Resource Assessment for Livestock and Agro-Industrial Wastes – Dominican Republic

Prepared for:

The Global Methane Initiative

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EXECUTIVE SUMMARY

The Global Methane Initiative (GMI) is an initiative to reduce global methane emissions with the purpose of enhancing economic growth, promoting energy security, improving the environment, and reducing greenhouse gases. The initiative focuses on cost-effective, near-term methane recovery and use as a clean energy source. The initiative functions internationally through collaboration among developed countries, developing countries, and countries with economies in transition—together with strong participation from the private sector.

GMI works in four main sectors: agriculture, landfills, oil and gas exploration and production, and coal mining. The Agriculture Subcommittee was created in November 2005 to focus on anaerobic digestion of livestock wastes; it has since expanded to include anaerobic digestion of wastes from agro-industrial processes. Representatives from Argentina and India currently serve as co-chairs of the subcommittee.

As part of GMI, the U.S. Environmental Protection Agency (U.S. EPA) is conducting a livestock and agro-industry resource assessment (RA) in the Dominican Republic to identify and evaluate the potential for incorporating anaerobic digestion into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy.

Table ES-1 summarizes the findings of the RA in terms of potential methane emission reductions and fossil fuel replacement carbon offsets in the Dominican Republic. The sectors with the highest potential for methane reduction and carbon offsets are swine (38 percent), rum distilleries (25 percent of the potential), sugar (25 percent), and dairy cattle (12 percent).

Table ES-1 – Summary of the Methane Emission Reduction Potential in the Livestock and Agro-Industrial Sector in the Dominican Republic

Sector	Methane Emission Reductions ($MT\ CH_4/yr$)	Carbon Emission Reductions ($MT\ CO_2e/yr$)	Fuel Replacement Offsets ($MT\ CO_2e/yr$)	Total Carbon Emission Reductions ($MT\ CO_2e/yr$)
Swine	5,500	116,200	18,200	134,400
Rum distilleries	3,700	78,100	12,200	90,400
Sugar	3,600	75,900	11,900	87,800
Dairy cattle	1,700	36,400	5,700	42,200
Total	14,600	306,700	48,100	354,800

Totals may not sum due to rounding

Table ES-2 presents a comparison of this resource assessment estimate of current baseline methane emissions with estimated emissions reported in the most recent national greenhouse gas emissions inventory (SEMARENA, 2009). The table also shows the percentage of current emissions that can readily be captured (namely emissions from open anaerobic lagoons).

Table ES-2 – Comparison of Estimated Methane Emissions by This Resource Assessment With National Greenhouse Gas Emissions Inventory Values

Sector	Baseline Emissions Estimates (MT CH_4/yr)		% Emissions That Can Be Captured	Potential Emission Reductions (MT CH_4/yr)
	National Inventory Estimate (2000)	RA Estimate		
Swine	—	6,700	83%	5,500
Dairy cattle	—	4,800	36%	1,700
Total livestock	10,100	11,500	—	7,200
Rum distilleries	—	3,700	100%	3,700
Sugar	—	3,600	100%	3,600
Total agro-industries	4,470	7,300	—	7,300

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LIST OF ABBREVIATIONS

Acronyms	Spanish	English
AMBR®		Anaerobic Migrating Blanket Reactor
ASBR		Anaerobic Sequencing Batch Reactor
APORCI	Asociación de Porcicultores del Cibao	Association of Swine Producers of Cibao
APORLI	Asociación de Porcicultores de Licey al Medio	Association of Swine Producers of Licey al Medio
BOD		Biochemical Oxygen Demand
CDM		Clean Development Mechanism
CEA	Consejo Estatal del Azucar	National Sugar Council
CEDAF	Centro de Desarrollo Agropecuario y Forestal	Center for Agriculture and Forestry Development
CH_4		Methane (chemical formula)
CO_2		Carbon Dioxide (chemical formula)
COAPI	Centro de Orientación, Apoyo y Promoción a la Inversión	Center for Investment Guidance, Support and Promotion
COD		Chemical Oxygen Demand
CNCCMDL	Consejo Nacional para el Cambio Climático y el Mecanismo de Desarrollo Limpio	National Council on Climate Change and Clean Development Mechanism
CONALECHE	Consejo Nacional para el Fomento y Reglamentación del Sector Lechero	National Council of Regulation and Promotion of the Dairy Industry
CONAPROPE	Consejo Nacional de Producción Pecuaria	National Council of Livestock Production
COOPCIBAO	Cooperativa de Criadores del Cibao	Swine Producers Cooperative of the Cibao Region
DAF		Dissolved Air Flotation
FAO		United Nations Food and Agriculture Organization
FEDOPOL	Federación Dominicana de Porcicultores	Dominican Federation of Swine Producers
FFB		Fresh Fruit Bunch
GDP		Gross Domestic Product
GHG		Greenhouse Gas
GMI		Global Methane Initiative

Acronyms	Spanish	English
GWP		Global Warming Potential
IIBI	Instituto de Inovación en Biotecnología e Industria	Institute of Innovation in Biotechnology and Industry
IICA	Instituto Interamericano de Cooperación para la Agricultura	Inter-American Cooperation Institute for Agriculture
INAZUCAR	Instituto Azucarero Dominicano	Dominican Sugar Institute
INESPRE	Instituto de Estabilización de Precios	Institute of Price Stabilization
IPCC		Intergovernmental Panel on Climate Change
JAD	Junta Agroempresarial Dominicana	Dominican Agro-business Board
JICA		Japan International Co-operation Agency
OLADE	Organización Latinoamericana de Energía	Latin American Organization of Energy
ONMDL	Oficina Nacional del Mecanismo de Desarrollo Limpio	National Office of CDM
MCF		Methane Conversion Factor
$MMTCO_2e$		Million Metric Tons of Carbon Dioxide Equivalent
MT		Metric Ton
$MTCO_2e$		Metric Tons of Carbon Dioxide Equivalent
RA		Resource Assessment
SEA	Secretaría de Estado de Agricultura	Ministry of Agriculture
SEMARENA	Secretaría de Estado de Medio Ambiente y Recursos Naturales	Ministry of Environment and Natural Resources
TS		Total Solids
TSS		Total Suspended Solids
UASB		Upflow Anaerobic Sludge Blanket
UNPHU	Universidad Nacional Pedro Henrique Ureña	National University Pedro Henrique Ureña
USAID		United States Agency for International Development

Acronyms	Spanish	English
U.S. EPA		United States Environmental Protection Agency
VS		Volatile solids

1. INTRODUCTION

The Global Methane Initiative (GMI) is a collaborative effort between national governments and others to capture methane emissions and use them as a clean energy source. The Initiative, begun in 2004 as the Methane to Markets Partnership, was expanded in 2010. Partners made formal declarations to minimize methane emissions from key sources, stressing the importance of implementing methane capture and use projects in developing countries and countries with economies in transition. GMI is focusing on a few key sources of methane including agriculture, coal mining, landfills, and oil and gas systems.

GMI brings together diverse organizations with national governments to catalyze the development of methane projects. Organizations include the private sector, the research community, development banks, and other governmental and nongovernmental organizations. Facilitating the development of methane projects will decrease greenhouse gas (GHG) emissions, increase energy security, enhance economic growth, improve local air quality, and improve industrial safety.

GMI is conducting resource assessments (RAs) in several countries to identify the types of livestock and agro-industrial subsectors (e.g., dairy farming, palm oil production, sugarcane processing) with the greatest opportunities for cost-effective implementation of methane recovery systems. The Dominican Republic RA's objectives are:

- Identify and characterize methane reduction potential in the Dominican Republic
- Develop market opportunities
- Provide the location of resources and a ranking of resources

Specifically, the RA will determine the potential for incorporating anaerobic digestion into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy in the Dominican Republic. This report summarizes the findings of the RA, discusses the most attractive sectors and locations, and prioritizes the sectors in terms of potential methane emission reductions.

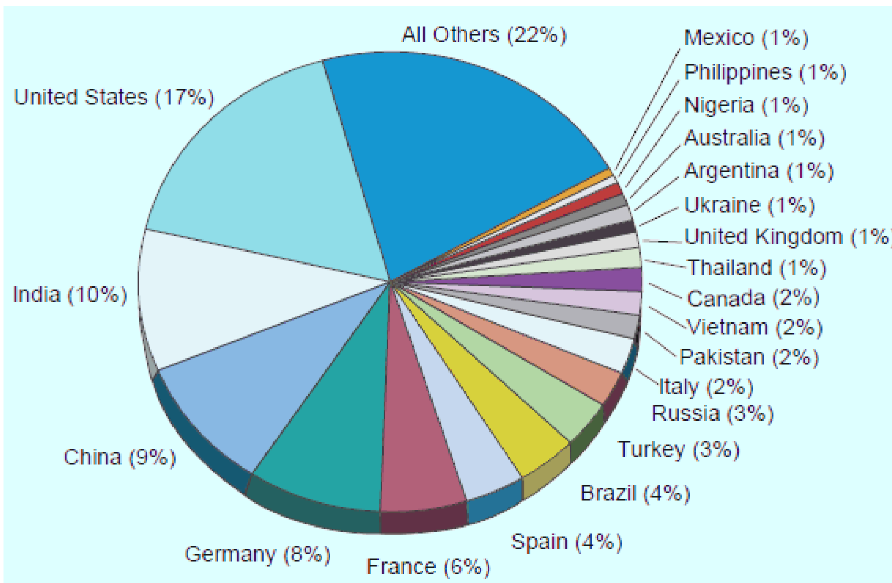
While there are other studies showing methane emissions from the sectors covered in this document, these studies usually consider total population or production levels as the baseline for calculating the emissions. This RA, however, uses a different approach, recognizing that not all waste management practices (e.g., pastures) generate methane. For this analysis, methane emission reduction estimates are based on the actual population (or number of industries) that generate methane from their waste management systems (e.g., lagoons) using the most accurate and validated data available for each subsector. For example, methane emissions from swine and dairy subsectors only take into account a reasonable fraction of the total number of animals and number of operations in the country. This fraction represents the number of animals that are assumed to be using waste management practices that generate methane. Estimating emission reductions using these assumptions provides a better basis for policy development and capital investments, and provides conservative estimates of potential emission reductions.

Finally, it is important to note that this RA limits its scope to emission reduction technical potential. It does not address the economic potential, which still needs to be determined based on subsector-specific feasibility studies.

1.1 METHANE EMISSIONS FROM LIVESTOCK WASTES

In 2005, livestock manure management globally contributed more than 230 million metric tons of carbon dioxide equivalents ($MMTCO_2e$) of methane emissions, or roughly 4 percent of total anthropogenic (human-induced) methane emissions. Three groups of animals accounted for more than 80 percent of total emissions: swine (40 percent); non-dairy cattle (20 percent); and dairy cattle (20 percent). In certain countries, poultry was also a significant source of methane emissions. Figure 1.1 represents countries with significant methane emissions from livestock manure management.

Figure 1.1 – Estimated Global Methane Emissions From Livestock Manure Management (2005)
Total = 234.57 $MMTCO_2e$

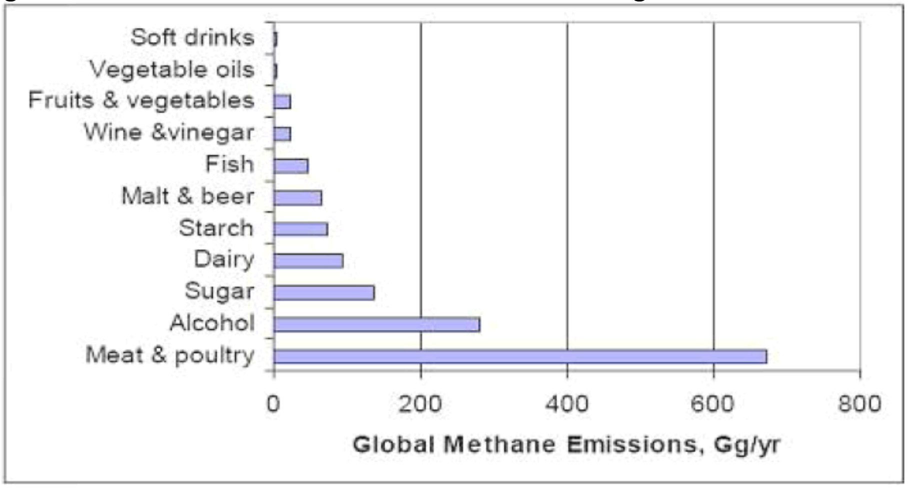


Source: Global Methane Initiative

1.2 METHANE EMISSIONS FROM AGRO-INDUSTRIAL WASTES

Waste from agro-industrial activities is an important source of methane emissions. The organic fraction of agro-industrial wastes typically is more readily biodegradable than the organic fraction of manure. Thus, greater reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), and volatile solids (VS) during anaerobic digestion can be realized. In addition, the higher readily biodegradable fraction of agro-industrial wastes translates directly into higher methane production potential than from manure. Figure 1.2 shows global estimates of methane (CH_4) emissions from agro-industrial wastes.

Figure 1.2 – Global Methane Emissions From Agro-Industrial Wastes



Source: Doorn et al., 1997

As shown in Table 1.1, the majority of agro-industrial wastes in developing countries is not treated before discharge, and only a minority is treated anaerobically. As a result, agro-industrial wastes represent a significant opportunity for methane emission reduction through the addition of appropriate anaerobic digestion systems.

Table 1.1 – Disposal Practices From Agro-Industrial Wastes

Sector	Region	Percent of Wastewater	
		Untreated Discharge	On-site Anaerobic Treatment
Meat, poultry, dairy, and fish processing	Africa	60	34
	Asia (except Japan)	70	22
	Eastern Europe	50	23
	Latin America	50	32
Fruit and vegetable processing	Africa	70	6
	Asia (except Japan)	70	5
	Eastern Europe	50	1
	Latin America	60	5
Alcohol, beer, wine, vegetable oil, sugar, and starch	Africa	60	17
	Asia (except Japan)	60	11
	Eastern Europe	20	8
	Latin America	20	13

Source: Doorn et al., 1997

1.3 METHANE EMISSIONS IN THE DOMINICAN REPUBLIC

According to the most recent Dominican Republic GHG inventory (SEMARENA, 2009), methane accounts for 21 percent of the total GHG emissions (see Table 1.2), with enteric fermentation accounting for 50 percent of all methane emissions. Animal waste management represents 4 percent of the total methane emissions; though it is small compared to enteric fermentation, it represents a significant opportunity for emission reduction with methane capture through the use of anaerobic digestion under controlled conditions with subsequent combustion either as an energy source or for disposal. Table 1.2 shows the contributions in gigagrams (Gg) of the main sources of GHGs in the Dominican Republic in 2000.

Table 1.2 – Main Sources of GHG Emissions in the Dominican Republic in 2000

Category	Gg CO_2	Gg CH_4	Gg N_2O
Energy	17,603.66	16.4	0.46
Industrial processes	811.06	0	0
Agriculture, including:		140.1	8.9
Enteric fermentation		*114.7*	
Manure management		*10.1*	
Waste, including:	2.03	73.83	0.39
Landfills		*33.13*	
Domestic and commercial wastewater		*36.22*	
Industrial wastewater		*4.47*	
Total	18,416.75	230.33	9.75
GWP factor	1	21	298
Total (Gg CO_2e)	18,417	4,837	2,906
Percentage	68%	18%	11%

Source: Based on SEMARENA, 2009

2. BACKGROUND AND CRITERIA FOR SELECTION

This report presents an assessment of methane emissions from wastes of the Dominican Republic's livestock and agro-industrial sectors. It focuses on the livestock and agro-industrial subsectors deemed to have the greatest potential for methane emission reduction or methane capture.

2.1 METHODOLOGY USED

In conducting the RA, the team used a variety of data sources:

- **Field visits** to sites of various sizes in the various sectors to characterize the waste management systems used and to verify the information collected through other sources.

- **Interviews** with local experts from pertinent industry associations and engineering/consulting companies and professionals working on agriculture and rural development, current users of anaerobic digestion technologies, and other stakeholders.

- **Published data** by national and international organizations (e.g., United Nations Food and Agriculture Organization [FAO] animal production data sets), specific subsector information from business and technical journals, and other documents, reports, and statistics.

The team took the following approach, which has also been used in other RAs in this series:

Step 1: The first step in the development of the Dominican Republic livestock and agro-industry RA involved constructing general profiles of the individual subsectors (or commodity groups), such as dairy and swine production and sugarcane and fruit processing. Each profile includes a list of operations within the subsector and the distribution of facilities by size and geographic location. For the various commodity groups in the livestock sector, the appropriate metric for delineating distribution by size is the average annual standing population (e.g., number of lactating dairy cows, pigs). For the various commodity groups in the agro-industry sector, the metric is the mass or volume of annual processing capacity or the mass or volume of the commodity processed annually.

Step 2: Based on available data, the team then tried to determine the composition of the livestock production and agro-industry sectors at the national level, as well as the relative significance of each of them geographically.

Step 3: With this information, the team focused on identifying the commodity groups in each sector with the greatest potential to emit methane from waste management activities. For example, a country's livestock sector might include dairy, beef, swine, and poultry operations, but poultry production might be insignificant due to lack of demand or considerable import of poultry products, with correspondingly low methane emissions. Thus, to most effectively use available resources, the team focused on identifying those commodity groups with higher emissions. In the best-case scenarios, these livestock production and agro-industry sector profiles were assembled from statistical information published by a government agency. If such information was unavailable or inadequate, the team used a credible secondary source, such as FAO.

Step 4: The team characterized the waste management practices used by the largest operations in each sector. Typically, only a small percentage of the total number of operations in each commodity group will be responsible for the majority of production, and thus the majority of the methane emissions. Additionally, the waste management practices employed by the largest producers in each commodity group should be relatively uniform. When information about waste management practices was incomplete or not readily accessible, the team identified and directly contacted producer associations and local consultants' and visited individual operations to obtain this information.

Step 5: The team then assessed the magnitude of current methane emissions to identify the commodity groups that should receive further analysis. As an example, in the livestock production sector, large operations in a livestock commodity group that relies primarily on a pasture-based production system will have only nominal methane emissions because manure decomposition will be primarily by aerobic microbial activity. Similarly, an agro-industry subsector with large operations that directly discharge untreated wastewater to a river, lake, or ocean will not be a source of significant methane emissions. Thus, the process of estimating current methane emissions was focused on those sectors that could most effectively use available resources, and thus the most promising candidate sectors and/or operations for technology demonstration.

2.2 ESTIMATION OF METHANE EMISSIONS IN THE LIVESTOCK AND AGRO-INDUSTRIAL SECTORS

This section describes the generally accepted methods for estimating methane emissions from livestock manures and agricultural commodity processing wastes, along with the modification of these methods to estimate the methane production potential with the addition of anaerobic digestion as a waste management system component.

2.2.1 Manure-Related Emissions

The team used the 2006 *IPCC Guidelines for National Greenhouse Gas Inventories* Tier 2 method to estimate methane emissions from each commodity group in the livestock production sector. Using the Tier 2 method, methane emissions for each livestock commodity group (M) and existing manure management system (S) and climate (k) combination are estimated as shown in Equation 2.1:

$$CH_{4(M)} = \left(VS_{(M)} \times H_{(M)} \times 365\ \text{days/yr}\right) \times \left[B_{o(M)} \times 0.67\ \text{kg}\ CH_4/\text{m}^3\ CH_4 \times MCF_{S,k}\right] \qquad (2.1)$$

where:
- $CH_{4\,(M)}$ = Estimated methane emissions from manure for livestock category M (kilograms [kg] CH_4/yr)
- $VS_{(M)}$ = Average daily volatile solids excretion rate for livestock category M (kg volatile solids/animal/day)
- $H_{(M)}$ = Average number of animals in livestock category M
- $B_{o(M)}$ = Maximum methane production capacity for manure produced by livestock category M (cubic meters [m^3] CH_4/kg volatile solids excreted)
- $MCF_{(S,k)}$ = Methane conversion factor for manure management system S for climate k (decimal)

Equation 2.1 requires an estimate of the average daily VS excretion rate for the livestock category under consideration. Table 2.1 lists the default values for dairy cows, breeding swine, and market swine. Default values for other types of livestock can be found in Tables 10A-4 through 10A-9 in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Table 2.1 – 2006 IPCC Volatile Solids Excretion Rate Default Values for Dairy Cows, Breeding Swine, and Market Swine (kg/Head/Day)

Region	Dairy Cows	Breeding Swine	Market Swine
North America	5.4	0.5	0.27
Western Europe	5.1	0.46	0.3
Eastern Europe	4.5	0.5	0.3
Oceania	3.5	0.5	0.28
Latin America	2.9	0.3	0.3
Middle East	1.9	0.3	0.3
Asia	2.8	0.3	0.3
Indian Subcontinent	2.6	0.3	0.3

Realistic estimates of methane emissions using Equation 2.1 also require identification of the appropriate MCF, which is a function of the current manure management system and climate. MCFs for various types of manure management systems for average annual ambient temperatures ranging from greater than or equal to 10°C to less than or equal to 28°C are summarized in Table 2.2, and can be found in Table 10.17 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Table 2.2 – Default MCF Values for Various Livestock Manure Management Systems

Climate	Manure Management System Default Methane Emission Factor, Percentage								
	Lagoons	Storage Tanks and Ponds	Solid Storage	Dry Lots	Pit < 1 Month	Pit > 1 Month	Daily Spread	Anaerobic Digestion	Pasture
Cool	66–73	17–25	2	1	3	17–25	0.1	0–100	1
Temperate	74–79	27–65	4	1.5	3	27–65	0.5	0–100	1.5
Warm	79–80	71–80	6	5	30	71–80	1	0–100	2

Finally, use of Equation 2.1 requires specification of the methane production potential (B_o) for the type of manure under consideration. Default values listed in Tables 10A-4 through 10A-9 of *the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* can be used. The default values for dairy cows, breeding swine, and market swine are listed in Table 2.3.

Table 2.3 – 2006 IPCC Methane Production Potential Default Values for Dairy Cows, Breeding Swine, and Market Swine, m^3 CH_4/kg VS

Region	Dairy Cows	Breeding Swine	Market Swine
North America	0.24	0.48	0.48
Western Europe	0.24	0.45	0.45
Eastern Europe	0.24	0.45	0.45
Oceania	0.24	0.45	0.45
Latin America	0.13	0.29	0.29
Middle East	0.13	0.29	0.29
Asia	0.13	0.29	0.29
Indian Subcontinent	0.13	0.29	0.29

2.2.2 Emissions Related to Agricultural Commodity Processing Waste

Agricultural commodity processing can generate two sources of methane emissions: wastewater and solid organic wastes. The latter can include raw material not processed or material discarded after processing due to spoilage or poor quality, or for other reasons. One example is the combination of wastewater and the solids removed by screening before wastewater treatment or direct disposal. These solid organic wastes may have relatively high moisture content and are commonly referred to as wet wastes. Appendix B illustrates a typical wastewater treatment unit process sequence. The method for estimating methane emissions from wastewater is presented below.

For agricultural commodity processing wastewaters, such as meat and poultry processing wastewaters from slaughterhouses, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Tier 2 methods (Section 6.2.3.1) are an acceptable way to estimate methane emissions. This methodology uses COD and wastewater flow data. Using the Tier 2 methods, the gross methane emissions for each waste category (W) and prior treatment system and discharge pathway (S) combination should be estimated as shown in Equation 2.2:

$$CH_{4(W)} = [(TOW_{(W)} - S_{(W)}) \times EF_{(W,S)}] - R_{(W)})] \quad (2.2)$$

where: $CH_{4\,(W)}$ = Annual methane emissions from agricultural commodity processing waste W (kg CH_4/yr)
$TOW_{(W)}$ = Annual mass of waste W COD generated (kg/yr)
$S_{(W)}$ = Annual mass of waste W COD removed as settled solids (sludge) (kg/yr)
$EF_{(W,S)}$ = Emission factor for waste W and existing treatment system and discharge pathway S (kg CH_4/kg COD)
$R_{(W)}$ = Mass of CH_4 recovered (kg/yr)

As indicated above, the emission factor in Equation 2.2 is a function of the type of waste, the existing treatment system and discharge pathway, and is estimated as shown in Equation 2.3:

$$EF_{(W,S)} = B_{o\,(W)} \times MCF_{(S)} \quad (2.3)$$

where: $B_{o\,(W)}$ = Maximum CH_4 production capacity (kg CH_4/kg COD)
$MCF_{(S)}$ = Methane conversion factor for the existing treatment system and discharge pathway (decimal)

If country- and waste-sector-specific values for B_o are not available, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* default value of 0.25 kg CH_4 per kg COD should be used. In the absence of more specific information, the appropriate MCF default value (see Table 2.4) also should be used.

Table 2.4 – Default MCF Values for Industrial Wastewaters, Decimal

Existing Treatment System and Discharge Pathway	Comments	MCF[a]	Range
Untreated			
Sea, river, or lake discharge	Rivers with high organic loadings may turn anaerobic, which is not considered here	0.1	0–0.2
Treated			
Aerobic treatment plant	Well managed	0	0–0.1
Aerobic treatment plant	Not well managed or overloaded	0.3	0.2–0.4
Anaerobic reactor (e.g., UASB, fixed film)	No methane capture and combustion	0.8	0.8–1.0
Shallow anaerobic lagoon	Less than 2 meters deep	0.2	0–0.3
Deep anaerobic lagoon	More than 2 meters deep	0.8	0.8–1.0

[a] Based on IPCC expert judgment.

If the annual mass of COD generated per year (TOW) is not known and it is not possible to collect the necessary data, the remaining option is estimation (as shown in Equation 2.4) with country-specific wastewater generation rate and COD concentration data obtained from the literature. In the absence of country-specific data, values listed in Table 2.5 can be used as default values to obtain first order estimates of methane emissions.

$$TOW_{(W)} = P_{(W)} \times W_{(W)} \times COD_{(W)} \tag{2.4}$$

where: $P_{(W)}$ = Product production rate (metric tons per yr)
$W_{(W)}$ = Wastewater generation rate (m^3/metric ton of product)
$COD_{(W)}$ = Wastewater COD concentration (kg/m^3)

Table 2.5 – Examples of Industrial Wastewater Data

Industry	Typical Wastewater Generation Rate, m^3/MT	Range of Wastewater Generation Rates, m^3/MT	Typical COD Concentration, kg/m^3	Range of COD Concentrations, kg/m^3
Alcohol	24	16–32	11	5–22
Beer	6.3	5.0–9.0	2.9	2–7
Coffee	NA	NA	9	3–15
Dairy products	7	3–10	2.7	1.5–5.2
Fish processing	NA	8–18	2.5	—
Meat and poultry processing	13	8–18	4.1	2–7
Starch production	9	4–18	10	1.5–42
Sugar refining	NA	4–18	3.2	1–6
Vegetable oils	3.1	1.0–5.0	NA	0.5–1.2
Vegetables, fruits, and juices	20	7–35	5.0	2–10
Wine and vinegar	23	11–46	1.5	0.7–3.0

Source: Doorn et al., 1997

2.3 DESCRIPTION OF SPECIFIC CRITERIA FOR DETERMINING POTENTIAL SECTORS

The specific criteria to determine methane emission reduction potential and feasibility of anaerobic digestion systems include:

- **Large sector/subsector:** The category is one of the major livestock production or agro-industries in the country.
- **Waste volume:** The livestock production or agro-industry generates a high volume of waste discharged to conventional anaerobic lagoons.
- **Waste strength:** The wastewater generated has a high concentration of organic compounds, measured in terms of BOD or COD or both.
- **Geographic distribution:** There is a concentration of priority sectors in specific regions of the country, making centralized or co-mingling projects potentially feasible.
- **Energy-intensive:** There is sufficient energy consumption to absorb the generation from recovered methane.

The top industries that meet all of the above criteria in the Dominican Republic are swine and dairy farms, rum distilleries, sugar mills, slaughterhouses, and palm oil processing. Two other sectors were also evaluated: cassava, and fruit processing. Although they could emit methane in the course of wastewater treatment current treatment practices already mitigate or minimize those emissions. Therefore these sectors were not included as part of the main report; more information on these sectors can be found in Appendix C.

2.4 EXAMPLES OF ANAEROBIC DIGESTION PROJECTS IN THE DOMINICAN REPUBLIC

A few examples of anaerobic digestion projects in the Dominican Republic are briefly described below.

2.4.1 Example of UASB Digesters at a Rum Distillery – La Isabela

The La Isabela distillery currently produces 26,300 liters of alcohol per day (L/day), and plans to increase its production to 70,000 L/day by 2011. The alcohol is produced exclusively from molasses, with a ratio of 5.7 L of alcohol produced per L of molasses. The rate of wastewater generation averages 12 L per L of alcohol produced and the average BOD is 85 kg/m^3. The plant recently installed three upflow anaerobic sludge blanket (UASB) digesters that will start operation at the end of 2010. The three digesters have a cumulative operation volume of 3,000 m^3. The biogas will be used for electricity generation for on-site consumption and the excess electricity will be sold to the grid. The plant estimates that it will generate approximately 1 MW to sell to the grid and 250 kW for on-site consumption.

Figure 2.1 – One of the Three UASB Digesters at La Isabela

Source: Tetra Tech

2.4.2 Example of a Small Bag Digester at a Swine Farm in Licey al Medio

The Association of Swine Producers of Licey al Medio (APORLI), with support from USAID, conducted anaerobic digestion demonstration projects on swine farms. The objective of the project was to show that anaerobic digestion can be used at swine farms to generate heat and electricity, reduce water pollution (Figure 2.2), and produce fertilizer. One example of a demonstration project conducted by USAID is at the 35-pig farm of the general manager of APORLI. The anaerobic digester consists of a plug-flow bag digester (13m long and 2m in diameter) (Figure 2.3). The biogas generated is used for cooking in the kitchen and for electricity generation through a 15kW electric generator constructed by COAPI from a 1,800cc four-cylinder motor (Figure 2.4). The average electricity generation is 4.5 to 5kW. The effluent is used as fertilizer for a small plantain plantation.

Figure 2.2 – The Open Anaerobic Lagoon Before the Project

Source: COAPI, 2010

Figure 2.3 – The Plug-Flow Bag Digester

Source: COAPI, 2010

Figure 2.4 – The Electric Generator Built From an 1,800cc Four-Cylinder Engine

Source: COAPI, 2010

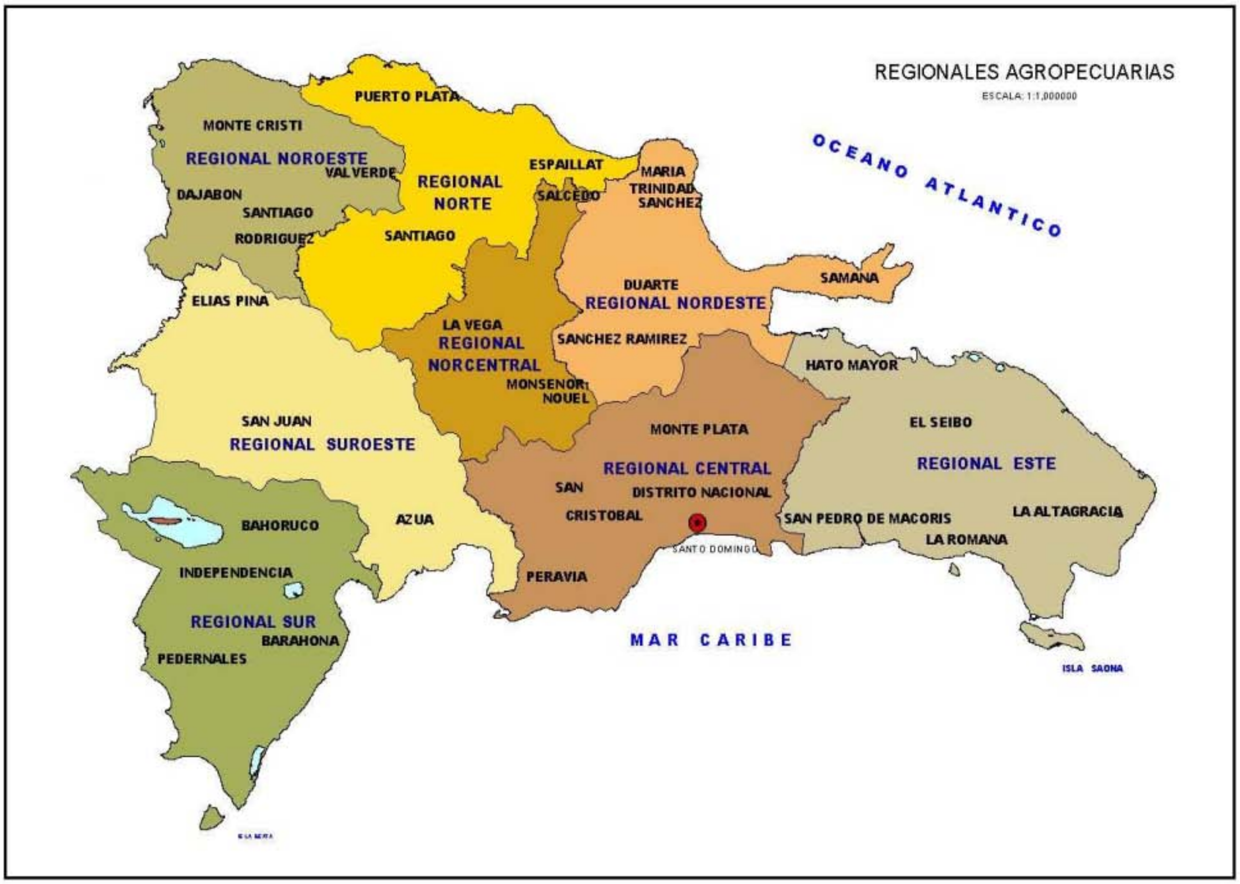
3.1 OVERVIEW OF DOMINICAN AGRICULTURE

The Dominican Republic occupies the eastern two-thirds of the island Hispaniola, which is part of the Greater Antilles archipelago in the Caribbean region. It is the second largest Caribbean nation both in terms of area and population, with a little less than 50,000 km^2 and nearly 10 million people (CIA, 2010). The country is divided into 31 provinces and the capital Santo Domingo, designated as the national district (Figure 3.1).

Figure 3.1 – State Map of Dominican Republic

In terms of agriculture and livestock production, the country can be divided into eight regions: northwest (NW), north (N), northeast (NE), north-central (NC), southwest (SW), south (S), central (C), and east (E) (Figure 3.2). The Cibao region, which regroups all the northern regions (NW, N, NE, NC) is the main agricultural center of the country.

Figure 3.2 – Map of the Agricultural Regions of Dominican Republic



Source: SEA, 2006
Key: noroeste (northwest, NW), norte (north, N), nordeste (northeast, NE), norcentral (north-central, NC), suroeste (southwest, SW), sur (south, S), central (central, C), este (east, E)

In 2009, agriculture represented 11.7 percent of the country's GDP and 14.6 percent of the total labor force (CIA, 2010). Table 3.1 shows the top food and other agricultural commodities produced in the Dominican Republic in 2008. From the tonnage standpoint, sugarcane is, by far, the main agricultural product, with 4.8 million metric tons per year. From the value standpoint, chicken, beef, and cow's milk rank first, second, and third respectively.

Table 3.1 – Food and Other Agricultural Commodities Production in the Dominican Republic in 2008

Rank	Commodity	Production (Int $1,000)	Production (MT)
1	Sugarcane	100,192	4,823,910
2	Rice, paddy	134,265	644,277
3	Cow's milk, whole, fresh	145,805	548,624
4	Bananas	62,642	439,569
5	Chicken meat	403,056	345,550
6	Plantains	75,497	340,370
7	Tomatoes	57,576	243,012
8	Avocados	110,793	187,398
9	Mangos, mangosteens, guavas	38,081	170,000
10	Cattle meat	209,103	101,100
11	Pineapples	19,441	100,528
12	Cassava	7,217	100,164
13	Coconuts	8,584	94,923
14	Oranges	15,875	90,337
15	Eggs	55,953	86,042

Source: FAOSTAT, 2010a

3.2 SUBSECTORS WITH POTENTIAL FOR METHANE EMISSION REDUCTION

As discussed in Section 2.1, two criteria were used to rank sectors: 1) the sector or subsector size and 2) the geographic concentration (particularly for anaerobic digestion centralized systems).

Table 3.2 summarizes the important subsectors of the livestock production and agricultural commodity processing sectors in the Dominican Republic, as identified in this RA: swine, dairy cattle, rum distilleries, sugar mills, slaughterhouses, and palm oil processing. A more detailed discussion of each of these subsectors is provided in either Sections 3.3, Section 3.4, or Appendix C. Subsectors that were evaluated but not considered to have the potential for methane reduction are tapioca production and fruit processing.

Table 3.2 – Identified Potential Sectors for Methane Emission Reductions in the Dominican Republic

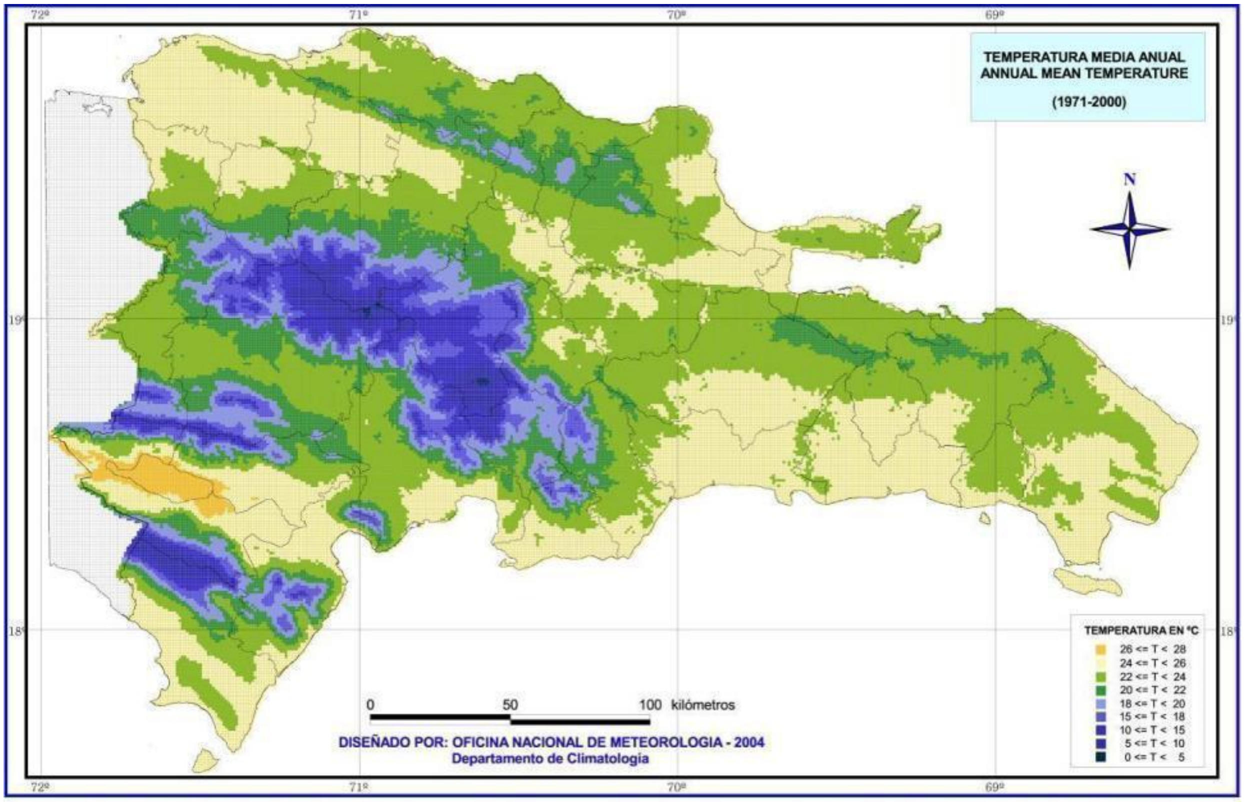
Subsector	Size (Production/Year)	Geographic Location	Potential[a]
Swine	925,000 head in 2009	North (35%), north-central (20%), central (16%), northeast (12%)	Large potential; 40% of organized farms use lagoons, the rest use direct discharge
Dairy cows	2.6 million cattle in 2008, 600 million liters of milk in 2009	Baní, Centro Cibao, Monte Plata	Medium potential; 10% of confined and semi-confined farms use open concrete tanks
Sugar mills	4.8 million MT of sugarcane in 2008	San Pedro de Macoris, La Romana, Barahona	Large potential (assume all four sugar mills use lagoons)
Distilleries	50 million liters of rum in 2005	San Pedro de Macorís (three plants) and Santo Domingo (one plant)	Large potential (two plants out of four use lagoons)
Palm oil	70,000 MT of fresh fruit bunch processed per year	Monte Plata (1 plant)	Low potential because there is only one large plant
Cassava processing (casabe)	166,000 MT of cassava roots in 2009	Provinces Santiago Rodriguez (Moncion municipality), Espaillat, Valverde, Hermanas Mirabal	Very low potential because of low production and direct discharge to water bodies
Slaughterhouses	350,000 MT (chicken), 100,000 MT (cattle), 72,000 MT (swine) in 2008	Santo Domingo	Very low potential; most slaughterhouses already have a wastewater treatment plant or use direct discharge

[a] Low potential: less than 20,000 $MTCO_2e$/yr. Medium potential: 20,000–80,000 $MTCO_2e$/yr. Large potential: above 80,000 $MTCO_2e$/yr.

Methane production is temperature dependent; methane production generally increases with increased temperature. In addition, the types of bacteria that break down waste and produce methane optimally require temperatures greater than 35° Celsius. Therefore, an important consideration in evaluating locations for potential methane capture is the temperature. In the Dominican Republic, the annual average annual temperature ranges between 18°C and 28°C (country average 25.5°C) and the average rainfall is between 350 and 2,743 mm per year (country average 1,500 mm) (SEMARENA, 2009).

The following map (Figure 3.3) shows the annual average temperature in degrees Celsius for the 1971–2000 period.

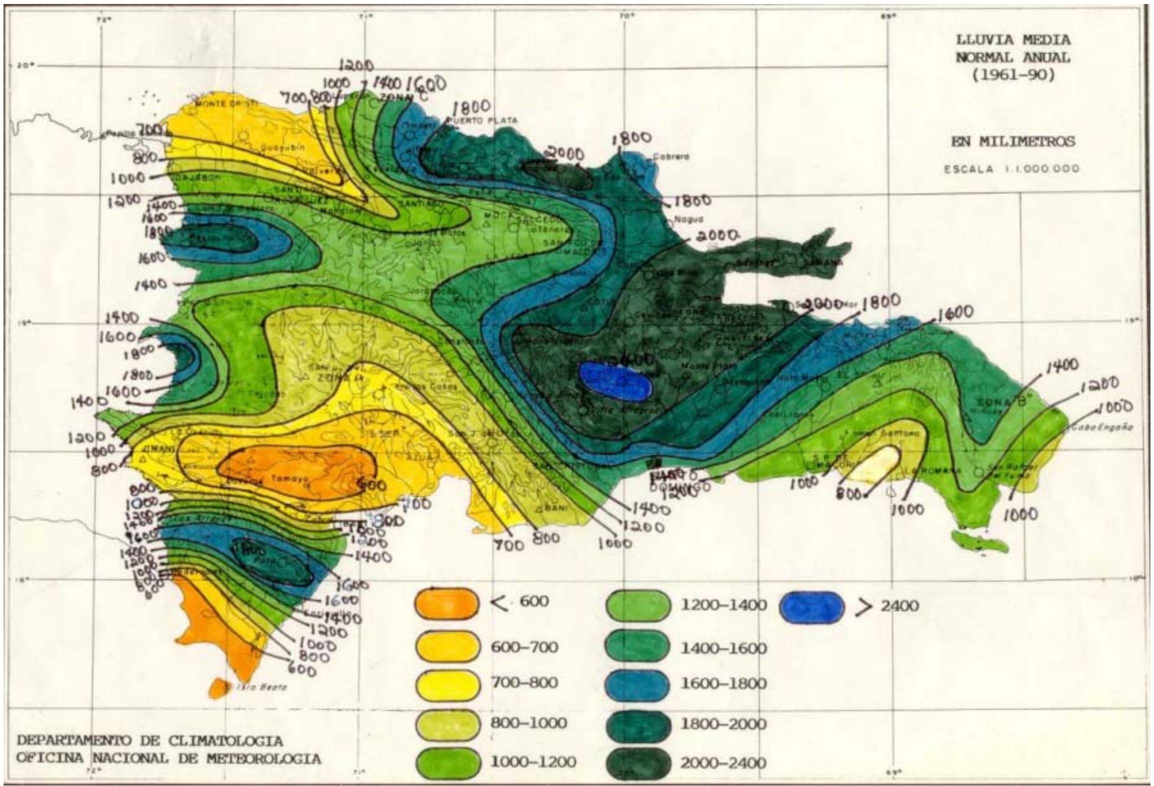
Figure 3.3 – Temperature Map of Dominican Republic



Source: National Office of Meteorology, Department of Climatology

Precipitation is another important factor to take into account, due to its affect on the applicable technologies and system costs. The following map (Figure 3.4) shows the annual average precipitation in mm per year for the 1961–1990 period.

Figure 3.4 – Precipitation Map of Dominican Republic



Source: SEA, 2006

3.3 LIVESTOCK PRODUCTION

According to the 2004 *Agricultural Statistics Yearbook of the Dominican Republic* published by the Ministry of Agriculture, the livestock sector represented approximately 47 percent of the agriculture GDP and 5 percent of the total GDP (SEA, 2006). The predominant livestock types in the Dominican Republic are chickens, beef and dairy cattle, and pigs (Table 3.3).

Table 3.3 – Number of Animals per Category in the Dominican Republic in 2008

Animal	Number of Head in 2008
Chicken	100,500,000
Cattle (beef and dairy)	2,652,600
Pigs	580,000
Horses	350,000
Goats	190,000
Donkeys	150,500
Mules	140,500
Sheep	123,000

Source: FAOSTAT, 2010a

The number of pigs provided by FAO's statistics division, or FAOSTAT (Table 3.3), is significantly lower than the number found in the agricultural census of the Ministry of Agriculture (Table 3.4). The calculations in this RA are based on the number from the Ministry of Agriculture. However, FAOSTAT values are presented in the table above in order to compare the size of the different animal herds.

3.3.1 Swine Production

a. DESCRIPTION OF SIZE, SCALE, AND GEOGRAPHIC LOCATION OF OPERATIONS

According to the Livestock Department of the Ministry of Agriculture (SEA), there were 850,000 pigs in the Dominican Republic in 2009, including 75,000 sows. The main pig-producing regions are the north (Santiago, Licey and Tamboril) with 35 percent of the total production and the North-Central region (La Vega and Moca) with 20 percent (Table 3.4).

Table 3.4 – Number of Pigs per Region in the Dominican Republic in 1998 and 2009

Region	SEA, 2009	
	Percentage of Total	Number of Animals
North	35%	300,900
North-central	20%	170,000
Central	16%	135,150
Northeast	12%	99,450
East	7%	56,100
Northwest	5%	42,500
South	3%	28,900
Southwest	2%	17,000
Total	**100%**	**850,000**

Source: SEA, personal contact

According to the swine census carried out by the Swine Commission of the National Council of Livestock Production (CONAPROPE) in 2002, there were 7,360 swine producers in the country (Table 3.5). SEA reported there were only 340 organized farms in the country; however, that number does not take into account backyard- or household-type producers. As can be seen by comparing Table 3.4 and Table 3.5, the regions with the most pig producers, the south (24 percent) and northeast (19 percent), do not have the highest numbers of pigs.

Table 3.5 – Number and Distribution of Swine Producers in the Dominican Republic in 2002

Region	Number of Producers	Percentage of Producers
North	953	13%
North-central	475	6%
Central	531	7%
Northeast	1,432	19%
East	861	12%
Northwest	1,078	15%
South	1,764	24%
Southwest	266	4%
Total	**7,360**	**100%**

Source: CONAPROPE, 2002, in Moreta, 2004

There are numerous associations of swine producers in the country (Table 3.6).

Table 3.6 – Some of the Main Pig Production Associations in the Dominican Republic in 2005

Association	Location	Region	Number of Producers
Asociación de Porcicultores de Moca (APORMO)	Juan López, Espaillat Province	N	200
Asociación de Porcicultores del CIBAO (APORCI)	La Vega	NC	166
Cooperativa Agropecuaria del Nordeste (COOPENOR)	San Francisco de Macorís	NE	162
Asociación de Porcicultores del Licey (APORLI)	Licey al Medio, Santiago Province	N	137
Asociación de Porcicultores Cayetano Germosén	Cayetano Germosén, Espaillat Province	N	132
Cooperativa de Porcicultores del CIBAO (COOPCIBAO)	Moca, Espaillat Province	N	100

Source: CONAPROPE, 2005 in IICA, 2006

In 2009, COOPCIBAO represented 169 active swine producers (an increase from 100 in 2005) representing a total of approximately 116,000 animals (14 percent of the total pig population). A study developed by International Resources Group (IRG) for USAID in 2010 (IRG, 2010) analyzed the current waste management system of swine farms within COOPCIBAO in the Espaillat province. The study found that the majority of farms operate as complete-cycle farms. The farms were classified in five categories: “family type” with less than 50 animals, small farms (51-200 animals), medium farms (201-600 animals), large farms (601-1000 animals) and industrial farms (more than 1000 animals). Although industrial farms represent only 20 percent of the total number of farms, they represent 76 percent of the total pig population in COOPCIBAO. Conversely, family-type and small farms represent 47 percent of the total number of farms but only 4 percent of the total pig population in COOPCIBAO. The number of farms and animals in COOPCIBAO per category of farm is presented in the table below (Table 3.7).

Table 3.7 – Distribution of Farms and Animals per Size in COOPCIBAO

Size of Farm	Number of Head per Farm	Number of Farms	Percentage of Total Farms	Number of Head	Percentage of Total Animals
Family	≤ 50 head	53	31%	721	1%
Small	51-200 head	27	16%	3043	3%
Medium	201-600 head	44	26%	15,169	13%
Large	601-1000 head	12	7%	9,565	8%
Industrial	≥ 1000 head	33	20%	87,848	76%
Total		**169**	**100%**	**116,346**	**100%**

Source: IRG, 2010

b. DESCRIPTION OF WASTE CHARACTERISTICS, HANDLING, AND MANAGEMENT

According to the study (IRG, 2010), the two main waste management systems used by COOPCIBAO members are direct discharge to nearby streams and rivers (35 percent of the producers) and anaerobic lagoons (62 percent).

According to a study of the entire swine production chain in the Dominican Republic (IICA, 2006), “the majority of the swine farms in the main swine producing regions do not have any system installed to treat the waste, liquid or solid, produced in the farm. These wastes are discharged directly to the environment."

According to SEA, 65 percent of the total pig population is raised in organized farms, i.e., confined farms with paved lots. The rest of the animals are raised in backyard farms: confined in unpaved lots (70 percent), tied to a rope (15 percent), or free-roaming (15 percent). Among the organized farms, 40 percent use open lagoons. The rest discharge the wastewater directly into a nearby water body (Table 3.8).

Table 3.8 – Description of the Waste Management Systems in the Swine Sector in the Dominican Republic in 2009

	Organized Farms	Backyard Farms
Description	Confined farms with paved lots	Backyard farms where the animals are either confined in unpaved lots (70%), tied to a rope (15%), or free-roaming (15%)
Diet	Balanced feed ration	50% feed grains and 50% kitchen waste, whey, etc.
Total number of animals	552,500 (65% of total population)	297,500 (35% of total population)
Number of confined animals	552,500 (100% of organized farms)	208,250 (70% of backyard animals)
Waste Management System	221,000 (40% of organized) use open lagoons; the rest discharge the wastewater directly into nearby rivers or use it for irrigation	Discharge the wastewater directly into nearby rivers or use it for irrigation

Source: SEA, personal contact

Two case studies are presented below.

Swine Farm 1

- Complete cycle farm with 150 sows and 10 to 11 boars. The owner does not keep track of the total number of animals. There are two litters per sow per year and a variable number of piglets per litter.
- Each pig is fed 2.3 kg of balanced feed and hay per day (about 1 kg in the morning and 1 kg in the afternoon).
- The animals are sold at 100 kg.
- The animals are fully confined in concrete soil pens, which are cleaned "manually" once a day with a water hose and brooms.
- The wastewater runs by gravity in open channels along the pens to three earthen ponds. One pond is 5 m deep and 10 m in diameter, the second is 3 m deep and 8 m in diameter, and the third is 5 m by 3 m by 9 m deep. There is a crust of solids at the surface of each pond and a significant amount of vegetation growing inside.


Pig pens

Cleaning of the pens

The earthen ponds where the wastewater is stored

Source: Site visit, Tetra Tech

Swine Farm 2

- Grower-finisher farm with 3,000 animals.
- The animals are sold at 90 to 100 kg.
- The pens are cleaned twice a day with pressurized water. Originally, the pens were flushed with a water hose using up to 26 m^3 per day; the farm switched to pressurized water after consulting Bioenergym (a Dominican clean energy company) and reduced water consumption by half.
- The flushed manure is transferred through open channels around the pens to a liquid/solid separator. The solids are used as cow feed and the liquid is stored in a lagoon (open earthen pond).

Pig pens

Lagoon

Methane bubbles at the surface of the lagoon

Solid separator

Source: Site visit, Tetra Tech

3.3.2 Dairy Cattle

a. DESCRIPTION OF SIZE, SCALE, AND GEOGRAPHIC LOCATION OF OPERATIONS

According to FAOSTAT, there were 2,652,600 cattle in the Dominican Republic in 2008, including 375,500 specialized dairy cattle. These numbers are consistent with the data provided by the National Council of Regulation and Promotion of the Dairy Industry (CONALECHE), according to which there were a total of 2,400,000 cattle in the Dominican Republic in 2004, including 726,000 dairy cows (specialized and dual purpose) and 720,000 beef cattle (Table 3-9). Dual purpose cows are cows that are raised for both meat and milk production. The rest of the animal population consisted of bulls, heifers, and calves (Table 3.10)

Table 3.9 – Number of Cattle in the Dominican Republic per Category

Source	CONALECHE, 2004		FAOSTAT, 2008	
Animal Type	Number of Animals	Percentage of Total	Number of Animals	Percentage of Total
Dairy cattle	360,000	15%	375,500	14%
Dual purpose cattle	1,320,000	55%		
Beef cattle	720,000	30%		
Total	**2,400,000**	**100%**	**2,652,600**	

Source: CONALECHE Statistics Unit, personal contact; FAOSTAT, 2008

Table 3.10 – Number of Dairy Cows in the Dominican Republic per Category in 2004

Animal Type	Total Number of Animals	Percentage of Cows per Category	Number of Cows
Dairy cattle	360,000	55%	198,000
Dual purpose cattle	1,320,000	40%	528,000
Total	**1,680,000**	**43%**	**726,000**

Source: CONALECHE Statistics Unit, personal contact

In 2009, the annual milk production reached nearly 600 million liters. The following table (Table 3.11) shows the annual milk production (in metric tons) in the Dominican Republic between 2004 and 2009.

Table 3.11 – Milk Production in the Dominican Republic per Year

	2004	2005	2006	2007	2008	2009
Milk production (MT/year)	384,414	561,379	501,346	566,561	609,725	595,833

Source: CONALECHE Statistics Unit, personal contact

Milk productivity is about 4-5 liters (L) per cow per day in pasture, 8-10 L/cow/day in semi-confined farms and 10-15 L/cow/day in confined farms. Milk use is summarized in Table 3.12.

Table 3.12 – Milk Production in the Dominican Republic per Category of Final Product in 2009

Product	Milk Quantity (MT/yr)	Percentage of Total Production (%)
Cheese	323,134	54%
Yogurt and sweets	30,165	5%
Pasteurized	97,933	17%
Unpasteurized	144,601	24%
Total	**595,833**	**100%**

Source: CONALECHE Statistics Unit, personal contact

According to the 1998 livestock census conducted by the Technical Planning Department of the Ministry of Agriculture published on the CONALECHE website, the majority of dairy cattle and dual purpose cattle are found in farms with 200 head or more (Table 3.). Based on the 1998 percentages, the distribution of animals by farm size was extrapolated to 2004.

Table 3.13 – Number of Dairy and Dual Purpose Cattle in the Dominican Republic per Farm Size in 1998 and 2004

Farm Size	Dairy Cattle			Dual Purpose Cattle		
	1998	% of Total	Extrapolation to 2004	1998	% of Total	Extrapolation to 2004
1–9	35,817	12%	42,642	102,488	9%	121,853
10–19	21,028	7%	25,035	87,858	8%	104,459
20–49	30,803	10%	36,673	137,741	12%	163,767
50–99	37,204	12%	44,294	144,918	13%	172,300
100–199	50,792	17%	60,471	148,673	13%	176,765
200–499	68,159	23%	81,147	161,249	15%	191,717
500+	58,576	19%	69,738	327,295	30%	389,138
Total	**302,379**	**100%**	**360,000**	**1,110,222**	**100%**	**1,320,000**

Source: CONALECHE, n.d.

According to Bolivar Toribio, expert in the dairy sector in the Dominican Republic, there are about 80 to 100 confined farms in the country, representing 1 to 3 percent of the total dairy cattle population and approximately 30 percent of the milk production. Semi-confined farms represent between 20 and 25 percent of the total farms, 20 to 30 percent of the animal population, and 50 percent of the milk produced. The remaining 20 percent of the milk is produced from cows on pasture. In total, Bolivar Toribio estimates that there are approximately 6,000 commercial farms with a production of 200 liters per day or more.

The breeds found in the Dominican Republic include Holstein, Brown-Swiss, and Jersey in confined farms and crossbreeds in pasture (e.g., Romana Red). The cows weigh an average of 450kg. The feed is a combination of grasses (king grass, transvala, pangola, estrella, and brachiaria) and feed concentrates (corn, soybeans and minerals) for confined animals.

The farms are spread out across the country but concentrated in three main regions, as shown in Figure 3.5: Monte Plata, Baní, and central Cibao. Baní accounts for most of the confined farms.

Figure 3.5 – Main Regions Housing Dairy Farms

It is interesting to note that the geographic location changed significantly between 1998 and 2009. In 1998, most dairy cattle were concentrated in the east (25 percent), north (18 percent), northeast (14 percent), and southwest (14 percent) (Table 3.5).

Table 3.5 – Geographic Distribution of Cattle in the Dominican Republic in 1998

	N	NW	NE	NC	SW	S	C	E	Number of Animals
Beef cattle	23%	6%	5%	9%	14%	6%	6%	33%	491,800
Dairy cattle	19%	10%	12%	10%	28%	3%	9%	8%	302,379
Dual purpose	17%	12%	14%	4%	11%	5%	7%	30%	1,110,222
Total cattle	19%	10%	11%	6%	14%	5%	7%	27%	1,904,401
Total dairy and dual purpose cattle	18%	11%	14%	5%	14%	4%	8%	25%	1,412,601

Source: SEA, 1998

According to the 1998 livestock census conducted by the Ministry of Agriculture, there were 68,656 cattle producers in the country, concentrated mainly in the southwest (22 percent), central (16 percent), and northeast (14 percent) regions (Table 3.6). As can be seen by comparing Table 3.5 and Table 3.65, the region with the greatest number of cattle producers does not correlate with the highest number of cattle.

Table 3.6 – Geographic Distribution of Cattle Producers in the Dominican Republic in 1998

	N	NW	NE	NC	SW	S	C	E	Total
Number of producers	7,489	8,312	9,505	6,013	15,013	4,844	11,362	6,118	68,656
% of total	11%	12%	14%	9%	22%	7%	16%	9%	100%

Source: SEA, 1998

b. DESCRIPTION OF WASTE CHARACTERISTICS, HANDLING, AND MANAGEMENT

According to the statistics unit of CONALECHE, most confined dairy farms are cleaned with pressurized water and the wastewater is stored in open lagoons or open concrete tanks before being used for irrigation. There are no known digesters already in place in the sector. Figure 3. shows a typical manure storage tank on dairy farms in the Dominican Republic; the tank is 10 meters in diameter and about 3 to 4 meters deep.

Figure 3.6 – Typical Manure Storage Tank in Dairies in the Dominican Republic

Source: Site visit, Tetra Tech

According to Bolivar Toribio, less than 10 percent of the confined and semi-confined farms use concrete open tanks (estercoleros) as shown in Figure 3..

Table 3.16 below summarizes the waste management systems in place on dairy farms surveyed for this study.

Table 3.7 – Waste Management System on Surveyed Farms

Farm	Province	Number of Dairy Cows	Farm Type	Manure Collection System	Manure Treatment/ Disposal
Farm 1	Peravia	1,500	Pasture	Not collected	Land application
Farm 2	Peravia	130	Confined (drylots)	Scraped with shovels	Land application
Farm 3	Peravia	289	Confined (freestall with unpaved soil)	Scraped with shovels	Land application
Farm 4	Monte Plata	70	Confined	Scraped and hosed to open tanks	Open concrete tank (“estercolero”) followed by land application
Farm 5	Monte Plata	400	Confined	Scraped and hosed to open tanks	Open concrete tank (“estercolero”) followed by land application

Source: Contact with each farm, Tetra Tech

3.4 AGRO-INDUSTRIAL SECTORS

This section focuses on sugarcane milling and rum production—the sectors with the greatest potential for methane emissions or capture and use.

3.4.1 Sugarcane Processing Industry

a. DESCRIPTION OF THE SIZE, SCALE, AND GEOGRAPHIC LOCATION OF OPERATIONS

i. Sugar

In 2008, the Dominican Republic was the second largest sugarcane producer in the Caribbean after Cuba and before Jamaica and Haiti (FAOSTAT, 2010b). In 2009, the Dominican Republic processed 4.62 million metric tons (MT) of sugarcane from which it produced 520,878 MT of sugar, 30.84 million gallons of molasses, and 24,708 MT of furfural. Furfural is an organic compound derived from agricultural byproducts such as sugarcane bagasse. The sugar production was divided between 367,492 MT of raw (brown) sugar and 153,386 MT of refined (white) sugar (INAZUCAR, 2009a, 2009b).

In 2010, there were four operating sugar mills in the country. All four sugar mills are located on the southern side of the island (Figure 3.7). The sugarcane and sugar production per mill during the 2008–2009 and 2009–2010 harvests are detailed in the table below (Table 3.17). Note: Sugar Mill 4 was not operating in 2009.

Figure 3.7 – Approximate Location of the Four Sugar Mills (Red) and the Four Distilleries (Blue) in the Dominican Republic

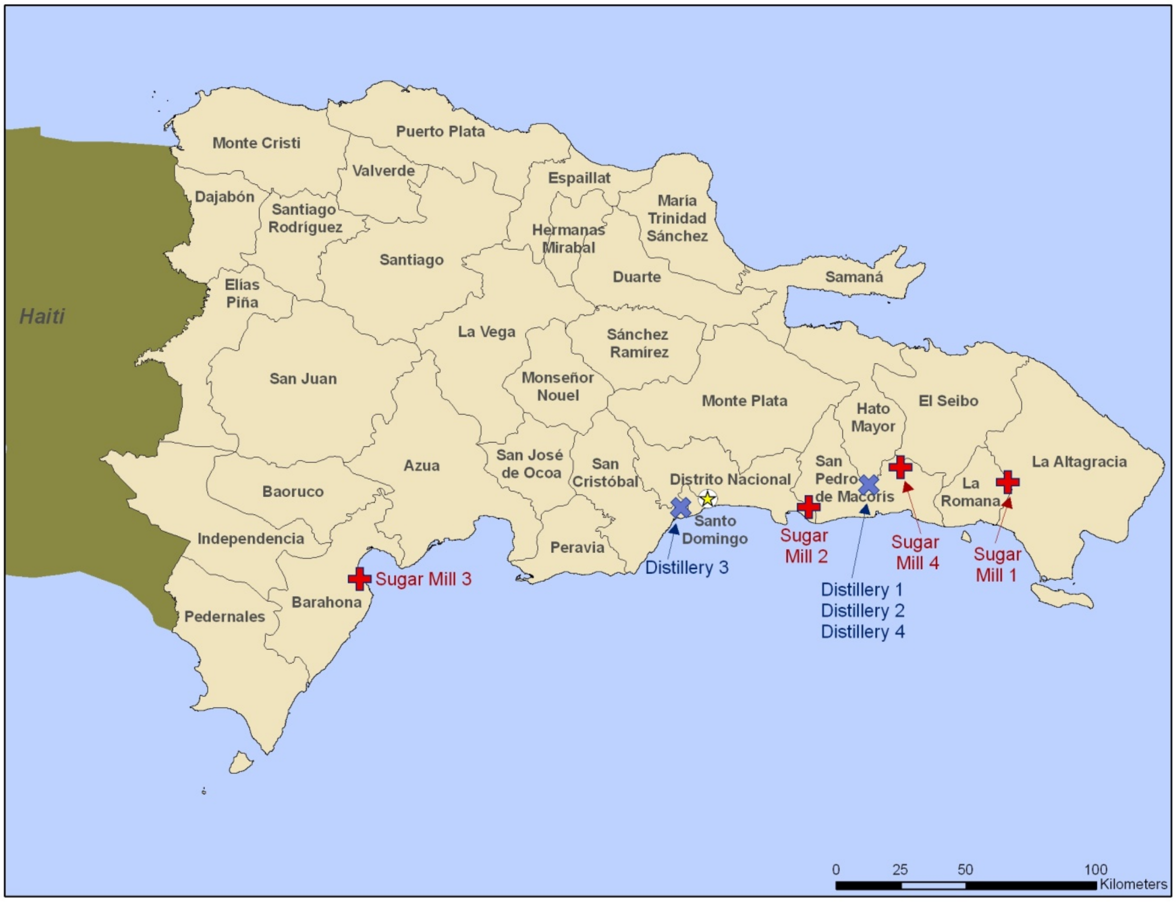


Table 3.17 –Sugarcane and Sugar Production per Mill

Name of Sugar Mill	Sugarcane Processed (MT)		Sugar Production, Raw and Refined (MT)	
	2008–2009 Harvest (Actual Production)	2009–2010 Harvest (Estimate)	2008–2009 Harvest (Actual Production)	2009–2010 Harvest (Estimate)
Sugar Mill 1	3,178,881	3,000,000	387,635	345,000
Sugar Mill 2	825,452	874,902	79,765	78,660
Sugar Mill 3	616,942	650,000	63,478	63,000
Sugar Mill 4	0	300,000	0	27,000
Total	4,621,275	4,824,902	520,878	513,660

Source: INAZUCAR, 2009b

It is important to note that in 1986, the National Council of Sugar (CEA in Spanish) started to diversify its production to non-sugar crops (e.g., fruit, palm oil). Sugarcane plantation area was reduced from 282,226 hectares cultivated in 1980 to 91,950 hectares in 2009, and numerous sugar mills were closed (INAZUCAR, 2009b); consequently, sugarcane production in the Dominican Republic decreased from 9.1 MT in 1980 to 4.6 million MT in 2009.

ii. Rum distilleries

The Dominican Republic produced 49.9 million liters of rum in 2005 (Table 3.) and was the largest exporter of rum to the European Union in 2009 by volume. About 15.5 million metric liters were exported (Export HelpDesk, n.d.).

Table 3.18 – Rum Production

Year	2001	2002	2003	2004	2005
Rum from sugarcane (thousand liters)	45,179	49,003	49,349	54,661	49,900

Source: CEI-RD, n.d.

There are four main distilleries in the country. One is located in Santo Domingo; the other three distilleries are located in the province of San Pedro de Macorís (Figure 3.7). Each distillery produces between 25,000 and 70,000 liters of rum per day (Table 3.9).

Table 3.9 – Rum Distilleries Production in the Dominican Republic

Name of Distillery	Production	Period of Production
Distillery 1	25,000 L/day; expects to grow to 40,000 L/day by the end of 2010	The objective of the plant is to operate 11 months per year (with one month maintenance)
Distillery 2	40,000 L/day	The objective of the plant is to reach continuous production in three to four years, except for 25 days of maintenance
Distillery 3	26,300 L/day; expects to grow to 70,000 L/day	
Distillery 4	22,000,000 L/year (~60,000 L/day)	The plant operates 12 months per year

Source: Contacts/visits to each distillery

b. DESCRIPTION OF THE CHARACTERISTICS OF WASTES, HANDLING, AND MANAGEMENT

i. Sugar

Due to limited availability of information, it was assumed that all four sugar mills use conventional anaerobic lagoons to treat their wastewaters.

ii. Rum distilleries

Through visits and contact with each distillery, it was found that the average wastewater generation rate ranges between 10 and 13 liters of distillery vinasse per liter of alcohol produced, which is within the range of the sector. The COD content of the wastewater is higher if the alcohol is produced from molasses and lower if produced from sugarcane juice directly. The majority of the rum produced in the Dominican Republic is produced from sugarcane molasses (CEI-RD, n.d.). Among the four main distilleries, only Distillery 1 produces alcohol from sugarcane. Two plants are currently using open lagoon systems, while the other two already use anaerobic digestion to treat their wastewater (Table 3.20).

Table 3.20 – Rum Distilleries Wastewater Characteristics and Treatment System

Name of Distillery	Wastewater Generation Rate	COD Content of Wastewater	Waste Management System
Distillery 1	12 L vinasse/L alcohol	40,000 ppm	Four open lagoons
Distillery 2	13 L vinasse/L alcohol	70,000 ppm	Two open lagoons
Distillery 3	11–12 L vinasse/L alcohol	BOD: 85,000 ppm	Three UASBs installed (operating end of 2010)
Distillery 4	~10 L vinasse/L alcohol	60,000–70,000 ppm	Two down-flow anaerobic digesters

Source: Contacts/visits to each distillery

4. POTENTIAL FOR METHANE EMISSION REDUCTION

This section presents an estimate of the potential for reducing GHGs from livestock manures and agricultural commodity processing wastes through the use of anaerobic digestion. Anaerobic digestion reduces GHG emissions in two ways. First, it directly reduces methane emissions by capturing and burning biogas that otherwise would escape from the waste management system into the atmosphere. Second, it indirectly reduces carbon dioxide, methane, and nitrous oxide by using biogas to displace fossil fuels that would otherwise be used to provide thermal energy or electricity. Section 4.1 explains the potential methane emission reduction from manure management systems and agricultural commodity processing wastes.

The feasibility of modifying existing livestock manure and agricultural commodity processing waste management systems by incorporating anaerobic digestion will depend on the ability to invest the necessary capital and generate adequate revenue to at least offset operating and management costs, as well as provide a reasonable return to the invested capital.

A number of options exist for anaerobically digesting wastes and utilizing the captured methane. For a specific enterprise, waste characteristics will determine which digestion technology options are applicable. Of the technically feasible options, the optimal approach will be determined by financial feasibility, subject to possible physical and regulatory constraints. For example, the optimal approach may not be feasible physically due to the lack of necessary land. Section 4.2 briefly describes types of anaerobic digestion technologies, methane utilization options, costs and benefits, and centralized projects. Appendix A provides more information on emissions avoided when wet wastes are diverted from landfills, as well as emissions from leakages and waste transportation in co-substrate projects.

4.1 METHANE EMISSION REDUCTION

Anaerobic digestion projects for both manure and agricultural commodity processing wastes may produce more methane than the existing waste management system because anaerobic digesters are designed to optimize methane production. For example, the addition of anaerobic digestion to a manure management operation where manure was applied daily to cropland or pasture would produce significantly more methane than the baseline system. As such, the direct methane emission reduction from a digester corresponds not to the total methane generated, but rather the baseline methane emissions from the waste management system prior to installation of the digester. The indirect emission reduction, as explained in Section 4.1.3, is based on the maximum methane production potential of the digester and how the biogas is used.

4.1.1 Direct Emission Reductions From Digestion of Manure

The methane production potential from manure is estimated as shown in Equation 2.1, and the methane conversion factor for the baseline manure management system used at the operation as shown in Equation 4.1:

$$CH_{4\,(M,P)} = \left(VS_{(M)} \times H_{(M)} \times 365\ \text{days/yr}\right) \times \left[B_{o(M)} \times 0.67\ \text{kg}\ CH_4/m^3\ CH_4 \times MCF_{AD}\right] \qquad (4.1)$$

where:
- $CH_{4\,(M,P)}$ = Estimated methane production potential from manure (kg/yr)
- $VS_{(M)}$ = Daily volatile solids excretion rate for livestock category M (kg dry matter/animal/day)
- $H_{(M)}$ = Average daily number of animals in livestock category M
- $B_{o(M)}$ = Maximum methane production capacity for manure produced by livestock category M (m^3 CH_4/kg volatile solids excreted)
- MCF_{AD} = Methane conversion factor for anaerobic digestion (decimal)

Table 4.1 and Table 4.2 show the estimated GHG emission reduction potential for swine and dairy operations in the Dominican Republic. The swine sector has the largest potential by far, with 134,400 $MTCO_2e$ per year.

Table 4.1 – Methane and Carbon Emission Reductions From Swine Manure

Parameter	Organized Farms		Backyard Farms	Total	Assumptions
$H_{(\#)}$	221,000	331,500	297,500	850,000	Assumes that 40 percent of the organized farm population uses lagoons
VS (kg/head/day)	0.27	0.27	0.3		IPCC default values for North America (organized farms) and Latin America (backyard)
B_o (m^3 CH_4/kg VS)	0.48	0.48	0.29		
MCF	0.79 (lagoon)	0.1 (direct discharge)	0.02 (drylot)		IPCC default values at 26°C
CH_4 (MT/yr)	5,533	1,051	89	6,673	Current baseline methane emissions
CO_2 (MT CO_2e/yr)	116,201	22,064	1,861	140,126	Assume GWP (CH_4): 21
Indirect emission reduction (MT CO_2e/yr)	18,211	—	—		Assume biogas is used to replace electricity from the grid
Total CO_2 (MT CO_2e/yr)	134,413	—	—	134,413	Emissions that can be captured readily

Table 4.2 – Methane and Carbon Emission Reductions From Dairy Manure

Parameter	Confined Farms		Semi-Confined Farms		Pasture	Total	Assumptions
H(#)	11,851		197,524		580,721	790,097	Assumes that 10 percent of the confined and semi-confined farm populations use lagoons
VS (kg/head/day)	5.4	5.4	2.9	2.9	2.9		IPCC default values for North America (confined farms) and Latin America (semi-confined and backyard)
B_0 (m^3 CH_4/kg VS)	0.24	0.24	0.13	0.13	0.13		
MCF	0.79 (lagoon)	0.1 (direct discharge)	0.79 (lagoon)	0.1 (direct discharge)	0.02 (pasture)		IPCC default values at 26°C
CH_4 (MT/yr)	297	338	1,439	1,639	1,071	4,783	Current baseline methane emissions
CO_2 (MT CO_2e/yr)	6,231	7,099	30,212	34,418	22,487	100,448	Assume GWP (CH_4): 21
Indirect emission reduction (MT CO_2e/yr)	977		4,735	—	—	5,711	Assume biogas is used to replace electricity from the grid
Total CO_2 (MT CO_2e/yr)	7,208		34,947	—	—	42,155	Emissions that can be captured readily

4.1.2 Direct Emission Reduction From Digestion of Agricultural Commodity Processing Wastes

The methane production potential from agricultural commodity wastes is estimated as shown in Equation 2.2, and the MCF for the baseline waste management system used at the operation is estimated as shown in Equations 4.2 and 4.3:

$$CH_{4(W)} = (TOW_{(W)} - S_{(W)}) \times EF_{(W,S)} \qquad (4.2)$$

where: $CH_{4\,(W)}$ = Annual methane emissions from agricultural commodity processing waste W (kg CH_4/yr)
$TOW_{(W)}$ = Annual mass of waste W COD generated (kg/yr)
$S_{(W)}$ = Annual mass of waste W COD removed as settled solids (sludge) (kg/yr)
$EF_{(W,S)}$ = Emission factor for waste W and existing treatment system and discharge pathway S (kg CH_4/kg COD)

The methane emission rate is a function of the type of waste and the existing treatment system and discharge pathway, as follows:

$$EF_{(W,S)} = B_{o(W)} \times MCF_{(S)} \qquad (4.3)$$

where: $B_{o\,(W)}$ = Maximum CH_4 production capacity (kg CH_4/kg COD)
$MCF_{(S)}$ = Methane conversion factor for the existing treatment system and discharge pathway (decimal)

Table 4.3 summarizes the assumptions used for calculating the methane emission reduction potential from three agro-industrial subsectors in the Dominican Republic.

Table 4.3 – Summary of the Assumptions Used for the Calculations of the Methane Emission Reduction Potential

Sector	Waste Management System	COD and W Values
Distilleries	Two distilleries use lagoons	W: 12–13 m^3/m^3 rum; COD: 40–70 kg/m^3
Sugar	Assume all four sugar mills use lagoons	W: 11 m^3/MT sugar; COD: 3.2 kg/m^3 (IPCC default value)

Table 4.4 shows the estimated GHG emission reduction potential for rum distilleries and sugar mills in the Dominican Republic. When indirect emissions are considered, the emission reduction potential ranges from 87,840 $MMTCO_2e$ for sugar mills to 90,376 $MMTCO_2e$ for rum distilleries. Based on limited data and best professional judgment, MCF_{AD} values of 0.80 were used to estimate methane production potential. Indirect emission reductions through fuel replacement were estimated using the assumptions described in section 4.1.3.

Table 4.4 – Methane and Carbon Emission Reductions From Agro-Industrial Waste

	Rum Distilleries	Sugar Mills
Production (MT or m^3/yr)	26,766	513,660
Wastewater (m^3/MT)	25	11
COD (kg/m^3)	110	3.2
COD (kg/yr)	18,602,833	18,080,832
B_0 (kg CH_4/kg COD)	0.25	0.25
MCF	0.8	0.8
EF (kg CH_4/kg COD)	0.2	0.2
CH_4 (MT CH_4/yr)	3,721	3,616
CO_2 (MT CO_2e/yr)	78,132	75,939
Indirect emission reduction (MT CO_2e/yr)	12,244	11,901
Total CO_2 (MT CO_2e/yr)	90,376	87,840

4.1.3 Indirect GHG Emission Reductions

The use of anaerobic digestion systems has the financial advantage of offsetting energy costs at the production facility. Biogas can be used to generate electricity or supplant the use of fossil fuels. Using biogas energy also reduces carbon emissions by displacing fossil fuels. The degree of emission reduction depends on how the biogas is used. Table 4.5 shows the potential uses of the biogas in each of the subsectors.

Table 4.5 – Potential Biogas Energy Use by Sector

Sector	Electricity Use	Thermal Energy Replacement
Swine	Feed mills	LPG for water heating
Dairy	Energy-intensive, particularly during milking operations	LPG for water heating
Sugar/ distilleries	Energy-intensive; sugar mills do not require electricity from the grid during harvest since they burn bagasse, but they could sell the energy generated in an anaerobic digestion system	Natural gas for boilers; large user of steam in the process, particularly for evaporation and crystallization operations

When biogas is used to generate electricity, the emission reduction depends on the energy sources used by the central power company to power the generators. In the Dominican Republic, the electricity generation sector is mainly composed of thermal plants (89 percent) and hydroelectric plants (11 percent), as illustrated in Figure 4.1. The fuels used by the thermal plants are distillate fuel oil, coal, natural gas, and biomass. Table 4. shows the associated carbon emission reduction rate from the replacement of fossil fuels when biogas is used to generate electricity.

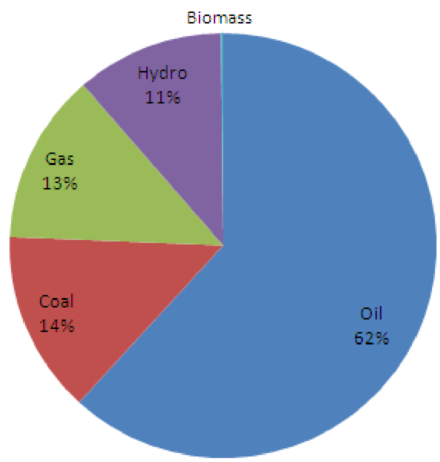
Table 4.6 – Reductions in Carbon Dioxide Emissions by Use of Biogas to Generate Electricity in Place of Fossil Fuels

Fuel for Generating Electricity Replaced	CO_2 Emission Reduction
Hydro and nuclear	0 kg/kWh generated
Coal	1.02 kg/kWh generated
Natural gas	2.01 kg/m^3 CH_4 used
LPG	2.26 kg/m^3 CH_4 used
Distillate fuel oil	2.65 kg/m^3 CH_4 used

Source: Hall Associates, 2010

Indirect emissions are estimated by first ascertaining the maximum production potential for methane from the digester and then determining the emissions associated with the energy that was offset from biogas use. For Tables 4.1, 4.2, and 4.4, it was assumed that the collected biogas would be used to generate electricity, replacing distillate fuel oil (62 percent), coal (14 percent), and natural gas (13 percent) in all the subsectors (Figure 4.).

Figure 4.1 – Distribution of Electricity Generation in the Dominican Republic (Total = 15,414 GWh in 2008)



Source: International Energy Agency, 2010

4.1.4 Summary

As illustrated by the equations presented in Section 2.2, the principal factor in the magnitude of methane emissions from livestock manures and agricultural commodity processing wastes is the waste management practice employed, which determines the MCF. As shown in Table 10.17 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and in Table 2.2 of this report, anaerobic lagoons have the highest potential for emitting methane from these wastes. Thus, replacing those waste management practices with anaerobic digestion has the greatest potential for reducing methane emissions. While the reduction in methane emissions realized by replacing other waste management practices with anaerobic digestion will not be as significant, the methane captured will be a source of renewable energy with the ability to reduce fossil fuel consumption and the associated GHG emissions from sequestered carbon.

Table 4.7 summarizes the findings of the RA in terms of potential methane emission reductions and carbon offsets in the Dominican Republic. The sectors with the highest potential for methane reduction and carbon offsets are rum distilleries (28 percent of the potential), swine (28 percent) and sugar (27 percent), followed by dairy cattle (12 percent).

Table 4.7 – Summary of Total Carbon Emission Reductions Identified in the Dominican Republic

Sector	Methane Emission Reductions (MT CH_4/yr)	Carbon Emission Reductions (MT CO_2e/yr)	Fuel Replacement Offsets (MT CO_2e/yr)	Total Carbon Emission Reductions (MT CO_2e/yr)
Swine	5,500	116,200	18,200	134,400
Rum distilleries	3,700	78,100	12,200	90,400
Sugar	3,600	75,900	11,900	87,800
Dairy cattle	1,700	36,400	5,700	42,200
Total	14,600	306,700	48,100	354,800

Totals may not sum due to rounding

4.2 TECHNOLOGY OPTIONS

4.2.1 Methane Production

There are a variety of anaerobic digestion processes, which can be broadly categorized as either suspended or attached growth processes. The applicability of any specific process is determined primarily by physical characteristics of the waste or mixture of wastes that will be anaerobically digested. Attached growth processes are suitable for wastes with low concentrations of particulate matter. For wastes with higher concentrations, suspended growth processes generally are more suitable. The anaerobic digestion process options that are applicable to the various types of livestock manures and agricultural commodity processing wastes are discussed below.

Livestock manures: There are four anaerobic digestion reactor options for livestock manures: plug-flow, mixed, covered lagoon, and attached growth. The appropriate option or options are determined by the concentration of particulate matter, generally measured as TS concentration in the collected manure, type of manure, and climate as shown in Table 4.8. The TS concentration in the collected manure is determined by the method of collection—scraping or flushing—and the volume of water used in flushing manure.

Table 4.8 – Overview of Anaerobic Digestion Options for Livestock Manures

	Plug-Flow	Mixed	Covered Lagoon	Attached Growth
Influent TS concentration	11–13 percent	3–10	0.5–3	< 3
Manure type	Only dairy cattle	Dairy and swine	Dairy and swine	Dairy and swine
Required pretreatment	None	None	Removal of coarse fiber from dairy cattle manure	Removal of coarse fiber from dairy cattle manure
Climate	All	All	Temperate and warm	Temperate and warm

Source: U.S. EPA, 2004

As indicated in Table 4.8, use of covered lagoons and attached growth reactors to produce methane from dairy cattle manure requires removal of coarse fiber, usually by screening, before anaerobic digestion. For the attached growth option, screening of swine manure to remove hair and foreign matter, such as ear tags, is advisable. Covered lagoons and attached growth reactors operate at ambient temperature and thus are only suitable for temperate and warm climates. In temperate climates, there may be seasonal variation in the rate of methane production.

Agricultural commodity processing wastewater: As discussed above, agricultural commodity processing operations may generate either liquid wastewater, solid waste, or both. No single treatment process, except for the covered anaerobic lagoon, is suitable for all of these wastewaters due to wide variation in physical and chemical characteristics. These characteristics can vary widely even for wastewater from the processing of a single commodity, reflecting differences in processing and sanitation practices. For example, some processing plants prevent solid wastes, to the extent possible, from entering the wastewater generated; others do not.

In addition, some plants employ wastewater pretreatment processes such as screening, gravitational settling, or dissolved air flotation (DAF) to remove particulate matter whereas others do not. Although the covered anaerobic lagoon has the advantages of universal applicability and simplicity of operation and maintenance, adequate land area must be available. If the volume of wastewater generated is low, co-digestion with livestock manure or wastewater treatment residuals may be a possibility. Other options for the anaerobic treatment of these wastewaters are briefly described below.

For wastewaters with high concentrations of particulate matter (total suspended solids) or extremely high concentrations of dissolved organic matter (BOD or COD), the complete mix, anaerobic contact, or anaerobic sequencing batch reactor (ASBR) processes are alternatives. These are typically operated at mesophilic (30 to 35°C) or thermophilic (50 to 55°C) temperatures.

As shown in Table 4.9, the anaerobic contact and ASBR processes operate at significantly shorter hydraulic retention times than the complete mix process. A shorter required hydraulic retention time translates directly into a smaller required reactor volume and system footprint; however, operation of the anaerobic contact and ASBR processes is progressively more complex.

Table 4.9 – Typical Organic Loading Rates for Anaerobic Suspended Growth Processes at 30°C

Process	Volumetric Organic Loading (kg COD/m³/Day)	Hydraulic Retention Time (Days)
Complete mix	1.0–5.0	15–30
Anaerobic contact	1.0–8.0	0.5–5
Anaerobic sequencing batch reactor	1.2–2.4	0.25–0.50

Source: Metcalf and Eddy, Inc., 2003

For wastewaters with low total suspended solids (TSS) concentrations or wastewaters with low TSS concentrations after screening or some other form of TSS reduction, such as dissolved air flotation, one of the anaerobic sludge blanket processes may be applicable. Included are basic USAB, anaerobic baffled reactor, and anaerobic migrating blanket reactor (AMBR) processes. The anaerobic sludge blanket processes allow for high volumetric COD loading rates due to the retention of a high microbial density in the granulated sludge blanket. Wastewaters that contain substances such as proteins and fats that adversely affect sludge granulation, cause foaming, or cause scum formation are problematic. Thus, use of anaerobic sludge blanket processes is generally limited to high-carbohydrate wastewaters.

Attached growth anaerobic processes are another option for agricultural commodity processing wastewaters with low TSS concentrations. Included are upflow packed-bed attached growth, upflow attached growth anaerobic expanded bed, attached growth anaerobic fluidized-bed, and downflow attached growth reactor processes. All have been used successfully in the anaerobic treatment of a variety of food and other agricultural commodity processing wastewaters, but are more operationally complex than the suspended growth and sludge blanket processes.

Agricultural commodity processing solid wastes: Generally, solid wastes from agricultural commodity processing are most amenable to co-digestion with livestock manure or wastewater treatment residuals in a mixed digester. Although it may be possible to anaerobically digest some of these wastes independently, it may be necessary to add nutrients (such as nitrogen or phosphorus) and a buffering compound to provide alkalinity and control pH.

4.2.2 Methane Use Options

Along with methane, carbon dioxide is a significant product of the anaerobic microbial decomposition of organic matter. Collectively the mixture of these two gases is known as biogas. (Typically, biogas also contains trace amounts of hydrogen sulfide, ammonia, and water vapor.) The energy content of biogas depends on the relative volumetric fractions of methane and carbon dioxide. Assuming the lower heating value of methane, 35,755 kilojoules per cubic meter, a typical biogas composition of 60 percent methane and 40 percent carbon dioxide has a lower heating value of 21,453 kilojoules per cubic meter. Thus, biogas has a lower energy density than conventional fuels.

Although the principal objective of the anaerobic digestion of livestock manure and agricultural commodity processing wastes is to reduce methane emissions to the atmosphere, biogas has value as a renewable fuel. It can be used in place of a fossil fuel in stationary internal combustion engines or microturbines connected to generator sets or pumps, and for water or space heating. Direct use for cooling or refrigeration is also a possibility.

Use of biogas in place of coal, natural gas, liquefied petroleum gas (LPG), or distillate or heavy fuel oil for water or space heating is the most attractive option. Existing boilers or furnaces can be modified to burn a lower-energy-density fuel. Conversion of a natural gas– or LPG-fueled boiler or furnace to biogas generally only requires replacement of the existing metal combustion assembly with a ceramic burner assembly with larger orifices. If there is seasonal variation in demand for water or space heating, biogas compression and storage should be considered if the cost of suitable storage can be justified.

Using biogas to fuel a modified natural gas internal combustion engine or microturbine to generate electricity is more complex. Livestock manures and most agricultural commodity processing wastes contain sulfur compounds, which are reduced to hydrogen sulfide during anaerobic digestion and partially desorbed. Thus, hydrogen sulfide, in trace amounts, is a common constituent of biogas and can cause serious corrosion problems in biogas-fueled internal combustion engines and microturbines. Hydrogen sulfide combines with the water produced during combustion to form sulfuric acid. Consequently, scrubbing to remove hydrogen sulfide may be necessary when biogas is used to generate electricity.

Using biogas to generate electricity also may require interconnection with the local electricity provider for periods when electricity demand exceeds biogas generation capacity, when generation capacity exceeds demand, or when generator shutdown for maintenance or repairs is necessary. One of the advantages of using biogas to generate electricity connected to the grid is the ability to use biogas as it is produced and use the local electricity grid to dispose of excess electrical energy when generation capacity exceeds on-site demand.

When avoided methane emissions and associated carbon credits are considered, simply flaring biogas produced from the anaerobic digestion of livestock manures and agricultural commodity processing wastes is also an option—but only to the degree that replacing a methane-emitting waste management practice with anaerobic digestion reduces methane emissions. Although systems using biogas from anaerobic digestion as a boiler or furnace fuel or for generating electricity should have the ability to flare excess biogas, flaring should be considered an option only if biogas production greatly exceeds the opportunity for utilization.

4.3 COSTS AND POTENTIAL BENEFITS

Costs

The cost of anaerobically digesting livestock manures and agricultural commodity processing wastes and using the methane captured as a fuel depends on the type of digester constructed and the methane utilization option employed. The cost will also vary geographically, reflecting local financing, material, and labor costs. However, it can be assumed that capital cost will increase as the level of technology employed increases. For digestion, the covered anaerobic lagoon generally will require the lowest capital investment, with anaerobic sludge blankets and attached growth processes requiring the highest. As the complexity of the anaerobic digestion process increases, operating and maintenance costs also increase. For example, only basic management and operating skills are required for covered lagoon operation, whereas a more sophisticated level of understanding of process fundamentals is required for anaerobic sludge blanket and attached growth processes.

For captured methane utilization, the required capital investment will be lowest for flaring and highest for generating electricity. Based on past projects developed in the United States and Latin America, the cost of an engine-generator set will be at least 25 percent of total project cost, including the anaerobic digester. In addition, while the operating and maintenance costs for flaring are minimal, they can be substantial for generating electricity. For example, using captured biogas to generate electricity requires a continuous engine-generator set maintenance program and may include operation and maintenance of a process to remove hydrogen sulfide.

Potential Benefits

Anaerobic digestion of livestock manure and agricultural commodity processing wastes can generate revenue to at least offset and ideally exceed capital and operation and maintenance costs. There are three potential sources of revenue.

The first is the carbon credits that can be realized from reducing methane emissions by adding anaerobic digestion. MCFs, and therefore reduction in methane emissions and the accompanying carbon credits earned, are determined by the existing waste management system and vary from essentially 0 to 100 percent. Thus, carbon credits will be a significant source of revenue for some projects and nearly nothing for others.

The second potential source of revenue is from the use of captured biogas as a fuel. However, the revenue realized depends on the value of the form of energy replaced and its local cost. Because biogas has no market-determined monetary value, revenue is determined by the cost of the conventional source of energy it replaces. If low-cost hydropower-generated electricity is available, the revenue derived from using biogas may not justify the required capital investment and operating and maintenance costs. Another consideration is the ability to sell excess electricity to the local electricity provider and the price that would be paid. There may be a substantial difference between the value of electricity used on site and the value of electricity delivered to the local grid. The latter may not be adequate to justify the use of biogas to generate electricity. Ideally, it should be possible to deliver excess generation to the local grid during periods of low on-site demand and reclaim it during periods of high on-site demand under some type of a net metering contract.

The third potential source of revenue is from the carbon credits realized from the reduction in the fossil fuel carbon dioxide emissions when use of biogas reduces fossil fuel use. As with the revenue derived directly from using biogas as a fuel, the carbon credits generated depend on the fossil fuel replaced. When biogas is used to generate electricity, the magnitude of the reduction in fossil fuel-related carbon dioxide emissions will depend on the fuel mix used to generate the electricity replaced. Thus, the fuel mix will have to be determined to support the validity of the carbon credits claimed.

4.4 CENTRALIZED PROJECTS

Generally, small livestock production and agricultural commodity processing enterprises are not suitable candidates for anaerobic digestion to reduce methane emissions from their waste streams due to high capital and operating costs. The same is true for enterprises that only generate wastes seasonally. If all of the enterprises are located in a reasonably small geographic area, combining compatible wastes from two or more enterprises for anaerobic digestion at one of the waste sources or a centralized location is a possible option. Increasing project scale will reduce unit capital cost. However, operating costs will increase; centralized digestion will not always be a viable option if enough revenue cannot be generated to at least offset the increased operating costs.

There are two possible models for centralized anaerobic digestion projects. In the first model, digestion occurs at one of the sources of waste with the waste from the other generators transported to that site. In the model that typically is followed, wastes from one or more agricultural commodity processing operations are co-digested with livestock manure. In the second model, wastes from all sources are transported to a separate site for digestion. The combination of the geographic distribution of waste sources and the options for maximizing revenue from the captured methane should be the basis for determining which model should receive further consideration in the analysis of a specific situation.

For centralized anaerobic digestion projects, the feasibility analysis should begin with the determination of a project location that will minimize transportation requirements for the wastes to be anaerobically digested and for the effluent to be disposed of. The optimal digester location could be determined by trial and error, but constructing and applying a simple transportation model should be a more efficient approach. Although obtaining the optimal solution manually is possible, use of linear programming should be considered. This approach can identify and compare optimal locations with respect to minimizing transportation costs for a number of scenarios. For example, the transportation costs associated with locating the anaerobic digester at the largest waste generator versus a geographically central location can be delineated and compared.

Next, the revenue that will be generated from selling the carbon credits realized from reducing methane emissions and using the captured methane as a fuel should be estimated. The latter will depend on a number of factors including the location of the digester and opportunities to use the captured methane in place of conventional sources of energy. Generally, captured methane that can be used to meet on-site electricity or heating demand will have the greatest monetary value and produce the most revenue to at least offset and ideally exceed system capital and operation and maintenance costs. Thus, an energy-use profile for each source of waste in a possible centralized system should be developed to determine the potential for on-site methane use, the revenue that would be realized, and the allocation of this revenue among the waste sources.

Ideally, the digester location that minimizes transportation cost will be at the waste source with the highest on-site opportunity for methane utilization. This minimizes waste transportation cost while maximizing revenue. However, the digester location that minimizes transportation costs may not maximize revenue from methane utilization due to low on-site energy demand; alternative digester locations should be evaluated to identify the location that maximizes the difference between revenue generation from methane utilization and transportation cost. Again, using a simple transportation-type model to determine the optimal digester location is recommended. If the optimal location is not at one of the waste sources, additional analysis incorporating site acquisition costs will be necessary.

APPENDIX A: IPCC METHODOLOGY FOR SOLID WASTE AND LEAKAGES

A.1 Solid Wastes

Solid wastes generated during the processing of agricultural commodities can be disposed of in various ways, including land application, composting, placement in a landfill, and open burning. In addition, rendering can be used to dispose of solid wastes from meat and poultry processing, such as solids separated from wastewater by screening and DAF.

If country- and waste sector–specific values for B_o are not available, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* default value of 0.25 kg CH_4 per kg COD for wastewater, based on stoichiometry, should be used. The use of this default value for the solid wastes from agricultural commodity processing is based in the assumption that the organic compounds in these wastes will degrade as rapidly as the wastewater organic fraction.

Because the mechanisms responsible for the degradation of these wastes are similar to those of livestock manure following land application, the appropriate MCF value for manure disposal by daily spreading listed in Table 10.17 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* should be used (see Table 2.2). For composting, the IPCC default value of 4 g CH_4 per kg of wet waste should be used. When agricultural commodity processing wastes are disposed of in landfills, the applicable MCF depends on the type of landfill as shown in Table A.1.

Table A.1 – Types of Solid Waste Landfills and Methane Conversion Factors

Type of Site	Methane Conversion Factor Default Value
Managed—anaerobic[1]	1.0
Managed—semi-anaerobic[2]	0.5
Unmanaged[3]—deep (> 5m waste) and/or high water table	0.8
Unmanaged[4]—shallow (< 5m waste)	0.4
Uncategorized solid waste disposal sites[5]	0.6

[1] **Anaerobic managed solid waste disposal sites.** Controlled placement of waste with one or more of the following: cover material, mechanical compacting, leveling
[2] **Semi-anaerobic managed solid waste disposal sites.** Controlled placement of wastes with all of the following structures for introducing air into the waste layer: permeable cover material, leachate drainage system, pondage regulation, and gas ventilation.
[3] **Unmanaged solid waste disposal sites—deep and/or with a high water table.** All sites not meeting the criteria of managed sites with depths greater than 5 m and/or a high water table near ground level.
[4] **Unmanaged solid waste disposal sites.** All sites not meeting the criteria of managed sites with depths less than 5 m.
[5] **Uncategorized solid waste disposal sites.**

For disposal of agricultural commodity processing solid wastes by open burning, the IPCC default value of 6.5 kg of methane per metric ton of waste should be used.

For all four disposal options, the commodity-specific rate of solid waste generation must be known. In addition, information about the concentration of COD in the solid waste, on a wet weight basis, is necessary for all but the composting disposal option. However, COD concentration generally has not been used as a parameter for agricultural commodity processing solid waste characterization. The alternative is to use published values from studies of methane production potential on a volume or mass of methane produced per unit mass of wet waste, or volatile solids added basis as a first-order estimate for B_o for the waste under consideration. If the COD concentration in the solid waste is known, the methane emissions resulting from land application and landfill disposal with the appropriate MCF is calculated using Equation A.1:

$$CH_{4(SW)} = TOW_{(SW)} \times B_o \times MCF_{(SW,D)} \qquad (A.1)$$

where:
- $CH_{4(SW)}$ = Annual methane emissions from agricultural commodity processing waste SW (kg CH_4 per year)
- $TOW_{(SW)}$ = Annual mass of solid waste SW COD generated (kg per year)
- B_0 = Maximum methane production capacity of the waste (kg CH_4 per kg COD)
- $MCF_{(SW, D)}$ = Methane conversion factor for solid waste W and existing disposal practice S (decimal)

A.2 Leakage- and Combustion-Related Emissions

The reduction in methane emissions realized when anaerobic digestion is incorporated into an existing livestock manure or agricultural commodity processing waste management system will be somewhat reduced by leakage- and combustion-related emissions.

There is very little information regarding methane leakage from anaerobic digestion systems, although some leakage probably occurs from all systems and should be incorporated into estimates of net methane emission reductions. The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* provides no guidance, with an MCF default value of 0 to 100 percent. Thus, the use of the *2008 California Climate Action Registry* default collection efficiency value of 85 percent in the following equation is recommended unless a higher value can be justified by supporting documentation.

$$LK_{(P)} = \left(\frac{CH_{4(P)}}{0.85} - CH_{4(P)} \right) \times 0.67\ kg/m^3 \qquad (A.2)$$

where:
- $LK_{(P)}$ = Project methane leakage (kg/year)
- $CH_{4(P)}$ = Estimated methane production potential from manure or agricultural commodity processing wastes or both (kg/year)
- 0.85 = Default methane capture efficiency (decimal)

Because no combustion process is 100 percent efficient and all captured methane should be disposed of by combustion, combustion-related methane emissions also should be accounted for in estimating a project's net methane emission reduction. Unless higher combustion efficiency values can be justified by supporting documentation, the default values listed in Table A.2 should be used.

Table A.2 Default Values for Methane Combustion Efficiencies, Decimal

Combustion Process		Default Value
Open flare	Continually operational	0.50
	Not continually operational	0
Enclosed flare	Continuous monitoring of compliance with manufacturer's specifications or continuous monitoring of methane destruction	0.90

Source: UNFCCC, 2008

Methane emissions associated with each combustion process should be based on the fraction of estimated methane production that will be captured and calculated as follows:

$$CE_{(P)} = \left[\left(CH_{4\,(P)} - LK_{(P)}\right) \times \left(1 - C_{eff}\right)\right] \qquad (A.3)$$

where: $CE_{(P)}$ = Combustion-related emissions (kg CH_4 per year)

$CH_{4\,(P)}$ = Estimated production potential (kg CH_4 per year)

C_{eff} = Combustion efficiency (decimal)

Fossil Fuel Use–Related Emissions

An anaerobic digestion project may result in increased fossil fuel use such as use of gasoline or diesel fuel for manure transport to a centralized anaerobic digestion facility or transport of another waste to a facility for co-digestion. The resulting increase in carbon dioxide emissions also should be accounted for using the default values for fossil fuel use–related carbon dioxide emission rates, as shown in Table A.3.

Table A.3 Default Values for Carbon Dioxide Factors for Gasoline and Diesel Fuel Use for Transportation

Fuel	CO_2 Emission Factor, kg/L
Gasoline	2.4
Diesel	2.7

Source: Derived from IPCC, 2006

Estimate the carbon dioxide emissions resulting from increased fossil fuel use due to transportation as follows.

$$FF_{(P)} = \frac{\left(FF_{(Use)} \times C_{factor}\right)}{21} \qquad (A.4)$$

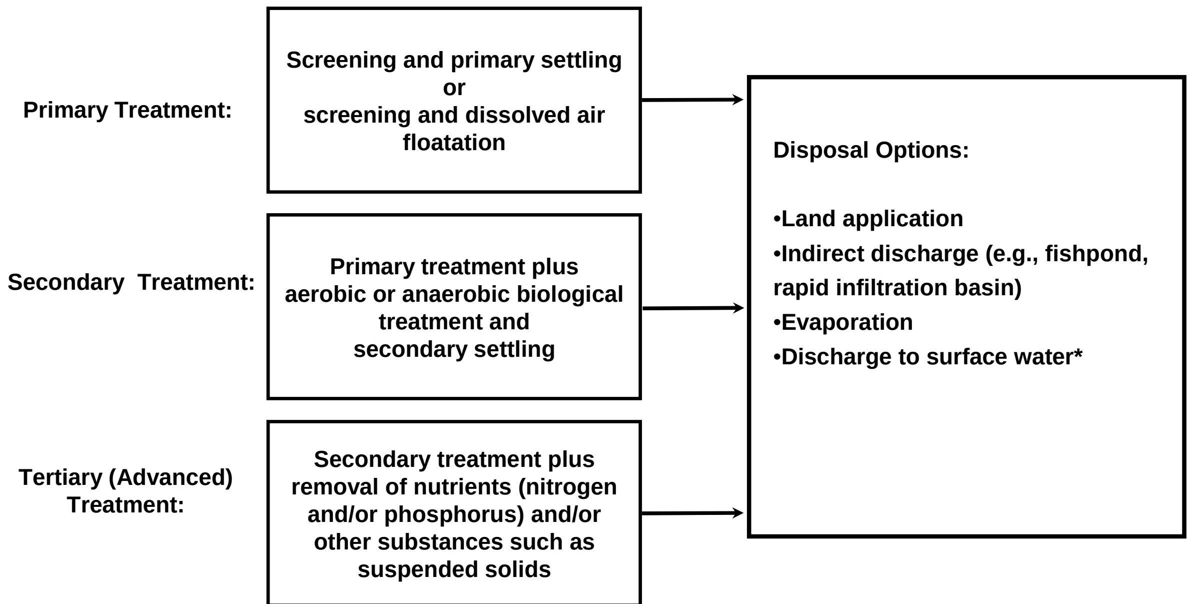
where: $FF_{(P)}$ = Fossil fuel–related carbon dioxide emissions on a methane equivalent basis (kg CH_4 per year)

$FF_{(Use)}$ = Additional fossil fuel use (L/yr)

E_{factor} = Emission factor (kg CO_2/L)

21 = GWP of methane as compared to carbon dioxide (kg CO_2/kg CH_4)

APPENDIX B: TYPICAL WASTEWATER TREATMENT UNIT PROCESS SEQUENCE



*According to applicable discharge standards

APPENDIX C: ADDITIONAL SECTOR INFORMATION

This appendix discusses four sectors not included in Chapter 3 (either because they have a low potential for methane emissions or because there was not enough information on their waste management practices): cassava, slaughterhouses, fruit processing, and palm oil.

C.1 CASSAVA

C.1.1 Description of Size, Scale, and Geographic Location of Operations

In 2009, the Dominican Republic produced nearly 166,000 metric tons of cassava roots (Table C.1). The main producing area is the Cibao region, including the provinces of Santiago Rodriguez, La Vega, San Juan, Moca, Salcedo (Hermanas Mirabal), Santiago, and Hato Mayor (SEA, 2010b).

Table C.1 – Cassava Root Production in the Dominican Republic

Year	2002	2003	2004	2005	2006	2007	2008	2009
Production (MT/yr)	120,244	123,614	90,514	98,267	128,369	128,340	106,291	165,688

Source: SEA, 2010a

The Dominican Republic produces both sweet and bitter cassava. In general, sweet cassava is used directly for human or animal consumption, while bitter cassava is used in the preparation of casabe, a flat, cracker-like bread.

The municipality of Moncion in the province of Santiago Rodriguez is one of the main production zones of cassava (yucca) and casabe in the country. The Cluster of Yucca and Casabe of Moncion—an association of 76 cassava producers and 19 casabe producers within the Center for Agriculture and Forestry Development, or CEDAF —produces 101,660 quintals (4,610 MT) of cassava per year, which is mainly used for casabe production (487,680 units of casabe per year). Out of the 19 casabe producers, five large plants account for about 50 percent of the total production (CEFINOSA, 2009a).

C.1.2 Description of the Characteristics of Wastes, Handling, and Management

According to Nicolas Almonte, director of the Cluster of Yucca and Casabe of Moncion, the common waste management practice in this sector is to discharge the wastewater directly into nearby rivers or streams. However, he also indicated that more and more industries are installing digesters to treat the wastewater. Figure C.1 shows a typical bag digester installed in a cassava pressing plant.

Figure C.1 – Bag Digesters installed by Bioenergym in a Cassava Processing Plant

Source: Almonte, 2010

The following table shows the wastewater characteristics of a cassava processing plant.

Table C.2 – Cassava Processing Wastewater Characteristics

Parameter	Value
BOD_5	21,322 mg/L
COD	38,380 mg/L
Suspended solids	13,380 mg/L
Oil and grease	16.77 mg/L

Source: IIBI

Since cassava production in the Dominican Republic is not very significant by volume and most of the industries discharge their wastewaters directly into nearby water bodies, the current baseline methane emissions are very low and the potential to readily capture methane is almost nonexistent.

C.2 SLAUGHTERHOUSES

C.2.1 Description of Size, Scale, and Geographic Location of Operations

The Dominican Republic is the largest meat producer in the Caribbean (FAOSTAT, 2010a). Chicken is the main type of meat produced by volume, followed by cattle and pig meat (Table C.3).

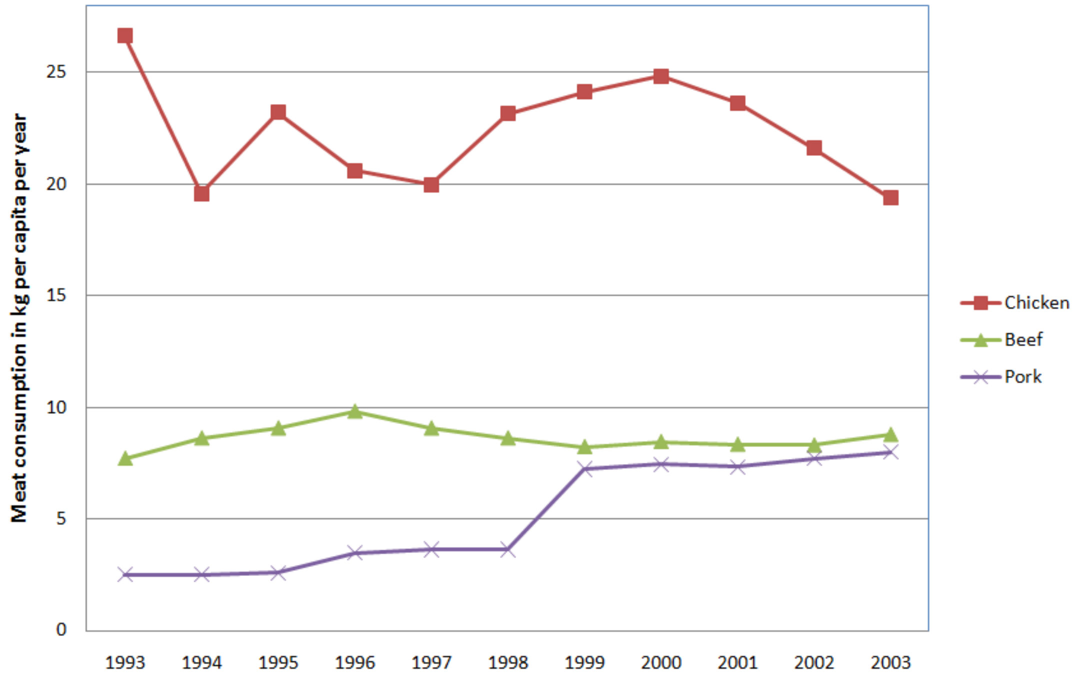
Table C.3 – Meat Production in the Dominican Republic

Animal Species	Meat Production (MT/yr)		Number of Animals Slaughtered
	In 2003 (Moreta, 2004a and b)	In 2008 (FAOSTAT, 2010a)	In 2008 (FAOSTAT, 2010a)
Chicken		346,408	288,700
Cattle	75,300	101,106	500,000
Pigs	69,900	72,150	1,110,000
Goat		720	60,000
Sheep		372	31,000

Source: Elaborated by the authors based on Moreta, 2004a and 2004b, and FAOSTAT, 2010a

Between 1990 and 2003, the apparent meat consumption in the Dominican Republic (national production + importation – exportation) varied between 718,000 MT in 1991 and 960,000 MT in 2002 (Moreta, 2004b). The main meat consumed was chicken with 20 to 25 kg per capita per year, followed by beef and pork with less than 10 kg per capita per year (Figure C.2).

Figure C.2 – Meat Consumption per Capita per Year



Source: Elaborated by the authors based on Moreta, 2004b

According to the daily newspaper El Caribe, the Dominican Republic is modernizing its meat industry through the implementation of better slaughtering techniques, meat management and infrastructures. The slaughterhouses constructed in the last few years already meet the quality standards necessary to export meat to the United States. The main concern is that municipal slaughterhouses do not meet quality standards. The Ministry of Public Health reported that there were 154 slaughterhouses in the country but only 30 satisfied the conditions to operate (Beltre, 2010). In the greater Santo Domingo area, only eight out of 14 slaughterhouses satisfied the conditions to operate and in Santiago two out of 25 (Viloria, 2010). The main swine slaughterhouses in the country in 2002 are listed in Table C.4.

Table C.4 – Main Swine Slaughterhouses in the Dominican Republic in 2002

Name of Company	Location	Capacity (Head/Year)	Market Share
Slaughterhouses with meat processing and packing units			
Slaughterhouse 1	La Vega	265,200	30%
Slaughterhouse 2	Puerto Plata	46,800	5%
Slaughterhouse 3	Santo Domingo	44,200	5%
Slaughterhouse 4	Santo Domingo	40,560	5%
Slaughterhouse 5	Santo Domingo	36,400	4%
Slaughterhouse 6	Santiago	31,200	3%
Slaughterhouse 7	Santiago	31,200	3%
Slaughterhouse 8	Santiago	26,000	3%
Slaughterhouse 9		20,800	2%
Slaughterhouse 10		20,800	2%
Slaughterhouse 11		15,600	2%
Slaughterhouse 12		15,600	2%
Slaughterhouse 13		10,400	1%
Slaughterhouse 14		10,400	1%
Slaughterhouse 15	Santiago	7,800	1%
Slaughterhouse 16		7,800	1%
Slaughterhouses only			
Slaughterhouse 17	Santo Domingo	46,800	5%
Slaughterhouse 18	Santo Domingo	46,800	5%
Slaughterhouse 19	Santo Domingo	41,600	5%
Slaughterhouse 20	Santo Domingo	40,560	5%
Slaughterhouse 21	Santo Domingo	26,000	3%
Slaughterhouse 22	Santo Domingo	18,720	2%
Slaughterhouse 23	Santo Domingo	13,000	1%
Slaughterhouse 24		9,360	1%
Slaughterhouse 25		6,760	1%
Slaughterhouse 26		6,500	1%
Slaughterhouse 27		4,680	1%
Total		**891,540**	**100%**

Source: Moreta, 2004a

C.2.2 Description of the Characteristics of Wastes, Handling, and Management

The following table shows the wastewater characteristics of a chicken slaughterhouse and a cattle slaughterhouse.

Table C.5 – Slaughterhouse Wastewater Characteristics

Parameter	Chicken Slaughterhouse (After a Solid Separator)	Cattle Slaughterhouse
pH		6.81
Temperature		30.3 ^{o}C
BOD_5	932 mg/L	1,300 mg/L
COD	1,435 mg/L	2,400 mg/L
Suspended solids	12mg/L	972 mg/L
Oil and grease	1.2 mg/L	106 mg/L

Source: Ministry of Environment, Quality Division, Monitoring Department, personal contact

According to a study of the entire swine production chain in the Dominican Republic (IICA, 2006), "the largest slaughterhouses and meat packing plants have a waste treatment system in place that generates treated wastewater and solids that can be used for fertilizer and animal food. However, there are also small plants that discharge their wastewaters directly into the sewer system or in natural water bodies."

Two case studies are presented below.

Beef Slaughterhouse – Case Study

This site is one of the largest bovine slaughterhouses in the country: it slaughters 130 bovine head per day. At another facility located at a different site, the company slaughters an additional 150–160 head per day.
Both facilities use similar waste management systems. The different stages of the treatment process are described below:

- Wastewater segregation: (1) the blood is disposed of in landfills, (2) WW#1 goes to a grease trap first then to the mixed tank, (3) WW#2 goes directly to the mixed tank
- One grease trap (WW#1 only)
- One tank with agitator
- One solid separator
- Four sedimentation tanks , calcium carbonate and other coagulants are added
- One aerobic tank
- One solid separation tank
- Two evaporation lagoons in series, methane bubbles can be seen on the surface of the two lagoons

The water is then used for irrigation. The solids are sent to a landfill.

Grease trap

Tank with agitator

Solid separator

Sedimentation tanks

Aeration tank

Solid separation tank

Lagoons (bubbles of methane can be seen at the surface)

Source: Site visit

Chicken Slaughterhouse – Case Study

- The plant slaughters and processes 350,000 chickens per month.
- The main stages of the process are unloading, hanging, stunning, bleeding, scalding, plucking, evisceration, washing and chilling, packing, storage, and transport.
- The blood from the bleeding process is segregated and sent to a landfill. It is estimated that each chicken weighs about 4 pounds and that its blood represents 2.5 percent of its total weight. Thus, the plant generates about 35,000 pounds of blood per month.
- The heads and non-edible entrails are sold to swine farmers or sent to a landfill. The feathers are collected and stored in bags and sent to a landfill.
- The wastewater generated from the different processes (cooling, cleaning, etc.) are treated by a solid separator, followed by a grease trap, and finally an open anaerobic lagoon. It is estimated that the plant uses 3.5 gallons of water per chicken, which corresponds to a wastewater generation rate of approximately 1,225,000 gallons per month.
- The volume of the lagoon is 70,000 gallons. The settled solids in the lagoon have never been removed. Since the filters at the exit of the lagoon are fouled, the water is removed by cistern trucks and used for crop irrigation.
- The grease retained in the grease trap is collected daily, stored in tanks, and sent to a landfill. About 117 tanks of 55 gallons each are filled with grease every month.

Source: Site visit

C.3 FRUIT PROCESSING

C.3.1 Description of Size, Scale, and Geographic Location of Operations

The production of the main fruit cultivated on the island is presented in the table below.

Table C.3 – Fruit Production in the Dominican Republic in 2008

Fruit	Production (MT)
Bananas	439,569
Plantains	340,370
Mangoes, mangosteens, guavas	170,000
Pineapples	100,528
Oranges	90,337
Papayas	22,500
Other melons (including cantaloupes)	18,917
Grapefruit (including pomelos)	11,023
Lemons and limes	3,000

Source: FAOSTAT, 2010a

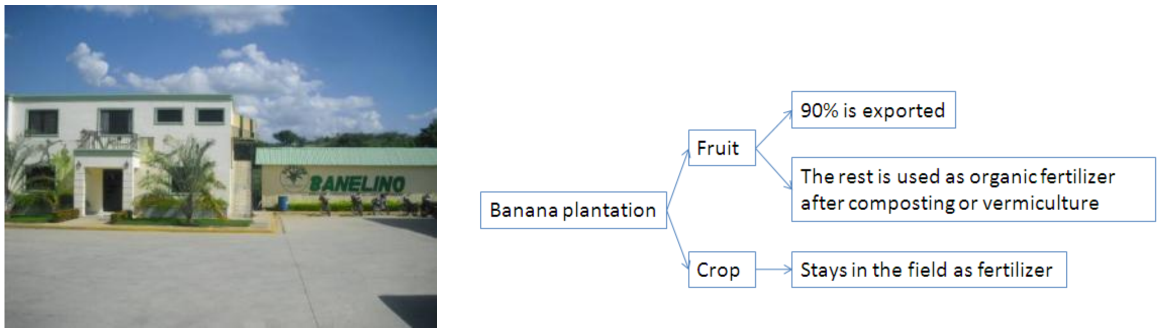
The Dominican Republic is one of the world's largest exporters of organic bananas. Most of its exports, about 85 percent of its organic production (approximately 160,000 MT), are directed to the European Union (CEFINOSA, 2009b).

C.3.2 Description of the Characteristics of Wastes, Handling, and Management

Based on interviews, it seems that most fruit processing plants in the country use lagoons. For example, the citrus processing plant Consorcio Citricos Dominicanos uses four open anaerobic lagoons to treat its wastewater. However, there was not enough information to confirm the specific waste management practices of this sector and estimate the current methane emissions.

A case study is presented below.

Fruit Production - Case Study
• This case study represents an association of 372 banana producers and five banana processing units, exporting 567,000 kg of bananas per week. • In the banana processing plants, the fruits are washed and packed. Each plant uses 5,000 gallons of water per day. The wastewater generated from the washing process in the packing plants is directly used for irrigation. • The residues from the harvest are left to decay on the ground to serve as fertilizer. The plastic bags are collected and sent to a landfill. The roots are ground, composted or vermicomposted, and finally used as fertilizer. The leachate from the composting process (approximately 100 gallons per day) is re-used in its totality in the composting process.



Source: Site visit – Tetra Tech

C.4 PALM OIL

C.4.1 Description of Size, Scale, and Geographic Location of Operations

There are only two palm oil processing plants in the Dominican Republic: Palm Oil Plant 1, and another plant which is much smaller. Palm Oil Plant 1 started cultivating African palm and operating a palm oil extraction plant in 1980. In 2007, Palm Oil Plant 1 processed 70,000 MT of fresh fruit bunch (FFB) and produced 16,000 MT of palm oil (UNPHU, 2007). There was no available data on the other small plant.

C.4.2 Description of the Characteristics of Wastes, Handling, and Management

Palm Oil Plant 1 generates 49,000 m^3 of wastewater each year, which corresponds to a wastewater generation rate of 0.7 m^3 per metric ton of FFB. The COD of the wastewater was reported to be between 51 and 67 kg/m^3 (UNPHU, 2007). The wastewater is currently being treated in open lagoons (Figure C.).

Figure C.3 – Open Lagoons at Palm Oil Plant 1

Source: UNPHU, 2007

APPENDIX D: GLOSSARY

Activated Sludge Process—A biological wastewater treatment process in which a mixture of wastewater and activated sludge (biosolids) is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater by sedimentation and wasted or returned to the process as needed.

Advanced Waste Treatment—Any physical, chemical or biological treatment process used to accomplish a degree of treatment greater than achieved by secondary treatment.

Aerobic—Requiring the presence of free elemental oxygen.

Aerobic Waste Treatment—Waste treatment brought about through the action of microorganisms in the presence of air or elemental oxygen. The activated sludge process is an aerobic waste treatment process.

Anaerobic—Requiring the absence of air or free elemental oxygen.

Anaerobic Digester—A tank or other vessel for the decomposition of organic matter under anaerobic conditions.

Anaerobic Digestion—The degradation of organic matter including manure by the action of microorganisms in the absence of free elemental oxygen.

Anaerobic Pond or Lagoon—An open treatment or stabilization structure that involves retention under anaerobic conditions.

Anaerobic Sequencing Batch Reactor (ASBR) Process—A batch anaerobic digestion process that consists of the repetition of following four steps: 1) feed, 2) mix, 3) settle, and 4) decant/effluent withdrawal.

Anaerobic Waste Treatment—Waste stabilization brought about through the action of microorganisms in the absence of air or elemental oxygen. Usually refers to waste treatment by methane fermentation. Anaerobic digestion is an anaerobic waste treatment process.

Attached Film Digester—An anaerobic digester in which the microorganisms responsible for waste stabilization and biogas production are attached to inert media.

Bagasse—Fibrous residue remaining after sugarcane stalks are crushed to extract their juice.

Biochemical Oxygen Demand (BOD)—A measure of the quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time and at a specified temperature. It is not related to the oxygen requirements in chemical combustion, being determined entirely by the availability of the material as biological food and by the amount of oxygen utilized by the microorganisms during oxidation.

Biogas—A mixture of methane and carbon dioxide produced by the bacterial decomposition of organic wastes and used as a fuel.

Cassava—Crop grown in tropical climates. When extracted, its starch is known as tapioca.

Chemical Oxygen Demand (COD)—A quantitative measure of the amount of oxygen required for the chemical oxidation of carbonaceous (organic) material in wastewater using inorganic dichromate or permanganate salts as oxidants in a two-hour test.

Complete Mix Digester—A controlled temperature, constant volume, mechanically or hydraulically mixed vessel operated for the stabilization of organic wastes including manures anaerobically with the capture of biogas generated as a product of waste stabilization.

Compost—The production of the microbial oxidation of organic wastes including livestock manures at an elevated temperature.

Composting—The process of stabilizing organic wastes including livestock manures by microbial oxidation with the conservation of microbial heat production to elevate process temperature.

Covered Lagoon Digester—A pond or lagoon operated for the stabilization of organic wastes including manures anaerobically and fitted with an impermeable cover to capture the biogas generated as the product of waste stabilization.

Digester—A tank or other vessel for the aerobic or anaerobic decomposition of organic matter present in biosolids or other concentrated forms of organic matter including livestock manures.

Dissolved Air Floatation (DAF)—A separation process in which air bubbles emerging from a supersaturated solution become attached to suspended solids in the liquid undergoing treatment and flat them up to the surface for removal by skimming.

Effluent—The discharge from a waste treatment or stabilization unit process.

Greenhouse Gas (GHG)—A gas present in the atmosphere, which is transparent to incoming solar radiation but absorbs the infrared radiation reflected form the earth's surface. The principal greenhouse gases are carbon dioxide, methane, and CFCs.

Hydraulic Retention Time—The volume of a reactor divided by the volumetric flow rate.

Influent—Wastewater flowing into a unit waste treatment or stabilization process.

Lagoon—Any large holding or detention structure, usually with earthen dikes, used to contain wastewater while sedimentation and biological oxidation or reduction occurs.

Liquid Manure—Manure having a total solids (dry matter) content not exceeding 5 percent.

Manure—The mixture of the fecal and urinary excretions of livestock, which may or may not contain bedding material.

Mesophilic Digestion—Digestion by biological action at 27 to 38 °C.

Methane—A colorless, odorless, flammable gaseous hydrocarbon that is a production of the anaerobic, microbial decomposition of organic matter.

Organic Matter—Chemical substances of animal or vegetable origin, or more correctly, containing carbon and hydrogen.

Plug-Flow—Flow in which fluid particles are discharged from a tank or pipe in the same order in which they entered it. The particles retain their discrete identities and remain in the tank for a time equal to the theoretical retention time.

Plug-Flow Digester—A controlled temperature, constant volume, unmixed vessel operated for the stabilization of organic wastes including manures anaerobically with the capture of biogas generated as a product of waste stabilization.

Primary Treatment*—1) The first major treatment in a wastewater treatment facility, usually sedimentation but not biological oxidation. 2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter. 3) Wastewater treatment processes usually consisting of clarification with or without chemical treatment to accomplish solid-liquid separation.

Secondary Treatment*—1) Generally, a level of treatment that produces removal efficiencies for BOD and suspended solids of at least 85 percent. 2) It is sometimes used interchangeably with the concept of biological wastewater treatment, particularly the activated sludge process. It is commonly applied to treatment that consists chiefly of clarification followed by a biological process, with separate sludge collection and handling.

Stabilization—Reduction in the concentration of putrescible material by either an aerobic or anaerobic process. Both aerobic and anaerobic digestion are examples of waste stabilization processes.

Suspended Solids—1) Insoluble solids that either float on the surface of or are in suspension in water, wastewater, or other liquids. 2) Solid organic or inorganic particles (colloidal, dispersed, coagulated, flocculated) physically held in suspension by agitation or flow. 3) The quantity of material removed from wastewater in a laboratory test, as prescribed in “Standard methods for the Examination of Water and Wastewater” and referred to as nonfilterable residue.

Tertiary Treatment*—The treatment of wastewater beyond the secondary or biological stage. The term normally implies the removal of nutrients, such as nitrogen and phosphorus, and a high percentage of suspended solids. It is now being replaced by a preferable term, advanced waste treatment.

Total Solids—The sum of dissolved and suspended solid constituents in water or wastewater.

Treatment—The use of physical, chemical, or biological processes to remove one or more undesirable constituents from a waste.

Upflow Anaerobic Sludge Blanket (UASB) Reactor—An anaerobic reactor in which influent flows upward through a blanket of flocculated sludge that has become granulated.

Vinasse—Wastewater with a high organic content generated via ethanol production through sugar juice or final molasses fermentation.

Volatile Solids—Materials, generally organic, which can be driven off by heating, usually to 550°C; non-volatile inorganic solids (ash) remain.

Wastewater—The spent or used water of a community or industry, which contains dissolved and suspended matter.

Wastewater Treatment System*—A sequence of unit processes designed to produce a final effluent that satisfies standards for discharge to surface or ground waters. It typically includes the combination of a primary and secondary treatment processes.

*Appendix B illustrates the typical wastewater treatment process.

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