## EXECUTIVE SUMMARY

There is increasing regulatory pressure to reduce groundwater contamination and non-point source methane emissions associated with large dairy, feedlot, swine or poultry operations. Manure management systems often can be integrated with energy conversion technologies to provide alternative means for manure disposal. This report analyzes manure resources by animal type for the Western Regional Biomass Energy Program (WRBEP) on a county basis, identifies pertinent regulations at the state level, summarizes commercial energy conversion technologies appropriate for manures, and presents an economic analysis of several hypothetical situations at the farm level.

Several major conclusions stem from the analyses in this report. First, substantial manure resources exist in the WRBEP area. Calculations and data provided in this report indicate an energy potential of about 111 trillion Btu produced on an annual basis in the WRBEP region. Table S.1 shows the ranking of the 13 WRBEP states in terms of energy potential of manure resources. All animal categories were combined to calculate the data presented in Table S.1. The energy potential reported in the last column is a composite figure that may not be representative of the true potential of the manure resource base. The real significance of the composite figure is to illustrate the magnitude of the manure resource. For WRBEP as a whole, the total annual potential, in oil equivalent, is 22 million barrels.

**Table S.1. Summary of WRBEP States Manure Resource Energy Potential**

| State | Total Solids (tons/day) | Volatile Solids (tons/yr.) | Collectable Solids (tons/yr.) | Potential Energy (MMBtu/yr.) |
|---|---:|---:|---:|---:|
| Nebraska | 23,359 | 7,137,861 | 5,548,689 | 31,432,811 |
| Texas | 18,165 | 5,288,556 | 4,396,126 | 26,203,432 |
| California | 14,248 | 4,163,179 | 3,530,725 | 20,841,160 |
| Kansas | 7,945 | 2,417,181 | 1,897,990 | 10,785,830 |
| Oklahoma | 4,599 | 1,271,552 | 1,133,594 | 6,906,154 |
| South Dakota | 3,391 | 995,384 | 839,111 | 4,700,018 |
| Colorado | 1,928 | 583,720 | 475,077 | 2,730,882 |
| Arizona | 1,454 | 436,080 | 361,104 | 2,088,017 |
| New Mexico | 1,133 | 337,599 | 283,399 | 1,653,411 |
| Utah | 1,153 | 334,025 | 264,537 | 1,568,116 |
| North Dakota | 1,054 | 308,414 | 270,541 | 1,544,703 |
| Nevada | 304 | 91,378 | 75,216 | 435,899 |
| Wyoming | 260 | 78,877 | 63,180 | 364,245 |
| **Total** | **78,993** | **23,443,806** | **19,139,289** | **111,254,678** |

Manures that are more appropriate for energy conversion tend to be associated with dairy and swine operations. Manure management systems, often liquid- or slurry-based, facilitate the ease of manure movement. Large agriculture-based economies in California, Texas and Nebraska, WRBEP's top three states in terms of manure energy potential, sustain substantial animal populations that contribute to their energy conversion potential. Warmer states within WRBEP, including Texas, New Mexico, Arizona, and California, may have the greatest potential for energy conversion of manures because of the ability to use low-cost lagoon technologies.

Federal and state environmental regulations fostering "best available control technologies" or "best management practices" are major forces influencing the adoption of manure management practices that merge well with energy conversion options. To the extent that regulatory agencies, working with state extension personnel, are able to implement the regulations, greater adoption of energy conversion technologies at the farm level will occur. The economic benefits to the farmer associated with the on-farm promotion/enforcement process should be emphasized to facilitate regulatory compliance.

An economic analysis was performed to assess the feasibility of five separate manure-fueled power plants: a South Dakota plug flow digester, a Nebraska complete-mix digester, a Texas covered lagoon digester, a California covered lagoon digester, and a California direct combustion facility. Three of the four digester power plants, the South Dakota plug flow digester, the Nebraska complete-mix digester, and the California covered lagoon digester, would be feasible, based on their positive net present values (NPVs), given the assumptions stated in this report. The Texas covered lagoon digester and the California manure-burning power plant are not feasible, based on the given assumptions. Table S.2 summarizes the important assumptions and figures for each power plant.

**Table S.2. Summary of Assumptions and Financial Analyses for Manure-Based Energy Conversion Technologies**

| | South Dakota Plug Flow Digester | Nebraska Complete-Mix Digester | Texas Covered Lagoon Digester | California Covered Lagoon Digester | California Combustion Power Plant |
|---|---|---|---|---|---|
| **Capacity (kW)** | 35 | 101 | 41 | 81 | 20,000 |
| **Yearly Energy Production (kWh)** | 216,047 | 624,137 | 252,055 | 504,111 | 115,632,000 |
| **Installed Cost** | $144,047 | $249,753 | $128,082 | $201,466 | $60,000,000 |
| **Net Present Value** | $43,484 | $14,167 | ($8,857) | $48,772 | ($33,365,506) |
| **Internal Rate of Return** | 21.51% | 10.27% | 3.96% | 21.36% | -21.44% |
| **Levelized Cost ($/kWh)** | $0.1126 | $0.0693 | $0.0847 | $0.0767 | $0.0847 |

Economic benefits to the farmer appear to be real. Energy conversion technologies such as anaerobic digestion, and to a limited extent, gasification, are more mature than when first promoted in the late 1970s. Lagoon digesters show positive economic results in the warmer WRBEP areas and plug digesters appear to have economic advantages in the colder climates.

Although it is critical to emphasize the site-specific nature of the economic analyses, it is clear that opportunities for energy conversion of manure resources exist for animal operations in a broad geographic range within WRBEP.

## 1.0 INTRODUCTION

The growth and concentration of the livestock industry has led to the generation of large quantities of manure at feedlots, dairies, poultry production plants, animal holding areas and pasturelands. If not properly managed, livestock waste can cause significant harm to both surface water and groundwater supplies. Facilities for storing manure in liquid form sometimes leak or burst, releasing large volumes of pollutants. Manure in earthen pits can form a semi-impervious seal of organic matter that may limit leaching potential, but seasonal draining and filling can cause the seal to break down. Short-term solid manure storage and abandoned storage areas can also be sources of groundwater contamination by nitrates.

Although significant progress has been made in cleaning up some sources of water pollution, livestock operations continue to contribute to a large portion of the nation's remaining water quality problems.[1] Studies also indicate that more than 40 percent of total U.S. methane emissions come from anaerobic lagoons/ponds and liquid/slurry storage systems.[2]

Throughout the nation, increasing regulatory pressure has been imposed to reduce groundwater contamination and non-point source methane emissions associated with large livestock operations. Consequently, waste management systems that facilitate energy recovery are attracting increasing attention since they address these pollution problems and allow for energy generation from manure resources.

The purpose of this report is to:

- present a state-by-state, county-by-county resource assessment for the 13 WRBEP states of available manure wastes (i.e., poultry, feedlot cattle, dairy and swine manures);
- describe and evaluate available energy conversion technologies;
- provide an economic analysis for energy conversion of manures;
- identify environmental and regulatory factors associated with manure collection, storage and disposal, and identify common disposal practices specific to animal types and areas within WRBEP; and
- outline future efforts.

Section 2 of this report provides the WRBEP resource assessment, by state, for manures. Section 3 details existing federal and state regulations regarding waste disposal and Section 4 provides an overview of common waste disposal practices. Section 5 describes available energy conversion technologies. An economic analysis of energy conversion of manure resources is given in Section 6. Section 7 provides conclusions. Section 8 outlines future action goals.

## 2.0 RESOURCE ASSESSMENT FOR MANURE

This section provides a state-by-state assessment of manure by source for each of the 13 WRBEP states. The animals inventoried here include: feedlot cattle, dairy cows, swine (breeder and market), and poultry (layers, broilers and turkeys). County-by-county population breakdowns, where available, are provided in Appendix A. State maps showing counties with high concentrations of livestock operations are located in Appendix D.

The intent of this resource assessment is to determine the order of magnitude for annual manure production on a county-by-county basis. Subsequently, estimates are presented of the energy potential of the manure resources. In calculating the energy potential of manure produced per animal type, the following factors were taken into consideration: typical animal mass (TAM), total solids per day, volatile solids per day, biogas energy content, waste management system loss and energy conversion efficiency. Calculations and assumptions used to calculate the energy potential of manure are located in Appendix B.

The energy potential of manure resources per ton varies greatly from animal to animal. Therefore, total animal numbers are not as significant as manure volume per animal type and the biogas content per ton. Table 2.1 shows the total solids, volatile solids, collectable solids and energy potential for manure per 1,000 head of each animal type for one year.

**Table 2.1. Annual Manure Energy Potential for 1,000 Animals**

| Animal | Total Solids (tons/day) | Volatile Solids (tons/year) | Collectable Solids (tons/year) | Potential Energy (MMBtu/year) |
|---|---|---|---|---|
| Dairy Cows | 7 | 2,044 | 1,840 | 10,817 |
| Feedlot Cattle | 3 | 1,040 | 780 | 4,494 |
| Swine Breeders | 1 | 321 | 257 | 1,336 |
| All Swine | 1 | 217 | 173 | 902 |
| Swine Market | 1 | 201 | 161 | 835 |
| Poultry Turkeys | 0 | 24 | 14 | 88 |
| Poultry Layers | 0 | 9 | 8 | 49 |
| Poultry Broilers | 0 | 6 | 5 | 33 |

* MMBtu refers to millions of Btu.

In general, state and county livestock inventories were obtained from each state's agricultural statistics department. Due to the consideration that the data provided varied from state to state, the data presented in this report also varies by category and by animal type for each state. All of the WRBEP states' agricultural statistics services provided statistics based on either 1989, 1990 or 1991 data. A full listing of references used is provided in the bibliography of this report. Where state or county data were not available from agricultural statistics departments, 1987 U.S. Census of Agriculture data were used. Below are special notes on how figures were obtained for the various livestock types.

*Feedlot Cattle*

Distinguishing between animal types is often difficult when combining data sets. For example, feedlot cattle are often divided into two groups: heifers and steer. Total animal mass, total solids and volatile solids differ slightly between the two groups since heifers are generally larger. State agricultural statistics services occasionally provided population breakdowns for feedlot cattle into heifers and steer, but gènerally data were provided only for the combined category: feedlot cattle. Feedlot herds have an average breakdown of 29 percent heifers, 71 percent steer.[3] In the absence of consistent data, this report presents data on only the combined feedlot cattle category.

Several states did not provide county inventories for feedlot cattle. For Texas, California and Colorado, 1987 U.S. Census of Agriculture breakdowns of feedlot cattle *sold* were used. The Census does not provide feedlot cattle inventories for any state. The turnover rate (number of times the entire contents of a feedlot is sold) for Colorado is 2.5.[4] Therefore, the number of feedlot cattle sold per year divided by 2.5 approximates the number of feedlot cattle present at one time. State statistics service information for California and Texas gave turnovers rates of 1 and 2 respectively. Approximations for feedlot cattle inventories for these three states were obtained by dividing feedlot cattle sold in 1987 by the turnover rate for that state.

*Dairy Cows*

Dairy herds are composed of dairy cows and dairy heifers. Heifer generally describes a young cow that has not given birth. Heifers, in general, weigh less, produce less manure and produce manure with a lower biogas content. Most state statistics offices gave numbers for dairy, or milking, cows, excluding heifers. For the states that did not specifically exclude heifers, it was assumed that heifers make up a small percentage of the herd. For all dairy figures calculated total animal mass, volatile solids, biogas production and collectable solids for the dairy cow category were used.

*Swine*

Swine are also categorized in two groups: breeder and market. Once again, while some states provided breakdowns between the groups, most simply provided data for all swine. States that did distinguish between breeder and market groups tended to do so on the state level only. From the WRBEP states that did provide breakdowns, we determined that the average herd contained 13 percent breeders.[5]

The total animal mass (TAM), total solids and volatile solids for breeder and market swine vary significantly (breeder TAM is 400, while market TAM is only 135). Where data allowed, swine are divided into breeder and market categories in this report. Otherwise they are combined into one category. To determine manure produced per county for the combined swine category, we calculated TAM, total solids and volatile solids from market and breeder figures based on the 13:87 average ratio of breeders to market swine.

*Poultry*

Poultry are grouped into three categories in this report: chicken layers, chicken broilers and turkeys. Since many states do not provide numbers for poultry due to disclosure concerns, we used state totals from the 1987 U.S. Census of Agriculture for states that did not provide data.

### 2.1 WRBEP Resource Summaries

In calculating the energy potential of manure produced per animal type, volatile solids produced per day, biogas energy content, waste management system loss, and energy conversion efficiency were all taken into consideration. Table 2.2 lists some of the assumptions used for each animal type. A complete list of assumptions is located in Appendix B.

**Table 2.2. Summary of Assumptions for Manure Resource Assessment**

| Assumptions | Feedlot Cattle | Dairy Cows | Market Hogs | Breeding Sows | Poultry Layers | Poultry Broilers | Turkeys |
|---|---|---|---|---|---|---|---|
| Volatile Solids (lb/TAM/day) | 5.7 | 11.2 | 1.1 | 1.76 | 0.048 | 0.032 | 0.13 |
| Biogas Production ($ft^3$/lb VS) | 9.6 | 14 | 8 | 8 | 8.6 | 8.6 | 8.6 |
| Typical Waste Mgmt System Handling Loss | 25% | 10% | 10% | 10% | 10% | 10% | 40% |
| Digester Efficiency | 50% | 35% | 50% | 50% | 60% | 60% | 60% |

Table 2.3 shows the ranking of the 13 WRBEP states in terms of energy potential of manure resources. All animal categories were combined to calculate the data presented in Table 2.3. The energy potential reported in the last column is a composite figure that is not representative of the true potential of the manure resource base. Composite figures are used solely to establish the magnitude of the resources, not the likely utilization potential. While we have accounted for such considerations as collection and energy conversion efficiencies in the reported figures, critical considerations such as transportation obscure the usefulness of such composite figures. The real significance of the composite figure is to illustrate the extent of the manure resource so that one may compare it with other measures. In this case, the annual energy potential in Nebraska is equivalent to 6.2 million barrels of oil, or about one day's U.S. oil production. For WRBEP as a whole, the total annual potential, in oil equivalent, is 22 million barrels.

Table 2.4 shows the ranking of each WRBEP state in terms of annual animal population by individual animal category. California, Nevada and Texas each rank first in at least one animal type; California ranks first in dairy cows, poultry layers and turkeys and second in broilers; Texas is first in poultry broilers and second in poultry layers, dairy cows and feedlot cattle; Nevada is first in feedlot cattle and swine. Nevada and Wyoming both ranked in the bottom third in every category.

**Table 2.3. Summary of WRBEP States Manure Resource Energy Potential**

| State | Total Solids (tons/day) | Volatile Solids (tons/yr.) | Collectable Solids (tons/yr.) | Potential Energy (MMBtu/yr.) |
|---|---|---|---|---|
| Nebraska | 23,359 | 7,137,861 | 5,548,689 | 31,432,811 |
| Texas | 18,165 | 5,288,556 | 4,396,126 | 26,203,432 |
| California | 14,248 | 4,163,179 | 3,530,725 | 20,841,160 |
| Kansas | 7,945 | 2,417,181 | 1,897,990 | 10,785,830 |
| Oklahoma | 4,599 | 1,271,552 | 1,133,594 | 6,906,154 |
| South Dakota | 3,391 | 995,384 | 839,111 | 4,700,018 |
| Colorado | 1,928 | 583,720 | 475,077 | 2,730,882 |
| Arizona | 1,454 | 436,080 | 361,104 | 2,088,017 |
| New Mexico | 1,133 | 337,599 | 283,399 | 1,653,411 |
| Utah | 1,153 | 334,025 | 264,537 | 1,568,116 |
| North Dakota | 1,054 | 308,414 | 270,541 | 1,544,703 |
| Nevada | 304 | 91,378 | 75,216 | 435,899 |
| Wyoming | 260 | 78,877 | 63,180 | 364,245 |
| Total | **78,993** | **23,443,806** | **19,139,289** | **111,254,678** |

**Table 2.4. Summary of WRBEP States' Rankings for Animal Types**

| State | Rank Within WRBEP | | | | | |
|---|---|---|---|---|---|---|
| | Feedlot Cattle | Swine | Dairy Cows | Poultry Layers | Poultry Broilers | Turkeys |
| Arizona | 7 | 9 | 6 | 9 | 13 | 9 |
| California | 5 | 7 | 1 | 1 | 2 | 1 |
| Colorado | 4 | 6 | 11 | 8 | 7 | 5 |
| Kansas | 3 | 3 | 5 | 4 | 6 | 4 |
| Nebraska | 1 | 1 | 4 | 13 | 11 | 6 |
| Nevada | 12 | 13 | 12 | 11 | 12 | 10 |
| New Mexico | 8 | 11 | 8 | 6 | 4 | 8 |
| North Dakota | 13 | 5 | 7 | 10 | 8 | 7 |
| Oklahoma | 9 | 8 | 10 | 7 | 3 | 8 |
| South Dakota | 6 | 2 | 3 | 3 | 5 | 3 |
| Texas | 2 | 4 | 2 | 2 | 1 | 8 |
| Utah | 10 | 10 | 9 | 5 | 10 | 2 |
| Wyoming | 11 | 12 | 13 | 12 | 9 | 8 |

### 2.2 State Resource Summaries

Below are brief resource assessments for the 13 WRBEP states. Complete data tables for each state are located in Appendix A.

*Kansas*

Within the WRBEP states, Kansas is among the top half for every source category. Two Kansas counties stand out for feedlot cattle: Gray with 98,300 head and Kearny with 96,400 head. For swine production Kansas' top two counties are Washington and Nemaha with 94,300 and 83,200 head respectively. For layers, top counties are McPherson, 573,700 birds, and Reno, 277,100 birds. Although Kansas ranks in the top half of WRBEP states for total dairy cows, no single county has more than 7,000 cows.

**Table 2.8. Kansas Manure Summary**

| Kansas | Population (000's) | Total Solids (tons/day) | Volatile Solids (tons/yr.) | Collectable Solids (tons/yr.) | Potential Energy (MMBtu/yr.) |
|---|---|---|---|---|---|
| FEEDLOT CATTLE | 1,760 | 5,896 | 1,830,840 | 1,373,130 | 7,909,229 |
| DAIRY COWS | 101 | 706 | 206,035 | 185,432 | 1,090,338 |
| SWINE | 1,383 | 1,245 | 353,357 | 318,021 | 1,653,708 |
| POULTRY LAYERS | 1,960 | 64 | 17,170 | 15,453 | 95,683 |
| POULTRY BROILERS | 50 | 1 | 290 | 261 | 1,614 |
| TURKEYS | 400 | 34 | 9,490 | 5,694 | 35,257 |
| **TOTAL** | **5,653** | **7,945** | **2,417,181** | **1,897,990** | **10,785,830** |

*Nebraska*

Nebraska is the top WRBEP state for feedlot cattle and swine, fourth in dairy cows and sixth in turkeys. Nebraska's top feedlot cattle counties are Cuming (490,000 head), Dawson (435,000 head) and Scotts Bluff (275,000 head). Cuming and Holt counties county rank first and second in swine production with 246,000 and 234,000 head respectively. No county in Nebraska has more than 6,500 dairy cows, and no county data were available for turkeys.

**Table 2.9. Nebraska Manure Summary**

| Nebraska | Population (000's) | Total Solids (tons/day) | Volatile Solids (tons/yr.) | Collectable Solids (tons/yr.) | Potential Energy (MMBtu/yr.) |
|---|---|---|---|---|---|
| FEEDLOT CATTLE | 5,610 | 18,794 | 5,835,803 | 4,376,852 | 25,210,667 |
| DAIRY CATTLE | 103 | 719 | 209,980 | 188,982 | 1,111,215 |
| SWINE | 4,274 | 3,846 | 1,091,969 | 982,772 | 5,110,413 |
| POULTRY LAYERS | 5 | 0 | 42 | 38 | 234 |
| POULTRY BROILERS | 3 | 0 | 17 | 16 | 96 |
| TURKEYS | 2 | 0 | 50 | 30 | 186 |
| TOTAL | **9,996** | **23,359** | **7,137,861** | **5,548,689** | **31,432,811** |

## NEBRASKA

**Responsible Agency**
Nebraska Department of Environmental Control (NDEC)
Permits and Compliance Section
Box 98922
Lincoln, NE 68509-8922
Phone: (402) 471-4239
Contact: W. Clark Smith, Supervisor, Permits and Compliance Section

**Appropriate Regulations**

| | |
|---|---|
| Title 130 | Rules and Regulations Pertaining to Livestock Waste Control, as amended March, 1989. |

A copy of Nebraska's regulations appears in Appendix E.

**Summary of Regulations**
The Nebraska DEC has the authority to administer the NPDES program for the U.S. EPA. Nebraska's standards are more stringent than the Federal standards. Nebraska regulations require that any size livestock operation that discharges waste to state surface waters, in absence of the 25-year, 24-hour storm event, must get an NPDES permit. The minimum required storage volume is containment of all runoff from the 25-year, 24-hour storm, plus the average runoff expected from rainfall during the month of June. Collected feedlot runoff must be disposed of before winter.

Livestock operations that are required to construct waste controls must obtain construction and operations permits from NDEC. Formed waste storage tanks, earthen basins, and anaerobic lagoons are all acceptable control methods. NDEC has adopted minimum design standards for anaerobic lagoons, but not for the other waste control systems.

## 4.0 LIVESTOCK WASTE STORAGE AND DISPOSAL METHODS

All state regulatory agencies within the WRBEP region have a goal of zero discharge of pollutants from livestock facilities to surface waters. The major concern is the control and disposal of animal waste generated at confined animal feeding operations such as beef feedlots, dairies, swine and poultry ranches. Livestock waste from pasture or rangeland is not considered to be a pollution hazard.

Basic regulations require that animal manure and manure contaminated rainfall run-off be prevented from leaving the farmsite and polluting surface waters. Some states require that the manure and runoff be collected and contained in some type of structure. Some states recommend that collected manures be field applied to benefit crop growth and protect surface and groundwater. This section describes animal waste collection, storage and management systems used in the WRBEP region and shows the predominant systems by region and animal type.

### 4.1 Description of Animal Waste Management Systems

The following brief description of the major waste systems used in the WRBEP region is drawn from a recent EPA report.[25]

*Manure Management*

Manure can be collected in either a liquid, semi-solid slurry or solid form. Wastewater or process water may be mixed with manure. The form of manure when collected determines the options for storage, treatment, biogas production and field application.

*Manure Collection*

Liquid Systems: Pig manure is dilute and usually handled as a liquid. In other animal facilities, treated wastewater and process water may be recycled and used to flush manure from the facility. The liquid/manure mixture usually flows by gravity to a treatment/storage lagoon or irrigation type application system.

Slurry Systems: Manure is handled as a pumpable slurry and not a free-flowing liquid. Manure is collected using a tractor scraper or with an underfloor cable scraper. Dairy manure is managed as a slurry more often than other types of manure. As a slurry, manure can be pumped and stored in pits, tanks or spread directly on land.

Solid Systems: In the west, the dry climate is often used to dehydrate manure to allow handling as a solid. Dairy and beef feedlots and chicken and turkey ranches often are designed to promote manure drying. Manure is picked up using a scoop tractor and is stockpiled, field spread or sold.

*Manure Management Systems*

The following waste management systems are presented in order of complexity from solids systems to liquid systems.

Pasture and Range: Manure from animals grazing on open rangelands is allowed to lie where it falls, and is not handled under any formal waste management system.

Daily Spread: Manure collected in any form can be spread daily on fields. This is common in some areas and not in others.

Solid Storage: Dairy or beef manure may be collected on a daily to biweekly basis as a solid or semi-solid and stacked and stored in bulk for several months before being applied to fields.

Deep Pit Solid Stacks: This type of manure management system is utilized for caged layers and occasionally broilers. Manure falls into deep, well ventilated pits where it dries in stacks. Manure is removed periodically and field applied.

Drylot (paddock): In drier climates, dairy, beef, broilers, turkeys and occasionally pigs are raised on unpaved, open or semi-covered feedlots where manure is allowed to accumulate. When dry, the manure is removed and disposed of, usually as a soil amendment.

Litter: Broiler chickens and young turkeys are often raised on beds of litter (wood shavings, sawdust, straw). Manure is deposited directly into the litter, and the litter is removed periodically. This manure remains in solid form, though it is not always dry.

Pit Storage: Swine are sometimes raised in buildings with a slatted floor and a storage pit below. The length of time manure stays in pit storage varies from 3 to 6 months. The manure is removed with a pump and usually field-spread with a tanker.

Liquid/Slurry Storage: Liquid or slurry manure collection systems may store waste in outside pits, tanks or lagoons. A typical lagoon for storage only has adequate total volume to retain 3 to 6 months waste.

Anaerobic Lagoon: A lagoon designed to treat waste to reduce odor, pathogens and BOD generally has a minimum volume of 3 to 6 months of waste with and additional 3 to 6 months of volume for storage. Lagoon size depends on farm size, climatic conditions, and local regulations. The lagoon water can be recycled for flushing or spray or surface irrigated on fields for fertilizer.

Anaerobic Digester: Manure in liquid or slurry form may be placed in a digester to undergo controlled decomposition to produce and recover methane for energy purposes. The amount of methane produced depends upon waste characteristics and digester design and operation. Digester effluent is stored or field applied for fertilizer value.

## 4.2 Animal Waste Management System Usage in the WRBEP Territory

Tables 4.1 through 4.5 show the predominant animal waste management systems being used in each state in the WRBEP territory, by type of animal.

**Table 4.1. Manure Management Systems for Beef Cattle**

| | Animal Waste Management Systems | | | | |
|---|---|---|---|---|---|
| State | An. Lagoon | Drylot | Liq/Slurry | Pasture | Other |
| AZ | 0 | 30 | 0 | 70 | 0 |
| CA | 0 | 12 | 0 | 88 | 0 |
| CO | 0 | 25 | 0 | 72 | 0 |
| KS | 2 | 23 | 0 | 76 | 0 |
| NE | 1 | 31 | 0 | 68 | 0 |
| NV | 0 | 5 | 0 | 95 | 0 |
| NM | 0 | 8 | 0 | 92 | 0 |
| ND | 0 | 2 | 0 | 98 | 0 |
| OK | 0 | 5 | 0 | 95 | 0 |
| SD | 1 | 5 | 0 | 94 | 0 |
| TX | 0 | 13 | 0 | 87 | 0 |
| UT | 0 | 5 | 0 | 95 | 0 |
| WY | 0 | 6 | 0 | 94 | 0 |
| AVG | < 1 | 13 | < 1 | 86 | 0 |

Numbers indicate the percent of manure being managed under each type of system
Source: Safely et. al., 1992

### Table 4.2 Manure Management Systems for Dairy Cattle

| State | Animal Waste Management Systems | | | | |
|---|---|---|---|---|---|
| | An. Lagoon | Liq/Slurry | Daily Spread | Solid Storage | Paddock |
| AZ | 10 | 0 | 0 | 0 | 90 |
| CA | 40 | 0 | 0 | 0 | 60 |
| CO | 5 | 10 | 85 | 0 | 0 |
| KS | 0 | 40 | 60 | 0 | 0 |
| NE | 0 | 5 | 35 | 0 | 60 |
| NV | 1 | 1 | 8 | 90 | 0 |
| NM | 90 | 0 | 10 | 0 | 0 |
| ND | 0 | 20 | 10 | 70 | 0 |
| OK | 15 | 0 | 5 | 0 | 80 |
| SD | 25 | 25 | 30 | 20 | 0 |
| TX | 25 | 60 | 15 | 0 | 0 |
| UT | 1 | 1 | 8 | 90 | 0 |
| WY | 12 | 19 | 39 | 23 | 7 |
| AVG | **17** | **14** | **23** | **23** | **23** |

Numbers indicate the percent of manure being managed under each type of system
Source: Safely et. al., 1992

### Table 4.3. Manure Management Systems for Swine

| State | Animal Waste Management Systems | | | | |
|---|---|---|---|---|---|
| | An. Lagoon | Drylot | Pit St. <1 Mnth | Pit St. >1 Mnth | Other |
| AZ | 100 | 0 | 0 | 0 | 0 |
| CA | 90 | 0 | 0 | 0 | 10 |
| CO | 24 | 25 | 21 | 24 | 6 |
| KS | 30 | 40 | 0 | 30 | 0 |
| NE | 35 | 5 | 55 | 5 | 0 |
| NV | 25 | 75 | 0 | 0 | 0 |
| NM | 10 | 70 | 10 | 10 | 0 |
| ND | 20 | 20 | 30 | 30 | 0 |
| OK | 60 | 30 | 10 | 0 | 0 |
| SD | 20 | 30 | 25 | 25 | 0 |
| TX | 35 | 20 | 15 | 10 | 20 |
| UT | 25 | 75 | 0 | 0 | 0 |
| WY | 24 | 25 | 21 | 24 | 6 |
| AVG | **38** | **32** | **14** | **12** | **3** |

Numbers indicate the percent of manure being managed under each type of system
Source: Safely et. al., 1992

Table 4.4. Manure Management Systems for Poultry: Caged Layers

| | Animal Waste Management Systems | | | |
|---|---|---|---|---|
| State | An. Lagoon | Deep Pit | Liq/Slurry | Other |
| AZ | 0 | 100 | 0 | 0 |
| CA | 7 | 45 | 3 | 45 |
| CO | 4 | 88 | 8 | 0 |
| KS | 0 | 100 | 0 | 0 |
| NE | 0 | 100 | 0 | 0 |
| NV | 0 | 75 | 0 | 25 |
| NM | 20 | 45 | 10 | 25 |
| ND | 5 | 90 | 5 | 0 |
| OK | 0 | 80 | 20 | 0 |
| SD | 20 | 80 | 0 | 0 |
| TX | 40 | 10 | 0 | 50 |
| UT | 0 | 50 | 0 | 50 |
| WY | 4 | 88 | 8 | 0 |
| AVG | **8** | **73** | **4** | **15** |

Numbers indicate the percent of manure being managed under each type of system
Source: Safely et. al., 1992

Table 4.5. Manure Management Systems for Poultry: Broilers and Turkeys

| | Animal Waste Management System | | | |
|---|---|---|---|---|
| | Broilers | | Turkeys | |
| State | Litter | Other | Litter | Range |
| AZ | | | | |
| CA | 100 | 0 | 93 | 7 |
| CO | | | | |
| KS | | | 100 | 0 |
| NE | 100 | 0 | 100 | 0 |
| NV | | | | |
| NM | | | | |
| ND | | | 40 | 60 |
| OK | 100 | 0 | | |
| SD | | | 100 | 0 |
| TX | 100 | 0 | | |
| UT | | | 0 | 100 |
| WY | | | | |
| AVG | **100** | **0** | **72** | **28** |

Numbers indicate the percent of manure being managed under each type of system

The amount of methane generated by each of the management systems discussed in section 4.1 varies greatly. Solid-based systems generally limit the amount of methane produced due to the aerobic nature of those systems. However, because there is a large number of animals being managed under these systems, methane emissions are still very high (about 60 percent of U.S. totals). It is very difficult to capture this methane, however, because of the dispersed nature of these systems. On the other hand, liquid and slurry based systems, which cause anaerobic conditions to develop (thus favoring methane production), are responsible for more than 40 percent of total U.S. emissions. Due to the centralized nature of liquid-based management systems and the propensity for anaerobic conditions, it is likely that these systems offer the greatest opportunities for capturing methane.