152,573	33,327	40,789	6,001	549,543	6,595		111,223

State	Produce 1000 h	Average Pop.	Mass (Mt)	VS (Mt/day)	f of B_o	Methane (mt/year)
AL	702,784	127,779	88,158	1,499	0.10	12,283
AR	896,832	163,060	112,980	1,921	0.10	15,217
CA	212,119	38,567	29,307	498	0.10	3,759
DE	217,455	39,537	26,854	457	0.10	3,303
FL	123,198	22,400	15,929	271	0.10	2,029
GA	772,825	140,514	97,488	1,657	0.10	12,000
HI	2,261	411	335	6	0.10	44
IA	3,000	545	1,169	20	0.10	119
KY	2,704	492	541	9	0.10	200
MD	252,400	45,891	31,405	534	0.10	3,848
MI	750	136	847	14	0.10	86
MN	33,100	6,018	5,037	86	0.10	606
MO	54,500	9,909	7,509	128	0.10	906
MS	360,971	65,631	45,524	774	0.10	6,603
NC	500,100	90,927	63,303	1,076	0.10	8,342
NE	1,129	205	423	7	0.10	35
NY	2,500	455	953	16	0.10	117
OH	12,000	2,182	3,133	53	0.10	284
OK	120,900	21,982	15,296	260	0.10	1,875
OR	17,300	3,145	2,333	40	0.10	302
PA	126,900	23,073	18,080	307	0.10	2,236
SC	70,832	12,879	9,412	160	0.10	1,417
TN	87,000	15,818	10,923	186	0.10	1,388
TX	266,300	48,418	34,127	580	0.10	4,836
VA	175,748	31,954	22,021	374	0.10	2,707
WA	28,200	5,127	3,981	68	0.10	469
WI	13,100	2,382	2,041	35	0.10	261
WV	35,166	6,394	4,392	75	0.10	559
Other	143,451	26,082	20,779	353	0.10	2,824
U.S.	5,235,605	951,914	674,280	11,463		88,652

TABLE B6: METHANE EMISSIONS FOR U.S. BROILERS.

TABLE B7: METHANE EMISSIONS FOR U.S. TURKEYS						
State	Produced 1000 h	Average Pop.	Mass (mt)	VS (mt/day)	*f* of B_o	Methane (mt/yr)
AR	18,000	4,000	13,520	123	0.10	892
CA	26,500	5,889	19,904	181	0.10	1,313
CT	30	7	23	0	0.10	1
GA	2,400	533	1,803	16	0.10	119
IA	7,800	1,733	5,859	53	0.10	387
IL	1,700	378	1,277	12	0.10	84
IN	12,900	2,867	9,689	88	0.10	639
KS	227	50	171	2	0.10	11
MA	150	33	113	1	0.10	7
MD	135	30	101	1	0.10	7
MI	3,000	667	2,253	21	0.10	149
MN	38,500	8,556	28,918	263	0.10	1,908
MO	16,500	3,667	12,393	113	0.10	818
NC	47,900	10,644	35,978	327	0.10	2,374
ND	1,200	267	901	8	0.10	59
NE	1,772	394	1,331	12	0.10	88
NH	26	6	20	0	0.10	1
NJ	100	22	75	1	0.10	5
NY	343	76	258	2	0.10	17
OH	3,600	800	2,704	25	0.10	178
OR	1,650	367	1,239	11	0.10	82
PA	7,900	1,756	5,934	54	0.10	392
SC	5,570	1,238	4,184	38	0.10	276
SD	2,370	527	1,780	16	0.10	117
UT	3,900	867	2,929	27	0.10	193
VA	16,300	3,622	12,243	111	0.10	808
WV	2,300	511	1,728	16	0.10	114
OTHER	19,250	4,278	14,459	132	0.10	954
U.S.	242,023	53,783	181,786	1,654		11,996

TABLE B8: METHANE EMISSIONS FOR U.S. SHEEP									
	1000 head								
	1 yr & older		under 1 yr.						
St.	Ewes	Rams/ Weth.	Ewes	Rams/ Weth.	On Feed	Mass (mt)	VS (mt/day)	f of B_o	Methane (mt/yr)
AK	1	1	0	0	0	1,325	12	0.10	100
AZ	185	9	26	19	160	22,325	205	0.10	1,090
CA	632	24	100	24	380	70,356	647	0.10	3,330
CO	355	13	64	13	0	34,407	317	0.10	1,450
CT	6	1	1	1	10	872	8	0.10	50
IA	285	12	48	5	98	29,867	275	0.10	1,350
ID	220	6	46	5	14	21,613	199	0.10	930
IL	98	5	19	4	9	9,903	91	0.10	430
IN	68	5	11	2	65	8,357	77	0.10	410
KS	135	8	16	5	0	13,037	120	0.10	550
KY	25	2	4	2	0	2,476	23	0.10	100
LA	12	2	2	1	0	1,298	12	0.10	50
MA	11	1	2	1	0	1,135	10	0.10	50
MA	10	1	2	1	0	1,034	10	0.10	40
MD	23	3	7	2	0	2,554	24	0.10	110
MI	72	4	10	3	26	7,647	70	0.10	350
MN	170	8	40	7	16	17,389	160	0.10	750
MO	87	5	14	3	30	9,263	85	0.10	420
MT	410	14	105	9	50	41,789	385	0.10	1,810
NC	10	1	2	1	21	1,511	14	0.10	100
ND	111	5	22	5	46	12,093	111	0.10	550
NE	97	4	15	3	2	9,377	86	0.10	400
NH	8	1	2	1	0	820	8	0.10	30
NJ	9	1	2	3	31	1,832	17	0.10	110
NM	384	21	70	10	0	37,656	346	0.10	1,590
NV	70	2	12	1	0	6,655	61	0.10	280
NY	52	2	14	13	0	5,647	52	0.10	240
OH	165	7	24	4	16	16,184	149	0.10	700
OK	94	5	14	7	0	9,271	85	0.10	390
OR	280	14	42	14	70	29,036	267	0.10	1,290
PA	91	10	22	11	0	9,867	91	0.10	420
SD	430	12	70	8	170	45,046	414	0.10	2,060
TN	8	1	1	0	23	1,378	13	0.10	80
TX	1,280	70	270	110	0	129,830	1,194	0.10	5,490
UT	405	12	57	6	43	39,175	360	0.10	1,700
VA	95	5	12	3	0	9,129	84	0.10	390
VT	11	1	3	2	0	1,216	11	0.10	50
WA	51	4	14	5	8	5,613	52	0.10	240
WI	60	3	11	2	0	5,880	54	0.10	250
WV	62	3	10	7	117	9,136	84	0.10	500
WY	555	23	125	17	0	54,779	504	0.10	2,310
OTHER	41	4	6	6	0	4,304	40	0.10	180
U.S.	7,173	333	1,337	345	1,450	742,081	6,827		32,739

TABLE B9: METHANE EMISSIONS FOR U.S. GOATS

State	Number 1000 h	Mass (mt)	VS (mt/day)	*f* of B_o	Methane (mt/year)
AK	0	14	0	0.10	1
AL	11	676	6	0.10	26
AR	14	877	8	0.10	34
AZ	100	6,400	61	0.11	262
CA	29	1,837	17	0.10	72
CO	7	467	4	0.10	18
CT	1	86	1	0.10	3
DE	0	30	0	0.10	1
FL	12	760	7	0.11	33
GA	20	1,300	12	0.10	51
HI	1	60	1	0.10	2
IA	7	473	4	0.10	18
ID	3	167	2	0.10	7
IL	8	528	5	0.10	21
IN	7	469	4	0.10	18
KS	9	565	5	0.10	22
KY	10	614	6	0.10	24
LA	4	249	2	0.10	10
MA	3	176	2	0.10	7
MD	3	208	2	0.10	8
ME	1	80	1	0.10	3
MI	21	1,370	13	0.10	53
MN	7	421	4	0.10	16
MO	17	1,105	10	0.10	43
MS	5	341	3	0.10	13
MT	2	127	1	0.10	5
NC	9	548	5	0.10	21
ND	2	103	1	0.10	4
NE	4	279	3	0.10	11
NH	1	92	1	0.10	4
NJ	3	169	2	0.10	7
NM	135	8,640	82	0.10	337
NV	1	86	1	0.10	3
NY	9	599	6	0.10	23
OH	17	1,074	10	0.10	42
OK	70	4,480	43	0.10	175
OR	11	687	7	0.10	27
PA	9	582	6	0.10	23
RI	0	31	0	0.10	1
SC	6	405	4	0.10	16
SD	2	119	1	0.10	5
TN	29	1,868	18	0.10	73
TX	1750	112,000	1,064	0.10	4,372
UT	2	97	1	0.10	4
VA	8	517	5	0.10	20
VT	1	62	1	0.10	2
WA	7	466	4	0.10	18
WI	9	566	5	0.10	22
WV	4	256	2	0.10	10
WY	4	228	2	0.10	9
U.S.	2,396	153,354	1,457		6,002

State	Number 1000 h	Mass (mt)	VS (mt/day)	f of B_o	Methane (mt/year)
AK	2	837	8	0.10	70
AL	35	15,606	156	0.10	1,240
AR	40	18,101	181	0.10	1,440
AZ	71	31,748	318	0.10	2,530
CA	149	66,932	669	0.10	5,340
CO	79	35,482	355	0.10	2,830
CT	7	3,115	31	0.10	250
DE	3	1,363	14	0.10	110
FL	61	27,387	274	0.13	2,730
GA	34	15,332	153	0.10	1,220
HI	4	1,598	16	0.10	130
IA	59	26,702	267	0.10	2,130
ID	56	25,247	253	0.10	2,010
IL	55	24,964	250	0.10	1,990
IN	53	23,704	237	0.10	1,890
KS	56	25,019	250	0.10	2,000
KY	90	40,456	405	0.10	3,230
LA	39	17,423	174	0.10	1,390
MA	12	5,375	54	0.10	430
MD	27	11,931	119	0.10	950
ME	6	2,846	29	0.10	230
MI	57	25,576	256	0.10	2,040
MN	54	24,436	244	0.10	1,950
MO	74	33,496	335	0.10	2,670
MS	28	12,681	127	0.10	1,010
MT	72	32,584	326	0.10	2,600
NC	30	13,476	135	0.10	1,070
ND	32	14,579	146	0.10	1,160
NE	51	23,069	231	0.10	1,840
NH	4	1,819	18	0.10	150
NJ	23	10,420	104	0.10	830
NM	52	23,341	233	0.10	1,860
NV	18	7,973	80	0.10	640
NY	53	24,046	241	0.10	1,920
OH	75	33,921	339	0.10	2,710
OK	96	43,390	434	0.10	3,460
OR	59	26,368	264	0.10	2,100
PA	65	29,341	293	0.10	2,340
RI	1	459	5	0.10	40
SC	17	7,546	76	0.10	600
SD	45	20,378	204	0.10	1,630
TN	62	28,086	281	0.10	2,240
TX	233	104,941	1,049	0.10	8,370
UT	40	17,780	178	0.10	1,420
VA	48	21,686	217	0.10	1,730
VT	8	3,415	34	0.10	270
WA	58	25,978	260	0.10	2,070
WI	48	21,501	215	0.14	2,320
WV	15	6,794	68	0.10	540
WY	48	21,563	216	0.10	1,720
U.S.	2,404	1,081,807	10,818		87,440

TABLE B11: METHANE EMISSIONS FOR U.S. DUCKS, MULES, AND DONKEYS

Animal	Number (1000 head)	Total Mass (mt)	VS (mt/day)	f of B_o	Methane (mt/yr)
Ducks	7,000	9,800	182	0.10	1,405
Mules	1	450	5	0.10	36
Donkeys	4	1,200	12	0.10	96

APPENDIX C: LIVESTOCK CATEGORY WEIGHTS FOR SELECTED COUNTRIES

APPENDIX C: LIVESTOCK CATEGORY WEIGHTS FOR SELECTED COUNTRIES

Data were obtained for livestock populations by age and weight categories for many developed countries from **Meat and Dairy Products** (1988). The appropriate live animal mass assigned to each category was taken from Taiganides and Stroshine (1971), and the average weight for the given animal type was then calculated for each country. These data are summarized in Table C1 and all of the data used are given in Tables C2 through C14. Some of the categories listed by some countries were not assigned a live animal mass in Taiganides and Stroshine (1971); the assumed live animal masses for all cases are included in Tables C2 through C14. Australia was not included in obtaining the average sheep mass to avoid skewing the average from their large sheep population and unusually high average mass. The former Soviet Union was not included in the average cattle mass to avoid skewing the average from their large cattle population combined with their limited detail about their cattle population.

TABLE C1: DEVELOPED COUNTRIES AVERAGE LIVESTOCK MASS (KG)

Country	Cattle	Dairy	Sheep	Pigs
Australia(A)	343	-	72	62
Austria	310	-	59	52
Belgium	393	-	67	60
Denmark	308	-	-	55
France	365	-	-	59
Western Germany	303	-	71	59
Ireland	349	655	72	55
Italy	319	-	-	64
Netherlands	295	-	54	58
South Africa	480	619	-	-
United Kingdom	369	657	66	57
Soviet Union (B)	349	-	-	-
Yugoslavia	383	-	69	66
Mass Weighted Average	361	649	67	59

A Australia excluded from average for sheep.
B As defined before August 1991. Soviet Union excluded from average for cattle.
\- No Data.

Sources: **Meat and Dairy Products** (1988) and Taiganides and Stroshine (1971).

TABLE C2: AUSTRALIA LIVESTOCK DATA 1987			
Livestock	Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE			
Cows & Heifers	10,560	440	4,646,400
Other meat cattle	5,510	318	1,752,180
Calves (under 1 yr)	5.500	181	995,500
Totals:	21,570		7,394,080
Average Weight:		343 kg	
SHEEP			
Ewes (over 1 yr)	81,500	86	7,009,000
Rams/Weth. (> 1 yr)	41,710	82	3,420,220
Lambs and hoggets	35,860	27	968,220
Totals:	159,070		11,397,440
Average Weight:		72 kg	
PIGS			
Breeding sows	350	171	59,850
Others	2,290	45	103,050
Totals:	2,640		162,900
Average Weight:		62 kg	

TABLE C3: AUSTRIA LIVESTOCK DATA 1987			
Livestock	Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE			
Under 3 mo	281	75	21,075
3 mo-1 yr old	559	225	125,775
1-2 yr old	628	400	251,200
Cows over 2 yrs	156	680	106,080
Totals:	1,624		504,130
Average Weight:		310 kg	
SHEEP			
Under 1 yr	112	27	3,024
Over 1 yr	147	84	12,348
Totals:	259		15,372
Average Weight:		59 kg	
PIGS			
Under 2 mo	1,204	11	13,244
2 mo & over	1,821	45	81,945
For slaughtering	502	75	37,650
6 mo & over	406	181	73,486
Totals:	3,933		206,325
Average Weight:		52 kg	

TABLE C4: BELGIUM LIVESTOCK DATA 1987			
Livestock	Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE			
Calves (under 1 yr)	798	181	144,438
Cattle (1-2 yr)	651	400	260,400
Cattle (over 2 yr)	1,531	500	765,500
Totals:	2,980		1,170,338
Average Weight:		393 kg	
SHEEP			
Sheep (under 1 yr)	42	27	1,134
Rams/Weth. (> 1 yr)	6	82	492
Ewes(over 1 yr)	81	86	6,966
Totals:	129		8,592
Average Weight:		67 kg	
PIGS			
Pigs (under 20 kg)	1,558	11	17,138
Pigs (20-50 kg)	1,626	35	56,910
Pigs (Fattening)	2,080	75	156,000
Boars	24	181	4,344
Sows	682	181	123,442
Totals:	5,970		357,834
Average Weight:		60 kg	

TABLE C5: DENMARK LIVESTOCK DATA 1987			
Livestock	Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE			
Calves (under 1 yr)	883	181	159,823
Male (1-2 yr)	55	318	17,490
Female (1-2 yr)	396	420	166,320
Cows/Bulls over 2 yr	182	680	123,760
Totals:	1,516		467,393
Average weight:		308 kg	
PIGS			
Pigs (under 20 kg)	2,730	11	30,030
Pigs (20-50 kg)	2,893	35	101,255
Pigs (Fattening)	2,393	75	179,475
Boars	39	181	7,059
Sows	993	181	179,733
Totals:	9,048		497,552
Average Weight:		55 kg	

TABLE C6: FRANCE LIVESTOCK DATA 1987

Livestock		Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE				
Calves	under 1 yr	5,366	181	971,246
Males	1-2 yr	1,231	318	391,458
Females	1-2 yr	2,848	420	1,196,160
Bulls		608	680	413,440
Cattle	over 2 yr	5,159	500	2,579,500
Totals:		15,212		5,551,804
Average Weight:			365 kg	
PIGS				
Pigs	under 20 kg	2,801	11	30,811
Pigs	20-50 kg	3,451	35	120,785
Pigs	fattening	4,454	75	334,050
Boars		67	181	12,127
Sows		1,142	181	206,702
Totals:		11,915		704,475
Average Weight:			59 kg	

TABLE C7: ITALY LIVESTOCK DATA 1987

Livestock		Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE				
Cattle	under 1 yr	2,511	181	454,491
Male	1-2 yr	903	318	287,154
Female	slaughter	164	420	68,880
Female	breeding	972	420	408,240
Bulls & Steers		113	355	40,115
Heifers	slaughter	48	420	20,160
Heifers	breeding	655	420	275,100
Cows		430	680	292,400
Totals:		5,796		1,846,540
Average Weight:			319 kg	
PIGS				
Boars		46	181	8,326
Pigs	under 20 kg	1,811	11	19,921
Pigs	20-50 kg	1,943	35	68,005
Pigs	over 50 kg	4,797	75	359,775
Sows	in pig	575	181	104,075
Sows	other	155	181	28,055
Other	not in pig	82	115	9,430
Totals:		9,409		597,587
Average Weight:			64 kg	

TABLE C8: WESTERN GERMANY LIVESTOCK DATA 1987

Livestock		Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE				
Cows	over 2 yr	199	680	135,320
Heif.	breed. >2 yr	635	600	381,000
Heif.	slaught.>2 yr	64	500	32,000
Bulls & Steers		161	355	57,155
Cattle	1-2 yr	3,502	400	1,400,800
Cattle	6 mo-1 yr	2,940	250	735,000
Calves	under 6 mo	2,309	100	230,900
Totals:		9,810		2,972,175
Average Weight:			303 kg	
SHEEP				
Ewes	breeding	1,003	86	86,258
Rams	breeding	33	82	2,706
Wethers	and others	35	55	1,925
Sheep	under 1 yr	343	27	9,261
Totals:		1,414		100,150
Average Weight:			71 kg	
PIGS				
Boars		106	181	19,186
Young sows	in pig	331	115	38,065
Other sows	in pig	1,396	181	252,676
Young sows	not in pig	265	115	30,475
Other sows	not in pig	660	181	119,460
Pigs	fattening	8,477	75	635,775
Young pigs	<20 kg	6,558	35	229,530
Young pigs	20-50 kg	5,876	11	64,636
Totals:		23,669		1,389,803
Average Weight:			59 kg	

TABLE C9: IRELAND LIVESTOCK DATA 1987			
Livestock	Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE			
Cows	421	680	286,280
Heifers in calf	50	500	25,000
Bulls breeding	17	680	11,560
OTHER CATTLE			
Male over 2 yr	623	400	249,200
Female over 2 yr	213	500	106,500
Male 1-2 yr	819	318	260,442
Female 1-2 yr	459	420	192,780
Male under 1 yr	727	181	131,587
Female under 1 yr	605	181	109,505
Totals:	3,934		1,372,854
Average Weight:		349 kg	
SHEEP			
Ewes breeding	2,402	86	206,572
Rams breeding	67	82	5,494
Other Sheep	783	27	21,141
Totals:	3,252		233,207
Average Weight:		72 kg	
PIGS			
Gilts in pig	14	115	1,610
Sows in pig	62	181	11,222
Other sows	23	181	4,163
Gilts not served	9	115	1,035
Boars	5	181	905
Other over 80 kg	76	85	6,460
Other 50-80 kg	259	65	16,835
Other 20-50 kg	295	35	10,325
Other under 20 kg	217	11	2,387
Totals:	960		52,555
Average Weight:		55 kg	
DAIRY CATTLE			
Heifers	202	476	96,152
Cows	1,444	680	981,920
Totals:	1,646		1,078,072
Average Weight:		655 kg	

TABLE C10: NETHERLANDS LIVESTOCK DATA 1987

Livestock		Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE				
Calves	under 1 yr	1,449	181	262,269
Male	1-2 yr	164	318	52,152
Female	1-2 yr	712	420	299,040
Bulls	over 2 yr	12	680	8,160
Cows		174	680	181,320
Totals:		2,511		739,941
Average Weight:			295 kg	
SHEEP				
Rams		11	82	902
Ewes		389	86	33,454
Lambs		468	27	12,636
Totals:		868		46,992
Average Weight:			54 kg	
PIGS				
Pigs	under 20 kg	4,913	11	54,043
Pigs	20-50 kg	2,906	35	101,710
Pigs	50-80 kg	2,876	65	186,940
Pigs	over 80 kg	1,927	97	186,919
Boars		58	181	10,498
Sows		1,546	181	279,826
Totals:		14 226		819,936
Average Weight:			58 kg	

TABLE C11: SOUTH AFRICA LIVESTOCK DATA 1987

Livestock		Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE				
Bulls		177	680	120,360
Cows	over 2 yr	3,133	680	2,130,440
Heifers	1-2 yr	996	420	418,320
Calves		1,463	181	264,803
Other	oxen,tollies	930	300	279,000
Totals:		6,699		3,212,923
Average Weight:			480 kg	
DAIRY CATTLE				
Cows		849	680	577,320
Heifers		361	476	171,836
Totals:		1,210		749,156
Average Weight:			619 kg	

TABLE C12: UNITED KINGDOM LIVESTOCK DATA 1987			
Livestock	Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE			
Beef Cows in milk	710	680	482,800
Beef Cows in calf	654	680	444,720
Beef Heifers	221	420	92,820
Bulls over 2 yr	54	680	36,720
Bulls 1-2 yr	18	420	7,560
Other over 2 yr	711	500	355,500
Other 1-2 yr	2,740	400	1,096,000
Other 6 mo-1 yr	1,735	250	433,750
Other under 6 mo	1,564	100	156,400
Totals:	8,407		3,106,270
Average Weight:		369 kg	
SHEEP			
Ewes breeding	17,375	86	1,494,250
Rams in service	487	82	39,934
Other	729	55	40,095
Lambs under 1 yr	9,228	27	249,156
Totals:	27,819		1,823,435
Average Weight:		66 kg	
PIGS			
Sows in pig	536	181	97,016
Gilts in pig	104	115	11,960
Other sows	182	181	32,942
Boars in service	45	181	8,145
Gilts 50 kg & over	79	115	9,085
Barren sows	14	181	2,534
Other over 110 kg	67	115	7,705
Other 80-110 kg	613	95	58,235
Other 50-80 kg	1,822	65	118,430
Other 20-50 kg	2,270	35	79,450
Other under 20 kg	2,183	11	24,013
Totals:	7,915		449,515
Average Weight:		57 kg	
DAIRY CATTLE			
Dairy cows in milk	2,456	680	1,670,080
Cows not in milk	596	680	405,280
Dairy heif.in calf	390	476	185,640
Totals:	3,442		2,261,000
Average Weight:		657 kg	

TABLE C13: SOVIET UNION LIVESTOCK DATA 1987[A]

Livestock		Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE				
Cattle	excl.cows	78,500	300	23,550,000
Cows	assume & heif	42,000	440	18,480,000
Totals:		120,500		42,030,000
Average Weight:			349 kg	

[A] As defined before August 1991.

TABLE C14: YUGOSLAVIA LIVESTOCK DATA 1987

Livestock	Number 1000 h	Weight (kg)	Total Weight (kg)
CATTLE			
Cows & Heifers	2,902	440	1,276,880
Other	1,979	300	593,700
Totals:	4,881		1,870,580
Average Weight:		383 kg	
SHEEP			
Breeding sheep	5,804	84	487,536
Other	2,020	27	54,540
Totals:	7,824		542,076
Average Weight:		69 kg	
PIGS			
Sows	1,385	171	236,835
Other	6,937	45	312,165
Totals:	8,322		549,000
Average Weight:		66 kg	

APPENDIX D: CANADA ANIMAL WASTE METHANE PRODUCTION

APPENDIX D: CANADA ANIMAL WASTE METHANE PRODUCTION

The methane emissions from livestock and poultry manure in Canada were estimated as described in Appendix B for the United States. The estimates for Canada are summarized in Table D1. The livestock populations and other details for Canadian methane emissions are shown in Tables D2 through D8. The waste management system usage for most provinces was determined from a request for data as shown in Figure G1. For most provinces a form was completed by a provincial agricultural specialist. Completed forms were not obtained for Newfoundland, Prince Edward Island, or Saskatchewan. System usage estimates for these provinces was supplied by Patni (1989). The livestock populations were taken from the **Handbook of Selected Agricultural Statistics - 1988** (Agriculture Canada 1989). Methane emissions for each province were calculated using equations B1 and B2.

Abbreviations used in these tables are:

Heif.	=	heifers
Heif. Slaug.	=	heifers for slaughter
f of B_o	=	Percent of B_o that is achieved (*f* of B_o = MCF • CAF).
VS	=	volatile solids produced per day
Meth	=	methane emissions

TABLE D1: CANADA METHANE EMISSIONS SUMMARY

Province	Beef	Dairy	Swine	Sheep	Chick.	Layers	Turkey	Other	Total
Alberta	39,786	8,226	12,002	409	756	542	410	4,350	66,481
British Columbia	7,028	6,387	1,982	114	790	197	387	770	17,656
Manitoba	10,493	4,307	23,753	49	456	446	373	1,150	41,027
New Brunswick	891	1,566	2,438	20	186	58	69	100	5,329
Newfoundland	46	225	202	15	93	123	4	10	720
Nova Scotia	891	1,697	1,212	82	267	65	105	100	4,419
Ontario	18,053	25,770	25,686	455	2,614	1,896	1,352	1,970	77,797
Prince Edward I.	801	1,311	1,530	14	10	46	4	90	3,805
Quebec	13,039	28,670	23,404	262	1,981	740	827	1,420	70,344
Saskatchewan	25,000	3,172	10,790	109	319	280	196	2,730	42,597
Total	116,029	81,332	102,998	1,531	7,472	4,395	3,728	12,690	330,174

Note: "Other" is the sum of goats, ducks, horses, and mules; taken from FAO populations (FAO, 1989). (Weighted among provinces by the same ratios as beef cattle.)

TABLE D2: CANADA METHANE EMISSIONS FROM BEEF CATTLE										
	1000 head									
						Heif.	Mass	VS		Meth
Province	Steers	Calves	Bulls	Cows	Heif.	Slaug.	mt	mt/day	*f* of B_o	mt/year
Alberta	490	1,340	90	1,360	52	274	1,516,734	10,920	0.080	39,786
British Columbia	46	228	15	223	40	24	243,580	1,754	0.080	7,028
Manitoba	95	375	21	380	29	44	400,019	2,880	0.080	10,493
New Brunswick	8	26	2	19	12	4	28,316	204	0.096	891
Newfoundland	<1	2	<1	1	1	<1	1,526	11	0.092	46
Nova Scotia	9	31	2	23	16	6	33,983	245	0.080	891
Ontario	350	540	26	350	240	230	655,450	4,719	0.084	18,053
Prince Edward I.	19	25	1	11	9	8	26,543	191	0.092	801
Quebec	58	374	26	170	248	20	331,398	2,386	0.120	13,039
Saskatchewan	210	760	47	810	20	85	828,735	5,967	0.092	25,000
Total	1,286	3,702	229	3,352	668	695	4,066,284	29,277		116,029

TABLE D3: CANADA METHANE EMISSIONS FROM DAIRY CATTLE MANURE						
	1000 head					
			Mass	VS		Methane
Province	Cows	Heifers	mt	mt/day	*f* of B_o	mt/yr
Alberta	124	52.0	109,072	1,091	0.130	8,226
British Columbia	75	40.0	70,040	700	0.157	6,387
Manitoba	66	29.5	58,922	589	0.126	4,307
New Brunswick	27	12.0	23,936	239	0.113	1,566
Newfoundland	4	0.8	3,237	32	0.120	225
Nova Scotia	34	16.0	30,464	305	0.096	1,697
Ontario	465	240.0	430,440	4304	0.103	25,770
Prince Edward I.	21	9.7	18,829	188	0.120	1,311
Quebec	568	248.0	504,288	5,043	0.098	28,670
Saskatchewan	53	20.0	45,560	456	0.120	3,172
Total	14,365	688.0	1,294,788	12,948		81,331

TABLE D4: CANADA METHANE EMISSIONS FROM SWINE MANURE									
	Breeding Pigs		Market Pigs						
	Boars	Sows	Pigs	Pigs	Pigs	Mass	VS		Methane
Province	1000 h	1000 h	<20 kg	45-60kg	> 60 kg	mt	mt/day	*f* of B_o	mt/yr
Alberta	12	175	488	542	518	103,889	893	0.154	12,002
British Columbia	2	23	71	71	70	13,846	119	0.191	1,982
Manitoba	8	120	353	371	348	70,775	609	0.448	23,753
New Brunswick	<1	10	34	26	25	5,317	46	0.613	2,438
Newfoundland	<1	2	5	6	4	958	8	0.282	202
Nova Scotia	<1	13	40	46	44	8,325	72	0.195	1,212
Ontario	23	355	1,025	1,032	935	198,578	1,708	0.173	25,686
Prince Edward I.	<1	14	42	39	31	7,266	63	0.281	1,530
Quebec	14	284	962	956	864	174,472	1,501	0.179	23,404
Saskatchewan	7	91	247	256	244	50,947	438	0.283	10,790
Total	68	1,086	3,267	3,344	3082	634,373	5,456		102,998

TABLE D5: CANADA METHANE EMISSIONS FROM SHEEP MANURE						
	Sheep (1000 head)		Mass	VS		Methane
Province	>1 yr	<1 yr	mt	mt/day	*f* of B_o	mt/yr
Alberta	88	110	11,572	106	0.08	409
British Columbia	26	28	3,229	30	0.08	114
Manitoba	12	10	1,388	13	0.08	49
New Brunswick	5	4	572	5	0.08	20
Newfoundland	4	4	435	4	0.08	15
Nova Scotia	19	19	2,327	21	0.08	82
Ontario	114	87	12,882	119	0.08	455
Prince Edward I.	3	3	384	4	0.08	14
Quebec	70	41	7,420	68	0.08	262
Saskatchewan	25	26	3,097	28	0.08	109
Total	366	332	43,306	398		1,531

TABLE D6: CANADA METHANE EMISSIONS FROM BROILER MANURE (AND OTHER CHICKENS, EXCEPT LAYERS).					
Province	Broilers & Chickens 1000 h	Mass mt	VS mt/day	f of B_o	Methane mt/yr
Alberta	8,516	7,664	130	0.08	756
British Columbia	8,900	8,010	136	0.08	790
Manitoba	5,137	4,623	79	0.08	456
New Brunswick	2,090	1,881	32	0.08	186
Newfoundland	1,047	942	16	0.08	93
Nova Scotia	3,010	2,709	46	0.08	267
Ontario	29,449	26,504	451	0.08	2,614
Prince Edward I.	116	104	2	0.08	10
Quebec	22,318	20,086	342	0.08	1,981
Saskatchewan	3,595	3,236	55	0.08	319
Total	84178	75,760	1,288		7,472

TABLE D7: CANADA METHANE EMISSIONS FROM CAGED LAYER MANURE					
Province	Layers 1000 h	Mass mt	VS mt/day	f of B_o	Methane mt/yr
Alberta	1,984	3,571	43	0.154	542
British Columbia	2,779	5,002	60	0.040	197
Manitoba	2,513	4,523	54	0.100	446
New Brunswick	514	925	11	0.064	58
Newfoundland	411	740	9	0.169	123
Nova Scotia	912	1,642	20	0.040	65
Ontario	8,615	15,507	186	0.124	1,896
Prince Edward Island	152	274	3	0.169	46
Quebec	3,723	6,701	80	0.112	740
Saskatchewan	933	1,679	20	0.169	280
Total	22,536	40,565	487		4,395

TABLE D8: CANADA METHANE EMISSIONS FROM TURKEY MANURE					
Province	Turkeys 1000 h	Mass mt	VS mt/day	*f* of B_o	Methane mt/yr
Alberta	1,143	7,772	71	0.08	410
British Columbia	1,078	7,330	67	0.08	387
Manitoba	1,040	7,072	64	0.08	373
New Brunswick	193	1,312	12	0.08	69
Newfoundland	12	82	<1	0.08	4
Nova Scotia	293	1,992	18	0.08	105
Ontario	3,766	25,609	233	0.08	1,352
Prince Edward I.	10	68	<1	0.08	4
Quebec	2,304	15,667	143	0.08	827
Saskatchewan	547	3,720	34	0.08	196
Total	10,386	70,625	643		3,728

APPENDIX E: GLOBAL ANIMAL WASTE METHANE PRODUCTION

APPENDIX E: GLOBAL ANIMAL WASTE METHANE PRODUCTION

The methane production rates from animal waste in each country are given in Tables E1 through E14. Methane emissions were calculated using Equations 3.1, 3.2, 3.3, and 3.4 in Chapter 3. The following data are necessary to estimate emissions:

- Volatile Solids (VS) production is calculated with the following data:
  - -- Number of animals (N) listed in Tables E1 to E14;
  - -- Typical Animal Mass (TAM) listed in Exhibit 5;
  - -- Volatile solids production per head listed in Exhibit 6; and
  - -- Volatile solids production per unit of animal mass listed in Exhibit 5.
- Maximum Methane Producing Capacity listed in Exhibit 10.
- Methane Conversion Factors (MCFs) for each waste system listed in Exhibit 12.
- Climate Adjustment Factors (CAFs) for each animal waste system are listed in Exhibit 13. All countries not listed are assigned a CAF of 1.
- Waste System Usage (WS%) information is summarized by region in Exhibits 17 to 23, and 25. Appendix I lists detailed waste system usage for the major animal types for each country of the world. Appendix H lists this information for each state in the U.S.

The following abbreviations are used in the :

1000 h	=	1000 head
VS	=	volatile solids production (mt/day)
f of B_o	=	Fraction of B_o that is achieved (f of B_o = MCF • CAF). Note: $0 \leq f$ of $B_o \leq 1$.

Note: the density of methane is assumed to be 0.662 kg/m^3 (72°F, 1 atm).

TABLE E1: METHANE EMISSIONS FROM NON-DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	*f* of B_o	Methane mt/yr
NORTH AMERICA					
Canada	9,931	235,844	29,277	0.090	116,029
USA	89,268	2,371,156	294,351		1,379,044
Total	99,199	2,607,000	323,628		1,495,073
WESTERN EUROPE					
Austria	1,627	29,200	3,621	0.160	46,213
Belgium	2,002	45,551	5,648	0.135	60,825
Denmark	1,459	26,016	3,226	0.100	25,733
Finland	899	18,789	2,330	0.096	17,841
France	11,863	250,684	31,085	0.160	396,733
Germany (Western)	9,947	174,491	21,637	0.160	276,150
Greece	455	9,509	1,179	0.160	15,067
Ireland	4,136	83,569	10,363	0.125	103,325
Italy	5,774	106,637	13,223	0.181	191,188
Netherlands	2,606	44,508	5,519	0.190	83,645
Norway	599	12,519	1,552	0.140	17,336
Portugal	970	20,273	2,514	0.110	22,058
Spain	3,233	67,570	8,379	0.120	80,202
Sweden	1,102	23,032	2,856	0.148	33,716
Switzerland	1,044	21,820	2,706	0.172	37,014
United Kingdom	8,797	187,932	23,304	0.160	297,421
Total	56,513	1,122,099	139,140		1,704,467
EASTERN EUROPE					
Albania	426	8,903	1,104	0.105	9,269
Bulgaria	1,001	20,921	2,594	0.121	25,139
Czechoslovakia	3,256	68,050	8,438	0.160	107,697
Germany (Eastern)	3,718	77,706	9,636	0.180	138,350
Hungary	1,084	22,656	2,809	0.082	18,286
Poland	5,382	112,484	13,948	0.092	102,360
Romania	5,120	107,008	13,269	0.102	108,081
Soviet Union	78,593	1,587,991	196,911	0.100	1,574,132
Yugoslavia	2,286	50,689	6,285	0.111	55,444
Total	100,866	2,056,408	254,995		2,138,758
OCEANIA					
Australia	21,290	422,774	52,424	0.100	418,177
Fiji	130	1,625	244	0.100	589
New Caledonia	118	2,466	306	0.100	2,439
New Zealand	5,868	122,641	15,208	0.100	121,308
Papua New Guinea	99	1,238	186	0.100	449
Vanuatu	105	1,313	197	0.100	476
Total	27,610	552,057	68,564		543,438

TABLE E1: METHANE EMISSIONS FROM NON-DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
LATIN AMERICA					
Argentina	47,952	599,400	89,910	0.100	217,332
Bolivia	5,375	67,188	10,078	0.100	24,361
Brazil	116,033	1,450,413	217,562	0.100	525,895
Chile	2,731	34,138	5,121	0.100	12,378
Colombia	20,907	261,338	39,201	0.100	94,756
Costa Rica	1,880	23,500	3,525	0.100	8,521
Cuba	4,401	55,013	8,252	0.100	19,947
Dominican Republic	1,904	23,800	3,570	0.100	8,629
Ecuador	3,206	40,075	6,011	0.100	14,531
El Salvador	886	11,075	1,661	0.100	4,016
Guatemala	1,740	21,750	3,263	0.098	7,728
Guyana	158	1,975	296	0.100	716
Haiti	1,450	18,125	2,719	0.100	6,572
Honduras	2,491	31,138	4,671	0.100	11,290
Jamaica	241	3,013	452	0.100	1,092
Mexico	24,800	310,000	46,500	0.100	112,401
Nicaragua	1,520	19,000	2,850	0.100	6,889
Panama	1,393	17,413	2,612	0.100	6,313
Paraguay	7,675	95,938	14,391	0.100	34,785
Peru	3,197	39,963	5,994	0.100	14,490
Puerto Rico	487	6,088	913	0.100	2,207
Uruguay	9,858	123,225	18,484	0.100	44,679
Venezuela	11,486	143,575	21,536	0.100	52,058
Total	271,771	3,397,138	509,571		1,231,586
EAST & SUBSAHARAN AFRICA					
Burundi	280	3,500	525	0.100	1,269
Central African Republic	2,268	28,350	4,253	0.100	10,279
Chad	3,654	45,675	6,851	0.050	8,280
Ethiopia	27,125	339,063	50,859	0.050	61,469
Kenya	7,545	94,313	14,147	0.050	17,098
Mali	4,264	53,300	7,995	0.050	9,663
Mauritania	978	12,225	1,834	0.050	2,216
Niger	2,970	37,125	5,569	0.050	6,730
Rwanda	500	6,250	938	0.100	2,266
Somalia	4,000	50,000	7,500	0.050	9,065
Tanzania	10,700	133,750	20,063	0.100	48,495
Uganda	2,830	35,375	5,306	0.100	12,826
Zaire	1,392	17,400	2,610	0.100	6,309
Total	68,506	856,325	128,449		195,967

TABLE E1: METHANE EMISSIONS FROM NON-DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
WEST & SOUTHERN AFRICA					
Angola	3,105	38,813	5,822	0.100	14,073
Benin	798	9,975	1,496	0.100	3,617
Botswana	2,060	25,750	3,863	0.050	4,668
Burkina Faso	2,348	29,350	4,403	0.050	5,321
Cameroon	4,374	54,675	8,201	0.100	19,824
Cote d'Ivoire	806	10,075	1,511	0.100	3,653
The Gambia	270	3,375	506	0.100	1,224
Ghana	1,105	13,813	2,072	0.100	5,008
Guinea	1,575	19,688	2,953	0.095	6,781
Guinea-Bissau	281	3,513	527	0.100	1,274
Lesotho	445	5,563	834	0.100	2,017
Madagascar	10,541	131,763	19,764	0.100	47,775
Malawi	905	11,313	1,697	0.070	2,871
Mozambique	970	12,125	1,819	0.100	4,396
Namibia	1,881	23,513	3,527	0.050	4,263
Nigeria	10,980	137,250	20,588	0.100	49,764
Senegal	2,348	29,350	4,403	0.100	10,642
Sierra Leone	280	3,500	525	0.100	1,269
South Africa	10,900	302,905	37,560	0.100	299,611
Swaziland	497	6,213	932	0.100	2,253
Togo	252	3,150	473	0.100	1,142
Zambia	2,414	30,175	4,526	0.100	10,941
Zimbabwe	5,557	69,463	10,419	0.100	25,186
Total	64,692	975,305	138,420		527,573
NEAR EAST & MEDITERRANEAN					
Afghanistan	2,430	30,375	4,556	0.050	5,507
Algeria	953	11,913	1,787	0.100	4,319
Egypt	470	5,875	881	0.063	1,331
Iran	6,000	75,000	11,250	0.050	13,597
Iraq	1,220	15,250	2,288	0.058	3,179
Israel	215	4,493	557	0.100	4,445
Jordan	11	138	21	0.050	25
Kuwait	10	125	19	0.100	45
Libya	166	2,075	311	0.050	376
Morocco	1,740	21,750	3,263	0.100	7,886
Oman	94	1,175	176	0.050	213
Saudi Arabia	200	2,500	375	0.050	453
Sudan	19,050	238,125	35,719	0.050	43,170
Syria	420	5,250	788	0.050	952
Tunisia	362	4,525	679	0.050	820
Turkey	7,000	87,500	13,125	0.100	31,726
Yemen Arab Republic	705	8,813	1,322	0.050	1,598
Total	41,046	514,881	77,115		119,643

TABLE E1: METHANE EMISSIONS FROM NON-DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
Bangladesh	19,249	240,613	36,092	0.090	78,518
Bhutan	299	3,738	561	0.090	1,220
Myanmar (Burma)	7,620	95,250	14,288	0.090	31,082
China	71,775	897,188	134,578	0.100	325,305
India	164,000	2,050,000	307,500	0.092	681,973
Indonesia	6,250	78,125	11,719	0.080	22,661
Japan	3,237	67,653	8,389	0.347	232,070
Kampuchea	288	3,600	540	0.090	1,175
North Korea	1,215	15,188	2,278	0.090	4,956
South Korea	2,119	26,488	3,973	0.090	8,644
Laos	552	6,900	1,035	0.090	2,252
Malaysia	582	7,275	1,091	0.098	2,572
Mongolia	1,931	24,138	3,621	0.050	4,376
Nepal	5,699	71,238	10,686	0.090	23,247
Pakistan	13,313	166,413	24,962	0.050	30,169
Philippines	1,685	21,063	3,159	0.075	5,728
Sri Lanka	1,170	14,625	2,194	0.090	4,772
Thailand	4,932	61,650	9,248	0.090	20,118
Viet Nam	2,878	35,975	5,396	0.090	11,740
Total	308,794	3,887,116	581,308		1,492,576
WORLD TOTAL	1,038,997	15,968,328	221,190		9,449,080

TABLE E2: METHANE EMISSIONS FROM DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	*f* of B_o	Methane mt/yr
NORTH AMERICA					
Canada	2,105	111,352	12,948	0.11	81,332
USA	14,416	769,386	89,463	0.20	1,013,428
Total	16,521	880,738	1,02,411		1,094,760
WESTERN EUROPE					
Austria	963	52,965	6,144	0.140	49,900
Belgium	948	52,140	6,048	0.115	40,351
Denmark	807	44,385	5,149	0.162	48,388
Finland	535	29,425	3,413	0.096	19,010
France	9,237	508,035	58,932	0.140	478,638
Germany (Western)	4,940	271,700	31,517	0.140	255,978
Greece	345	18,975	2,201	0.140	17,877
Ireland	1,444	81,281	9,429	0.140	76,578
Italy	3,020	166,100	19,268	0.130	145,311
Netherlands	1,940	106,700	12,377	0.130	93,345
Norway	346	19,030	2,207	0.137	17,591
Portugal	417	22,935	2,660	0.110	16,978
Spain	1,747	96,085	11,146	0.113	72,743
Sweden	565	31,075	3,605	0.108	22,585
Switzerland	793	43,615	5,059	0.097	28,324
United Kingdom	3,052	172,319	19,989	0.140	162,348
Total	31,099	1,716,765	199,145		1,545,944
EASTERN EUROPE					
Albania	246	13,530	1,569	0.100	9,105
Bulgaria	648	35,640	4,134	0.115	27,582
Czechoslovakia	1,788	98,340	11,407	0.090	59,296
Germany (Eastern)	2,003	110,165	12,779	0.115	85,256
Hungary	580	31,900	3,700	0.084	18,032
Poland	4,940	271,700	31,517	0.088	160,901
Romania	2,000	110,000	12,760	0.096	71,064
Soviet Union	42,000	2,310,000	267,960	0.096	1,492,342
Yugoslavia	2,595	142,725	16,556	0.110	105,652
Total	56,800	3,124,000	362,384		2,029,230
OCEANIA					
Australia	2,210	121,550	14,100	0.100	81,798
Fiji	29	452	68	0.100	230
New Caledonia	6	330	38	0.100	222
New Zealand	2,194	120,670	13,998	0.100	81,205
Papua New Guinea	2	31	5	0.100	16
Total	4,441	243,034	28,208		163,470

TABLE E2: METHANE EMISSIONS FROM DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
LATIN AMERICA					
Argentina	2,830	44,148	6,622	0.063	14,006
Bolivia	75	1,170	176	0.098	579
Brazil	18,100	282,360	42,354	0.063	89,582
Chile	640	9,984	1,498	0.055	2,787
Colombia	3,400	53,040	7,956	0.098	26,251
Costa Rica	310	4,836	725	0.098	2,393
Cuba	583	9,095	1,364	0.098	4,501
Dominican Republic	225	3,510	527	0.098	1,737
Ecuador	801	12,496	1,874	0.063	3,964
El Salvador	258	4,025	604	0.098	1,992
Guatemala	400	6,240	936	0.102	3,215
Guyana	52	811	122	0.111	455
Haiti	95	1,482	222	0.098	733
Honduras	333	5,195	779	0.100	2,637
Jamaica	49	764	115	0.098	378
Mexico	6,400	99,840	14,976	0.063	31,675
Nicaragua	180	2,808	421	0.098	1,390
Panama	109	1,700	255	0.075	647
Paraguay	105	1,638	246	0.098	811
Peru	703	10,967	1,645	0.098	5,428
Puerto Rico	92	1,435	215	0.075	546
Uruguay	550	8,580	1,287	0.075	3,267
Venezuela	1,270	19,812	2,972	0.075	7,543
Total	37,560	585,936	87,890		206,519
EAST & SUBSAHARAN AFRICA					
Burundi	60	936	140	0.100	475
Central African Republic	45	702	105	0.100	356
Chad	406	6,334	950	0.053	1,688
Ethiopia	3,875	60,450	9,068	0.053	16,110
Kenya	2,255	35,178	5,277	0.053	9,375
Mali	474	7,394	1,109	0.053	1,971
Mauritania	272	4,243	636	0.053	1,131
Niger	530	8,268	1,240	0.053	2,203
Rwanda	160	2,496	374	0.100	1,267
Somalia	1,000	15,600	2,340	0.053	4,157
Tanzania	2,800	43,680	6,552	0.100	22,173
Uganda	1,080	16,848	2,527	0.100	8,552
Zaire	8	125	19	0.100	63
Total	12,965	202,254	30,338		69,522

TABLE E2: METHANE EMISSIONS FROM DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
WEST & SOUTHERN AFRICA					
Angola	295	4,602	690	0.100	2,336
Benin	116	1,810	271	0.100	919
Botswana	290	4,524	679	0.053	1,206
Burkina Faso	461	7,192	1,079	0.053	1,917
Cameroon	97	1,513	227	0.100	768
Cote d'Ivoire	154	2,402	360	0.100	1,219
The Gambia	30	468	70	0.100	238
Ghana	195	3,042	456	0.100	1,544
Guinea	225	3,510	527	0.100	1,782
Guinea-Bissau	59	920	138	0.100	467
Lesotho	80	1,248	187	0.100	634
Madagascar	59	920	138	0.100	467
Malawi	95	1,482	222	0.100	752
Mozambique	390	6,084	913	0.100	3,088
Namibia	169	2,636	395	0.050	669
Nigeria	1,220	19,032	2,855	0.100	9,661
Senegal	260	4,056	608	0.100	2,059
Sierra Leone	50	780	117	0.100	396
South Africa	920	48,940	5,677	0.052	16,961
Swaziland	153	2,387	358	0.100	1,212
Togo	38	593	89	0.100	301
Zambia	270	4,212	632	0.100	2,138
Zimbabwe	143	2,231	335	0.100	1,132
Total	5,769	124,584	17,024		51,865
NEAR EAST & MEDITERRANEAN					
Afghanistan	1,170	18,252	2,738	0.050	4,633
Algeria	570	8,892	1,334	0.100	4,514
Egypt	1,450	22,620	3,393	0.063	7,176
Iran	2,350	36,660	5,499	0.050	9,305
Iraq	380	5,928	889	0.058	1,730
Israel	106	5,830	676	0.113	4,414
Jordan	18	281	42	0.050	71
Kuwait	16	250	37	0.100	127
Libya	49	764	115	0.050	194
Morocco	1,560	24,336	3,650	0.100	12,353
Oman	42	655	98	0.050	166
Saudi Arabia	125	1,950	293	0.050	495
Sudan	3,450	53,820	8,073	0.050	13,660
Syria	290	4,524	679	0.050	1,148
Tunisia	250	3,900	585	0.050	990
Turkey	5,000	78,000	11,700	0.100	39,594
Yemen Arab Republic	348	5,429	814	0.050	1,378
Total	17,174	272,091	40,615		101,948

TABLE E2: METHANE EMISSIONS FROM DAIRY CATTLE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
Bangladesh	3,540	55,224	8,284	0.095	26,631
Bhutan	110	1,716	257	0.095	828
Myanmar (Burma)	2,380	37,128	5,569	0.095	17,904
China	2,188	34,133	5,120	0.175	30,356
India	29,000	452,400	67,860	0.092	210,700
Indonesia	250	3,900	585	0.170	3,365
Japan	1,430	78,650	9,123	0.605	320,002
Kampuchea	98	1,529	229	0.095	737
North Korea	35	546	82	0.095	263
South Korea	267	4,165	625	0.100	2,114
Laos	38	593	89	0.095	286
Malaysia	43	671	101	0.108	366
Mongolia	595	9,282	1,392	0.058	2,709
Nepal	675	10,530	1,580	0.095	5,078
Pakistan	3,813	59,483	8,922	0.050	15,097
Philippines	15	234	35	0.195	232
Sri Lanka	650	10,140	1,521	0.095	4,890
Thailand	68	1,061	159	0.095	512
Viet Nam	45	702	105	0.095	339
Total	45,240	762,086	111,639		642,408
WORLD TOTAL	227,569	7,911,488	979,654		5,905,665

TABLE E3: METHANE EMISSIONS FROM SWINE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NORTH AMERICA					
Canada	10,847	53,922	5,456	0.22	102,998
USA	55,299	291,568	29,504	0.44	1,125,080
Total	66,146	345,490	34,960		1,228,078
WESTERN EUROPE					
Austria	3,947	17,394	1,757	0.180	34,396
Belgium	5,881	29,903	3,020	0.180	59,135
Denmark	9,214	42,947	4,338	0.162	76,435
Finland	1,309	6,545	661	0.136	9,779
France	12,577	62,885	6,351	0.180	124,357
Germany (Western)	23,670	118,350	11,953	0.180	234,040
Greece	1,190	5,950	601	0.180	11,766
Ireland	960	4,475	452	0.100	4,916
Italy	9,383	50,891	5,140	0.180	100,638
Netherlands	14,226	69,924	7,062	0.174	133,668
Norway	788	3,940	398	0.152	6,579
Portugal	2,800	14,000	1,414	0.140	21,533
Spain	16,941	84,705	8,555	0.160	148,895
Sweden	2,217	11,085	1,120	0.160	19,485
Switzerland	1,941	9,705	980	0.198	21,111
United Kingdom	7,915	38,233	3,862	0.180	75,608
Total	114,959	570,932	57,664		1,082,342
EASTERN EUROPE					
Albania	214	1,070	108	0.120	1,411
Bulgaria	4,034	20,170	2,037	0.120	26,591
Czechoslovakia	7,235	36,175	3,654	0.234	92,839
Germany (Eastern)	12,503	62,515	6,314	0.292	200,547
Hungary	8,216	41,080	4,149	0.694	313,393
Poland	19,605	98,025	9,901	0.088	94,770
Romania	15,224	76,120	7,688	0.096	80,282
Soviet Union	77,403	387,015	39,089	0.096	408,177
Yugoslavia	8,323	46,552	4,702	0.140	71,601
Total	152,757	768,722	77,641		1,289,612
OCEANIA					
Australia	2,720	14,292	1,443	0.740	116,188
Fiji	29	119	12	0.100	84
New Caledonia	47	235	24	0.740	1,911
New Zealand	428	2,140	216	0.740	17,398
Papua New Guinea	1,700	6,970	704	0.100	4,935
Vanuatu	79	324	33	0.100	229
Total	5,003	24,079	2,432		140,744

TABLE E3: METHANE EMISSIONS FROM SWINE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
LATIN AMERICA					
Argentina	4,100	16,810	1,698	0.110	13,092
Bolivia	1,750	7,175	725	0.100	5,080
Brazil	32,700	134,070	13,541	0.110	104,414
Chile	1,360	5,576	563	0.054	2,112
Colombia	2,586	10,603	1,071	0.100	7,507
Costa Rica	223	914	92	0.100	647
Cuba	2,500	10,250	1,035	0.100	7,257
Dominican Republic	409	1,677	169	0.100	1,187
Ecuador	4,160	17,056	1,723	0.110	13,283
El Salvador	442	1,812	183	0.100	1,283
Guatemala	875	3,588	362	0.100	2,540
Guyana	185	759	77	0.097	518
Haiti	900	3,690	373	0.100	2,613
Honduras	600	2,460	248	0.100	1,742
Jamaica	250	1,025	104	0.100	726
Mexico	16,500	67,650	6,833	0.110	52,686
Nicaragua	745	3,055	309	0.100	2,163
Panama	240	984	99	0.110	766
Paraguay	2,108	8,643	873	0.100	6,119
Peru	2,400	9,840	994	0.100	6,967
Puerto Rico	195	800	81	0.110	623
Uruguay	215	882	89	0.110	687
Venezuela	2,707	11,099	1,121	0.110	8,644
Total	78,150	320,415	32,362		242,654
EAST & SUBSAHARAN AFRICA					
Burundi	80	328	33	0.105	244
Central African Republic	382	1,566	158	0.105	1,164
Chad	12	49	5	0.058	20
Ethiopia	19	78	8	0.058	32
Kenya	102	418	42	0.058	170
Mali	60	246	25	0.100	174
Niger	37	152	15	0.058	62
Rwanda	92	377	38	0.105	280
Somalia	10	41	4	0.058	17
Tanzania	184	754	76	0.105	561
Uganda	440	1,804	182	0.105	1,341
Zaire	800	3,280	331	0.105	2,438
Total	2,218	9,094	918		6,503

TABLE E3: METHANE EMISSIONS FROM SWINE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
WEST & SOUTHERN AFRICA					
Angola	480	1,968	199	0.105	1,463
Benin	648	2,657	268	0.105	1,975
Botswana	9	37	4	0.058	15
Burkina Faso	500	2,050	207	0.058	835
Cameroon	1,178	4,830	488	0.105	3,590
Cote d'Ivoire	450	1,845	186	0.105	1,372
The Gambia	13	53	5	0.105	40
Guinea	50	205	21	0.105	152
Guinea-Bissau	290	1,189	120	0.105	884
Lesotho	72	295	30	0.105	219
Madagascar	1,400	5,740	580	0.105	4,267
Malawi	210	861	87	0.200	1,219
Mozambique	160	656	66	0.105	488
Namibia	48	197	20	0.050	70
Nigeria	1,300	5,330	538	0.105	3,962
Senegal	470	1,927	195	0.105	1,433
Sierra Leone	50	205	21	0.105	152
South Africa	1,460	7,300	737	0.075	6,015
Swaziland	19	78	8	0.105	58
Togo	300	1,230	124	0.105	914
Zambia	180	738	75	0.105	549
Zimbabwe	190	779	79	0.105	579
Total	10,227	43,245	4,368		32,537
NEAR EAST & MEDITERRANEAN					
Algeria	5	21	2	0.115	17
Egypt	15	62	6	0.088	38
Israel	130	650	66	0.155	1,107
Morocco	9	37	4	0.115	30
Syria	1	4	0	0.073	2
Tunisia	4	16	2	0.073	8
Turkey	10	41	4	0.115	33
Total	174	830	84		1,236

TABLE E3: METHANE EMISSIONS FROM SWINE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
Bhutan	63	258	26	0.135	247
Myanmar (Burma)	3,000	12,300	1,242	0.135	11,756
China	334,862	1,372,934	138,666	0.143	1,388,076
India	10,300	42,230	4,265	0.100	29,899
Indonesia	6,500	26,650	2,692	0.140	26,416
Japan	11,354	56,770	5,734	0.341	212,554
Kampuchea	1,500	6,150	621	0.135	5,878
North Korea	3,100	12,710	1,284	0.135	12,148
South Korea	4,281	17,552	1,773	0.150	18,640
Laos	1,520	6,232	629	0.135	5,957
Malaysia	2,200	9,020	911	0.130	8,286
Mongolia	80	328	33	0.103	238
Nepal	479	1,964	198	0.135	1,877
Philippines	7,580	31,078	3,139	0.130	28,604
Sri Lanka	101	414	42	0.135	396
Thailand	4,260	17,466	1,764	0.135	16,694
Viet Nam	12,051	49,409	4,990	0.135	47,225
Total	403,231	1,663,466	168,010		1,814,892
WORLD TOTAL	832,865	3,746,273	378,439		5,838,598

TABLE E4: METHANE EMISSIONS FROM SHEEP WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NORTH AMERICA					
Canada	697	1,732	398	0.08	1,531
USA	10,639	29,683	6,827	0.10	32,739
Total	11,336	31,415	7,225		34,270
WESTERN EUROPE					
Austria	24	57	13	0.100	60
Belgium	184	497	114	0.100	525
Denmark	128	346	79	0.100	365
Finland	63	170	39	0.080	144
France	10,360	27,972	6,434	0.100	29,548
Germany (Western)	1,414	4,046	931	0.100	4,274
Greece	10,816	29,203	6,717	0.100	30,848
Ireland	4,301	12,479	2,870	0.100	13,182
Italy	11,457	30,934	7,115	0.100	32,676
Netherlands	1,100	2,394	551	0.100	2,529
Norway	2,306	6,226	1,432	0.110	7,235
Portugal	5,220	14,094	3,242	0.100	14,888
Spain	17,894	48,314	11,112	0.100	51,035
Sweden	402	1,085	250	0.040	459
Switzerland	367	991	228	0.100	1,047
United Kingdom	27,820	73,993	17,018	0.100	78,161
Total	93,856	252,801	58,144		266,973
EASTERN EUROPE					
Albania	1,432	3,866	889	0.100	4,084
Bulgaria	8,886	23,992	5,518	0.100	25,344
Czechoslovakia	1,075	2,903	668	0.080	2,453
Germany (Eastern)	2,656	7,171	1,649	0.100	7,575
Hungary	2,333	6,299	1,449	0.080	5,323
Poland	4,377	11,818	2,718	0.080	9,987
Romania	18,793	50,741	11,670	0.080	42,879
Soviet Union	140,783	380,114	87,426	0.080	321,219
Yugoslavia	7,824	21,755	5,004	0.100	22,981
Total	188,159	508,660	116,992		441,845
OCEANIA					
Australia	164,000	475,845	109,444	0.050	251,323
New Caledonia	3	8	2	0.100	9
New Zealand	64,970	175,419	40,346	0.100	185,299
Papua New Guinea	9	14	3	0.100	10
Total	228,982	651,286	149,796		436,642

TABLE E4: METHANE EMISSIONS FROM SHEEP WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
LATIN AMERICA					
Argentina	29,202	46,723	10,746	0.100	33,769
Bolivia	9,600	15,360	3,533	0.100	11,101
Brazil	20,000	32,000	7,360	0.100	23,128
Chile	6,540	10,464	2,407	0.100	7,563
Colombia	2,652	4,243	976	0.100	3,067
Costa Rica	6	10	2	0.100	7
Cuba	382	611	141	0.100	442
Dominican Republic	100	160	37	0.100	116
Ecuador	1,707	2,731	628	0.100	1,974
El Salvador	5	8	2	0.100	6
Guatemala	660	1,056	243	0.098	744
Guyana	120	192	44	0.100	139
Haiti	94	150	35	0.100	109
Honduras	7	11	3	0.100	8
Jamaica	3	5	1	0.100	3
Mexico	6,000	9,600	2,208	0.100	6,938
Nicaragua	3	5	1	0.100	3
Paraguay	430	688	158	0.100	497
Peru	13,320	21,312	4,902	0.100	15,403
Puerto Rico	7	11	3	0.100	8
Uruguay	26,049	41,678	9,586	0.100	30,123
Venezuela	425	680	156	0.100	491
Total	117,312	187,699	43,171		135,640
EAST & SUBSAHARAN AFRICA					
Burundi	350	560	129	0.100	405
Central African Republic	120	192	44	0.100	139
Chad	2,245	3,592	826	0.050	1,298
Ethiopia	23,400	37,440	8,611	0.050	13,530
Kenya	7,300	11,680	2,686	0.050	4,221
Mali	5,500	8,800	2,024	0.060	3,816
Mauritania	4,100	6,560	1,509	0.050	2,371
Niger	3,500	5,600	1,288	0.050	2,024
Rwanda	360	576	132	0.100	416
Somalia	13,500	21,600	4,968	0.050	7,806
Tanzania	47,400	75,840	17,443	0.100	54,813
Uganda	1,740	2,784	640	0.100	2,012
Zaire	880	1,408	324	0.100	1,018
Total	110,395	176,632	40,625		93,868

TABLE E4: METHANE EMISSIONS FROM SHEEP WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
WEST & SOUTHERN AFRICA					
Angola	265	424	98	0.100	306
Benin	860	1,376	316	0.100	995
Botswana	220	352	81	0.050	127
Burkina Faso	2,972	4,755	1,094	0.050	1,718
Cameroon	2,897	4,635	1,066	0.100	3,350
Cote d'Ivoire	1,500	2,400	552	0.100	1,735
The Gambia	200	320	74	0.100	231
Ghana	2,500	4,000	920	0.100	2,891
Guinea	460	736	169	0.100	532
Guinea-Bissau	205	328	75	0.100	237
Lesotho	1,440	2,304	530	0.100	1,665
Madagascar	611	978	225	0.100	707
Malawi	210	336	77	0.100	243
Mozambique	119	190	44	0.100	138
Namibia	6,400	10,240	2,355	0.050	3,700
Nigeria	13,200	21,120	4,858	0.100	15,264
Senegal	3,792	6,067	1,395	0.100	4,385
Sierra Leone	330	528	121	0.100	382
South Africa	29,800	80,460	18,506	0.050	42,496
Swaziland	35	56	13	0.100	40
Togo	100	160	37	0.100	116
Zambia	80	128	29	0.100	93
Zimbabwe	580	928	213	0.100	671
Total	68,776	142,822	32,849		82,022
NEAR EAST & MEDITERRANEAN					
Afghanistan	17,000	27,200	6,256	0.050	9,829
Algeria	14,325	22,920	5,272	0.050	8,283
Egypt	1,165	1,864	429	0.050	674
Iran	34,500	55,200	12,696	0.050	19,948
Iraq	9,200	14,720	3,386	0.050	5,319
Israel	280	756	174	0.100	799
Jordan	1,220	1,952	449	0.050	705
Kuwait	300	480	110	0.100	347
Libya	5,750	9,200	2,116	0.050	3,325
Morocco	15,700	25,120	5,778	0.100	18,155
Oman	218	349	80	0.050	126
Saudi Arabia	7,466	11,946	2,747	0.050	4,317
Sudan	18,500	29,600	6,808	0.050	10,697
Syria	13,304	21,286	4,896	0.050	7,692
Tunisia	5,900	9,440	2,171	0.050	3,411
Turkey	40,000	64,000	14,720	0.100	46,256
Yemen Arab Republic	2,674	4,278	984	0.050	1,546
Total	187,502	300,311	69,072		141,429

TABLE E4: METHANE EMISSIONS FROM SHEEP WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
Bangladesh	140	224	52	0.100	162
Bhutan	27	43	10	0.100	31
Myanmar (Burma)	295	472	109	0.100	341
China	102,655	164,248	37,777	0.100	118,710
India	51,684	82,694	19,020	0.100	59,767
Indonesia	5,415	8,664	1,993	0.200	12,524
Japan	29	78	18	0.100	83
Kampuchea	1	2	0	0.100	1
North Korea	372	595	137	0.100	430
South Korea	3	5	1	0.100	3
Malaysia	99	158	36	0.090	103
Mongolia	13,234	21,174	4,870	0.063	9,565
Nepal	833	1,333	307	0.100	963
Pakistan	27,479	43,966	10,112	0.050	15,888
Philippines	30	48	11	0.060	21
Sri Lanka	28	45	10	0.100	32
Thailand	95	152	35	0.100	110
Viet Nam	23	37	8	0.100	27
Total	202,442	323,939	74,506		218,762
WORLD TOTAL	1,208,760	2,575,565	592,379		1,851,450

TABLE E5: METHANE EMISSIONS FROM GOAT WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NORTH AMERICA					
Canada	26	68	18	0.100	74
USA	2,396	6,288	1,457	0.100	6,002
Total	2,422	6,356	1,475		6,076
WESTERN EUROPE					
Austria	34	88	24	0.100	97
Belgium	8	21	6	0.100	23
Finland	3	8	2	0.080	7
France	1,150	2,990	795	0.100	3,268
Germany (Western)	46	120	32	0.100	131
Greece	3,488	9,069	2,412	0.100	9,913
Ireland	9	23	6	0.100	26
Italy	1,206	3,136	834	0.100	3,427
Netherlands	34	88	24	0.100	97
Norway	94	244	65	0.134	357
Portugal	745	1,937	515	0.100	2,117
Spain	2,900	7,540	2,006	0.100	8,242
Switzerland	72	187	50	0.091	187
United Kingdom	58	151	40	0.100	165
Total	9,847	25,602	6,810		28,055
EASTERN EUROPE					
Albania	979	2,545	677	0.100	2,782
Bulgaria	428	1,113	296	0.100	1,216
Czechoslovakia	50	130	35	0.080	114
Germany (Eastern)	19	49	13	0.100	54
Hungary	16	42	11	0.080	36
Poland	10	26	7	0.080	23
Romania	990	2,574	685	0.080	2,251
Soviet Union	6,400	16,640	4,426	0.080	14,551
Yugoslavia	126	328	87	0.100	358
Total	9,018	23,447	6,237		21,385
OCEANIA					
Australia	600	1,560	415	0.050	853
Fiji	60	108	29	0.100	90
New Caledonia	21	55	15	0.100	60
New Zealand	1,317	3,424	911	0.100	3,743
Papua New Guinea	12	22	6	0.100	18
Vanuatu	12	22	6	0.100	18
Total	2,022	5,190	1,381		4,782

TABLE E5: METHANE EMISSIONS FROM GOAT WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
LATIN AMERICA					
Argentina	3,200	5,760	1,532	0.100	4,815
Bolivia	2,350	4,230	1,125	0.100	3,536
Brazil	11,000	19,800	5,267	0.100	16,550
Chile	600	1,080	287	0.100	903
Colombia	932	1,678	446	0.100	1,402
Costa Rica	10	18	5	0.100	15
Cuba	110	198	53	0.100	166
Dominican Republic	534	961	256	0.100	803
Ecuador	301	542	144	0.100	453
El Salvador	15	27	7	0.100	23
Guatemala	76	137	36	0.098	111
Guyana	77	139	37	0.100	116
Haiti	1,200	2,160	575	0.100	1,805
Honduras	25	45	12	0.100	38
Jamaica	440	792	211	0.100	662
Mexico	10,500	18,900	5,027	0.100	15,798
Nicaragua	6	11	3	0.100	9
Panama	7	13	3	0.100	11
Paraguay	138	248	66	0.100	208
Peru	1,700	3,060	814	0.100	2,558
Puerto Rico	14	25	7	0.100	21
Uruguay	14	25	7	0.100	21
Venezuela	1,400	2,520	670	0.100	2,106
Total	34,649	62,368	16,590		52,129
EAST & SUBSAHARAN AFRICA					
Burundi	750	1,350	359	0.100	1,128
Central African Republic	1,159	2,086	555	0.100	1,744
Chad	2,245	4,041	1,075	0.050	1,689
Ethiopia	17,500	31,500	8,379	0.050	13,165
Kenya	8,500	15,300	4,070	0.050	6,394
Mali	5,500	9,900	2,633	0.060	4,965
Mauritania	3,200	5,760	1,532	0.050	2,407
Niger	7,550	13,590	3,615	0.050	5,680
Rwanda	1,200	2,160	575	0.100	1,805
Somalia	20,000	36,000	9,576	0.050	15,046
Tanzania	6,600	11,880	3,160	0.100	9,930
Uganda	2,800	5,040	1,341	0.100	4,213
Zaire	3,040	5,472	1,456	0.100	4,574
Total	80,044	144,079	38,325		72,741

TABLE E5: METHANE EMISSIONS FROM GOAT WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	*f* of B_o	Methane mt/yr
WEST & SOUTHERN AFRICA					
Angola	975	1,755	467	0.100	1,467
Benin	960	1,728	460	0.100	1,444
Botswana	1,100	1,980	527	0.050	828
Burkina Faso	5,198	9,356	2,489	0.050	3,910
Cameroon	2,906	5,231	1,391	0.100	4,372
Cote d'Ivoire	1,500	2,700	718	0.100	2,257
The Gambia	200	360	96	0.100	301
Ghana	3,000	5,400	1,436	0.100	4,514
Guinea	460	828	220	0.100	692
Guinea-Bissau	210	378	101	0.100	316
Lesotho	1,030	1,854	493	0.100	1,550
Madagascar	1,080	1,944	517	0.100	1,625
Malawi	950	1,710	455	0.100	1,429
Mozambique	375	675	180	0.100	564
Namibia	2,500	4,500	1,197	0.050	1,881
Nigeria	26,000	46,800	12,449	0.000	0
Senegal	1,150	2,070	551	0.100	1,730
Sierra Leone	180	324	86	0.100	271
South Africa	5,840	15,184	4,039	0.050	8,299
Swaziland	320	576	153	0.100	481
Togo	900	1,620	431	0.100	1,354
Zambia	420	756	201	0.100	632
Zimbabwe	1,650	2,970	790	0.100	2,483
Total	58,904	110,699	29,446		42,400
NEAR EAST & MEDITERRANEAN					
Afghanistan	2,800	5,040	1,341	0.050	2,106
Algeria	3,570	6,426	1,709	0.050	2,686
Egypt	1,620	2,916	776	0.050	1,219
Iran	13,620	24,516	6,521	0.050	10,246
Iraq	1,550	2,790	742	0.050	1,166
Israel	128	333	89	0.100	364
Jordan	460	828	220	0.050	346
Kuwait	20	36	10	0.100	30
Libya	965	1,737	462	0.050	726
Morocco	5,800	10,440	2,777	0.100	8,727
Oman	712	1,282	341	0.050	536
Saudi Arabia	3,600	6,480	1,724	0.050	2,708
Sudan	13,500	24,300	6,464	0.050	10,156
Syria	1,078	1,940	516	0.050	811
Tunisia	1,115	2,007	534	0.050	839
Turkey	13,100	23,580	6,272	0.100	19,710
Yemen Arab Republic	1,079	1,942	517	0.050	812
Total	64,717	116,593	31,014		63,186

TABLE E5: METHANE EMISSIONS FROM GOAT WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
Bangladesh	10,700	19,260	5,123	0.100	16,099
Bhutan	32	58	15	0.100	48
Myanmar (Burma)	1,100	1,980	527	0.100	1,655
China	77,894	140,209	37,296	0.100	117,197
India	105,000	189,000	50,274	0.100	157,980
Indonesia	12,700	22,860	6,081	0.200	38,216
Japan	41	107	28	0.100	117
Kampuchea	1	2	0	0.100	2
North Korea	285	513	136	0.100	429
South Korea	166	299	79	0.100	250
Laos	76	137	36	0.100	114
Malaysia	347	625	166	0.100	522
Mongolia	4,388	7,898	2,101	0.053	3,466
Nepal	5,125	9,225	2,454	0.100	7,711
Pakistan	33,018	59,432	15,809	0.050	24,839
Philippines	2,120	3,816	1,015	0.098	3,110
Sri Lanka	503	905	241	0.100	757
Thailand	80	144	38	0.100	120
Viet Nam	414	745	198	0.100	623
Total	253,990	457,215	121,619		373,255
WORLD TOTAL	515,613	951,549	252,896		664,009

TABLE E6: METHANE EMISSIONS FROM CHICKEN WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NORTH AMERICA					
Canada	106,714	6,894	1,775	0.086	11,867
USA	1,307,383	92,648	58,198	0.044	199,875
Total	1,414,097	99,542	59,973		211,742
WESTERN EUROPE					
Austria	15,000	1,500	291	0.100	2,245
Belgium	34,000	3,400	660	0.150	7,669
Denmark	15,000	1,500	291	0.100	2,246
Finland	6,000	600	116	0.105	942
France	189,000	18,900	3,667	0.100	28,297
Germany (Western)	72,000	7,200	1,397	0.100	10,780
Greece	31,000	3,100	601	0.100	4,641
Ireland	7,000	700	136	0.098	1,026
Italy	120,000	12,000	2,328	0.077	13,857
Netherlands	98,000	9,800	1,901	0.121	17,757
Norway	4,000	400	78	0.105	628
Portugal	18,000	1,800	349	0.091	2,452
Spain	55,000	5,500	1,067	0.098	8,063
Sweden	11,000	1,100	213	0.107	1,762
Switzerland	6,000	600	116	0.088	797
United Kingdom	127,000	12,700	2,464	0.100	19,014
Total	808,000	80,800	15,675		122,174
EASTERN EUROPE					
Albania	6,000	600	116	0.084	755
Bulgaria	40,000	4,000	776	0.122	7,317
Czechoslovakia	46,000	4,600	892	0.126	8,704
Germany (Eastern)	51,000	5,100	989	0.126	9,651
Hungary	61,000	6,100	1,183	0.132	12,108
Poland	57,000	5,700	1,106	0.135	11,511
Romania	136,000	13,600	2,638	0.121	24,642
Soviet Union	1,129,000	112,900	21,903	0.121	204,565
Yugoslavia	73,000	7,300	1,416	0.091	9,944
Total	1,599,000	159,900	31,021		289,197
OCEANIA					
Australia	56,000	5,600	1,086	0.077	6,466
Fiji	2,000	240	47	0.100	293
New Caledonia	1,000	100	19	0.077	115
New Zealand	9,000	900	175	0.077	1,039
Papua New Guinea	3,000	360	70	0.100	439
Total	71,000	7,200	1,397		8,353

TABLE E6: METHANE EMISSIONS FROM CHICKEN WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
LATIN AMERICA					
Argentina	55,000	6,600	1,280	0.110	8,852
Bolivia	12,000	1,440	279	0.105	1,843
Brazil	550,000	66,000	12,804	0.110	88,517
Chile	21,000	2,520	489	0.110	3,380
Colombia	39,000	4,680	908	0.105	5,991
Costa Rica	5,000	600	116	0.105	768
Cuba	27,000	3,240	629	0.105	4,148
Dominican Republic	27,000	3,240	629	0.105	4,148
Ecuador	48,000	5,760	1,117	0.110	7,725
El Salvador	3,000	360	70	0.105	461
Guatemala	15,000	1,800	349	0.103	2,250
Guyana	15,000	1,800	349	0.095	2,085
Haiti	13,000	1,560	303	0.105	1,997
Honduras	8,000	960	186	0.100	1,170
Jamaica	6,000	720	140	0.105	922
Mexico	224,000	26,880	5,215	0.110	36,051
Nicaragua	5,000	600	116	0.105	768
Panama	7,000	840	163	0.105	1,075
Paraguay	16,000	1,920	372	0.105	2,458
Peru	52,000	6,240	1,211	0.105	7,988
Puerto Rico	11,000	1,320	256	0.113	1,811
Uruguay	8,000	960	186	0.113	1,317
Venezuela	57,000	6,840	1,327	0.113	9,382
Total	1,224,000	146,880	28,495		195,107
EAST & SUBSAHARAN AFRICA					
Burundi	4,000	480	93	0.098	571
Central African Republic	3,000	360	70	6.809	428
Chad	4,000	480	93	0.055	322
Ethiopia	57,000	6,840	1,327	0.055	4,587
Kenya	23,000	2,760	535	0.055	1,851
Mali	19,000	2,280	442	0.050	1,390
Mauritania	4,000	480	93	0.055	322
Niger	17,000	2,040	396	0.055	1,368
Rwanda	1,000	120	23	0.099	143
Somalia	3,000	360	70	0.055	241
Tanzania	30,000	3,600	698	0.098	4,280
Uganda	15,000	1,800	349	0.098	2,140
Zaire	19,000	2,280	442	0.098	2,710
Total	199,000	23,880	4,632		20,352

TABLE E6: METHANE EMISSIONS FROM CHICKEN WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
WEST & SOUTHERN AFRICA					
Angola	6,000	720	140	0.098	856
Benin	23,000	2,760	535	0.098	3,281
Botswana	1,000	120	23	0.055	80
Burkina Faso	21,000	2,520	489	0.055	1,690
Cameroon	16,000	1,920	372	0.098	2,282
Cote d'Ivoire	16,000	1,920	372	0.098	2,282
Ghana	12,000	1,440	279	0.098	1,712
Guinea	13,000	1,560	303	0.098	1,854
Guinea-Bissau	1,000	120	23	0.098	143
Lesotho	1,000	120	23	0.098	143
Madagascar	21,000	2,520	489	0.098	2,996
Malawi	8,000	960	186	0.085	995
Mozambique	21,000	2,520	489	0.098	2,996
Namibia	1,000	120	23	0.055	80
Nigeria	190,000	22,800	4,423	0.098	27,104
Senegal	11,000	1,320	256	0.098	1,569
Sierra Leone	6,000	720	140	0.098	856
South Africa	37,000	3,700	718	0.077	4,272
Swaziland	1,000	120	23	0.098	143
Togo	3,000	360	70	0.098	428
Zambia	15,000	1,800	349	0.098	2,140
Zimbabwe	10,000	1,200	233	0.098	1,427
Total	434,000	51,340	9,960		59,329
NEAR EAST & MEDITERRANEAN					
Afghanistan	7,000	840	163	0.063	640
Algeria	23,000	2,760	535	0.063	2,103
Egypt	30,000	3,600	698	0.063	2,743
Iran	110,000	13,200	2,561	0.063	10,059
Iraq	76,000	9,120	1,769	0.063	6,950
Israel	23,000	2,300	446	0.112	3,849
Jordan	60,000	7,200	1,397	0.063	5,487
Kuwait	28,000	3,360	652	0.100	4,097
Libya	37,000	4,440	861	0.063	3,383
Morocco	37,000	4,440	861	0.100	5,413
Oman	2,000	240	47	0.063	183
Saudi Arabia	69,000	8,280	1,606	0.063	6,310
Sudan	29,000	3,480	675	0.063	2,652
Syria	12,000	1,440	279	0.063	1,097
Tunisia	17,000	2,040	396	0.063	1,555
Turkey	58,000	6,960	1,350	0.100	8,486
Yemen Arab Republic	23,000	2,760	535	0.063	2,103
Total	641,000	76,460	14,833		67,110

TABLE E6: METHANE EMISSIONS FROM CHICKEN WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
Bangladesh	81,000	9,720	1,886	0.105	12,444
Myanmar (Burma)	34,000	4,080	792	0.105	5,223
China	1,849,000	221,880	43,045	0.101	273,772
India	260,000	31,200	6,053	0.120	45,649
Indonesia	410,000	49,200	9,545	0.147	87,881
Japan	334,000	33,400	6,480	0.233	116,990
Kampuchea	7,000	840	163	0.105	1,075
North Korea	20,000	2,400	466	0.105	3,072
South Korea	59,000	7,080	1,374	0.110	9,495
Laos	9,000	1,080	210	0.105	1,383
Malaysia	58,000	6,960	1,350	0.102	8,656
Nepal	10,000	1,200	233	0.105	1,536
Pakistan	150,000	18,000	3,492	0.082	17,919
Philippines	60,000	7,200	1,397	0.100	8,779
Sri Lanka	9,000	1,080	210	0.105	1,383
Thailand	85,000	10,200	1,979	0.105	13,058
Viet Nam	69,000	8,280	1,606	0.105	10,600
Total	3,504,000	413,800	80,277		618,915
WORLD TOTAL	9,894,097	1,059,802	246,263		1,592,278

TABLE E7: METHANE EMISSIONS FROM DUCK WASTE					
Country	Number (1000 h)	Total Manure mt/day	VS mt/day	*f* of B_o	Methane mt/yr
NORTH AMERICA					
Canada	1,000	150	26	0.100	201
USA	7,000	1,050	182	0.100	1,405
Total	8,000	1,200	208		1,606
WESTERN EUROPE					
Denmark	1,000	150	26	0.100	201
France	11,000	1,650	285	0.100	2,208
Germany (Western)	1,000	150	26	0.100	201
United Kingdom	2,000	300	52	0.100	401
Total	15,000	2,250	389		3,011
EASTERN EUROPE					
Hungary	2,000	300	52	0.080	321
Poland	4,000	600	104	0.080	642
Romania	5,000	750	130	0.080	803
Yugoslavia	2,000	300	52	0.100	401
Total	13,000	1,950	337		2,168
LATIN AMERICA					
Argentina	2,000	240	42	0.100	261
Brazil	6,000	720	125	0.100	783
Mexico	7,000	840	145	0.100	913
Total	15,000	1,800	311		1,957
EAST & SUBSAHARAN AFRICA					
Tanzania	3,000	360	62	0.100	391
Total	3,000	360	62		391
WEST & SOUTHERN AFRICA					
Madagascar	5,000	600	104	0.100	652
Mozambique	1,000	120	21	0.100	130
Total	6,000	720	125		783
NEAR EAST & MEDITERRANEAN					
Egypt	4,000	480	83	0.050	261
Total	4,000	480	83		261
ASIA & FAR EAST					
Bangladesh	32,000	3,840	664	0.100	4,175
China	325,000	39,000	6,747	0.100	42,403
Indonesia	29,000	3,480	602	0.100	3,784
Kampuchea	3,000	360	62	0.100	391
South Korea	1,000	120	21	0.100	130
Malaysia	4,000	480	83	0.100	522
Pakistan	1,000	120	21	0.050	65
Philippines	6,000	720	125	0.100	783
Thailand	16,000	1,920	332	0.100	2,088
Viet Nam	27,000	3,240	561	0.100	3,523
Total	444,000	53,280	9,217		57,864
WORLD TOTAL	508,000	62,040	10,733		68,041

TABLE E8: METHANE EMISSIONS FROM TURKEY WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NORTH AMERICA					
Canada	10,386	3,107	643	0.08	3,728
USA	53,783	8,544	1,654	0.10	11,996
Total	64,169	11,651	2,297		15,724
WESTERN EUROPE					
France	20,000	6,000	1,164	0.100	8,441
Germany (Western)	3,000	900	175	0.100	1,266
Ireland	1,000	300	58	0.100	422
Italy	23,000	6,900	1,339	0.100	9,707
Netherlands	1,000	300	58	0.100	422
United Kingdom	9,000	2,700	524	0.100	3,798
Total	57,000	17,100	3,317		24,057
EASTERN EUROPE					
Bulgaria	1,000	300	58	0.100	422
Czechoslovakia	1,000	300	58	0.080	338
Hungary	1,000	300	58	0.080	338
Poland	1,000	300	58	0.080	338
Romania	1,000	300	58	0.080	338
Soviet Union	48,000	14,400	2,794	0.080	16,207
Yugoslavia	2,000	600	116	0.100	844
Total	55,000	16,500	3,201		18,823
LATIN AMERICA					
Argentina	3,000	780	151	0.100	878
Brazil	5,000	1,300	252	0.100	1,463
Mexico	12,000	3,120	605	0.100	3,511
Total	20,000	5,200	1,009		5,852
WEST & SOUTHERN AFRICA					
Madagascar	4,000	1,040	202	0.100	1,170
Total	4,000	1,040	202		1,170
NEAR EAST & MEDITERRANEAN					
Egypt	1,000	260	50	0.095	278
Israel	7,000	2,100	407	0.100	2,954
Turkey	3,000	780	151	0.100	878
Total	11,000	3,140	609		4,110
ASIA & FAR EAST					
China	1,000	260	50	0.100	293
Total	1,000	260	50		293
WORLD TOTAL	212,169	54,891	10,686		70,030

TABLE E9: METHANE EMISSIONS FROM BUFFALO WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	*f* of B_o	Methane mt/yr
NORTH AMERICA					
Canada	0	0	0	0	0
USA	0	0	0	0	0
Total	0	0	0	0	0
WESTERN EUROPE					
Greece	1	21	3	0.160	17
Italy	104	2,174	270	0.120	1,329
Total	105	2,194	272		1,346
EASTERN EUROPE					
Albania	2	42	5	0.105	22
Bulgaria	24	502	62	0.120	307
Romania	210	4,389	544	0.100	2,236
Soviet Union	320	6,688	829	0.100	3,408
Yugoslavia	25	522	65	0.110	293
Total	581	12,143	1,506		6,266
LATIN AMERICA					
Brazil	1,100	13,750	2,063	0.100	4,986
Total	1,100	13,750	2,063		4,986
NEAR EAST & MEDITERRANEAN					
Egypt	2,600	32,500	4,875	0.063	7,365
Iran	230	2,875	431	0.050	521
Iraq	145	1,813	272	0.058	378
Syria	1	13	2	0.050	2
Turkey	540	6,750	1,013	0.100	2,447
Total	3,516	43,950	6,593		10,714
ASIA & FAR EAST					
Bangladesh	1,950	24,375	3,656	0.090	7,954
Bhutan	7	88	13	0.090	29
Myanmar (Burma)	2,200	27,500	4,125	0.090	8,974
China	20,858	260,725	39,109	0.100	94,534
India	72,000	900,000	135,000	0.092	299,403
Indonesia	3,000	37,500	5,625	0.080	10,877
Kampuchea	700	8,750	1,313	0.090	2,855
Laos	1,000	12,500	1,875	0.090	4,079
Malaysia	220	2,750	413	0.098	972
Nepal	2,900	36,250	5,438	0.090	11,829
Pakistan	14,020	175,250	26,288	0.050	31,771
Philippines	2,890	36,125	5,419	0.075	9,824
Sri Lanka	1,050	13,125	1,969	0.090	4,283
Thailand	6,000	75,000	11,250	0.090	24,474
Viet Nam	2,809	35,113	5,267	0.090	11,458
TOTAL	131,604	1,645,050	246,758		523,318
WORLD TOTAL	136,906	1,717,087	257,190		546,629

TABLE E10: METHANE EMISSIONS FROM HORSE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NORTH AMERICA					
Canada	341	7,843	1,537	0.100	12,262
USA	2,404	55,172	10,818	0.100	87,440
Total	2,745	63,015	12,355		99,702
WESTERN EUROPE					
Austria	45	1,035	203	0.100	1,618
Belgium	23	529	104	0.100	827
Denmark	29	667	131	0.100	1,043
Finland	36	828	162	0.080	1,036
France	292	6,716	1,316	0.100	10,500
Germany (Western)	350	8,050	1,578	0.100	12,586
Greece	60	1,380	270	0.100	2,158
Ireland	55	1,265	248	0.100	1,978
Italy	250	5,750	1,127	0.100	8,990
Netherlands	64	1,472	289	0.100	2,301
Norway	17	391	77	0.120	734
Portugal	29	667	131	0.100	1,043
Spain	250	5,750	1,127	0.100	8,990
Sweden	58	1,334	261	0.080	1,669
Switzerland	49	1,127	221	0.100	1,762
United Kingdom	180	4,140	811	0.100	6,473
Total	1,787	41,101	8,056		63,706
EASTERN EUROPE					
Albania	42	966	189	0.100	1,510
Bulgaria	123	2,829	554	0.100	4,423
Czechoslovakia	33	759	149	0.080	949
Germany (Eastern)	104	2,392	469	0.100	3,740
Hungary	88	2,024	397	0.080	2,532
Poland	1,051	24,173	4,738	0.080	30,235
Romania	693	15,939	3,124	0.080	19,936
Soviet Union	5,885	135,355	26,530	0.080	169,297
Yugoslavia	362	8,326	1,632	0.100	13,017
Total	8,381	192,763	37,782		245,639
OCEANIA					
Australia	401	9,223	1,808	0.060	8,652
Fiji	42	773	151	0.100	952
New Caledonia	10	230	45	0.100	360
New Zealand	100	2,300	451	0.100	3,596
Papua New Guinea	1	18	4	0.100	23
Vanuatu	3	55	11	0.100	68
Total	557	12,599	2,469		13,650

TABLE E10: METHANE EMISSIONS FROM HORSE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
LATIN AMERICA					
Argentina	3,100	57,040	11,180	0.100	70,263
Bolivia	315	5,796	1,136	0.100	7,140
Brazil	5,850	107,640	21,097	0.100	132,593
Chile	490	9,016	1,767	0.098	10,828
Colombia	1,950	35,880	7,032	0.100	44,198
Costa Rica	114	2,098	411	0.100	2,584
Cuba	703	12,935	2,535	0.100	15,934
Dominican Republic	313	5,759	1,129	0.100	7,094
Ecuador	438	8,059	1,580	0.100	9,927
El Salvador	93	1,711	335	0.100	2,108
Guatemala	112	2,061	404	0.098	2,475
Guyana	2	37	7	0.100	45
Haiti	430	7,912	1,551	0.100	9,746
Honduras	170	3,128	613	0.100	3,853
Jamaica	4	74	14	0.100	91
Mexico	6,160	113,344	22,215	0.100	139,619
Nicaragua	250	4,600	902	0.100	5,666
Panama	171	3,146	617	0.100	3,876
Paraguay	328	6,035	1,183	0.100	7,434
Peru	655	12,052	2,362	0.100	14,846
Puerto Rico	22	405	79	0.100	499
Uruguay	473	8,703	1,706	0.100	10,721
Venezuela	495	9,108	1,785	0.100	11,219
Total	22,638	416,539	81,642		512,758
EAST & SUBSAHARAN AFRICA					
Chad	150	2,760	541	0.050	1,700
Ethiopia	1,610	29,624	5,806	0.050	18,246
Kenya	2	37	7	0.050	23
Mali	62	1,141	224	0.100	1,405
Mauritania	17	313	61	0.050	193
Niger	296	5,446	1,067	0.050	3,354
Somalia	1	18	4	0.050	11
Total	2,138	39,339	7,710		24,932

TABLE E10: METHANE EMISSIONS FROM HORSE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
WEST & SOUTHERN AFRICA					
Angola	1	18	4	0.100	23
Benin	6	110	22	0.100	136
Botswana	25	460	90	0.050	283
Burkina Faso	70	1,288	252	0.050	793
Cameroon	25	460	90	0.100	567
Cote d'Ivoire	1	18	4	0.100	23
Ghana	4	74	14	0.100	91
Guinea	1	18	4	0.100	23
Guinea-Bissau	1	18	4	0.100	23
Lesotho	119	2,190	429	0.100	2,697
Madagascar	1	18	4	0.100	23
Namibia	50	920	180	0.050	567
Nigeria	250	4,600	902	0.100	5,666
Senegal	208	3,827	750	0.100	4,714
South Africa	230	5,290	1,037	0.075	6,203
Swaziland	2	37	7	0.100	45
Togo	1	18	4	0.100	23
Zimbabwe	23	423	83	0.100	521
Total	1,018	19,789	3,879		22,420
NEAR EAST & MEDITERRANEAN					
Afghanistan	410	7,544	1,479	0.093	8,596
Algeria	187	3,441	674	0.093	3,921
Egypt	10	184	36	0.093	210
Iran	316	5,814	1,140	0.093	6,625
Iraq	55	1,012	198	0.093	1,153
Israel	4	92	18	0.100	144
Jordan	3	55	11	0.093	63
Kuwait	3	55	11	0.100	68
Libya	56	1,030	202	0.093	1,174
Morocco	182	3,349	656	0.100	4,125
Saudi Arabia	3	55	11	0.093	63
Sudan	20	368	72	0.093	419
Syria	43	791	155	0.093	902
Tunisia	56	1,030	202	0.093	1,174
Turkey	620	11,408	2,236	0.100	14,053
Yemen Arab Republic	3	55	11	0.093	63
Total	1,971	36,285	7,112		42,751

TABLE E10: METHANE EMISSIONS FROM HORSE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
Bangladesh	45	828	162	0.100	1,020
Bhutan	16	294	58	0.100	363
Myanmar (Burma)	139	2,558	501	0.100	3,150
China	10,691	196,714	38,556	0.100	242,316
India	953	17,535	3,437	0.100	21,600
Indonesia	722	13,285	2,604	0.200	32,729
Japan	22	506	99	0.100	791
Kampuchea	15	276	54	0.100	340
North Korea	43	791	155	0.100	975
South Korea	3	55	11	0.100	68
Laos	42	773	151	0.100	952
Malaysia	5	92	18	0.100	113
Mongolia	2,047	37,665	7,382	0.050	23,198
Pakistan	455	8,372	1,641	0.050	5,156
Philippines	300	5,520	1,082	0.100	6,800
Sri Lanka	1	18	4	0.100	23
Thailand	19	350	69	0.100	431
Viet Nam	136	2,502	490	0.100	3,082
Total	15,654	288,135	56,474		343,106
WORLD TOTAL	56,889	1,109,566	217,479		1,368,665

TABLE E11: METHANE EMISSIONS FROM MULE WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	*f* of B_o	Methane mt/yr
NORTH AMERICA					
Canada	4	92	18	0.100	144
USA	1	23	5	0.100	36
Total	5	115	23		180
WESTERN EUROPE					
Belgium	1	23	5	0.100	36
France	12	276	54	0.100	432
Greece	83	1,909	374	0.100	2,985
Ireland	2	46	9	0.100	72
Italy	50	1,150	225	0.100	1,798
Portugal	90	2,070	406	0.100	3,236
Spain	110	2,530	496	0.100	3,956
Total	348	8,004	1,569		12,514
EASTERN EUROPE					
Albania	22	506	99	0.100	791
Bulgaria	25	575	113	0.100	899
Soviet Union	1	23	5	0.080	29
Yugoslavia	10	230	45	0.100	360
Total	58	1,334	261		2,078
LATIN AMERICA					
Argentina	165	3,036	595	0.100	3,740
Bolivia	80	1,472	289	0.100	1,813
Brazil	1,980	36,432	7,141	0.100	44,877
Chile	10	184	36	0.100	227
Colombia	600	11,040	2,164	0.100	13,599
Costa Rica	5	92	18	0.100	113
Cuba	32	589	115	0.100	725
Dominican Republic	140	2,576	505	0.100	3,173
Ecuador	122	2,245	440	0.100	2,765
El Salvador	23	423	83	0.100	521
Guatemala	38	699	137	0.100	861
Haiti	85	1,564	307	0.100	1,927
Honduras	68	1,251	245	0.100	1,541
Jamaica	10	184	36	0.100	227
Mexico	3,130	57,592	11,288	0.100	70,943
Nicaragua	45	828	162	0.100	1,020
Panama	5	92	18	0.100	113
Paraguay	14	258	50	0.100	317
Peru	220	4,048	793	0.100	4,986
Puerto Rico	2	37	7	0.100	45
Uruguay	4	74	14	0.100	91
Venezuela	72	1,325	260	0.100	1,632
Total	6,850	126,040	24,704		155,258

TABLE E11: METHANE EMISSIONS FROM MULE WASTE					
Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
EAST & SUBSAHARAN AFRICA					
Ethiopia	1,500	27,600	5,410	0.050	16,999
Somalia	23	423	83	0.050	261
Total	1,523	28,023	5,493		17,260
WEST & SOUTHERN AFRICA					
Botswana	4	74	14	0.050	45
Lesotho	1	18	4	0.100	23
Namibia	6	110	22	0.050	68
South Africa	14	322	63	0.050	252
Zimbabwe	1	18	4	0.100	23
Total	26	543	106		410
NEAR EAST & MEDITERRANEAN					
Algeria	160	2,944	577	0.050	1,813
Egypt	1	18	4	0.050	11
Iran	123	2,263	444	0.050	1,394
Iraq	26	478	94	0.050	295
Israel	2	46	9	0.100	72
Jordan	3	55	11	0.050	34
Morocco	500	9,200	1,803	0.100	11,333
Saudi Arabia	6	110	22	0.050	68
Sudan	1	18	4	0.050	11
Tunisia	76	1,398	274	0.050	861
Turkey	210	3,864	757	0.100	4,760
Total	1,108	20,396	3,998		20,652
ASIA & FAR EAST					
Bhutan	9	166	32	0.100	204
Myanmar (Burma)	9	166	32	0.100	204
China	5,248	96,563	18,926	0.100	118,948
India	135	2,484	487	0.100	3,060
North Korea	2	37	7	0.100	45
Pakistan	65	1,196	234	0.050	737
Total	5,468	100,611	19,720		123,198
WORLD TOTAL	15,386	285,067	55,873		331,550

TABLE E12: METHANE EMISSIONS FROM DONKEY WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NORTH AMERICA					
Canada	0	0	0	0	0
USA	4	61	12	0.100	96
Total	4	61	12	0.100	96
WESTERN EUROPE					
France	23	352	69	0.100	550
Greece	175	2,678	525	0.100	4,186
Ireland	20	306	60	0.100	478
Italy	86	1,316	258	0.100	2,057
Portugal	175	2,678	525	0.100	4,186
Spain	131	2,004	393	0.100	3,134
Switzerland	2	31	6	0.100	48
United Kingdom	5	77	15	0.100	120
Total	617	9,440	1,850		14,759
EASTERN EUROPE					
Albania	52	796	156	0.100	1,244
Bulgaria	333	5,095	999	0.100	7,966
Hungary	5	77	15	0.080	96
Romania	36	551	108	0.080	689
Soviet Union	300	4,590	900	0.080	5,741
Yugoslavia	9	138	27	0.100	215
Total	735	11,246	2,204		15,950
LATIN AMERICA					
Argentina	90	1,098	215	0.100	1,353
Bolivia	620	7,564	1,483	0.100	9,317
Brazil	1,310	15,982	3,132	0.100	19,687
Chile	28	342	67	0.100	421
Colombia	650	7,930	1,554	0.100	9,768
Costa Rica	7	85	17	0.100	105
Cuba	4	49	10	0.100	60
Dominican Republic	146	1,781	349	0.100	2,194
Ecuador	279	3,404	667	0.100	4,193
El Salvador	2	24	5	0.100	30
Guatemala	9	110	22	0.100	135
Guyana	1	12	2	0.100	15
Haiti	216	2,635	516	0.100	3,246
Honduras	22	268	53	0.100	331
Jamaica	23	281	55	0.100	346
Mexico	3,183	38,833	7,611	0.100	47,835
Nicaragua	8	98	19	0.100	120
Paraguay	31	378	74	0.100	466
Peru	490	5,978	1,172	0.100	7,364
Puerto Rico	2	24	5	0.100	30
Uruguay	1	12	2	0.100	15
Venezuela	440	5,368	1,052	0.100	6,612
Total	7,562	92,256	18,082		113,643

TABLE E12: METHANE EMISSIONS FROM DONKEY WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
EAST & SUBSAHARAN AFRICA					
Chad	255	3,111	610	0.050	1,916
Ethiopia	3,930	47,946	9,397	0.050	29,530
Mali	550	6,710	1,315	0.050	4,133
Mauritania	149	1,818	356	0.050	1,120
Niger	512	6,246	1,224	0.050	3,847
Somalia	25	305	60	0.050	188
Tanzania	172	2,098	411	0.100	2,585
Uganda	17	207	41	0.100	255
Total	5,610	68,442	13,415		43,574
WEST & SOUTHERN AFRICA					
Angola	5	61	12	0.100	75
Benin	1	12	2	0.100	15
Botswana	145	1,769	347	0.050	1,090
Burkina Faso	200	2,440	478	0.050	1,503
Cameroon	39	476	93	0.100	586
The Gambia	4	49	10	0.100	60
Ghana	25	305	60	0.100	376
Guinea	3	37	7	0.100	45
Guinea-Bissau	3	37	7	0.100	45
Lesotho	126	1,537	301	0.100	1,894
Malawi	1	12	2	0.100	15
Mozambique	20	244	48	0.100	301
Namibia	68	830	163	0.050	511
Nigeria	700	8,540	1,674	0.100	10,520
Senegal	210	2,562	502	0.100	3,156
South Africa	210	3,213	630	0.050	2,512
Swaziland	14	171	33	0.100	210
Togo	3	37	7	0.100	45
Zambia	2	24	5	0.100	30
Zimbabwe	101	1,232	242	0.100	1,518
Total	1,880	23,587	4,623		24,505

TABLE E12: METHANE EMISSIONS FROM DONKEY WASTE					
Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
NEAR EAST & MEDITERRANEAN					
Afghanistan	1,300	15,860	3,109	0.050	9,768
Algeria	475	5,795	1,136	0.050	3,569
Egypt	1,950	23,790	4,663	0.050	14,652
Iran	1,800	21,960	4,304	0.050	13,525
Iraq	410	5,002	980	0.050	3,081
Israel	5	77	15	0.100	120
Jordan	19	232	45	0.050	143
Libya	61	744	146	0.050	458
Morocco	800	9,760	1,913	0.100	12,023
Oman	24	293	57	0.050	180
Saudi Arabia	110	1,342	263	0.050	827
Sudan	650	7,930	1,554	0.050	4,884
Syria	200	2,440	478	0.050	1,503
Tunisia	220	2,684	526	0.050	1,653
Turkey	1,200	14,640	2,869	0.100	18,034
Yemen Arab Republic	520	6,344	1,243	0.050	3,907
Total	9,744	118,892	23,303		88,327
ASIA & FAR EAST					
Bhutan	18	220	43	0.100	271
China	10,856	132,443	25,959	0.100	163,145
India	1,328	16,202	3,176	0.100	19,957
North Korea	3	37	7	0.100	45
Pakistan	3,022	36,868	7,226	0.050	22,708
Total	15,227	185,769	36,411		206,126
WORLD TOTAL	41,379	509,694	99,900		506,981

TABLE E13: METHANE EMISSIONS FROM CAMEL WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	*f* of B_o	Methane mt/yr
NORTH AMERICA					
Canada	0	0	0	0	0
USA	0	0	0	0	0
Total	0	0	0	0	0
EASTERN EUROPE					
Soviet Union	265	6,095	975	0.080	4,903
Total	265	6,095	975		4,903
EAST & SUBSAHARAN AFRICA					
Chad	509	9,366	1,498	0.050	3,803
Ethiopia	1,060	19,504	3,121	0.050	7,920
Kenya	790	14,536	2,326	0.050	5,903
Mali	241	4,434	710	0.050	1,801
Mauritania	810	14,904	2,385	0.050	6,052
Niger	417	7,673	1,228	0.050	3,116
Somalia	6,680	122,912	19,666	0.050	49,914
Total	10,507	193,329	30,933		78,509
WEST & SOUTHERN AFRICA					
Burkina Faso	5	92	15	0.050	37
Nigeria	18	331	53	0.100	269
Senegal	8	147	24	0.100	120
Total	31	570	91		426
NEAR EAST & MEDITERRANEAN					
Afghanistan	265	4,876	780	0.050	1,980
Algeria	130	2,392	383	0.050	971
Egypt	70	1,288	206	0.050	523
Iran	27	497	79	0.050	202
Iraq	55	1,012	162	0.050	411
Israel	10	230	37	0.100	231
Jordan	14	258	41	0.050	105
Kuwait	8	147	24	0.100	120
Libya	185	3,404	545	0.050	1,382
Morocco	54	994	159	0.100	807
Oman	82	1,509	241	0.050	613
Saudi Arabia	417	7,673	1,228	0.050	3,116
Sudan	2,850	52,440	8,390	0.050	21,296
Syria	5	92	15	0.050	37
Tunisia	184	3,386	542	0.050	1,375
Turkey	3	55	9	0.100	45
Yemen Arab Republic	63	1,159	185	0.050	471
Total	4,422	81,411	13,026		33,684

TABLE E13: METHANE EMISSIONS FROM CAMEL WASTE

Country	Number (1000 h)	Total Manure mt/day	VS mt/day	f of B_o	Methane mt/yr
ASIA & FAR EAST					
China	475	8,740	1,398	0.100	7,099
India	1,390	25,576	4,092	0.100	20,772
Mongolia	547	10,065	1,610	0.050	4,087
Pakistan	949	17,462	2,794	0.050	7,091
Total	3,361	61,842	9,895		39,049
WORLD TOTAL	18,586	343,247	54,920		156,572

APPENDIX F: REQUESTS FOR DATA - UNITED STATES AND WORLD

Extensive review of the open literature revealed little information on the extent of use of different types of animal waste management systems around the United States. To overcome this scarcity of data, Extension personnel in each state were contacted and asked to provide the waste management system information shown in Exhibit F1.

As with the United States, there was very little information in the open literature on the use of different animal waste management systems around the world. The Ministries of Agriculture for the 127 countries in Exhibit 14 (excluding the United States) were contacted and asked to provide this information for their country. In addition, individual researchers in many countries were also contacted and asked to provide this information. One of the forms shown in Exhibits F2 and F3 was sent with each request, depending on whether the country is classified as developed or developing by the Food and Agriculture Organization of the United Nations (FAO, 1989).

EXHIBIT F1: REQUEST FOR DATA SENT TO U.S. EXTENSION PERSONNEL

Types of Animal Waste Management Systems

STATE:______________________________ DATE:_________

NAME OF PERSON COMPLETING FORM:______________________________

For each animal type (1 - 9), please estimate the percentage of animals in your state that are currently being handled with each type of waste management system.

		% of Animal Type
1. Dairy		
* Daily spread (solid/semi-solid)		______
* Tie-stall/stanchion (solid, with storage)		______
* Free stall - Liquid/slurry storage		______
- Anaerobic lagoon		______
* Other (please specify if over 5%):__________		______
	Total:	100%
2. Beef (finishing only)		
* Drylot		______
* Anaerobic lagoon		______
* Slurry storage		______
* Other (please specify if over 5%):__________		______
	Total	100%
3. Swine		
* Pit storage - stored less than one month		______
- stored more than one month		______
* Anaerobic lagoons		______
* Dry lot		______
* Other (please specify if over 5%:__________		______
	Total:	100%
4. Caged layers		
* Deep pit stacking		______
* Anaerobic lagoons		______
* Slurry storage		______
* Other (please specify if over 5%):__________		______
	Total:	100%
5. Broilers		
* Litter		______
* Other (please specify if over 5%) :__________		______
	Total:	100%
6. Turkeys		
* Litter		______
* Range		______
* Other (please specify if over 5%):__________		______
	Total:	100%
7. Sheep		
* Pasture		______
* Other (please specify if over 5%):__________		______
8. Goats		
* Pasture		______
* Other (please specify if over 5%) :__________		______
	Total:	100%
9. Horses		
* Paddock		______
* Pasture		______
* Other (please specify if over 5%) :__________		______
	Total:	100%

Comments:

EXHIBIT F2: REQUEST FOR DATA SENT TO DEVELOPED COUNTRIES.

Types of Animal Waste Management Systems

COUNTRY:______________________________ DATE:________

NAME OF PERSON COMPLETING FORM:__________________ Title________

For each animal type (1 - 9), please estimate the percentage of animals in your country that are currently being handled with each type of waste management system.

		% of Animal Type
1. Dairy Cattle		
* Daily spread (solid/semi-solid)		________
* Solid Storage		________
* Liquid/slurry storage		________
* Anaerobic lagoon		________
* Other (please specify if over 5%):__________		________
	Total:	100%
2. Beef Cattle, Buffaloes		
* Pasture		________
* Drylot		________
* Anaerobic lagoon		________
* Slurry storage		________
* Other (please specify if over 5%):__________		________
	Total:	100%
3. Swine		
* Pit storage - stored less than one month		________
- stored more than one month		________
* Solid Storage		________
* Anaerobic lagoons		________
* Drylot		________
* Other (please specify if over 5%):__________		________
	Total:	100%
4. Laying Hens		
* Deep pit stacking		________
* Anaerobic lagoons		________
* Slurry storage		________
* Other (please specify if over 5%):__________		________
	Total:	100%
5. Broilers		
* Litter		________
* Other (please specify if over 5%) :__________		________
	Total:	100%
6. Turkeys		
* Litter		________
* Range		________
* Other (please specify if over 5%):__________		________
	Total:	100%
7. Sheep		
* Pasture		________
* Drylot		________
* Other (please specify if over 5%):__________		________
8. Goats		
* Pasture		________
* Other (please specify if over 5%) :__________		________
	Total:	100%
9. Horses, Mules, Donkeys		
* Paddock		________
* Pasture		________
* Other (please specify if over 5%) :__________		________
	Total:	100%

Comments:____

EXHIBIT F3: REQUEST FOR DATA SENT TO DEVELOPING COUNTRIES

Types of Animal Waste Management Systems

COUNTRY:____ DATE:________

NAME OF PERSON COMPLETING FORM:______________________ Title________

For each animal type (1 - 9), please estimate the percentage of animals in your country that are currently being handled with each type of waste management system.

		% of Animal Type
1. Dairy Cattle		
* Pasture		______
* Daily spread (solid/semi-solid)		______
* Solid Storage		______
* Liquid/slurry storage		______
* Anaerobic lagoon		______
* Anaerobic digester		______
* Burned for fuel		______
* Other (please specify if over 5%): ________		______
	Total:	100%
2. Beef Cattle, Buffaloes		
* Pasture		______
* Drylot		______
* Anaerobic digester		______
* Daily spread (solid/semi-solid)		______
* Burned for fuel		______
* Other (please specify if over 5%): ________		______
	Total:	100%
3. Swine		
* Daily Spread (solid/semi-solid)		______
* Solid Storage		______
* Anaerobic digester		______
* Drylot		______
* Liquid/slurry storage		______
* Other (please specify if over 5%): ________		______
	Total:	100%
4. Chickens, Ducks, Turkeys		
* Range		______
* Anaerobic digester		______
* Litter		______
* Deep Pit Stacking		______
* Slurry storage		______
* Other (please specify if over 5%) : ________		______
	Total:	100%
5. Sheep		
* Pasture		______
* Anaerobic Digester		______
* Other (please specify if over 5%): ________		______
6. Goats		
* Pasture		______
* Anaerobic digester		______
* Other (please specify if over 5%) : ________		______
	Total:	100%
7. Horses, Mules, Donkeys, Camels		
* Paddock		______
* Pasture		______
* Anaerobic digester		______
* Other (please specify if over 5%) : ________		______
	Total:	100%

Comments:____

APPENDIX G: U.S. WASTE MANAGEMENT SYSTEM METHANE PRODUCTION

The amount of methane produced by each type of waste management system for each animal type in the United States is given in Tables G1 through G9. The state category "other" refers to animal populations that could not be specifically identified with a state. The following abbreviations are used in the tables:

AWMS	=	Animal Waste Management System
An.Lag.	=	Anaerobic Lagoon
Daily-Spr	=	Daily Spread
Sol-Stor	=	Solid Storage
Liq/Slur	=	Liquid/Slurry Storage
Other	=	Other Animal Waste Management Systems
Pit <1mo	=	Pit Storage for less than 1 month
Pit >1mo	=	Pit Storage for more than 1 month

TABLE G1: METHANE EMISSIONS FROM U.S. BEEF AWMS'S (METRIC TONS/YEAR)

State	Rank	An.Lag	Liq/Slur	Drylot	Pasture	Other	Total
AK	49	0	0	0	103	0	103
AL	16	416	0	416	25,456	0	26,288
AR	17	0	0	137	25,384	0	25,521
AZ	33	0	0	3,944	9,548	0	13,492
CA	9	0	0	6,143	43,626	0	49,770
CO	8	0	0	11,594	32,510	11,594	55,699
CT	46	0	0	0	403	0	403
DE	48	0	0	0	238	0	238
FL	14	771	0	86	29,108	0	29,965
GA	24	0	51	146	20,191	0	20,388
HI	41	0	0	284	2,571	0	2,855
IA	6	744	165	8,097	54,730	0	63,736
ID	20	0	247	2,935	18,882	31	22,096
IL	12	4,033	896	3,585	21,789	0	30,304
IN	28	1,371	305	2,743	13,546	0	17,965
KS	2	13,185	0	20,401	67,241	0	100,827
KY	11	0	0	287	32,221	0	32,508
LA	30	0	0	103	15,399	0	15,501
MA	45	0	0	0	481	0	481
MD	40	63	56	105	2,692	0	2,916
ME	43	0	0	0	674	0	674
MI	32	1,651	367	2,568	8,968	0	13,554
MN	15	0	789	3,550	23,786	0	28,125
MO	5	4,966	0	552	60,274	0	65,792
MS	26	0	14	130	19,768	0	19,912
MT	10	0	0	1,048	37,214	0	38,261
NC	34	239	213	27	10,355	213	11,047
ND	18	402	45	411	23,228	0	24,086
NE	3	5,194	0	28,277	62,502	0	95,972
NH	47	0	0	0	372	0	372
NJ	44	0	0	35	559	0	594
NM	27	0	0	1,604	18,306	0	19,910
NV	38	16	2	327	6,945	0	7,289
NY	37	0	21	188	8,281	10	8,500
OH	23	1,141	253	2,281	16,907	0	20,583
OK	4	0	0	3,679	67,911	0	71,590
OR	25	589	44	1,004	18,382	0	20,019
PA	31	0	18	880	13,511	0	14,409
RI	50	0	0	0	41	0	41
SC	36	0	0	233	8,300	0	8,533
SD	7	5,708	317	2,378	47,624	0	56,028
TN	13	0	0	229	29,886	0	30,115
TX	1	0	0	26,438	183,442	0	209,880
UT	35	0	0	573	10,053	0	10,626
VA	21	0	93	419	21,090	0	21,602
VT	42	0	0	0	1,286	0	1,286
WA	29	0	0	2,439	14,283	0	16,722
WI	19	0	115	1,093	22,692	0	23,899
WV	39	0	0	116	7,143	0	7,259
WY	22	0	163	1,226	19,918	0	21,308
Total		40,489	4,174	142,713	1,179,819	11,848	1,379,044

TABLE G2: METHANE EMISSIONS FROM U.S. DAIRY AWMS'S (METRIC TONS/YEAR)

State	Rank	An.Lag	Liq/Slur	Solid	Spread	Other	Total
AK	49	82	130	2	1	103	318
AL	25	8,663	0	0	481	0	9,144
AR	26	7,589	0	0	1,265	0	8,854
AZ	30	3,763	0	0	0	3,763	7,527
CA	1	193,781	0	0	0	32,297	226,078
CO	37	1,704	757	0	1,610	0	4,071
CT	40	0	1,873	9	411	0	2,293
DE	48	185	287	0	123	0	595
FL	24	1,491	0	0	414	7,290	9,196
GA	15	16,403	521	0	130	5,155	22,209
HI	38	1,629	666	0	18	35	2,347
IA	16	4,197	6,217	10,103	622	622	21,760
ID	14	7,701	14,546	0	86	257	22,589
IL	22	4,545	3,030	1,010	2,272	2,525	13,381
IN	17	8,379	11,172	931	931	0	21,413
KS	33	0	4,188	0	1,570	0	5,758
KY	10	18,281	1,711	0	1,604	4,597	26,192
LA	31	2,247	0	0	83	4,120	6,451
MA	45	0	831	186	415	0	1,432
MD	29	988	5,268	274	1,235	0	7,765
ME	41	0	1,288	289	644	0	2,221
MI	9	8,075	10,767	2,153	4,038	1,436	26,469
MN	6	0	25,303	12,651	8,434	0	46,388
MO	3	61,564	0	0	2,280	0	63,844
MS	32	3,060	68	68	34	3,179	6,410
MT	39	1,274	448	271	230	83	2,306
NC	28	2,359	3,670	524	1,311	0	7,864
ND	46	85	19	849	38	0	990
NE	34	0	489	0	856	3,522	4,867
NH	44	0	884	442	110	0	1,436
NJ	43	0	879	197	439	0	1,515
NM	12	23,710	0	0	146	0	23,856
NV	35	0	1,621	2,836	203	0	4,659
NY	7	0	16,067	4,017	14,058	0	34,142
OH	8	8,702	11,603	2,321	4,351	1,547	28,523
OK	13	7,003	0	0	130	16,600	23,733
OR	11	18,610	3,446	49	123	1,674	23,902
PA	20	0	1,455	1,091	17,277	0	19,823
RI	50	0	73	16	36	0	125
SC	21	14,628	203	102	102	0	15,034
SD	19	15,143	3,365	1,346	1,010	0	20,863
TN	18	4,580	8,142	0	1,018	7,124	20,865
TX	4	38,966	20,782	0	1,299	0	61,046
UT	36	360	80	3,597	160	0	4,196
VA	23	0	11,716	0	976	0	12,693
VT	27	0	4,739	1,062	2,369	0	8,170
WA	5	41,014	11,393	0	570	0	52,977
WI	2	0	27,178	13,589	31,708	0	72,476
WV	42	234	1,041	260	195	104	1,836
WY	47	456	160	97	82	30	825
Total		531,451	218,074	60,342	107,497	96,063	1,013,428

TABLE G3: METHANE EMISSIONS FROM U.S. SWINE AWMS'S (METRIC TONS/YEAR)							
State	Rank	An.Lag.	Drylot	Pit < 1 mo	Pit > 1 mo	Other	Total
AK	50	40	0	0	0	0	40
AL	18	15,364	0	0	379	0	15,743
AR	17	18,000	571	0	571	0	19,143
AZ	24	6,398	0	0	0	0	6,398
CA	25	5,516	0	0	0	68	5,584
CO	28	2,691	311	262	598	75	3,937
CT	46	49	0	0	0	31	79
DE	38	321	18	0	250	0	589
FL	30	2,449	498	8	0	0	2,955
GA	10	39,878	1,303	0	1,303	130	42,614
HI	36	665	16	39	166	18	906
IA	1	20,559	22,843	8,376	59,391	25,889	137,057
ID	31	1,617	67	22	314	22	2,044
IL	3	70,816	4,721	3,147	28,326	1,574	108,584
IN	5	54,455	2,420	1,210	29,043	0	87,128
KS	13	22,060	3,268	0	4,902	0	30,230
KY	9	42,158	703	410	117	0	43,388
LA	29	3,163	18	0	0	0	3,182
MA	42	48	93	4	148	0	292
MD	27	4,268	95	0	759	0	5,122
ME	45	13	26	1	41	0	82
MI	12	28,315	899	300	5,843	225	35,580
MN	11	0	5,213	5,213	20,852	10,426	41,703
MO	2	118,277	3,285	0	0	0	121,562
MS	22	7,342	194	69	249	180	8,033
MT	33	0	535	334	668	134	1,671
NC	4	90,873	2,164	0	4,327	0	97,64
ND	26	3,432	381	572	1,144	0	5,529
NE	6	68,892	1,094	12,029	2,187	0	84,202
NH	47	24	48	0	5	0	78
NJ	40	62	121	5	192	0	379
NM	43	134	104	15	30	0	282
NV	44	205	68	0	0	0	274
NY	34	336	224	37	896	0	1,493
OH	7	41,135	988	124	11,365	988	54,599
OK	23	6,843	380	127	0	0	7,350
OR	32	1,360	36	212	145	266	2,019
PA	21	0	2,059	53	6,335	0	8,446
RI	49	8	16	1	26	0	51
SC	15	19,911	123	0	246	0	20,279
SD	14	17,670	2,945	2,454	4,908	0	27,978
TN	8	42,108	877	0	585	0	43,570
TX	19	10,035	637	478	637	1,274	13,061
UT	39	418	139	0	0	0	557
VA	16	18,801	0	0	464	0	19,265
VT	48	9	17	1	28	0	54
WA	35	808	0	30	359	0	1,197
WI	20	0	721	1,442	10,093	0	12,256
WV	37	543	60	60	121	0	784
WY	41	250	29	24	56	7	365
Total		788,317	60,331	37,057	198,070	41,306	1,125,080

TABLE G4: METHANE EMISSIONS FROM U.S. CAGED LAYERS AWMS'S (MT/YEAR)

State	Rank	An.Lag.	Liq/Slur	Deep Pit	Other	Total
AK	50	1	0	0	0	2
AL	1	15,086	419	105	0	15,610
AR	2	10,883	3,628	0	0	14,510
AZ	44	0	0	28	0	28
CA	6	3,850	367	1,375	2,750	8,341
CO	28	223	99	273	0	595
CT	32	0	0	435	0	435
DE	42	0	0	67	0	67
FL	9	2,460	273	797	273	3,804
GA	10	158	351	526	2,262	3,296
HI	15	1,441	0	0	180	1,621
IA	17	289	128	722	64	1,203
ID	37	0	225	37	0	262
IL	20	535	0	268	0	803
IN	12	0	413	1,963	0	2,376
KS	39	0	0	164	0	164
KY	13	1,913	230	5	10	2,159
LA	11	2,583	0	0	15	2,598
MA	41	0	33	74	18	126
MD	33	0	0	343	0	343
ME	25	0	176	396	98	670
MI	19	251	56	474	111	892
MN	16	0	894	671	0	1,565
MO	18	0	479	479	0	959
MS	5	8,883	116	0	232	9,231
MT	40	49	22	60	0	130
NC	4	7,758	287	216	1,437	9,698
ND	43	20	4	20	0	44
NE	34	0	0	337	0	337
NH	46	0	0	22	0	22
NJ	38	0	55	124	31	210
NM	31	382	42	48	53	526
NV	49	0	0	1	1	2
NY	22	0	470	235	78	784
OH	14	0	0	1,720	0	1,720
OK	29	0	287	287	0	574
OR	23	482	88	195	0	765
PA	8	0	373	1,212	2,238	3,824
RI	45	0	7	16	4	26
SC	7	3,715	0	258	103	4,076
SD	30	436	0	97	0	533
TN	21	207	591	5	0	802
TX	3	9,962	0	138	2,767	12,868
UT	36	0	0	93	186	280
VA	27	0	0	110	513	623
VT	47	0	6	12	3	21
WA	26	0	194	436	0	629
WI	24	0	62	172	499	733
WV	35	0	0	0	313	313
WY	48	1	0	1	0	3
Total		71,568	10,377	15,016	14,242	111,203

TABLE G5: METHANE EMISSIONS FROM U.S. BROILER AWMS'S (METRIC TONS/YEAR)							
State	Rank	An.Lag	Liq/Slur	Litter	Deep Pit	Other	Total
AK	50	0	0	0	0	0	0
AL	2	1,579	44	10,649	11	0	12,283
AR	1	1,221	407	13,589	0	0	15,217
AZ	45	0	0	0	2	0	2
CA	8	251	24	3,214	90	180	3,759
CO	34	12	5	0	14	0	31
CT	37	0	0	0	18	0	18
DE	9	0	0	3,295	8	0	3,303
FL	13	105	12	1,867	34	12	2,029
GA	3	14	31	11,710	46	199	12,000
HI	32	3	4	34	2	0	44
IA	27	18	8	45	44	4	119
ID	38	0	13	0	2	0	15
IL	30	37	0	0	19	0	56
IN	26	0	30	0	142	0	172
KS	42	0	0	0	11	0	11
KY	24	141	17	41	0	1	200
LA	25	176	0	0	0	1	177
MA	43	0	2	0	5	1	9
MD	7	0	0	3,824	24	0	3,848
ME	36	0	8	0	17	4	29
MI	29	21	5	11	40	9	86
MN	18	0	60	502	45	0	606
MO	17	0	40	826	40	0	906
MS	5	1,091	14	5,469	0	29	6,603
MT	41	5	2	0	6	0	13
NC	4	611	23	7,578	17	113	8,342
ND	44	2	0	0	2	0	4
NE	33	0	0	17	18	0	35
NH	47	0	0	0	2	0	2
NJ	39	0	4	0	9	2	15
NM	35	21	2	0	3	3	29
NV	51	0	0	0	0	0	0
NY	28	0	48	38	24	8	117
OH	22	0	0	182	102	0	284
OK	14	0	21	1,832	21	0	1,875
OR	21	25	5	262	10	0	302
PA	11	0	31	1,923	99	184	2,236
RI	48	0	0	0	0	0	1
SC	15	313	0	1,073	22	9	1,417
SD	31	40	0	0	9	0	48
TN	16	18	51	1,318	0	0	1,388
TX	6	620	0	4,035	9	172	4,836
UT	40	0	0	0	5	10	15
VA	10	0	0	2,663	8	36	2,707
VT	46	0	0	0	1	0	2
WA	20	0	13	427	29	0	469
WI	23	0	5	198	15	42	261
WV	19	0	0	533	0	26	559
WY	49	0	0	0	0	0	0
Other	12	0	0	2,174	0	0	2,174
Total		6,324	929	79,329	1,025	1,045	88,652

TABLE G6: METHANE EMISSIONS FROM U.S. TURKEY AWMS'S (METRIC TONS/YEAR)

State	Rank	Range	Litter	Other	Total
AK		0	0	0	0
AL		0	0	0	0
AR	5	45	848	0	892
AZ		0	0	0	0
CA	3	92	1,222	0	1,313
CO		0	0	0	0
CT	27	1	0	0	1
DE		0	0	0	0
FL		0	0	0	0
GA	15	59	59	0	119
HI		0	0	0	0
IA	10	0	387	0	387
ID		0	0	0	0
IL	19	13	72	0	84
IN	8	32	607	0	639
KS	23	0	11	0	11
KY		0	0	0	0
LA		0	0	0	0
MA	24	2	6	0	7
MD	25	1	6	0	7
ME		0	0	0	0
MI	14	10	138	0	149
MN	2	0	1,908	0	1,908
MO	6	0	818	0	818
MS		0	0	0	0
MT		0	0	0	0
NC	1	237	2,137	0	2,374
ND	21	36	24	0	59
NE	18	0	88	0	88
NH	28	0	1	0	1
NJ	26	1	4	0	5
NM		0	0	0	0
NV		0	0	0	0
NY	22	0	17	0	17
OH	13	0	178	0	178
OK		0	0	0	0
OR	20	0	82	0	82
PA	9	39	352	0	392
RI		0	0	0	0
SC	11	14	262	0	276
SD	16	0	117	0	117
TN		0	0	0	0
TX		0	0	0	0
UT	12	193	0	0	193
VA	7	48	759	0	808
VT		0	0	0	0
WA		0	0	0	0
WI		0	0	0	0
WV	17	11	103	0	114
WY		0	0	0	0
OTHER	4	114	840	0	954
Total		950	11,046	0	11,996

TABLE G7: METHANE EMISSIONS FROM U.S. SHEEP AWMS'S (METRIC TONS/YEAR)

State	Rank	Pasture	Other	Total
AK	34	99	0	99
AL		0	0	0
AR		0	0	0
AZ	11	1,095	0	1,095
CA	2	2,999	333	3,332
CO	8	1,381	73	1,454
CT	40	23	23	46
DE		0	0	0
FL		0	0	0
GA		0	0	0
HI		0	0	0
IA	9	1,341	14	1,355
ID	12	880	46	926
IL	18	406	21	427
IN	21	373	41	415
KS	16	551	0	551
KY	33	99	5	105
LA	37	55	0	55
MA	41	29	15	44
MD	31	71	37	108
ME	39	32	16	48
MI	25	327	21	348
MN	13	675	75	750
MO	19	378	42	420
MS		0	0	0
MT	5	1,777	36	1,813
NC	35	82	15	97
ND	15	527	28	554
NE	22	358	40	398
NH	42	35	0	35
NJ	32	70	36	107
NM	7	1,591	0	1,591
NV	26	276	6	281
NY	29	155	84	239
OH	14	664	35	699
OK	23	392	0	392
OR	10	1,177	116	1,293
PA	20	208	208	417
RI		0	0	0
SC		0	0	0
SD	4	2,064	0	2,064
TN	36	80	0	80
TX	1	4,389	1,097	5,486
UT	6	1,611	85	1,696
VA	24	386	0	386
VT	38	34	17	51
WA	28	245	0	245
WI	27	241	7	248
WV	17	447	50	497
WY	3	2,199	116	2,315
Other	30	182	0	182
Total		30,000	2,739	32,739

TABLE G8: METHANE EMISSIONS FROM U.S. GOAT AWMS'S (METRIC TONS/YEAR)				
State	Rank	Pasture	Other	Total
AK	50	1	0	1
AL	14	31	0	31
AR	11	39	0	40
AZ	3	275	29	304
CA	6	0	83	83
CO	25	21	0	21
CT	44	4	0	4
DE	49	1	0	1
FL	12	27	10	38
GA	8	59	0	59
HI	47	2	0	3
IA	23	21	0	21
ID	37	7	1	8
IL	21	24	0	24
IN	24	21	0	21
KS	19	26	0	26
KY	15	27	0	28
LA	32	11	0	11
MA	35	8	0	8
MD	34	9	0	9
ME	45	4	0	4
MI	7	61	1	62
MN	27	19	0	19
MO	9	50	0	50
MS	29	15	1	15
MT	38	6	0	6
NC	20	22	2	25
ND	40	5	0	5
NE	30	13	0	13
NH	42	4	0	4
NJ	36	8	0	8
NM	2	391	0	391
NV	43	4	0	4
NY	16	27	0	27
OH	10	49	0	49
OK	4	203	0	203
OR	13	26	5	31
PA	17	26	0	26
RI	48	1	0	1
SC	28	18	0	18
SD	39	5	0	5
TN	5	84	0	84
TX	1	4,050	1,013	5,063
UT	41	4	0	4
VA	22	23	0	23
VT	46	3	0	3
WA	26	21	0	21
WI	18	24	1	26
WV	31	9	2	12
WY	33	10	0	10
Total		5,801	1,149	6,950

TABLE G9: METHANE EMISSIONS FROM U.S. HORSE AWMS'S (METRIC TONS/YEAR)					
State	Rank	Pasture	Paddock	Other	Total
AK	49	60	7	0	67
AL	32	622	622	0	1,245
AR	29	1,299	144	0	1,444
AZ	10	1,646	886	0	2,532
CA	2	4,271	1,068	0	5,339
CO	5	2,349	481	0	2,830
CT	44	124	124	0	248
DE	48	54	54	0	109
FL	6	1,311	328	1,092	2,731
GA	33	734	404	86	1,223
HI	47	70	57	0	127
IA	14	1,960	170	0	2,130
ID	18	1,208	705	101	2,014
IL	20	797	597	597	1,991
IN	23	945	945	0	1,891
KS	19	1,796	200	0	1,996
KY	4	2,259	968	0	3,227
LA	31	1,042	347	0	1,390
MA	42	279	150	0	429
MD	37	619	333	0	952
ME	45	148	79	0	227
MI	17	1,306	734	0	2,040
MN	21	975	975	0	1,949
MO	8	2,405	267	0	2,672
MS	36	607	405	0	1,012
MT	9	2,573	26	0	2,599
NC	35	699	107	269	1,075
ND	34	814	349	0	1,163
NE	25	1,748	92	0	1,840
NH	46	15	131	0	145
NJ	38	540	291	0	831
NM	24	465	1,396	0	1,862
NV	39	509	127	0	636
NY	22	480	959	480	1,918
OH	7	135	2,570	0	2,706
OK	3	2,769	692	0	3,461
OR	15	1,157	947	0	2,103
PA	11	1,170	1,170	0	2,341
RI	50	24	13	0	37
SC	40	301	301	0	602
SD	28	1,300	325	0	1,626
TN	13	1,680	560	0	2,240
TX	1	5,023	0	3,348	8,371
UT	30	1,135	284	0	1,418
VA	26	1,713	17	0	1,730
VT	43	177	95	0	272
WA	16	1,036	1,036	0	2,072
WI	12	858	257	1,201	2,315
WV	41	135	406	0	542
WY	27	1,428	292	0	1,720
Total		56,769	23,498	7,173	87,440

APPENDIX H: U.S. ANIMAL WASTE MANAGEMENT SYSTEM USAGE

Tables H1 to H9 list the percent of animal wastes managed by the animal waste management systems in each state of the U.S. The following abbreviations are used in the tables:

An.Lag.	=	Anaerobic Lagoon
Liq/Slur	=	Liquid/Slurry Storage
Other	=	Other Animal Waste Management Systems
Pit St. <1 mnth	=	Pit Storage for less than 1 month
Pit St. >1 mnth	=	Pit Storage for more than 1 month

TABLE H1: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. BEEF					
STATE	An.Lag	Drylot	Liq/Slur	Pasture	Other
AL	0%	2%	0%	98%	0%
AK	0%	0%	0%	100%	0%
AZ	0%	30%	0%	70%	0%
AR	0%	1%	0%	99%	0%
CA	0%	12%	0%	88%	0%
CO	0%	25%	0%	72%	3%
CT	0%	0%	0%	100%	0%
DE	0%	0%	0%	100%	0%
FL	0%	0%	0%	99%	0%
GA	0%	1%	0%	99%	0%
HI	0%	10%	0%	90%	0%
ID	0%	13%	1%	86%	0%
IL	2%	14%	2%	83%	0%
IN	1%	17%	1%	81%	0%
IA	0%	13%	0%	87%	0%
KS	2%	23%	0%	76%	0%
KY	0%	1%	0%	99%	0%
LA	0%	1%	0%	99%	0%
ME	0%	0%	0%	100%	0%
MD	0%	4%	1%	95%	0%
MA	0%	0%	0%	100%	0%
MI	2%	22%	2%	75%	0%
MN	0%	13%	1%	85%	0%
MS	0%	1%	0%	99%	0%
MO	1%	1%	0%	98%	0%
MT	0%	3%	0%	97%	0%
NE	1%	31%	0%	68%	0%
NV	0%	5%	0%	95%	0%
NH	0%	0%	0%	100%	0%
NJ	0%	6%	0%	94%	0%
NM	0%	8%	0%	92%	0%
NY	0%	2%	0%	97%	0%
NC	0%	0%	1%	97%	1%
ND	0%	2%	0%	98%	0%
OH	1%	12%	1%	87%	0%
OK	0%	5%	0%	95%	0%
OR	0%	5%	0%	94%	0%
PA	0%	6%	0%	94%	0%
RI	0%	0%	0%	100%	0%
SC	0%	3%	0%	97%	0%
SD	1%	5%	0%	94%	0%
TN	0%	1%	0%	99%	0%
TX	0%	13%	0%	87%	0%
UT	0%	5%	0%	95%	0%
VT	0%	0%	0%	100%	0%
VA	0%	2%	0%	98%	0%
WA	0%	15%	0%	85%	0%
WV	0%	2%	0%	98%	0%
WI	0%	5%	0%	95%	0%
WY	0%	6%	0%	94%	0%
U.S. Average	<1%	10%	<1%	89%	0%

STATE	An. Lagoon	Liq/ Slurry	Daily Spread	Solid Stor	Other
TABLE H2: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. DAIRY					
AL	50%	0%	50%	0%	0%
AK	10%	71%	2%	2%	15%
AZ	10%	0%	0%	0%	90%
AR	25%	0%	75%	0%	0%
CA	40%	0%	0%	0%	60%
CO	5%	10%	85%	0%	0%
CT	0%	53%	47%	1%	0%
DE	5%	35%	60%	0%	0%
FL	2%	0%	10%	0%	88%
GA	35%	5%	5%	0%	55%
HI	31%	57%	6%	0%	6%
ID	10%	85%	2%	0%	3%
IL	5%	15%	45%	10%	25%
IN	10%	60%	20%	10%	0%
IA	3%	20%	8%	65%	4%
KS	0%	40%	60%	0%	0%
KY	19%	8%	30%	0%	43%
LA	6%	0%	4%	0%	90%
ME	0%	29%	58%	13%	0%
MD	2%	48%	45%	5%	0%
MA	0%	29%	58%	13%	0%
MI	5%	30%	45%	12%	8%
MN	0%	30%	40%	30%	0%
MS	10%	1%	2%	2%	85%
MO	60%	0%	40%	0%	0%
MT	12%	19%	39%	23%	7%
NE	0%	5%	35%	0%	60%
NV	1%	1%	8%	90%	0%
NH	0%	40%	20%	40%	0%
NJ	0%	29%	58%	13%	0%
NM	90%	0%	10%	0%	0%
NY	0%	20%	70%	10%	0%
NC	5%	35%	50%	10%	0%
ND	0%	20%	10%	70%	0%
OH	5%	30%	45%	12%	8%
OK	15%	0%	5%	0%	80%
OR	42%	35%	5%	1%	17%
PA	0%	2%	95%	3%	0%
RI	0%	29%	58%	13%	0%
SC	80%	5%	10%	5%	0%
SD	25%	25%	30%	20%	0%
TN	5%	40%	20%	0%	35%
TX	25%	60%	15%	0%	0%
UT	1%	1%	8%	90%	0%
VT	0%	29%	58%	13%	0%
VA	0%	75%	25%	0%	0%
WA	40%	50%	10%	0%	0%
WV	2%	40%	30%	20%	8%
WI	0%	15%	70%	15%	0%
WY	12%	19%	39%	23%	7%
U.S. Average	11%	21%	41%	18%	8%

TABLE H3: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. SWINE					
STATE	An. Lagoon	Drylot	Pit St. <1 mnth	Pit St. >1 mnth	Other
AL	90%	0%	0%	10%	0%
AK	100%	0%	0%	0%	0%
AZ	100%	0%	0%	0%	0%
AR	70%	20%	0%	10%	0%
CA	90%	0%	0%	0%	10%
CO	24%	25%	21%	24%	6%
CT	15%	0%	0%	0%	85%
DE	20%	10%	0%	70%	0%
FL	35%	64%	1%	0%	0%
GA	68%	20%	0%	10%	2%
HI	32%	7%	17%	36%	8%
ID	40%	15%	5%	35%	5%
IL	25%	15%	10%	45%	5%
IN	25%	10%	5%	60%	0%
IA	3%	30%	11%	39%	13%
KS	30%	40%	0%	30%	0%
KY	80%	12%	7%	1%	0%
LA	95%	5%	0%	0%	0%
ME	3%	53%	2%	42%	0%
MD	50%	10%	0%	40%	0%
MA	3%	53%	2%	42%	0%
MI	42%	12%	4%	39%	3%
MN	0%	20%	20%	40%	20%
MS	59%	14%	5%	9%	13%
MO	80%	20%	0%	0%	0%
MT	0%	40%	25%	25%	10%
NE	35%	5%	55%	5%	0%
NV	25%	75%	0%	0%	0%
NH	5%	90%	0%	5%	0%
NJ	3%	53%	2%	42%	0%
NM	10%	70%	10%	10%	0%
NY	5%	30%	5%	60%	0%
NC	70%	15%	0%	15%	0%
ND	20%	20%	30%	30%	0%
OH	37%	8%	1%	46%	8%
OK	60%	30%	10%	0%	0%
OR	25%	6%	35%	12%	22%
PA	0%	39%	1%	60%	0%
RI	3%	53%	2%	42%	0%
SC	90%	5%	0%	5%	0%
SD	20%	30%	25%	25%	0%
TN	80%	15%	0%	5%	0%
TX	35%	20%	15%	10%	20%
UT	25%	75%	0%	0%	0%
VT	3%	53%	2%	42%	0%
VA	90%	0%	0%	10%	0%
WA	30%	0%	10%	60%	0%
WV	25%	25%	25%	25%	0%
WI	0%	10%	20%	70%	0%
WY	24%	25%	21%	24%	6%
U.S. Average	29%	20%	12%	32%	7%

STATE	An. Lagoon	Deep Pit	Liq/ Slurry	Other
TABLE H4: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. CAGED LAYERS				
AL	80%	10%	10%	0%
AK	15%	63%	12%	10%
AZ	0%	100%	0%	0%
AR	40%	0%	60%	0%
CA	7%	45%	3%	45%
CO	4%	88%	8%	0%
CT	0%	100%	0%	0%
DE	0%	100%	0%	0%
FL	12%	70%	6%	12%
GA	1%	30%	5%	65%
HI	80%	10%	0%	10%
ID	0%	40%	60%	0%
IL	10%	90%	0%	0%
IN	0%	95%	5%	0%
IA	2%	90%	4%	4%
KS	0%	100%	0%	0%
KY	61%	3%	33%	3%
LA	95%	0%	0%	5%
ME	0%	81%	9%	10%
MD	0%	100%	0%	0%
MA	0%	81%	9%	10%
MI	3%	85%	3%	10%
MN	0%	75%	25%	0%
MI	85%	0%	5%	10%
MO	0%	80%	20%	0%
MT	4%	88%	8%	0%
NE	0%	100%	0%	0%
NV	0%	75%	0%	25%
NH	0%	100%	0%	0%
NJ	0%	81%	9%	10%
NM	20%	45%	10%	25%
NY	0%	60%	30%	10%
NC	30%	15%	5%	50%
ND	5%	90%	5%	0%
OH	0%	100%	0%	0%
OK	0%	80%	20%	0%
OR	11%	80%	9%	0%
PA	0%	65%	5%	30%
RI	0%	81%	9%	10%
SC	40%	50%	0%	10%
SD	20%	80%	0%	0%
TN	7%	3%	90%	0%
TX	40%	10%	0%	50%
UT	0%	50%	0%	50%
VT	0%	81%	9%	10%
VA	0%	30%	0%	70%
WA	0%	90%	10%	0%
WV	0%	0%	0%	100%
WI	0%	55%	5%	40%
WY	4%	88%	8%	0%
U.S. Average	14%	56%	10%	20%

TABLE H5: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. BROILERS		
State	Litter	Other
AL	100%	0%
AK		
AZ		
AR	100%	0%
CA	100%	0%
CO		
CT		
DE	100%	0%
FL	100%	0%
GA	100%	0%
HI	100%	0%
ID		
IL		
IN		
IA	100%	0%
KS		
KY	100%	0%
LA		
ME		
MA		
MD	100%	0%
MI	100%	0%
MN	100%	0%
MS	100%	0%
MO	100%	0%
MT		
NC	100%	0%
ND		
NH		
NJ		
NM		
NY	100%	0%
NE	100%	0%
NV		
OH	100%	0%
OK	100%	0%
OR	100%	0%
PA	100%	0%
RI		
SC	100%	0%
SD		
TN	100%	0%
TX	100%	0%
UT		
VA	100%	0%
VT		
WV	100%	0%
WA	100%	0%
WI	100%	0%
WY		
Other	100%	0%
U.S. Average	100%	0%

TABLE H6: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. TURKEYS			
State	Litter	Range	Other
AR	95%	5%	0%
AK			
AZ			
AR			
CA	93%	7%	0%
CO			
CT	0%	100%	0%
DE			
FL			
GA	50%	50%	0%
HI			
ID			
IL	85%	15%	0%
IN	95%	5%	0%
IA	100%	0%	0%
KS	100%	0%	0%
KY			
LA			
ME			
MA	75%	25%	0%
MD	90%	10%	0%
MI	93%	7%	0%
MN	100%	0%	0%
MS			
MO	100%	0%	0%
MT			
NC	90%	10%	0%
ND	40%	60%	0%
NH	100%	0%	0%
NJ	75%	25%	0%
NM			
NY	100%	0%	0%
NE	100%	0%	0%
NV			
OH	100%	0%	0%
OK			
OR	100%	0%	0%
PA	90%	10%	0%
RI			
SC	95%	5%	0%
SD	100%	0%	0%
TN			
TX			
UT	0%	100%	0%
VA	94%	6%	0%
VT			
WV	90%	10%	0%
WA			
WI			
WY			
Other	88%	12%	0%
U.S. Average	92%	8%	0%

TABLE H7: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. SHEEP		
STATE	Pasture	Other
AL		
AK	100%	0%
AZ	100%	0%
AR		
CA	90%	10%
CO	95%	5%
CT	50%	50%
DE		
FL		
GA		
HI		
ID	95%	5%
IL	95%	5%
IN	90%	10%
IA	99%	1%
KS	100%	0%
KY	95%	5%
LA	100%	0%
ME	66%	34%
MD	66%	34%
MA	66%	34%
MI	94%	6%
MN	90%	10%
MS		
MO	90%	10%
MT	98%	2%
NE	90%	10%
NV	98%	2%
NH	100%	0%
NJ	66%	34%
NM	100%	0%
NY	65%	35%
NC	98%	2%
ND	95%	5%
OH	95%	5%
OK	100%	0%
OR	91%	9%
PA	50%	50%
RI		
SC		
SD	100%	0%
TN	100%	0%
TX	80%	20%
UT	95%	5%
VT	66%	34%
VA	100%	0%
WA	100%	0%
WV	90%	10%
WI	97%	3%
WY	95%	5%
Other	100%	
U.S. Average	92%	8%

TABLE H8: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. GOATS		
STATE	Pasture	Other
AL	100%	0%
AK	100%	0%
AZ	95%	5%
AR	99%	1%
CA	0%	100%
CO	100%	0%
CT	100%	0%
DE	100%	0%
FL	80%	20%
GA	100%	0%
HI	92%	8%
ID	92%	8%
IL	100%	0%
IN	100%	0%
IA	100%	0%
KS	100%	0%
KY	99%	1%
LA	100%	0%
ME	100%	0%
MD	100%	0%
MA	100%	0%
MI	99%	1%
MN	100%	0%
MS	95%	5%
MO	100%	0%
MT	99%	1%
NE	100%	0%
NV	98%	2%
NH	100%	0%
NJ	100%	0%
NM	100%	0%
NY	100%	0%
NC	90%	10%
ND	100%	0%
OH	100%	0%
OK	100%	0%
OR	84%	16%
PA	100%	0%
RI	100%	0%
SC	100%	0%
SD	100%	0%
TN	100%	0%
TX	80%	20%
UT	100%	0%
VT	100%	0%
VA	99%	1%
WA	100%	0%
WV	80%	20%
WI	95%	5%
WY	100%	0%
Other		
U.S. Average	84%	16%

TABLE H9: ANIMAL WASTE MANAGEMENT SYSTEMS FOR U.S. HORSES

STATE	Paddock	Pasture	Other
AL	50%	50%	0%
AK	10%	90%	0%
AZ	35%	65%	0%
AR	10%	90%	0%
CA	20%	80%	0%
CO	17%	83%	0%
CT	50%	50%	0%
DE	50%	50%	0%
FL	15%	60%	25%
GA	33%	60%	7%
HI	45%	55%	0%
ID	35%	60%	5%
IL	30%	40%	30%
IN	50%	50%	0%
IA	8%	92%	0%
KS	10%	90%	0%
KY	30%	70%	0%
LA	25%	75%	0%
ME	35%	65%	0%
MD	35%	65%	0%
MA	35%	65%	0%
MI	36%	64%	0%
MN	50%	50%	0%
MS	40%	60%	0%
MO	10%	90%	0%
MT	1%	99%	0%
NE	5%	95%	0%
NV	20%	80%	0%
NH	90%	10%	0%
NJ	35%	65%	0%
NM	75%	25%	0%
NY	50%	25%	25%
NC	10%	65%	25%
ND	30%	70%	0%
OH	95%	5%	0%
OK	20%	80%	0%
OR	45%	55%	0%
PA	50%	50%	0%
RI	35%	65%	0%
SC	50%	50%	0%
SD	20%	80%	0%
TE	25%	75%	0%
TX	0%	60%	40%
UT	20%	80%	0%
VT	35%	65%	0%
VA	1%	99%	0%
WA	50%	50%	0%
WV	75%	25%	0%
WI	15%	50%	35%
WY	17%	83%	0%
U.S. Average	27%	66%	7%

APPENDIX I: GLOBAL ANIMAL WASTE MANAGEMENT SYSTEM USAGE

Tables I1 to I5 list the percent of animal wastes managed by the animal waste management systems (AWMS) for the major animal types in each country of the world.

TABLE I1: GLOBAL AWMS USAGE FOR NON-DAIRY CATTLE[D]							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
NORTH AMERICA							
Canada	0%	9%	0%	50%	27%	0%	15%
United States	<1%	<1%	0%	10%	89%	0%	<1%
Average	<1%	1%	0%	14%	84%	0%	1%
WESTERN EUROPE							
Austria	0%	60%	0%	0%	30%	0%	10%
Belgium	0%	35%	0%	0%	30%	0%	35%
Denmark	0%	0%	0%	0%	100%	0%	0%
Finland	0%	20%	0%	0%	30%	0%	50%
France	0%	60%	0%	0%	30%	0%	10%
Germany (Western)	0%	60%	0%	0%	30%	0%	10%
Greece	0%	60%	0%	0%	30%	0%	10%
Ireland	0%	25%	0%	0%	60%	0%	15%
Italy	0%	79%	0%	21%	0%	0%	0%
Netherlands	0%	90%	0%	0%	10%	0%	0%
Norway	0%	75%	0%	0%	0%	0%	25%
Portugal	0%	10%	0%	0%	90%	0%	0%
Spain	0%	20%	0%	0%	80%	0%	0%
Sweden	0%	85%	0%	10%	5%	0%	0%
Switzerland	0%	80%	17%	0%	3%	0%	0%
United Kingdom	0%	60%	0%	0%	30%	0%	10%
Average	0%	55%	0%	2%	33%	0%	9%
EASTERN EUROPE							
Albania	0%	5%	0%	0%	95%	0%	0%
Bulgaria	0%	20%	0%	0%	40%	0%	40%
Czechoslovakia	0%	100%	0%	0%	0%	0%	0%
Germany (Eastern)	0%	80%	0%	0%	20%	0%	0%
Hungary	0%	2%	0%	0%	49%	0%	49%
Poland	0%	15%	0%	0%	25%	0%	60%
Romania	0%	25%	0%	0%	25%	0%	50%
Soviet Union	0%	25%	0%	0%	25%	0%	50%
Yugoslavia	0%	10%	0%	0%	90%	0%	0%
Average	0%	29%	0%	0%	27%	0%	45%
OCEANIA							
Australia	0%	0%	0%	0%	100%	0%	0%
Fiji	0%	0%	0%	0%	100%	0%	0%
New Caledonia	0%	0%	0%	0%	100%	0%	0%
New Zealand	0%	0%	0%	0%	100%	0%	0%
Papua New Guinea	0%	0%	0%	0%	100%	0%	0%
Vanuatu	0%	0%	0%	0%	100%	0%	0%
Average	0%	0%	0%	0%	100%	0%	0%
LATIN AMERICA							
Argentina	0%	0%	0%	0%	99%	0%	1%
Bolivia	0%	0%	0%	1%	99%	0%	0%
Brazil	0%	0%	0%	0%	99%	0%	1%
Chile	0%	0%	0%	0%	99%	0%	1%
Colombia	0%	0%	0%	1%	99%	0%	0%
Costa Rica	0%	0%	0%	1%	99%	0%	0%
Cuba	0%	0%	0%	1%	99%	0%	0%
Dominican Republic	0%	0%	0%	1%	99%	0%	0%
Ecuador	0%	0%	0%	0%	99%	0%	1%

TABLE I1: GLOBAL AWMS USAGE FOR NON-DAIRY CATTLE[D]							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
LATIN AMERICA (continued)							
El Salvador	0%	0%	0%	1%	99%	0%	0%
Guatemala	0%	0%	3%	0%	95%	1%	1%
Guyana	0%	0%	0%	1%	98%	0%	1%
Haiti	0%	0%	0%	1%	99%	0%	0%
Honduras	0%	0%	0%	2%	98%	0%	0%
Jamaica	0%	0%	0%	1%	99%	0%	0%
Mexico	0%	0%	0%	0%	99%	0%	1%
Nicaragua	0%	0%	0%	1%	99%	0%	0%
Panama	0%	0%	0%	2%	98%	0%	0%
Paraguay	0%	0%	0%	1%	99%	0%	0%
Peru	0%	0%	0%	1%	99%	0%	0%
Puerto Rico	0%	0%	0%	2%	98%	0%	0%
Uruguay	0%	0%	0%	2%	98%	0%	0%
Venezuela	0%	0%	0%	2%	98%	0%	0%
Average	0%	0%	0%	0%	99%	0%	1%
AFRICA							
Angola	0%	0%	0%	0%	100%	0%	0%
Benin	0%	0%	0%	0%	100%	0%	0%
Botswana	0%	0%	0%	0%	100%	0%	0%
Burkina Faso	0%	0%	0%	0%	100%	0%	0%
Burundi	0%	0%	0%	0%	100%	0%	0%
Cameroon	0%	0%	0%	0%	100%	0%	0%
Central African Rep.	0%	0%	0%	0%	100%	0%	0%
Chad	0%	0%	0%	0%	100%	0%	0%
Cote d'Ivoire	0%	0%	0%	0%	100%	0%	0%
Ethiopia	0%	0%	0%	0%	100%	0%	0%
The Gambia	0%	0%	0%	0%	100%	0%	0%
Ghana	0%	0%	0%	0%	100%	0%	0%
Guinea	0%	0%	10%	5%	85%	0%	0%
Guinea-Bissau	0%	0%	0%	0%	100%	0%	0%
Kenya	0%	0%	0%	0%	100%	0%	0%
Lesotho	0%	0%	0%	0%	100%	0%	0%
Madagascar	0%	0%	0%	0%	100%	0%	0%
Malawi	0%	0%	60%	0%	40%	0%	0%
Mali	0%	0%	9%	0%	80%	11%	0%
Mauritania	0%	0%	0%	0%	100%	0%	0%
Mozambique	0%	0%	0%	0%	100%	0%	0%
Namibia	0%	0%	0%	0%	100%	0%	0%
Niger	0%	0%	0%	0%	100%	0%	0%
Nigeria	0%	0%	0%	0%	100%	0%	0%
Rwanda	0%	0%	0%	0%	100%	0%	0%
Senegal	0%	0%	0%	0%	100%	0%	0%
Sierra Leone	0%	0%	0%	0%	100%	0%	0%
Somalia	0%	0%	0%	0%	100%	0%	0%
South Africa	0%	0%	0%	20%	80%	0%	0%
Swaziland	0%	0%	0%	0%	100%	0%	0%
Tanzania	0%	0%	0%	0%	100%	0%	0%
Togo	0%	0%	0%	0%	100%	0%	0%
Uganda	0%	0%	0%	0%	100%	0%	0%
Zaire	0%	0%	0%	0%	100%	0%	0%
Zambia	0%	0%	0%	0%	100%	0%	0%

TABLE I1: GLOBAL AWMS USAGE FOR NON-DAIRY CATTLE[D]

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
AFRICA *(continued)*							
Zimbabwe	0%	0%	0%	0%	100%	0%	0%
Average	0%	0%	1%	3%	96%	0%	0%
NEAR EAST & MEDITERRANEAN							
Afghanistan	0%	0%	0%	0%	85%	15%	0%
Algeria	0%	0%	0%	0%	85%	15%	0%
Egypt	0%	0%	25%	0%	0%	50%	25%
Iran	0%	0%	0%	0%	85%	15%	0%
Iraq	0%	0%	15%	0%	30%	40%	15%
Israel	0%	0%	0%	50%	50%	0%	0%
Jordan	0%	0%	0%	0%	85%	15%	0%
Kuwait	0%	0%	0%	0%	85%	15%	0%
Libya	0%	0%	0%	0%	85%	15%	0%
Morocco	0%	0%	0%	0%	85%	15%	0%
Oman	0%	0%	0%	0%	85%	15%	0%
Saudi Arabia	0%	0%	0%	0%	85%	15%	0%
Sudan	0%	0%	0%	0%	85%	15%	0%
Syria	0%	0%	0%	0%	85%	15%	0%
Tunisia	0%	0%	0%	0%	85%	15%	0%
Turkey	0%	0%	0%	0%	85%	15%	0%
Yemen Arab Rep.	0%	0%	0%	0%	85%	15%	0%
Average							
ASIA							
Bangladesh	0%	0%	20%	0%	50%	30%	0%
Bhutan	*0%*	*0%*	*20%*	*0%*	*50%*	*30%*	*0%*
China	0%	0%	0%	50%	50%	0%	0%
India	0%	0%	15%	5%	13%	68%	0%
Indonesia	0%	20%	80%	0%	0%	0%	0%
Japan	31%	1%	0%	56%	12%	0%	0%
Kampuchea	0%	0%	20%	0%	50%	30%	0%
Laos	0%	0%	20%	0%	50%	30%	0%
Malaysia	0%	0%	5%	2%	5%	0%	88%
Mongolia	0%	0%	20%	0%	50%	30%	0%
Myanmar (Burma)	0%	0%	20%	0%	50%	30%	0%
Nepal	0%	0%	20%	0%	50%	30%	0%
North Korea	0%	0%	20%	0%	50%	30%	0%
Pakistan	0%	0%	50%	0%	50%	0%	0%
Philippines	0%	0%	10%	0%	70%	0%	20%
South Korea	0%	0%	20%	2%	68%	10%	0%
Sri Lanka	0%	0%	20%	0%	50%	30%	0%
Thailand	0%	0%	20%	0%	50%	30%	0%
Viet Nam	0%	0%	20%	0%	50%	30%	0%
Average	0%	0%	16%	14%	29%	40%	0%
GLOBAL AVERAGE	<1%	6%	6%	7%	62%	14%	5%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes buffalo.

TABLE I2: GLOBAL AWMS USAGE FOR DAIRY CATTLE

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
Canada	<1%	35%	3%	62%	0%	0%	0%
United States	11%	21%	41%	18%	0%	0%	8%
Average	10%	23%	37%	23%	0%	0%	7%
WESTERN EUROPE							
Austria	0%	55%	30%	15%	0%	0%	0%
Belgium	0%	15%	0%	35%	50%	0%	0%
Denmark	0%	62%	0%	38%	0%	0%	0%
Finland	0%	20%	0%	50%	30%	0%	0%
France	0%	55%	30%	15%	0%	0%	0%
Germany (Western)	0%	55%	30%	15%	0%	0%	0%
Greece	0%	55%	30%	15%	0%	0%	0%
Ireland	0%	40%	0%	10%	50%	0%	0%
Italy	0%	30%	0%	70%	0%	0%	0%
Netherlands	0%	50%	40%	10%	0%	0%	0%
Norway	0%	7%	0%	3%	25%	0%	65%
Portugal	0%	20%	20%	0%	60%	0%	0%
Spain	0%	25%	25%	0%	50%	0%	0%
Sweden	0%	35%	0%	65%	0%	0%	0%
Switzerland	0%	30%	67%	3%	0%	0%	0%
United Kingdom	0%	55%	30%	15%	0%	0%	0%
Average	0%	46%	24%	21%	8%	0%	1%
EASTERN EUROPE							
Albania	0%	10%	20%	0%	70%	0%	0%
Bulgaria	0%	15%	0%	65%	20%	0%	0%
Czechoslovakia	0%	13%	2%	85%	0%	0%	0%
Germany (Eastern)	0%	15%	0%	85%	0%	0%	0%
Hungary	0%	5%	0%	95%	0%	0%	0%
Poland	0%	10%	0%	70%	20%	0%	0%
Romania	0%	20%	0%	70%	10%	0%	0%
Soviet Union	0%	20%	0%	70%	10%	0%	0%
Yugoslavia	0%	20%	20%	0%	60%	0%	0%
Average	0%	18%	1%	67%	13%	0%	0%
OCEANIA							
Australia	0%	0%	0%	0%	100%	0%	0%
Fiji	0%	0%	0%	0%	100%	0%	0%
New Caledonia	0%	0%	0%	0%	100%	0%	0%
New Zealand	0%	0%	0%	0%	100%	0%	0%
Papua New Guinea	0%	0%	0%	0%	100%	0%	0%
Average	0%	18%	1%	67%	13%	0%	1%

TABLE I2: GLOBAL AWMS USAGE FOR DAIRY CATTLE

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
LATIN AMERICA							
Argentina	0%	0%	75%	0%	25%	0%	0%
Bolivia	0%	0%	5%	5%	90%	0%	0%
Brazil	0%	0%	75%	0%	25%	0%	0%
Chile	0%	0%	90%	0%	10%	0%	0%
Colombia	0%	0%	5%	5%	90%	0%	0%
Costa Rica	0%	0%	5%	5%	90%	0%	0%
Cuba	0%	0%	5%	5%	90%	0%	0%
Dominican Republic	0%	0%	5%	5%	90%	0%	0%
Ecuador	0%	0%	75%	0%	25%	0%	0%
El Salvador	0%	0%	5%	5%	90%	0%	0%
Guatemala	1%	2%	10%	2%	76%	5%	4%
Guyana	1%	3%	0%	5%	90%	1%	0%
Haiti	0%	0%	5%	5%	90%	0%	0%
Honduras	0%	0%	0%	1%	99%	0%	0%
Jamaica	0%	0%	5%	5%	90%	0%	0%
Mexico	0%	0%	75%	0%	25%	0%	0%
Nicaragua	0%	0%	5%	5%	90%	0%	0%
Panama	0%	10%	70%	0%	20%	0%	0%
Paraguay	0%	0%	5%	5%	90%	0%	0%
Peru	0%	0%	5%	5%	90%	0%	0%
Puerto Rico	0%	10%	70%	0%	20%	0%	0%
Uruguay	0%	10%	70%	0%	20%	0%	0%
Venezuela	0%	10%	70%	0%	20%	0%	0%
Average	0%	1%	62%	1%	36%	0%	0%
AFRICA							
Angola	0%	0%	0%	0%	95%	0%	5%
Benin	0%	0%	0%	0%	95%	0%	5%
Botswana	0%	0%	0%	0%	95%	0%	5%
Burkina Faso	0%	0%	0%	0%	95%	0%	5%
Burundi	0%	0%	0%	0%	95%	0%	5%
Cameroon	0%	0%	0%	0%	95%	0%	5%
Central African Rep.	0%	0%	0%	0%	95%	0%	5%
Chad	0%	0%	0%	0%	95%	0%	5%
Cote d'Ivoire	0%	0%	0%	0%	95%	0%	5%
Ethiopia	0%	0%	0%	0%	95%	0%	5%
The Gambia	0%	0%	0%	0%	95%	0%	5%
Ghana	0%	0%	0%	0%	95%	0%	5%
Guinea	0%	0%	0%	0%	95%	0%	5%
Guinea-Bissau	0%	0%	0%	0%	95%	0%	5%
Kenya	0%	0%	0%	0%	95%	0%	5%
Lesotho	0%	0%	0%	0%	95%	0%	5%
Madagascar	0%	0%	0%	0%	95%	0%	5%
Malawi	0%	0%	0%	5%	95%	0%	0%
Mali	0%	0%	24%	0%	50%	21%	5%
Mauritania	0%	0%	0%	0%	95%	0%	5%
Mozambique	0%	0%	0%	0%	95%	0%	5%

TABLE I2: GLOBAL AWMS USAGE FOR DAIRY CATTLE

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
AFRICA (continued)							
Namibia	0%	0%	0%	0%	100%	0%	0%
Niger	0%	0%	0%	0%	95%	0%	5%
Nigeria	0%	0%	0%	0%	95%	0%	5%
Rwanda	0%	0%	0%	0%	95%	0%	5%
Senegal	0%	0%	0%	0%	95%	0%	5%
Sierra Leone	0%	0%	0%	0%	95%	0%	5%
Somalia	0%	0%	0%	0%	95%	0%	5%
South Africa	0%	0%	97%	0%	0%	0%	3%
Swaziland	0%	0%	0%	0%	95%	0%	5%
Tanzania	0%	0%	0%	0%	95%	0%	5%
Togo	0%	0%	0%	0%	95%	0%	5%
Uganda	0%	0%	0%	0%	95%	0%	5%
Zaire	0%	0%	0%	0%	95%	0%	5%
Zambia	0%	0%	0%	0%	95%	0%	5%
Zimbabwe	0%	0%	0%	0%	95%	0%	5%
Average	0%	0%	12%	0%	83%	0%	5%
NEAR EAST & MEDITERRANEAN							
Afghanistan	0%	0%	0%	0%	85%	15%	0%
Algeria	0%	0%	0%	0%	85%	15%	0%
Egypt	0%	0%	25%	25%	0%	50%	0%
Iran	0%	0%	0%	0%	85%	15%	0%
Iraq	0%	0%	15%	15%	30%	40%	0%
Israel	0%	25%	25%	25%	25%	0%	0%
Jordan	0%	0%	0%	0%	85%	15%	0%
Kuwait	0%	0%	0%	0%	85%	15%	0%
Libya	0%	0%	0%	0%	85%	15%	0%
Morocco	0%	0%	0%	0%	85%	15%	0%
Oman	0%	0%	0%	0%	85%	15%	0%
Saudi Arabia	0%	0%	0%	0%	85%	15%	0%
Sudan	0%	0%	0%	0%	85%	15%	0%
Syria	0%	0%	0%	0%	85%	15%	0%
Tunisia	0%	0%	0%	0%	85%	15%	0%
Turkey	0%	0%	0%	0%	85%	15%	0%
Yemen Arab Rep.	0%	0%	0%	0%	85%	15%	0%
Average	0%	0%	3%	3%	76%	18%	0%

TABLE I2: GLOBAL AWMS USAGE FOR DAIRY CATTLE

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
ASIA							
Bangladesh	0%	5%	20%	0%	50%	25%	0%
Bhutan	0%	5%	20%	0%	50%	25%	0%
China	5%	50%	32%	0%	10%	3%	0%
India	0%	0%	15%	0%	18%	68%	0%
Indonesia	0%	80%	20%	0%	0%	0%	0%
Japan	65%	2%	32%	1%	0%	0%	0%
Kampuchea	0%	5%	20%	0%	50%	25%	0%
Myanmar (Burma)	0%	5%	20%	0%	50%	25%	0%
North Korea	0%	5%	20%	0%	50%	25%	0%
South Korea	1%	2%	20%	5%	62%	10%	0%
Laos	0%	5%	20%	0%	50%	25%	0%
Malaysia	1%	2%	5%	5%	5%	0%	82%
Mongolia	0%	5%	20%	0%	50%	25%	0%
Nepal	0%	5%	20%	0%	50%	25%	0%
Pakistan	0%	0%	50%	0%	50%	0%	0%
Philippines	15%	15%	20%	0%	20%	0%	30%
Sri Lanka	0%	5%	20%	0%	50%	25%	0%
Thailand	0%	5%	20%	0%	50%	25%	0%
Viet Nam	0%	5%	20%	0%	50%	25%	0%
Average	6%	4%	21%	0%	24%	46%	0%
GLOBAL AVERAGE	2%	19%	19%	29%	23%	6%	1%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.

TABLE I3: GLOBAL AWMS USAGE FOR SWINE							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
NORTH AMERICA							
Canada	6%	82%	0%	12%	0%	0%	0%
United States	29%	44%	0%	20%	0%	0%	7%
Average	25%	50%	0%	18%	0%	0%	6%
WESTERN EUROPE							
Austria	0%	80%	0%	20%	0%	0%	0%
Belgium	0%	80%	0%	20%	0%	0%	0%
Denmark	0%	62%	0%	38%	0%	0%	0%
Finland	0%	70%	0%	30%	0%	0%	0%
France	0%	80%	0%	20%	0%	0%	0%
Germany (Western)	0%	80%	0%	20%	0%	0%	0%
Greece	0%	80%	0%	20%	0%	0%	0%
Ireland	0%	100%	0%	0%	0%	0%	0%
Italy	0%	100%	0%	0%	0%	0%	0%
Netherlands	0%	79%	0%	21%	0%	0%	0%
Norway	0%	5%	0%	10%	0%	0%	85%
Portugal	0%	40%	0%	60%	0%	0%	0%
Spain	0%	60%	0%	40%	0%	0%	0%
Sweden	0%	100%	0%	0%	0%	0%	0%
Switzerland	0%	98%	0%	2%	0%	0%	0%
United Kingdom	0%	80%	0%	20%	0%	0%	0%
Average	0%	77%	0%	23%	0%	0%	0%
EASTERN EUROPE							
Albania	0%	20%	0%	80%	0%	0%	0%
Bulgaria	0%	40%	0%	60%	0%	0%	0%
Czechoslovakia	20%	80%	0%	0%	0%	0%	0%
Germany (Eastern)	20%	80%	0%	0%	0%	0%	0%
Hungary	96%	0%	0%	4%	0%	0%	0%
Poland	0%	0%	0%	90%	0%	0%	10%
Romania	0%	40%	0%	60%	0%	0%	0%
Soviet Union	0%	40%	0%	60%	0%	0%	0%
Yugoslavia	0%	40%	0%	60%	0%	0%	0%
Average	8%	39%	0%	52%	0%	0%	1%
OCEANIA							
Australia	80%	0%	0%	0%	0%	0%	20%
Fiji	0%	0%	0%	55%	0%	0%	45%
New Caledonia	80%	0%	0%	0%	0%	0%	20%
New Zealand	80%	0%	0%	0%	0%	0%	20%
Papua New Guinea	0%	0%	0%	55%	0%	0%	45%
Vanuatu	0%	0%	0%	55%	0%	0%	45%
Average	55%	0%	0%	17%	0%	0%	28%

TABLE I3: GLOBAL AWMS USAGE FOR SWINE							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
LATIN AMERICA							
Argentina	0%	10%	0%	50%	0%	0%	40%
Bolivia	0%	0%	0%	55%	0%	0%	45%
Brazil	0%	10%	0%	50%	0%	0%	40%
Chile	0%	0%	90%	5%	0%	3%	2%
Colombia	0%	0%	0%	55%	0%	0%	45%
Costa Rica	0%	0%	0%	55%	0%	0%	45%
Cuba	0%	0%	0%	55%	0%	0%	45%
Dominican Republic	0%	0%	0%	55%	0%	0%	45%
Ecuador	0%	10%	0%	50%	0%	0%	40%
El Salvador	0%	0%	0%	55%	0%	0%	45%
Guatemala	0%	5%	5%	80%	0%	5%	5%
Guyana	0%	1%	0%	90%	0%	9%	0%
Haiti	0%	0%	0%	55%	0%	0%	45%
Honduras	0%	0%	0%	10%	0%	0%	90%
Jamaica	0%	0%	0%	55%	0%	0%	45%
Mexico	0%	10%	0%	50%	0%	0%	40%
Nicaragua	0%	0%	0%	55%	0%	0%	45%
Panama	0%	10%	0%	60%	0%	0%	30%
Paraguay	0%	0%	0%	55%	0%	0%	45%
Peru	0%	0%	0%	55%	0%	0%	45%
Puerto Rico	0%	10%	0%	60%	0%	0%	30%
Uruguay	0%	10%	0%	60%	0%	0%	30%
Venezuela	0%	10%	0%	60%	0%	0%	30%
Average	0%	8%	2%	51%	0%	0%	40%
AFRICA							
Angola	0%	5%	0%	95%	0%	0%	0%
Benin	0%	5%	0%	95%	0%	0%	0%
Botswana	0%	5%	0%	95%	0%	0%	0%
Burkina Faso	0%	5%	0%	95%	0%	0%	0%
Burundi	0%	5%	0%	95%	0%	0%	0%
Cameroon	0%	5%	0%	95%	0%	0%	0%
Central African Rep.	0%	5%	0%	95%	0%	0%	0%
Chad	0%	5%	0%	95%	0%	0%	0%
Cote d'Ivoire	0%	5%	0%	95%	0%	0%	0%
Ethiopia	0%	5%	0%	95%	0%	0%	0%
The Gambia	0%	5%	0%	95%	0%	0%	0%
Ghana	0%	5%	0%	95%	0%	0%	0%
Guinea	0%	5%	0%	95%	0%	0%	0%
Guinea-Bissau	0%	5%	0%	95%	0%	0%	0%
Kenya	0%	5%	0%	95%	0%	0%	0%
Lesotho	0%	5%	0%	95%	0%	0%	0%
Madagascar	0%	5%	0%	95%	0%	0%	0%
Malawi	0%	100%	0%	0%	0%	0%	0%
Mali	0%	0%	0%	100%	0%	0%	0%
Mozambique	0%	5%	0%	95%	0%	0%	0%
Namibia	0%	0%	0%	100%	0%	0%	0%

TABLE I3: GLOBAL AWMS USAGE FOR SWINE

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
AFRICA (continued)							
Niger	0%	5%	0%	95%	0%	0%	0%
Nigeria	0%	5%	0%	95%	0%	0%	0%
Rwanda	0%	5%	0%	95%	0%	0%	0%
Senegal	0%	5%	0%	95%	0%	0%	0%
Sierra Leone	0%	5%	0%	95%	0%	0%	0%
Somalia	0%	5%	0%	95%	0%	0%	0%
South Africa	0%	5%	0%	95%	0%	0%	0%
Swaziland	0%	5%	0%	95%	0%	0%	0%
Tanzania	0%	5%	0%	95%	0%	0%	0%
Togo	0%	5%	0%	95%	0%	0%	0%
Uganda	0%	5%	0%	95%	0%	0%	0%
Zaire	0%	5%	0%	95%	0%	0%	0%
Zambia	0%	5%	0%	95%	0%	0%	0%
Zimbabwe	0%	5%	0%	95%	0%	0%	0%
Average	0%	7%	0%	93%	0%	0%	0%
NEAR EAST AND MEDITERRANEAN							
Algeria	0%	15%	0%	85%	0%	0%	0%
Egypt	0%	25%	0%	75%	0%	0%	0%
Israel	0%	35%	0%	65%	0%	0%	0%
Morocco	0%	15%	0%	85%	0%	0%	0%
Tunisia	0%	15%	0%	85%	0%	0%	0%
Turkey	0%	15%	0%	85%	0%	0%	0%
Average	0%	32%	0%	68%	0%	0%	0%
ASIA							
Bhutan	0%	35%	0%	65%	0%	0%	0%
China	0%	40%	0%	53%	0%	7%	0%
India	0%	0%	0%	100%	0%	0%	0%
Indonesia	0%	60%	15%	0%	0%	25%	0%
Japan	31%	0%	15%	53%	0%	0%	1%
Kampuchea	0%	35%	0%	65%	0%	0%	0%
Laos	0%	35%	0%	65%	0%	0%	0%
Malaysia	0%	30%	0%	5%	0%	1%	65%
Mongolia	0%	35%	0%	65%	0%	0%	0%
Myanmar (Burma)	0%	35%	0%	65%	0%	0%	0%
Nepal	0%	35%	0%	65%	0%	0%	0%
North Korea	0%	35%	0%	65%	0%	0%	0%
Philippines	0%	50%	17%	0%	0%	33%	0%
South Korea	0%	50%	0%	50%	0%	0%	0%
Sri Lanka	0%	35%	0%	65%	0%	0%	0%
Thailand	0%	35%	0%	65%	0%	0%	0%
Viet Nam	0%	35%	0%	65%	0%	0%	0%
Average	1%	38%	1%	53%	0%	7%	0%
GLOBAL AVERAGE	5%	42%	1%	45%	0%	3%	5%

A Includes liquid/slurry storage and pit storage.
B Includes anaerobic digesters and burned for fuel.
C Includes deep pit stacks, and litter, and other.

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylots	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
NORTH AMERICA							
Canada	0%	6%	0%	0%	7%	0%	87%
United States	6%	4%	0%	0%	0%	0%	90%
Average	5%	4%	0%	0%	1%	0%	90%
WESTERN EUROPE							
Austria	0%	15%	0%	0%	0%	0%	85%
Belgium	0%	46%	0%	0%	0%	0%	54%
Denmark	0%	14%	0%	0%	8%	0%	78%
Finland	0%	5%	0%	41%	0%	0%	54%
France	0%	11%	0%	0%	6%	0%	84%
Germany (Western)	0%	13%	0%	0%	2%	0%	85%
Greece	0%	15%	0%	0%	0%	0%	85%
Ireland	0%	10%	0%	0%	2%	0%	89%
Italy	0%	0%	0%	0%	0%	0%	100%
Netherlands	0%	27%	0%	4%	0%	0%	69%
Norway	0%	5%	0%	41%	0%	0%	54%
Portugal	0%	9%	0%	0%	0%	0%	91%
Spain	0%	14%	0%	0%	0%	0%	86%
Sweden	0%	46%	0%	0%	0%	0%	54%
Switzerland	0%	7%	0%	2%	0%	0%	91%
United Kingdom	0%	12%	0%	0%	2%	0%	86%
Average	0%	13%	0%	1%	2%	0%	84%
EASTERN EUROPE							
Albania	0%	5%	0%	0%	0%	0%	95%
Bulgaria	0%	28%	0%	0%	0%	0%	72%
Czechoslovakia	0%	44%	0%	0%	0%	0%	56%
Germany (Eastern)	0%	47%	0%	0%	0%	0%	53%
Hungary	0%	34%	0%	0%	3%	0%	62%
Poland	0%	35%	0%	0%	7%	0%	58%
Romania	0%	28%	0%	0%	4%	0%	68%
Soviet Union	0%	27%	0%	0%	0%	0%	73%
Yugoslavia	0%	8%	0%	0%	3%	0%	88%
Average	0%	28%	0%	0%	1%	0%	71%
OCEANIA							
Australia	0%	0%	0%	0%	0%	0%	100%
Fiji	0%	0%	0%	0%	30%	0%	70%
New Caledonia	0%	0%	0%	0%	0%	0%	100%
New Zealand	0%	0%	0%	0%	0%	0%	100%
Papua New Guinea	0%	0%	0%	0%	30%	0%	70%
Average	0%	0%	0%	0%	2%	0%	98%
LATIN AMERICA							
Argentina	0%	9%	0%	0%	39%	0%	53%
Bolivia	0%	5%	0%	0%	50%	0%	45%
Brazil	0%	10%	0%	0%	40%	0%	50%
Chile	0%	10%	0%	0%	40%	0%	50%
Colombia	0%	5%	0%	0%	50%	0%	45%
Costa Rica	0%	5%	0%	0%	50%	0%	45%
Cuba	0%	5%	0%	0%	50%	0%	45%
Dominican Republic	0%	5%	0%	0%	50%	0%	45%
Ecuador	0%	10%	0%	0%	40%	0%	50%

TABLE I4: GLOBAL AWMS USAGE FOR POULTRY[D]							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylots	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
LATIN AMERICA (continued)							
El Salvador	0%	5%	0%	0%	50%	0%	45%
Guatemala	0%	10%	0%	0%	40%	10%	40%
Guyana	0%	0%	0%	0%	36%	0%	64%
Haiti	0%	5%	0%	0%	50%	0%	45%
Honduras	0%	0%	0%	0%	45%	0%	55%
Jamaica	0%	5%	0%	0%	50%	0%	45%
Mexico	0%	9%	0%	0%	38%	0%	53%
Nicaragua	0%	5%	0%	0%	50%	0%	45%
Panama	0%	5%	0%	0%	50%	0%	45%
Paraguay	0%	5%	0%	0%	50%	0%	45%
Peru	0%	5%	0%	0%	50%	0%	45%
Puerto Rico	0%	15%	0%	0%	30%	5%	50%
Uruguay	0%	15%	0%	0%	30%	5%	50%
Venezuela	0%	15%	0%	0%	30%	5%	50%
Average	0%	9%	0%	0%	41%	0%	50%
AFRICA							
Angola	0%	0%	0%	0%	85%	0%	15%
Benin	0%	0%	0%	0%	85%	0%	15%
Botswana	0%	0%	0%	0%	85%	0%	15%
Burkina Faso	0%	0%	0%	0%	85%	0%	15%
Burundi	0%	0%	0%	0%	85%	0%	15%
Cameroon	0%	0%	0%	0%	85%	0%	15%
Central African Rep.	0%	0%	0%	0%	85%	0%	15%
Chad	0%	0%	0%	0%	85%	0%	15%
Cote d'Ivoire	0%	0%	0%	0%	85%	0%	15%
Ethiopia	0%	0%	0%	0%	85%	0%	15%
Ghana	0%	0%	0%	0%	85%	0%	15%
Guinea	0%	0%	0%	0%	85%	0%	15%
Guinea-Bissau	0%	0%	0%	0%	85%	0%	15%
Kenya	0%	0%	0%	0%	85%	0%	15%
Lesotho	0%	0%	0%	0%	85%	0%	15%
Madagascar	0%	0%	0%	0%	68%	0%	32%
Malawi	0%	0%	0%	0%	70%	0%	30%
Mali	0%	0%	0%	0%	80%	0%	20%
Mauritania	0%	0%	0%	0%	85%	0%	15%
Mozambique	0%	0%	0%	0%	86%	0%	14%
Namibia	0%	0%	0%	0%	90%	0%	10%
Niger	0%	0%	0%	0%	85%	0%	15%
Nigeria	0%	0%	0%	0%	85%	0%	15%
Rwanda	0%	0%	0%	0%	85%	0%	15%
Senegal	0%	0%	0%	0%	85%	0%	15%
Sierra Leone	0%	0%	0%	0%	85%	0%	15%
Somalia	0%	0%	0%	0%	85%	0%	15%
South Africa	0%	0%	0%	0%	0%	0%	100%
Swaziland	0%	0%	0%	0%	85%	0%	15%
Tanzania	0%	0%	0%	0%	86%	0%	14%
Togo	0%	0%	0%	0%	85%	0%	15%
Uganda	0%	0%	0%	0%	85%	0%	15%
Zaire	0%	0%	0%	0%	85%	0%	15%

TABLE I4: GLOBAL AWMS USAGE FOR POULTRY[D]							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylots	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
AFRICA (continued)							
Zambia	0%	0%	0%	0%	85%	0%	15%
Zimbabwe	0%	0%	0%	0%	85%	0%	15%
Average	0%	0%	0%	0%	80%	0%	20%
NEAR EAST AND MEDITERRANEAN							
Afghanistan	0%	0%	0%	0%	75%	0%	25%
Algeria	0%	0%	0%	0%	75%	0%	25%
Egypt	0%	0%	0%	0%	74%	0%	26%
Iran	0%	0%	0%	0%	75%	0%	25%
Iraq	0%	0%	0%	0%	75%	0%	25%
Israel	0%	12%	0%	0%	5%	0%	83%
Jordan	0%	0%	0%	0%	75%	0%	25%
Kuwait	0%	0%	0%	0%	75%	0%	25%
Libya	0%	0%	0%	0%	75%	0%	25%
Morocco	0%	0%	0%	0%	75%	0%	25%
Oman	0%	0%	0%	0%	75%	0%	25%
Saudi Arabia	0%	0%	0%	0%	75%	0%	25%
Sudan	0%	0%	0%	0%	75%	0%	25%
Syria	0%	0%	0%	0%	75%	0%	25%
Tunisia	0%	0%	0%	0%	75%	0%	25%
Turkey	0%	0%	0%	0%	68%	0%	32%
Yemen Arab Rep.	0%	0%	0%	0%	75%	0%	25%
Average	0%	1%	0%	0%	70%	0%	29%
ASIA							
Bangladesh	0%	7%	0%	0%	33%	0%	59%
China	0%	0%	0%	0%	54%	3%	43%
India	0%	20%	0%	0%	20%	0%	60%
Indonesia	0%	1%	0%	0%	56%	0%	42%
Japan	9%	0%	0%	0%	0%	0%	91%
Kampuchea	0%	7%	0%	0%	35%	0%	58%
Laos	0%	10%	0%	0%	10%	0%	80%
Malaysia	0%	2%	0%	0%	17%	0%	81%
Myanmar (Burma)	0%	10%	0%	0%	10%	0%	80%
Nepal	0%	10%	0%	0%	10%	0%	80%
North Korea	0%	10%	0%	0%	10%	0%	80%
Pakistan	0%	0%	0%	0%	37%	0%	63%
Philippines	0%	0%	0%	0%	17%	0%	83%
South Korea	0%	10%	0%	0%	21%	0%	69%
Sri Lanka	0%	10%	0%	0%	10%	0%	80%
Thailand	0%	9%	0%	0%	23%	0%	69%
Viet Nam	0%	7%	0%	0%	33%	0%	59%
Average	1%	2%	0%	0%	44%	1%	52%
GLOBAL AVERAGE	1%	8%	0%	<1%	34%	1%	57%

A Includes liquid/slurry storage and pit storage.
B Includes anaerobic digesters and burned for fuel.
C Includes deep pit stacks, litter, and other.
D Includes chickens, turkeys, and ducks.

TABLE I5: GLOBAL AWMS USAGE FOR ALL OTHER LIVESTOCK[D]

Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
NORTH AMERICA							
Canada	0%	0%	0%	35%	35%	0%	30%
United States	0%	0%	0%	<1%	92%	0%	8%
Average	0%	0%	0%	1%	91%	0%	9%
WESTERN EUROPE							
Austria	0%	0%	0%	0%	99%	0%	1%
Belgium	0%	0%	0%	0%	100%	0%	0%
Denmark	0%	0%	0%	0%	100%	0%	0%
Finland	0%	0%	0%	0%	40%	0%	60%
France	0%	0%	0%	0%	89%	0%	11%
Germany (Western)	0%	0%	0%	0%	95%	0%	5%
Greece	0%	0%	0%	0%	90%	0%	10%
Ireland	0%	0%	0%	0%	94%	0%	6%
Italy	0%	0%	0%	15%	84%	0%	1%
Netherlands	0%	0%	0%	0%	17%	0%	83%
Norway	0%	0%	0%	0%	49%	0%	51%
Portugal	0%	0%	0%	0%	100%	0%	0%
Spain	0%	0%	0%	0%	100%	0%	0%
Sweden	0%	0%	0%	0%	0%	0%	100%
Switzerland	0%	0%	0%	0%	88%	0%	12%
United Kingdom	0%	0%	0%	0%	86%	0%	14%
Average	0%	0%	0%	2%	89%	0%	9%
EASTERN EUROPE							
Albania	0%	0%	0%	0%	100%	0%	0%
Bulgaria	0%	0%	0%	0%	100%	0%	0%
Czechoslovakia	0%	0%	0%	0%	61%	0%	39%
Germany (Eastern)	0%	0%	0%	0%	57%	0%	43%
Hungary	0%	0%	0%	0%	100%	0%	0%
Poland	0%	0%	0%	0%	26%	0%	74%
Romania	0%	0%	0%	0%	78%	0%	22%
Soviet Union	0%	0%	0%	0%	78%	0%	22%
Yugoslavia	0%	0%	0%	0%	100%	0%	0%
Average	0%	0%	0%	0%	78%	0%	22%
OCEANIA							
Australia	0%	0%	0%	0%	100%	0%	0%
Fiji	0%	0%	0%	0%	100%	0%	0%
New Caledonia	0%	0%	0%	0%	100%	0%	0%
New Zealand	0%	0%	0%	0%	100%	0%	0%
Papua New Guinea	0%	0%	0%	0%	100%	0%	0%
Vanuatu	0%	0%	0%	0%	100%	0%	0%
Average	0%	0%	0%	0%	100%	0%	0%
LATIN AMERICA							
Argentina	0%	0%	0%	0%	100%	0%	0%
Bolivia	0%	0%	0%	0%	100%	0%	0%
Brazil	0%	0%	0%	0%	100%	0%	0%
Chile	0%	0%	0%	0%	98%	2%	0%
Colombia	0%	0%	0%	0%	100%	0%	0%
Costa Rica	0%	0%	0%	0%	100%	0%	0%
Cuba	0%	0%	0%	0%	100%	0%	0%
Dominican Republic	0%	0%	0%	0%	100%	0%	0%

TABLE I5: GLOBAL AWMS USAGE FOR ALL OTHER LIVESTOCK[D]							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
LATIN AMERICA (continued)							
Ecuador	0%	0%	0%	0%	100%	0%	0%
El Salvador	0%	0%	0%	0%	100%	0%	0%
Guatemala	0%	0%	0%	0%	92%	4%	4%
Guyana	0%	0%	0%	0%	100%	0%	0%
Haiti	0%	0%	0%	0%	100%	0%	0%
Honduras	0%	0%	0%	0%	100%	0%	0%
Jamaica	0%	0%	0%	0%	100%	0%	0%
Mexico	0%	0%	0%	0%	100%	0%	0%
Nicaragua	0%	0%	0%	0%	100%	0%	0%
Panama	0%	0%	0%	0%	100%	0%	0%
Paraguay	0%	0%	0%	0%	100%	0%	0%
Peru	0%	0%	0%	0%	100%	0%	0%
Puerto Rico	0%	0%	0%	0%	100%	0%	0%
Uruguay	0%	0%	0%	0%	100%	0%	0%
Venezuela	0%	0%	0%	0%	100%	0%	0%
Average	0%	0%	0%	0%	100%	0%	0%
AFRICA							
Angola	0%	0%	0%	0%	100%	0%	0%
Benin	0%	0%	0%	0%	100%	0%	0%
Botswana	0%	0%	0%	0%	100%	0%	0%
Burkina Faso	0%	0%	0%	0%	100%	0%	0%
Burundi	0%	0%	0%	0%	100%	0%	0%
Cameroon	0%	0%	0%	0%	100%	0%	0%
Central African Rep.	0%	0%	0%	0%	100%	0%	0%
Chad	0%	0%	0%	0%	100%	0%	0%
Cote d'Ivoire	0%	0%	0%	0%	100%	0%	0%
Ethiopia	0%	0%	0%	0%	100%	0%	0%
The Gambia	0%	0%	0%	0%	100%	0%	0%
Ghana	0%	0%	0%	0%	100%	0%	0%
Guinea	0%	0%	0%	0%	81%	0%	19%
Guinea-Bissau	0%	0%	0%	0%	100%	0%	0%
Kenya	0%	0%	0%	0%	100%	0%	0%
Lesotho	0%	0%	0%	0%	100%	0%	0%
Madagascar	0%	0%	0%	0%	100%	0%	0%
Malawi	0%	0%	0%	0%	100%	0%	0%
Mali	0%	0%	0%	0%	87%	0%	13%
Mauritania	0%	0%	0%	0%	100%	0%	0%
Mozambique	0%	0%	0%	0%	100%	0%	0%
Namibia	0%	0%	0%	0%	100%	0%	0%
Niger	0%	0%	0%	0%	100%	0%	0%
Nigeria	0%	0%	0%	0%	100%	0%	0%
Rwanda	0%	0%	0%	0%	100%	0%	0%
Senegal	0%	0%	0%	0%	100%	0%	0%
Sierra Leone	0%	0%	0%	0%	100%	0%	0%
Somalia	0%	0%	0%	0%	100%	0%	0%
South Africa	0%	0%	0%	2%	98%	0%	0%
Swaziland	0%	0%	0%	0%	100%	0%	0%
Tanzania	0%	0%	0%	0%	100%	0%	0%
Togo	0%	0%	0%	0%	100%	0%	0%
Uganda	0%	0%	0%	0%	100%	0%	0%

TABLE I5: GLOBAL AWMS USAGE FOR ALL OTHER LIVESTOCK[D]							
Country	Anaerobic Lagoons	Liquid Systems[A]	Daily Spread	Solid Storage & Drylot	Pasture, Range & Paddock	Used for Fuel[B]	Other Systems[C]
AFRICA (continued)							
Zaire	0%	0%	0%	0%	100%	0%	0%
Zambia	0%	0%	0%	0%	100%	0%	0%
Zimbabwe	0%	0%	0%	0%	100%	0%	0%
Average	0%	0%	0%	0%	99%	0%	1%
NEAR EAST AND MEDITERRANEAN							
Egypt	0%	0%	0%	0%	100%	0%	0%
Iran	0%	0%	0%	0%	100%	0%	0%
Iraq	0%	0%	0%	0%	100%	0%	0%
Israel	0%	0%	0%	0%	100%	0%	0%
Jordan	0%	0%	0%	0%	100%	0%	0%
Kuwait	0%	0%	0%	0%	100%	0%	0%
Libya	0%	0%	0%	0%	100%	0%	0%
Morocco	0%	0%	0%	0%	100%	0%	0%
Oman	0%	0%	0%	0%	100%	0%	0%
Saudi Arabia	0%	0%	0%	0%	100%	0%	0%
Sudan	0%	0%	0%	0%	100%	0%	0%
Syria	0%	0%	0%	0%	100%	0%	0%
Tunisia	0%	0%	0%	0%	100%	0%	0%
Turkey	0%	0%	0%	0%	100%	0%	0%
Yemen Arab Rep.	0%	0%	0%	0%	100%	0%	0%
Average	0%	0%	0%	0%	100%	0%	0%
ASIA							
Bangladesh	0%	0%	0%	0%	95%	0%	5%
Bhutan	0%	0%	0%	0%	98%	0%	2%
China	0%	0%	0%	0%	93%	0%	7%
India	0%	0%	0%	0%	100%	0%	0%
Indonesia	0%	0%	0%	0%	0%	0%	100%
Japan	0%	0%	0%	0%	100%	0%	0%
Kampuchea	0%	0%	0%	0%	100%	0%	0%
Laos	0%	0%	0%	0%	99%	0%	1%
Malaysia	0%	0%	0%	0%	95%	0%	5%
Mongolia	0%	0%	0%	0%	92%	0%	8%
Myanmar (Burma)	0%	0%	0%	0%	95%	0%	5%
Nepal	0%	0%	0%	0%	93%	0%	7%
North Korea	0%	0%	0%	0%	91%	0%	9%
Pakistan	0%	0%	0%	0%	100%	0%	0%
Philippines	0%	0%	0%	0%	97%	2%	0%
South Korea	0%	0%	0%	0%	100%	0%	0%
Sri Lanka	0%	0%	0%	0%	94%	0%	6%
Thailand	0%	0%	0%	0%	92%	0%	8%
Viet Nam	0%	0%	0%	0%	98%	0%	2%
Average	0%	0%	0%	0%	92%	0%	8%
GLOBAL AVERAGE	0%	0%	0%	<1%	95%	0%	5%

[A] Includes liquid/slurry storage and pit storage.
[B] Includes anaerobic digesters and burned for fuel.
[C] Includes deep pit stacks, litter, and other.
[D] Includes goats, horses, mules, donkeys, and camels.

APPENDIX J: GLOBAL ANIMAL WASTE PRODUCTION

The following tables list the amount of manure produced by the major animal types in each country of the world. Manure production was calculated using the animal populations listed in Appendix E and the manure production per animal values listed in Exhibits 4, 5, and 6. The non-dairy category includes buffaloes; the poultry category includes chickens, turkeys, and ducks; and the other category includes sheep, goats, horses, mules, donkeys, and camels.

APPENDIX J: GLOBAL ANIMAL WASTE PRODUCTION (1000 METRIC TONS/YEAR)						
Country	Non-Dairy[A]	Dairy	Swine	Poultry	Other	Total
NORTH AMERICA						
Canada	86,083	40,643	19,682	3,705	3,520	153,633
USA	865,472	280,826	106,422	37,318	33,298	1,323,336
Total	951,555	321,469	126,104	41,023	36,817	1,476,969
WESTERN EUROPE						
Austria	10,658	19,332	6,349	548	431	37,317
Belgium	16,626	19,031	10,915	1,241	390	48,203
Denmark	9,496	16,201	15,676	602	370	42,344
Finland	6,858	10,740	2,389	219	367	20,573
France	91,500	185,433	22,953	9,691	13,982	323,558
Germany (Western)	63,689	99,171	43,198	3,011	4,459	213,527
Greece	3,479	6,926	2,172	1,132	16,147	29,855
Ireland	30,503	29,668	1,633	365	5,154	67,322
Italy	39,716	60,627	18,575	6,899	15,434	141,250
Netherlands	16,245	38,946	25,522	3,687	1,443	85,843
Norway	4,569	6,946	1,438	146	2,504	15,604
Portugal	7,400	8,371	5,110	657	7,828	29,366
Spain	24,663	35,071	30,917	2,008	24,140	116,799
Sweden	8,407	11,342	4,046	402	883	25,080
Switzerland	7,964	15,919	3,542	219	853	28,497
United Kingdom	68,595	62,896	13,955	5,731	28,601	179,779
Total	410,367	626,619	208,390	36,555	122,986	1,404,917
EASTERN EUROPE						
Albania	3,265	4,938	391	219	3,168	11,981
Bulgaria	7,819	13,009	7,362	1,570	12,265	42,025
Czechoslovakia	24,838	35,894	13,204	1,789	1,384	77,109
Germany (Eastern)	28,363	40,210	22,818	1,862	3,509	96,761
Hungary	8,269	11,644	14,994	2,446	3,081	40,434
Poland	41,057	99,171	35,779	2,409	13,146	191,561
Romania	40,660	40,150	27,784	5,347	25,479	139,420
Soviet Union	582,058	843,150	141,260	46,465	198,128	1,811,061
Yugoslavia	18,692	52,095	16,992	2,993	11,233	102,005
Total	755,021	1,140,260	280,584	65,098	271,394	2,512,356
OCEANIA						
Australia	154,313	44,366	5,216	2,044	177,619	383,558
Fiji	593	165	43	88	321	1,211
New Caledonia	900	120	86	37	107	1,250
New Zealand	44,764	44,045	781	329	66,117	156,035
Papua New Guinea	452	11	2,544	131	20	3,158
Vanuatu	479	0	118	0	28	625
Total	201,501	88,707	8,789	2,628	244,213	545,838
LATIN AMERICA						
Argentina	218,781	16,114	6,136	2,781	41,485	285,297
Bolivia	24,523	427	2,619	526	12,564	40,659
Brazil	534,419	103,061	48,936	24,827	77,327	788,570
Chile	12,460	3,644	2,035	920	7,696	26,756
Colombia	95,388	19,360	3,870	1,708	22,181	142,507
Costa Rica	8,578	1,765	334	219	840	11,736
Cuba	20,080	3,320	3,741	1,183	5,249	33,572
Dominican Republic	8,687	1,281	612	1,183	4,102	15,865

APPENDIX J: GLOBAL ANIMAL WASTE PRODUCTION (1000 METRIC TONS/YEAR)						
Country	Non-Dairy[A]	Dairy	Swine	Poultry	Other	Total
LATIN AMERICA (continued)						
Ecuador	14,627	4,561	6,225	2,102	6,198	33,714
El Salvador	4,042	1,469	661	131	801	7,105
Guatemala	7,939	2,278	1,309	657	1,483	13,666
Guyana	721	296	277	657	139	2,089
Haiti	6,616	541	1,347	569	5,264	14,337
Honduras	11,365	1,896	898	350	1,717	16,226
Jamaica	1,100	279	374	263	487	2,503
Mexico	113,150	36,442	24,692	11,257	86,968	272,508
Nicaragua	6,935	1,025	1,115	219	2,023	11,316
Panama	6,356	621	359	307	1,187	8,829
Paraguay	35,017	598	3,155	701	2,777	42,247
Peru	14,586	4,003	3,592	2,278	16,954	41,413
Puerto Rico	2,222	524	292	482	183	3,703
Uruguay	44,977	3,132	322	350	18,430	67,211
Venezuela	52,405	7,231	4,051	2,497	6,935	73,119
Total	1,244,974	213,867	116,951	56,166	322,990	1,954,948
AFRICA						
Angola	14,167	1,680	718	263	824	17,652
Benin	3,641	661	970	1,007	1,178	7,456
Botswana	9,399	1,651	13	44	1,692	12,799
Burkina Faso	10,713	2,625	748	920	6,545	21,551
Burundi	1,278	342	120	175	697	2,611
Cameroon	19,956	552	1,763	701	3,943	26,915
Central African Rep.	10,348	256	572	131	832	12,139
Chad	16,671	2,312	18	175	8,347	27,524
Cote d'Ivoire	3,677	877	673	701	1,868	7,797
Ethiopia	123,758	22,064	28	2,497	70,669	219,016
The Gambia	1,232	171	19	0	266	1,688
Ghana	5,042	1,110	1,122	526	3,569	11,369
Guinea	7,186	1,281	75	569	591	9,702
Guinea-Bissau	1,282	336	434	44	278	2,374
Kenya	34,424	12,840	153	1,007	15,167	63,591
Lesotho	2,030	456	108	44	2,885	5,522
Madagascar	48,093	336	2,095	1,518	1,073	53,116
Malawi	4,129	541	314	350	751	6,086
Mali	19,455	2,699	90	832	11,310	34,385
Mauritania	4,462	1,549	0	175	10,714	16,901
Mozambique	4,426	2,221	239	964	405	8,254
Namibia	8,582	962	72	44	6,059	15,719
Niger	13,551	3,018	55	745	14,073	31,441
Nigeria	50,096	6,947	1,945	8,322	29,708	97,018
Rwanda	2,281	911	138	44	999	4,372
Senegal	10,713	1,480	703	482	5,356	18,734
Sierra Leone	1,278	285	75	263	311	2,211
Somalia	18,250	5,694	15	131	66,159	90,250
South Africa	110,560	17,863	2,665	1,351	38,131	170,570
Swaziland	2,268	871	28	44	306	3,517
Tanzania	48,819	15,943	275	1,445	32,784	99,266
Togo	1,150	216	449	131	670	2,616
Uganda	12,912	6,150	658	657	2,931	23,308
Zaire	6,351	46	1,197	832	2,511	10,937

APPENDIX J: GLOBAL ANIMAL WASTE PRODUCTION (1000 METRIC TONS/YEAR)						
Country	Non-Dairy[A]	Dairy	Swine	Poultry	Other	Total
AFRICA (continued)						
Zambia	11,014	1,537	269	657	332	13,809
Zimbabwe	25,354	814	284	438	2,034	28,924
Total	668,545	119,296	19,104	28,229	345,967	1,181,140
NEAR EAST & MEDITERRANEAN						
Afghanistan	11,087	6,662	0	307	22,090	40,145
Algeria	4,348	3,246	7	1,007	16,030	24,639
Egypt	14,007	8,256	22	1,584	10,972	34,842
Iran	28,424	13,381	0	4,818	40,241	86,865
Iraq	6,228	2,164	0	3,329	9,130	20,851
Israel	1,640	2,128	237	1,606	560	6,171
Jordan	50	102	0	2,628	1,234	4,014
Kuwait	46	91	0	1,226	262	1,625
Libya	757	279	0	1,621	5,882	8,539
Morocco	7,939	8,883	13	1,621	21,485	39,940
Oman	429	239	0	88	1,253	2,008
Saudi Arabia	913	712	0	3,022	10,076	14,723
Sudan	86,916	19,644	0	1,270	41,850	149,680
Syria	1,921	1,651	1	526	9,691	13,790
Tunisia	1,652	1,424	6	745	7,280	11,106
Turkey	34,401	28,470	15	2,825	42,905	108,616
Yemen Arab Rep.	3,217	1,982	0	1,007	5,029	11,235
Total	203,973	99,313	303	29,229	245,969	578,788
ASIA & FAR EAST						
Bangladesh	96,720	20,157	0	4,949	7,414	129,240
Bhutan	1,396	626	94	0	285	2,402
China	422,638	12,458	501,121	95,316	269,705	1,301,239
India	1,076,750	165,126	15,414	11,388	121,724	1,390,402
Indonesia	42,203	1,424	9,727	19,228	16,355	88,937
Japan	24,693	28,707	20,721	12,191	252	86,565
Kampuchea	4,508	558	2,245	438	102	7,850
Laos	7,081	216	2,275	394	332	10,298
Malaysia	3,659	245	3,292	2,716	319	10,231
Mongolia	8,810	3,388	120	0	28,033	40,351
Myanmar (Burma)	44,804	13,552	4,490	1,489	1,889	66,223
Nepal	39,233	3,843	717	438	3,854	48,085
North Korea	5,543	199	4,639	876	720	11,978
Pakistan	124,707	21,711	0	6,614	61,063	214,095
Philippines	20,873	85	11,343	2,891	3,425	38,618
South Korea	9,668	1,520	6,407	2,628	131	20,354
Sri Lanka	10,129	3,701	151	394	354	14,729
Thailand	49,877	387	6,375	4,424	236	61,299
Viet Nam	25,947	256	18,034	4,205	1,199	49,641
Total	2,019,241	278,161	607,165	170,579	517,392	3,592,538
WORLD TOTAL	6,455,177	2,887,693	1,367,390	429,508	2,107,727	13,247,494

A Includes buffaloes.

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APPENDIX L: IPCC WORKSHOP FINDINGS

Two international workshops held in support of the Intergovernmental Panel on Climate Change (IPCC) provided information on current methane emissions and opportunities for reducing these emissions. The first workshop, held on December 12-14, 1989, by the U.S. Environmental Protection Agency and the U.S. Department of Agriculture, examined greenhouse gas emissions from agriculture in support of the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) of the Response Strategies Working Group.

The second workshop was held on April 9-13, 1990. Funded jointly by the Environment Agency of Japan, the U.S. Environmental Protection Agency and the U.S. Agency for International Development, this workshop examined methane emissions from natural gas systems, coal mining activities, and waste management in support of the Energy and Industry Subgroup (EIS) of the Response Strategies Working Group.

Below are excerpts of the workshop findings for waste management systems and for livestock.

7. FINDINGS FOR WASTE MANAGEMENT SYSTEMS

1. Emissions Estimates

1.1 There are currently large uncertainties in estimates of methane emissions from waste management systems, including landfills, animal waste management systems, and wastewater treatment lagoons.

1.2 Despite these uncertainties, waste management systems appear to be significant anthropogenic sources of methane emissions.

- Landfills emit an estimated 25 to 40 million metric tons of methane globally each year. This methane is produced by the anaerobic decomposition of wastes in the landfills. Although landfill gas monitoring and other detailed landfill analyses have been performed in various countries, global methane emissions from landfills are uncertain because the factors driving the level of methane emissions are highly site specific, including: the waste composition; the extent and rate of waste decomposition; the pathways of methane transport out of the landfill; and the extent of methane oxidation prior to release from the landfill.

- Preliminary analysis and limited monitoring indicate that anaerobic wastewater treatment lagoons that treat wastewater with high BOD (biochemical oxygen demand) loading can produce large amounts of methane emissions. Global emissions from wastewater treatment lagoons may be on the order of 20 to 25 million metric tons each year. This estimate of global methane emissions is very uncertain due to a lack of data on the amount and type of wastewater treated in anaerobic lagoons.

- Preliminary analysis and limited monitoring indicate that animal wastes emit about 30 to 40 million metric tons of methane each year. Wastes managed under anaerobic conditions as part of confined animal management systems are the major source of these emissions. This estimate of global methane emissions is uncertain due to a lack of data on the amount of wastes managed under anaerobic conditions and the extent to which these wastes are decomposed to methane.

Estimates of methane emissions from these systems have been developed for a number of different countries or regions of the world as shown in the following table.

Methane Emissions from Waste Management Systems (million metric tons)

Region/Country	Landfills	Animal Wastes	Wastewater Treatment
Canada	1.8	.3 -.6	?
Japan	0.17	-	0.02
Oceania	1.25	1-2	?
USA	8-18	2-5	?
Western Europe	?	3-8	?
USSR and Eastern Europe	5-8	5-12	?
Developing Countries	4-7	10-19	?
Global Total	25-40	20-40	20-25

1.3 Methane emissions from waste management systems could likely double by 2025 with continued population and economic growth, assuming the continuation in ongoing trends in waste management practices.

2. Steps to Improve Emissions Estimates

2.1 Landfills. Substantial uncertainty remains in methane emissions from landfills. To improve the understanding of these emissions, research is required to:

- Understand how the rate of methane emissions is influenced by key landfill characteristics, such as landfill design and operation; waste characteristics (e.g., composition; degradability; and moisture content); landfill size; and local conditions (e.g., climate and ground cover).

- Characterize current and expected future landfills in terms of those characteristics that influence methane emissions.

- Obtain field measurements of methane emissions from landfills in different regions using different management practices and receiving different types of wastes. Measurement techniques must be developed to collect these data.

- Examine how methane oxidation influences methane emissions.

- Develop a carbon balance for landfills that describes the fate of the carbon added to landfills over time. This carbon balance should describe: carbon storage; methane and carbon dioxide generation; methane oxidation; and methane and carbon dioxide emissions. This balance should be sensitive to various landfill characteristics such as: waste composition (e.g., lignin/cellulose ratios); moisture content; and landfill design.

- Develop methods for scaling up limited measurements and data to develop national and global emissions estimates that reflect differences in cultures, waste generation, and waste management practices.

2.2 Wastewater Treatment Systems. The management of wastewater effluent from domestic, commercial, and industrial facilities has the potential to produce globally significant amounts of methane emissions. While in many cases wastewater is managed in a manner that is presumed to produce negligible methane emissions, emissions data from individual facilities in developed and developing countries indicate that emissions are large in certain circumstances. To better understand methane emissions from wastewater treatment systems, research is required to:

- Collect available data on wastewater management practices throughout the world.
- Identify those areas and facility types that are potentially important sources of methane emissions. Candidate facility types include food processing facilities such as: fruit and vegetable processing; meat packing; sugar production; creameries; and distilleries.
- Characterize and measure the emissions at the important facilities.

2.3 Animal Wastes. While animal wastes are potentially a globally significant source of methane emissions, uncertainties remain as to the quantity of emissions due to a lack of field data. To improve the understanding of these emissions research is required to:

- improve current enumerations of animal numbers and waste quantities managed with various practices;
- develop methane emissions measurement techniques;
- measure methane emissions from those situations that appear to be most important from an overall emissions perspective; and
- assess changes in methane emissions over time as management practices change.

The measurements of methane emissions from animal wastes must consider local and seasonal factors that affect emissions.

3. Technical Potential for Reducing Emissions

3.1 Landfills. Technologies and practices exist to reduce methane emissions from landfills by collecting and flaring or utilizing the methane generated in the landfill. In many circumstances these technologies and practices appear to be cost effective. Use of these technologies and practices is believed to reduce methane emissions by 40 to 70 percent at existing landfills. In new landfills, it is believed that methane emissions can be reduced by 70 to 95 percent using currently available technologies and practices.

Steps taken to reduce methane emissions from landfills provide other significant environmental and safety benefits. Additionally, when utilized as an energy source, the methane recovered from landfills to reduce emissions may displace more carbon intensive fuels, thereby also reducing carbon dioxide emissions. To promote the reduction of methane emissions from landfills, analyses of existing technologies and practices would be useful, including:

- Defining the best control/recovery/utilization technologies and practices that are appropriate for various landfill situations, including new versus existing landfills.

- Examining the effect of alternative waste management and treatment programs on emissions of methane and other greenhouse gases, including: waste stream separation and recycling; and incineration with energy recovery.

To improve the currently available technologies and practices, research is necessary to:

- Develop techniques for enhancing methane generation in cases where the methane can be captured and utilized.

- Develop cost beneficial uses of recovered methane from landfills (particularly small landfills), such as lower cost electricity generation technologies.

3.2 <u>Wastewater Treatment Systems</u>. Technologies and practices exist to manage wastewater without producing methane emissions, including aerobic treatment and anaerobic treatment with methane recovery and utilization. Therefore, methane emissions from wastewater treatment systems can technically be eliminated virtually entirely. In many circumstances, anaerobic treatment with methane recovery and utilization appears to be cost effective due to the value of the energy produced. To promote the reduction of methane emissions from wastewater treatment systems, the best wastewater management practices should be defined based on the demonstrated technical and economic feasibility and the other environmental benefits of the various existing approaches for managing wastewater. The approach of collecting and utilizing the methane produced by anaerobic wastewater treatment should be examined as part of the process of defining best practices. In some areas, existing wastewater management technologies may need to be demonstrated.

3.3 Animal Wastes. Technologies and practices exist that can reduce methane emissions by 50 to 80 percent from animal waste management systems that are used for large numbers of confined animals. These approaches primarily involve anaerobic treatment (e.g., in a lagoon) with methane recovery and utilization. These approaches appear to be cost effective in many circumstances due to the value of the energy produced. To promote the reduction of methane emissions from animal wastes, the following is required:

- The best waste management practices for reducing methane emissions that are consistent with other environmental objectives, including groundwater protection, water management, and nutrient management, need to be defined.
- Approaches for reducing methane emissions need to be demonstrated under a wider range of conditions than has been demonstrated to date.
- To improve the existing approaches, further work is needed to identify and demonstrate gas utilization opportunities in the agricultural setting.

4. Policy Options for Reducing Methane Emissions from Waste Management Systems

4.1 Market and institutional barriers exist that limit the implementation of cost-effective technologies and practices that will reduce methane emissions from waste management facilities. These barriers should be identified and evaluated. Approaches, including financial incentives, should be identified to overcome these barriers.

- A lack of financing and the unavailability of some technologies are important barriers that must be overcome in some areas.
- In the design of incentives to overcome identified barriers, the incentives should reflect the environmental benefits that will accrue from the implementation of the technologies and practices.

4.2 Analyses of policies that will promote the reduction of methane emissions from waste management systems are necessary, including analyses of policies that:

- promote capacity expansion in the recycling and recovery industries;
- encourage methane recovery and utilization, for example by:
  - -- setting fair-market sales prices for recovered methane or electricity produced from recovered methane;
  - -- eliminating institutional barriers that limit competition in electricity production, transportation, and sales;
  - -- increasing the costs of producing commercial energy from fossil sources, e.g., by imposing carbon dioxide emissions fees;
  - -- providing financial incentives for recovering methane, e.g., by providing tax incentives; and
  - -- creating a market for energy produced from recovered methane, e.g., by setting goals for non-fossil fuel energy production.

9. FINDINGS FOR LIVESTOCK

The following are the findings that were adopted by consensus by those attending the workshop. These findings indicate that there are promising opportunities for reducing methane emissions from livestock management systems. Such opportunities remain to be assessed and demonstrated in the field. Undertaking such assessments and demonstrations is a recognized priority.

1. GENERAL

1.1 Given the fact that methane (CH_4) concentrations are increasing globally and will affect global climate and tropospheric air quality, it is recognized that opportunities for reducing CH_4 emissions must be identified, evaluated, and applied in order to reduce global warming and increases in tropospheric ozone.

1.2 Given the diverse set of CH_4 emissions sources globally, emissions reductions from any single country or source will be small compared to total CH_4 emissions, and small compared to total emissions of all greenhouse gases. Consequently, programs to reduce CH_4 emissions from many sources will be required in many countries.

1.3 Although emissions-reduction programs will be required in many countries to achieve significant emissions reductions, individual countries can make valuable contributions by developing, demonstrating, and implementing emissions-reduction technologies.

2. THE ROLE OF MANAGED LIVESTOCK IN THE GLOBAL METHANE BUDGET

2.1 Livestock, and in particular ruminants, are comparatively an important source of CH_4 emissions on a global scale.

2.2 Animals produce significant quantities of CH_4 as part of their digestive processes. CH_4 emissions from the digestive processes of all animals have been estimated to be between 60 and 100 Tg/year,[15] accounting for about 15 percent of total global CH_4 emissions from all sources.

2.3 Previous estimates of global CH_4 emissions from ruminant digestive processes have several notable deficiencies, including the following:

-- Previous estimates failed to reflect important differences in CH_4 emissions associated with various stages of animal growth and management. For example, in the U.S. about 25 percent of beef cattle are in fact calves with CH_4 emissions rates significantly lower than emissions associated with adult beef cows.

-- For cattle on poor quality forages, previous CH4 emissions estimates appear to underestimate feed intakes and overestimate CH_4 yield per amount of feed intake. The net effect of these two factors is that overall emissions associated with these populations of animals appear to be underestimated, possibly by large amounts.

-- Previous estimates have neglected potential emissions from animal wastes.

-- Previous estimates failed to consider differences in animal sizes and differences in the feed base of the animals.

-- Estimates of global animal populations need to be refined.

2.4 While previous estimates of CH_4 emissions from ruminant digestive processes are deficient in various respects, the overall magnitude of the estimates is reasonable. Key analyses should be undertaken to improve the emissions estimates, especially for areas in which interventions are most likely to be cost effective. The major animal management systems should be enumerated, and the analyses should focus on the key systems that contribute most to global emissions, and that have the potential to be controlled.

2.5 Animal wastes (including the wastes from non-ruminants such as poultry and swine) are a potentially large source of methane emissions. Under anaerobic waste management systems, uncontrolled CH_4 emissions from

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15 1 Tg = 10^{12} grams = 10^9 kilograms = 10^6 metric tons.

cattle wastes are likely to be of the same magnitude as the CH_4 emissions from the cattle digestive processes. Animal wastes under aerobic conditions do not produce CH_4 emissions. Additional analyses should be performed over the next year to quantify the magnitude of CH_4 emissions from animal wastes. Preliminary analyses indicate that emissions from this source may be on the order of 15 Tg/year globally, or about 20 percent of the CH_4 emissions from the digestive processes of animals.

2.6 Reductions in CH_4 emissions from animals will assist in reducing the rate of CH_4 increases, and may be one important component in attempts to stabilize atmospheric CH_4 concentrations.

3. EMISSIONS REDUCTION OPPORTUNITIES

3.1 While many uncertainties exist, it appears that there are a number of technologies that can likely reduce CH_4 emissions from livestock systems by <u>25 to 75 percent per unit of product</u>.

3.2 Total reductions achievable depend on how effectively available interventions are deployed, and whether interventions lead to increases in consumption of livestock products.

3.3 Emerging and available technologies for reducing CH_4 emissions from livestock systems should be widely tested under applicable field conditions as soon as practical. With adequate resources these tests would identify the best technologies and practices that could be implemented where appropriate.

3.4 Promising avenues of investigation have been identified that could result in additional opportunities for reducing CH_4 emissions from livestock systems.

3.5 Better estimates of CH_4 emissions will allow targeting of cost effective interventions to reduce emissions. The emissions reductions achievable with the best technologies will vary within and among countries with variations in animal, management, and feeding characteristics.

3.6 Animal production research that aims at increasing efficiency of animal production will have considerable impact on CH_4 emissions. This research must be stimulated in all countries with large livestock populations.

4. KEY RESEARCH NEEDED ON SPECIFIC EMISSIONS-REDUCTION OPPORTUNITIES

4.1 Strategic supplementation of extensively managed cattle. Large populations of cattle are consuming forages of variable quality (particularly seasonally) under grazing conditions. The relative productivity of these animals (e.g., in terms of reproductive efficiency) is low in some cases. By providing strategic supplementation of nutrients to these animals, CH_4 emissions could be reduced by: (1) providing a better balance in the rumen, which would reduce CH_4 emissions per amount of feed consumed; and (2) increasing efficiency and productivity such that given levels of production could be achieved with smaller animal numbers.

-- The size of the animal population that could benefit from this supplementation must be estimated. It is expected that in some areas, the applicable population may be a significant portion of the total animal population.

-- The types of supplementation appropriate for each area must be defined.

-- Techniques for delivering the technology efficiently must be identified. Avenues to explore include: range improvement; nutrient feed blocks; bolus.

-- The monetary and energy costs of producing and distributing the technology must be estimated and balanced against improvements in animal performance.

-- The reductions in CH_4 emissions and improvements in animal performance (that lead to overall system-wide CH_4 emissions reductions) must be documented and validated under field conditions.

4.2 Diet modifications for intensively managed animals. A significant literature of experimental data from whole animal calorimetry experiments demonstrates that CH_4 emissions vary under different diets. Both increasing the intake of the animals and modifying the composition of the diet can reduce CH_4 emissions per unit of product. Other feed inputs also appear to have promising impacts on CH_4 emissions levels (e.g., whole cotton seeds or polyunsaturated fats). Modifying feeding practices toward low-CH_4 rations could potentially reduce CH_4 emissions by large amounts in certain circumstances.

-- The size and location of the animal populations for which feed modifications are a promising alternative must be identified.

-- Promising strategies for lowering CH_4 should be identified for these populations of animals taking into account the costs and availability of the candidate feeds. Opportunities for reducing costs and increasing the availability of the candidate feeds should be explored.

-- The potential CH_4 emissions reduction from these approaches should be quantified (e.g., using rumen digestion and animal production models) and verified with experimental data.

4.3 Use of bST or other agents to increase production per cow. The use of bST (or similar technologies) can reduce CH_4 emissions per amount of product produced by: (1) further diluting the maintenance requirements of individual lactating cows (a reduction of about 3 to 5%); and (2) reducing (by about 15%) the size of the herd necessary to support the lactating cows (i.e., dry cows and growing heifers). Economic evaluations have indicated that the use of bST is economic in its own right in some circumstances.

-- The potential system-wide reduction in CH_4 emissions associated with the use of bST should be estimated so that its importance in this regard can be assessed. This assessment should be performed with a range of accepted values for the anticipated performance response from the administration of bST.

-- The CH_4 emissions implications of using other growth regulating agents should also be evaluated.

4.4 Defaunation of the rumen. Based on experimental data, under certain feeding systems, the elimination of protozoa in the rumen results in lower CH_4 emissions and may enhance animal performance.

-- The population of animals whose performance could be increased and whose CH_4 emissions could be decreased through defaunation should be estimated.

-- Techniques for achieving defaunation should be defined and demonstrated under field conditions. The costs of administering these techniques should be estimated and balanced against the benefits of improved animal performance. Initial assessments are that the costs of the defaunation may be economically justified solely by improvements in performance.

-- The overall system-wide CH_4 emissions reduction anticipated must be estimated.

4.5 <u>Strategic supplementation of ruminants fed crop residues and by-products to correct nutrient deficiencies</u>. Research and practice in India and other developing countries indicate that improved rumen performance can be achieved through the use of locally-produced supplements. This improved rumen performance allows for significantly improved animal productivity and increased digestion efficiency, both of which can contribute to significant CH_4 emissions reductions per unit of animal product. Based on experience in India, strategic supplementation systems can be self-sustaining and economic investments.

-- While it has been estimated that strategic supplementation can reduce CH_4 emissions significantly in individual segments of animal populations (e.g., by over 60%), evaluations of overall system-wide performance must be performed that reflect the diverse products produced by cattle and buffalo. In particular, the economic responses to changes in costs of production and demand must be examined. Also, social impacts must be evaluated. Preferred strategies that reduce CH_4 emissions through the use of supplementation should be identified, and the obstacles to their implementation should be identified.

-- Key areas where strategic supplementation should be investigated include those countries with large cattle and buffalo populations. Examples include: additional expansion in India; Pakistan; Bangladesh; Sub-Saharan Africa; and China. Assessments of these areas should be performed that include infrastructure and marketing needs as well as potential local sources of supplementation inputs.

4.6 Improve reproductive efficiency to reduce brood herd requirements. Improvements in reproductive efficiency will reduce CH_4 emissions by reducing the size of the brood herd needed to sustain a given level of production. Opportunities to accelerate promising developments in this area should be explored.

4.7 Microbiological Approaches.

-- Improve microbial growth efficiency to optimize fiber digestion in the rumen and microbial synthesis. CH_4 emissions may be reduced by balancing the rumen processes so that maximum efficiency is achieved. Microbiological approaches for promoting and achieving this balance should be explored. Analyses of feeds, feed combinations, feed treatments, bio-engineering opportunities and other techniques should be explored.

-- Reduce CH_4 production by manipulating VFA proportions and/or modifying the activities of the methanogens. Techniques for promoting propionate production (a hydrogen sink) should be explored. Additionally, inhibiting methanogens may provide an opportunity for altering the fate of H_2 in the rumen such that less CH_4 is produced.

4.8 Modifications to animal waste management practices. It is anticipated that anaerobic animal waste management practices produce significant CH_4 emissions. Reductions in these emissions are possible.

-- Opportunities for modifying waste management practices in a manner that is consistent with other environmental objectives (such as protecting groundwater quality) should be identified.

-- Opportunities for recovering CH_4 from animal wastes should be explored on various levels, including: (1) integrated resource recovery systems that produce a variety of useful products; (2) anaerobic digesters that produce gas that can be used as a commercial energy source or flared; and (3) small scale projects applicable for small farmers.

-- The costs of the alternative waste management systems must be estimated and balanced against the value of products produced. Indications are that under certain conditions, the systems are economic to implement in their own right.

5. OTHER KEY RESEARCH NEEDS

5.1 Estimates of global CH_4 emissions from livestock should be improved by enumerating the major livestock managements systems (including animal waste management systems) and performing more realistic assessments of the major systems that drive global emissions. These assessments should reflect the stages in animal growth and production and prevailing levels of feed intake.

5.2 Techniques for taking field measurements of CH_4 emissions from animal systems should be developed and applied. Such techniques will be useful for verifying estimates of emissions and validating the effectiveness of emissions reduction techniques in the field. Approaches that should be pursued include:

-- Explore direct and indirect methods of assessing CH_4 emissions for field applications.

6. INSTITUTIONAL ISSUES

6.1 Reducing emissions from livestock is a particularly attractive option because it usually is accompanied or accomplished by improved animal productivity.

6.2 In designing interventions to reduce CH_4 emissions from livestock, consideration should be given to the impacts of these interventions on other greenhouse gases and other environmental and social areas of interest.

6.3 The implementation of technologies to reduce CH_4 emissions will, in general, succeed only if induced by: incentives, technology transfer, and/or the provision of adequate financing. A mandatory emissions limitation is unlikely to be successful in reducing emissions.

6.4 It is essential that countries maintain or build up the scientific infrastructure required to greatly increase levels of research to find solutions to limiting CH_4 emissions from livestock.

6.5 Current funding specifically to investigate, develop, test, and implement CH_4 reduction technologies and programs does not exist.

6.6 Key national and international authoritative bodies should cooperate in identifying and evaluating the best techniques for reducing CH_4 emissions from livestock systems.

6.7 Potential CH_4 emissions reductions associated with modifications to eating habits of humans are beyond the scope of the meeting, and is primarily a question of social choice and human nutrition and health needs.

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