Resource Assessment for Livestock and Agro-Industrial Wastes – Turkey

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Global Methane Initiative

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EXECUTIVE SUMMARY

The Global Methane Initiative is an international public-private partnership that works to reduce global methane emissions with the purpose of enhancing economic growth, promoting energy security, improving the environment, and reducing greenhouse gases (GHGs). 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.

The initiative works in five main sectors: agriculture, landfills, oil and gas exploration and production, coal mining, and municipal wastewater[1]. 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 the Global Methane Initiative, the U.S. Environmental Protection Agency (U.S. EPA) conducted this livestock and agro-industry (agricultural commodity processing) resource assessment (RA) in Turkey to identify and evaluate the potential for incorporating anaerobic digestion into livestock manure and agro-industrial waste management systems to reduce methane emissions and provide a renewable source of energy.

The following table summarizes the findings of the RA in terms of potential methane emissions reductions and fossil fuel replacement carbon offsets in Turkey. The sector with the highest potential for methane reduction and carbon offsets is the sugar beet sector, followed by fruit processing, dairy, and slaughterhouses. There is the potential to produce 31,800 kW of electricity annually from the sectors evaluated in this RA.

Table ES-1 – Summary of the Methane Emissions Reduction Potential in the Livestock and Agro-Industrial Sector in Turkey

Sector	Methane Emissions Reductions (/yr)	Carbon Emissions Reductions (/yr)	Fuel Replacement Offsets (/yr)	Total Carbon Emissions Reductions (/yr)
Sugar beet	21,200	444,400	55,400	499,800
Fruit processing	11,800	247,700	30,900	278,600
Dairy	7,400	155,700	25,000	180,700
Slaughterhouses	6,500	137,200	25,800	163,000
Alcoholic beverages	3,600	76,000	9,500	85,500
Olive oil	3,600	76,900	4,500	81,400
Corn starch	1,200	25,200	3,100	28,300
Fish Processing	320	6,700	840	7,600
Non-alcoholic beverages	140	2,900	360	3,200
Total	55,300	1,172,700	155,400	1,328,100

[1] GMI added municipal wastewater as a new sector at its October 2011 meeting in Krakow, Poland.

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LIST OF ABBREVIATIONS

AMBR®	Anaerobic migrating blanket reactor
ASBR	Anaerobic sequencing batch reactor
BESD-BIR	White Meat Processors and Breeders Association
BOD	Biochemical oxygen demand
CCAR	California Climate Action Registry
	Methane (chemical formula)
	Carbon dioxide equivalent
COD	Chemical oxygen demand
DAF	Dissolved air flotation
FAO	United Nations Food and Agriculture Organization
FAOSTAT	Statistics Division of the United Nations Food and Agriculture Organization
GDP	Gross domestic product
GHG	Greenhouse gas
HRT	Hydraulic retention time
IPCC	Intergovernmental Panel on Climate Change
MCF	Methane conversion factor
	Million metric tons of carbon dioxide equivalent
MT	Metric ton
	Metric tons of carbon dioxide equivalent
RA	Resource assessment
SBS	Starch-based sweetener
TOW	Annual mass of COD generated per year
TS	Total solids
TSC	Turkish Sugar Corporation
TSS	Total suspended solids
UASB	Upflow anaerobic sludge blanket
U.S. EPA	United States Environmental Protection Agency
VS	Volatile solids
WWTP	Wastewater treatment plant

1.

The Global Methane Initiative (the Initiative) is a collaborative effort between national governments and others to capture methane emissions and use them as a clean energy source. The Global Methane Initiative was originally launched in 2004 as the Methane to Markets Partnership. Partners make 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. The Initiative is focused on a few key sources of methane, including agriculture, coal mining, landfills, oil and gas systems, and municipal wastewater.

The role of the Initiative is to bring diverse organizations together with national governments to catalyze the development of methane projects. Organizations include the private sector, the research community, development banks, and other governmental and non-governmental 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.

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

- Identify and characterize methane reduction potential
- Develop country market opportunities
- Provide the location of resources and a ranking of them

The main objective of this RA is to identify the potential for incorporating anaerobic digestion into livestock manure and agro-industrial waste management systems to reduce methane emissions and provide a renewable source of energy in Turkey. This report summarizes the findings of the RA, discusses the most attractive sectors and locations, and prioritizes the sectors in terms of potential methane emissions reductions.

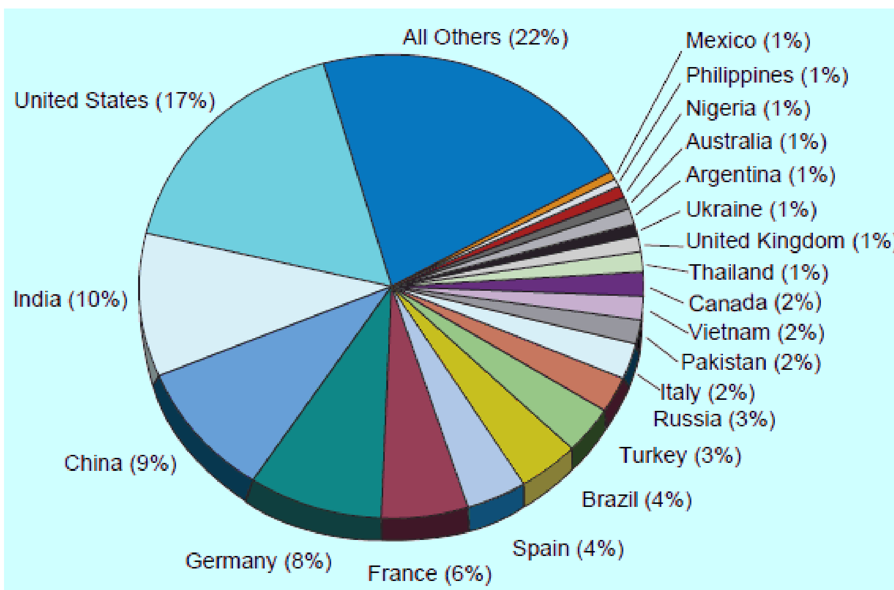
While there are other studies that examine methane emissions from the sectors covered in this document, those studies usually take total population or production levels as the baseline for calculating the emissions. Recognizing that not all waste management operations (e.g., pastures) generate methane, this RA uses a different approach. For this analysis, methane emissions reduction estimates are based on the actual population (or number of industries) that generate methane via their waste management system (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 associated with waste management practices that generate methane. Estimating emissions reductions using these assumptions provides a better basis for policy development and capital investments and provides conservative estimates of emissions reductions.

Finally, it is important to note that this RA limits its scope to emissions 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 contributed more than 230 million metric tons of carbon dioxide equivalent ( ) of methane emissions globally, 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

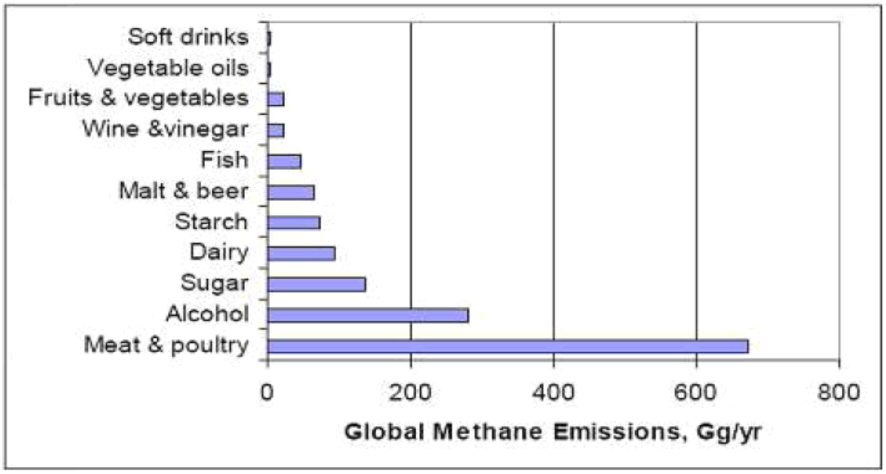


Source: Global Methane Initiative, 2008

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 () 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 are not treated before discharge, and only a minority is treated anaerobically. As a result, agro-industrial wastes represent a significant opportunity for methane emissions reductions through the addition of appropriate anaerobic digestion systems.

Table 1.1 – Disposal Practices From Agro-Industrial Wastes

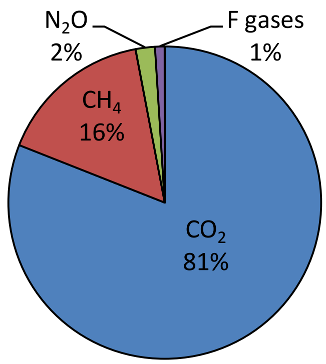
Sector	Region	Percent of Wastewater	
		Untreated Discharge	Onsite Anaerobic Treatment
Meat, poultry, dairy, and fish processing	Africa	60	34
	Asia (except Japan)	70	22
	Eastern Europe	50	23
	Latin America	50	32
Fruit and vegetable processing	Africa	70	6
	Asia (except Japan)	70	5
	Eastern Europe	50	1
	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 TURKEY

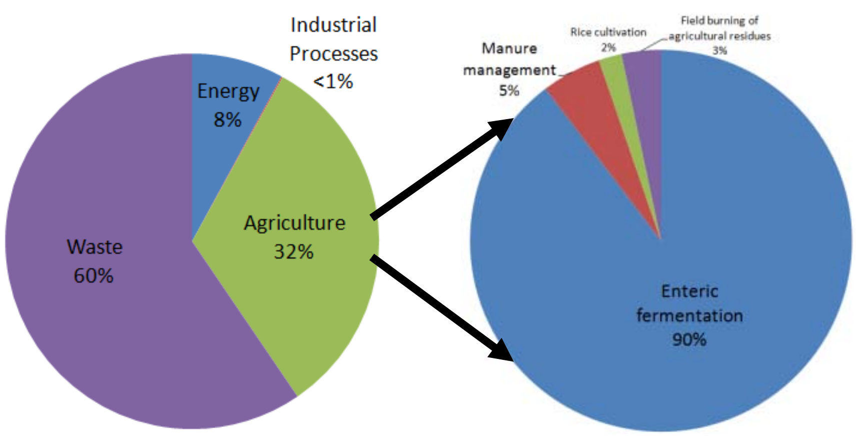
According to the most recent Turkish GHG inventory (MoEF, 2007), methane contributes 15.6 percent of the total GHG emissions (Figure 1.3), with enteric fermentation accounting for 29 percent of all methane emissions. Animal manure management represents 2 percent of the total methane emissions (Figure 1.4). Although this is a small portion compared to enteric fermentation, it represents a significant opportunity for emissions reductions with methane capture through the use of anaerobic digestion under controlled conditions with subsequent combustion either as an energy source or with a flare.

Figure 1.3 – GHG Emissions in Turkey (Equivalent) (2004)



Source: Prepared by the authors, based on data from MoEF, 2007

Figure 1.4 – Sources of Methane Emissions in Turkey (2004)



Source: Prepared by the authors, based on data from MoEF, 2007

2. BACKGROUND AND CRITERIA FOR SELECTION

Below is a description of the methodologies used in this RA.

2.1 METHODOLOGY USED

A variety of data sources were used for conducting the RA, including:

- **Published data,** such as national and international data (e.g., United Nations Food and Agriculture Organization [FAO] animal production datasets); specific subsector information from business and technical journals; and other documents, reports, and statistics.
- **Interviews** with local experts from pertinent ministries (e.g., ministries of agriculture, environment, and energy), local non-government organizations, and engineering/consulting companies working in agriculture and rural development; current users of anaerobic digestion; and other stakeholders.
- **Field visits** to sites of various sizes in the different sub-sectors to characterize the waste management systems used and verify the information collected through other sources.

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

Step 1: The first step in the development of the livestock and agro-industry RA involved constructing general profiles of the individual subsectors (or commodity groups), such as dairy or swine production or sugar. Each profile includes a list of operations within the subsector and the distribution of facilities by size and geographical 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 or 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 geographically.

Step 3: With this information, the team focused on identifying those 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 utilize available resources, we 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 utilized 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 is incomplete or not readily accessible (which was often the case for the livestock and agro-industrial sectors in Turkey), 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 magnitudes of current methane emissions to identify those commodity groups that should receive further analysis. For 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-industrial subsector with large operations that perform direct discharge of 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 utilize available resources. This profiling exercise could aid in identifying the more 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 *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Tier 2 methods were used for estimating methane emissions from each commodity group in the livestock production sector. Using the Tier 2 methods, methane emissions for each livestock commodity group (M) and existing manure management system (S) and climate (k) combination are estimated as follows (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: $_{(M)}$ = Estimated methane emissions from manure for livestock category M (kg per year)

$VS_{(M)}$ = Average daily volatile solids excretion rate for livestock category M (kg volatile solids per animal-day)

$H_{(M)}$ = Average number of animals in livestock category M

$_{(M)}$ = Maximum methane production capacity for manure produced by livestock category M (per kg volatile solids excreted)

$MCF_{(S,k)}$ = Methane conversion factor for manure management system S for climate k (decimal)

As shown, Equation 2.1 requires an estimate of the average daily VS excretion rate for the livestock category under consideration. The default values for dairy cows, breeding swine, and market swine are listed in Table 2.1. 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 identifying 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 Emissions Factor, %								
	Lagoons	Storage Tanks & Ponds	Solid Storage	Dry Lots	Pit <1 Month	Pit >1 Month	Daily Spreading	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, using Equation 2.1 requires specification of the methane production potential () 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, /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 Agricultural Commodity Processing Waste-Related Emissions

Agricultural commodity processing can generate two sources of methane emissions: wastewater and solid organic wastes. The latter can include unprocessed raw material or material discarded after processing due to spoilage, poor quality, or other reasons. One example are the solids removed by screening from wastewater 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 A illustrates a typical wastewater treatment unit process sequence. The methods for estimating methane emissions from wastewater and solid wastes are presented below

2.2.2.1 Wastewater

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 methodology for estimating methane emissions. This methodology utilizes 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 using Equation 2.2:

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

where:

$_{(W)}$ = Annual methane emissions from agricultural commodity processing waste W (kg per year)

$TOW_{(W)}$ = Annual mass of waste W COD generated (kg per year)

$S_{(W)}$ = Annual mass of waste W COD removed as settled solids (sludge) (kg per year)

$EF_{(W,S)}$ = Emissions factor for waste W and existing treatment system and discharge pathway S (kg per kg COD)

$R_{(W)}$ = Mass of recovered (kg per year)

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

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

where: $_{(W)}$ = Maximum production capacity (kg per kg COD)
$MCF_{(S)}$ = Methane conversion factor for the existing treatment system and discharge pathway (decimal)

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

Table 2.4 – Default MCF Values for Industrial Wastewaters, Decimal

Existing Treatment System and Discharge Pathway	Comments		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 Intergovernmental Panel on Climate Change (IPCC) expert judgment.

If the total amount of organically degradable material in wastewater (TOW) is not known and the collection of the necessary data is not possible, the remaining option is estimation using 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 year)
$W_{(W)}$ = Wastewater generation rate (per metric ton of product)
$COD_{(W)}$ = Wastewater COD concentration (kg per)

Table 2.5 – Examples of Industrial Wastewater Data

Industry	Typical Wastewater Generation Rate, /metric ton	Range of Wastewater Generation Rates, /metric ton	Typical COD Concentration, kg/	Range of COD Concentrations, kg/
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 & 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 & 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 emissions reduction potential and feasibility of anaerobic digestion systems include the following:

- **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 as measured in terms of its BOD and COD, or both.
- **Geographic distribution:** There is a concentration of priority sectors in specific regions of the country, making centralized or commingling 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 Turkey are the dairy sector, slaughterhouses, sugar beet, olive oil, fruit processing, corn starch, fish processing, and beverages. These sectors are discussed in detail in Sections 3.2, 3.3, and 3.4.

3. SECTOR CHARACTERIZATION

3.1 OVERVIEW OF TURKISH AGRICULTURE

Turkey, situated in both Asia and Europe (southwestern Asia and southeastern Europe), is the 34th largest country in the world, encompassing 783,562 km. Turkey's population was 71.2 million in 2004 (MoEF, 2007) and was estimated at 77.8 million in 2010 (CIA, 2010). The country is divided into 81 provinces (Figure 3.1), which are themselves divided into 923 districts. The names of most provinces are the same as their provincial capital cities.

Figure 3.1 – Map of Turkey's Provinces

The provinces are organized into seven regions: Marmara, Black Sea, Aegean, Central Anatolia, Eastern Anatolia, Mediterranean, and Southeastern Anatolia (Figure 3.2).

Figure 3.2 – Map of Turkey's Regions

In 2009, agriculture represented 9.3 percent of the country's gross domestic product (GDP) and 29.5 percent of the total labor force (CIA, 2010). Table 3.1 shows the top food and other agricultural commodities produced in Turkey in 2008. From the tonnage standpoint, wheat is the main agricultural product, with 17.8 million metric tons produced per year, followed by sugar beet and cow milk, with 15.5 and 11.3 million metric tons, respectively. From the value standpoint, milk and wheat rank first and second, while tomatoes are third and grapes are fourth.

Table 3.1 – Production of Food and Other Agricultural Commodities in Turkey, 2008

Rank	Commodity	Production (Int $1,000)	Production (MT)
1	Wheat	2,428,920	17,782,000
2	Sugar beet	712,927	15,488,300
3	Cow milk, whole, fresh	2,993,207	11,255,200
4	Tomatoes	2,212,343	10,985,400
5	Barley	123,894	5,923,000
6	Corn	192,775	4,274,000
7	Potatoes	565,770	4,196,520
8	Watermelons	291,925	4,002,290
9	Grapes	1,817,764	3,918,440
10	Apples	719,339	2,504,490
11	Onions, dry	369,892	2,007,120
12	Chilies and peppers, green	619,842	1,796,180
13	Other melons (including cantaloupes)	217,190	1,749,940
14	Cucumbers and gherkins	283,191	1,678,770
15	Olives	732,519	1,464,250
16	Oranges	250,808	1,427,160
17	Indigenous chicken meat	1,266,757	1,086,020
18	Cottonseed	176,482	1,077,440
19	Sunflower seed	230,131	992,000
20	Hen eggs, in shell	673,454	824,419

Source: FAOSTAT

3.2 SUBSECTORS WITH POTENTIAL FOR METHANE EMISSIONS REDUCTIONS

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

Table 3.2 summarizes the subsectors of the livestock production and agricultural commodity processing sectors in Turkey identified in this RA as having the greatest potential for methane emissions reductions. These include the dairy, slaughterhouse, sugar beet, olive oil, fruit processing, corn starch, fish processing, and beverage sectors. A more detailed discussion of each of these subsectors is provided in Sections 3.3 and 3.4.

Table 3.2 – Identified Potential Sectors for Methane Emissions Reductions in Turkey

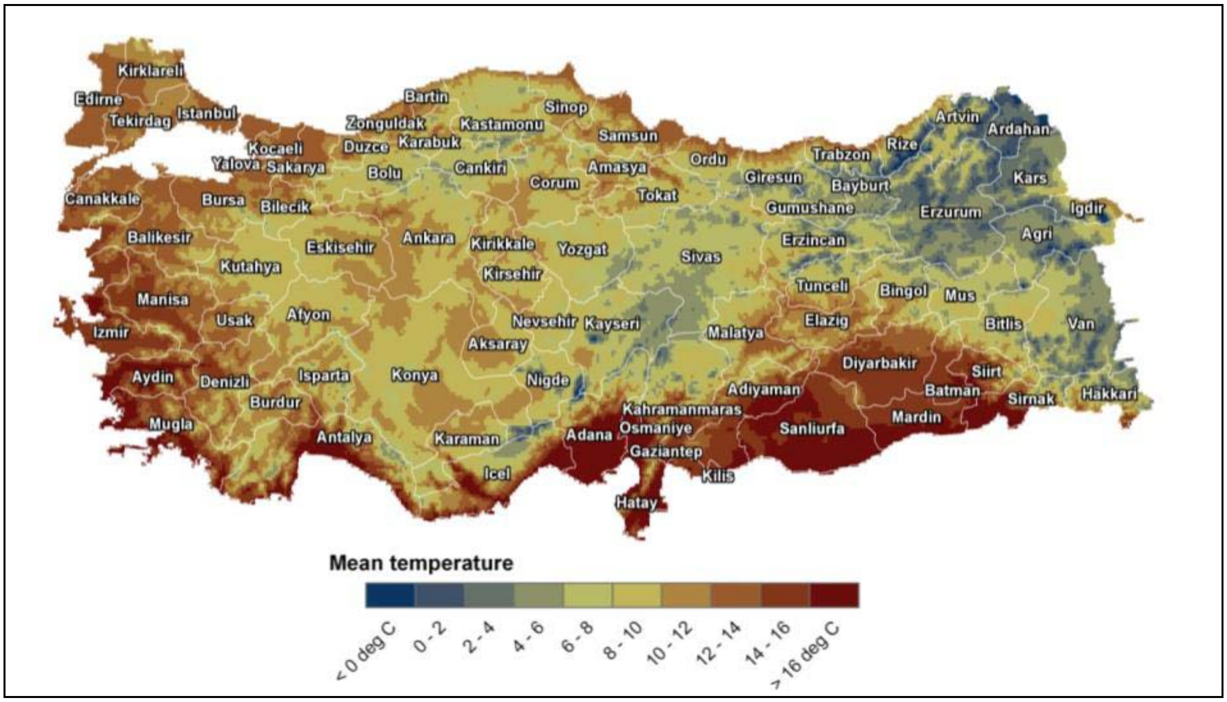
Subsector	Size (Production/Year)	Geographic Location	Potential [a]
Dairy sector	4.1 million dairy cattle, 11.6 MMT milk in 2009	Aegean, Northeastern Anatolia, Western Black Sea	Medium potential
Slaughterhouses	1.3 MMT (poultry); 371,000 MT (cattle); 110,000 MT (sheep/goat) in 2009	Aegean, Marmara, Central Anatolia	Medium potential
Sugar beet	16 MMT in 2010	Central Anatolia, Middle Black Sea	Large potential
Olive Oil	143,600 MT in 2009[2]	Marmara, Aegean, Mediterranean and South-Eastern Anatolia	Low potential
Fruit processing	737,200 MT of fruit processed in 2007[3]	No information available	Medium potential
Corn starch	~500,000 MT in 2007[4]	Istanbul, Marmara and Adana, Mediterranean	Low potential
Fish processing	61,500 MT in 2008	Marmara, Black Sea	Low potential
Alcoholic beverages	One billion liters (beer), 69 million liters (raki), 25 million liters (wine)[5]	Marmara, Aegean, Anatolia (raki); Marmara, Central Anatolia, Mediterranean and Aegean (beer)	Low potential
Non-alcoholic beverages	8,568 in 2008	No information available	Low potential

[a] Low potential: less than 100,000 /yr. Medium potential: 100,000–400,000 /yr. Large potential: more than 400,000 /yr.

Because methane production is temperature-dependent, an important consideration when evaluating locations for potential methane capture is temperature. In Turkey the annual average annual temperature ranges between 3.5°C and 20°C (Figure 3.3) with a country average for 1971–2000 of about 13°C (Sensoy, 2008). The average rainfall is between 250 and 2,200 millimeters per year (Figure 3.4) with a country average for 1971–2000 of about 640 mm (Sensoy, 2008).

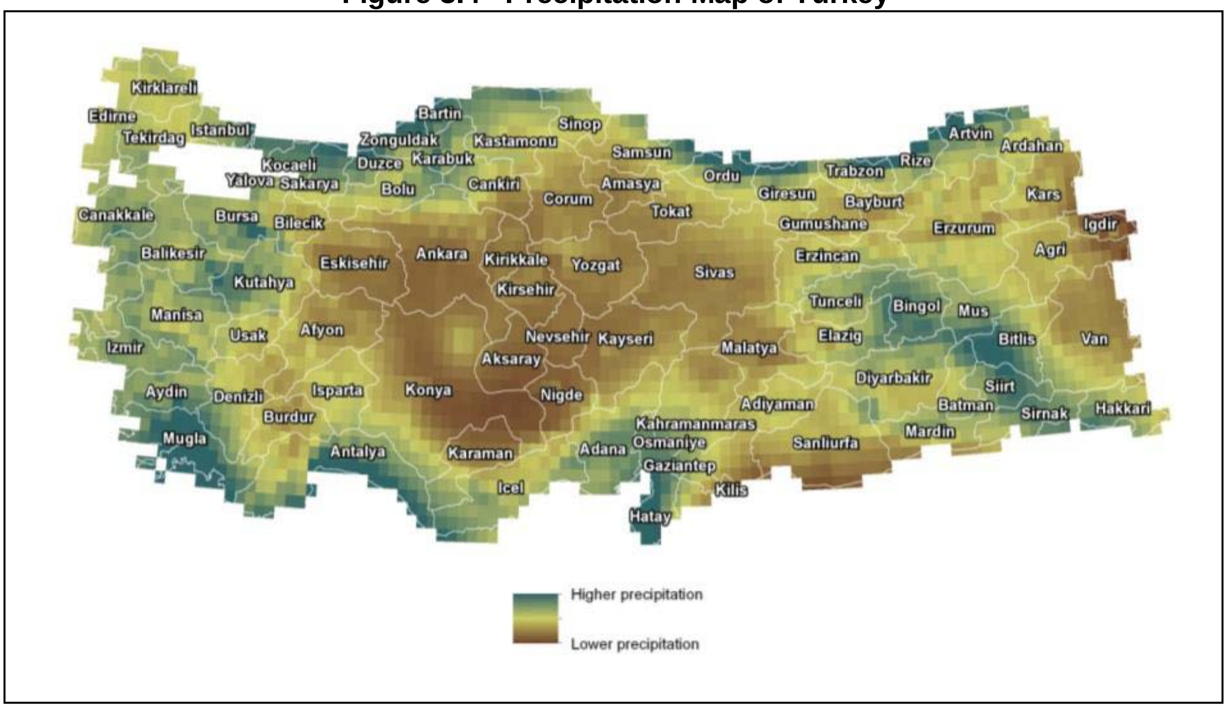
[2] FAOSTAT
[3] Eks, 2007
[4] Ataman, 2007
[5] Turkstat, 2009. Statistical Yearbook, Section 12.

Figure 3.3 – Temperature Map of Turkey



Source: Created by the authors based on data from Sensoy, 2008

Figure 3.4 –Precipitation Map of Turkey



Source: Created by the authors based on data from Sensoy, 2008

3.3 LIVESTOCK PRODUCTION

The predominant livestock in Turkey are chickens, sheep, cattle, and goats (Table 3.3).

Table 3.3 – Number of Animals Per Category in Turkey in 2008

Animal	Number of Head in 2008
Chickens	244,280,000
Sheep	23,974,591
Cattle	10,859,942
Goats	5,593,561
Turkeys, Geese, Ducks	4,763,000
Horses	179,855
Buffalo	86,297
Pigs	1,717

Source: Turkstat, 2010

3.3.1 Dairy Cattle

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

According to the statistics division of the United Nations Food and Agriculture Organization (FAOSTAT), there were a total of 10.9 million cattle in Turkey in 2009, including 4.1 million dairy cattle. Milk production from dairy cattle reached 11.6 million metric tons (MT) in 2009, and dairy sheep, goats, and buffalo contributed nearly another 1 million MT of milk. The Turkish Statistical Insititute (Turkstat) also gives the breakdown of number of animals and milk production per category of cattle. Table 3.4 presents the data from FAOSTAT and Turkstat.

Table 3.4 – Number of Milk Animals and Milk Production in Turkey in 2009

Animal	Number of Head	Milk Production (MT/yr)
Total Cattle	4,133,147	11,583,313
Cattle (culture)[a]	*1,470,886*	*5,713,004*
Cattle (crossbred)[a]	*1,686,064*	*4,585,859*
Cattle (native)[a]	*976,198*	*1,284,450*
Sheep	9,407,866	734,219
Goats	1,830,813	192,210
Buffalo	32,361	32,443
Total	15,404,188	12,542,185

[a] **Culture cattle are imported breeds of cattle, native cattle are domestic breeds of cattle, and crossbred cattle are a crossbreed of the two**

Source: FAOSTAT and Turkstat, 2009

The region with the highest concentration of dairy cattle in Turkey is Anatolia, with more than 1.7 million dairy cattle, followed by the Black Sea region, the Marmara region, and the Mediterranean region (Table 3.5).

Table 3.5 – Number of Bovine Milk Animals Per Animal Category and Per Geographical Region in Turkey in 2009

Regions	Cattle (crossbred)	Cattle (culture)	Cattle (native)	Buffalo	Total
Anatolia	740,593	362,022	635,785	12,446	1,750,846
North-eastern Anatolia	283,726	44,067	277,531	4,094	609,418
Central Anatolia	171,020	111,823	68,144	2,670	353,657
Middle-eastern Anatolia	124,930	62,212	135,826	3,228	326,196
Western Anatolia	86,225	112,520	33,884	266	232,895
South-eastern Anatolia	74,692	31,400	120,400	2,188	228,680
Black Sea	355,340	140,842	206,134	10,124	712,440
Western Black Sea	239,595	113,630	156,062	9,572	518,859
Eastern Black Sea	115,745	27,212	50,072	552	195,581
Marmara	183,261	426,097	45,871	4,351	659,580
Western Marmara	79,546	320,737	15,627	2,436	418,346
Eastern Marmara	103,715	105,360	30,244	1,915	241,234
Aegean	186,729	386,373	56,069	1,554	630,725
Mediterranean	196,681	149,720	30,806	242	377,449
Istanbul	21,459	5,832	1,534	3,645	32,470
Total	1,686,064	1,470,886	976,198	32,361	4,165,509

Source: Turkstat, 2009

According to the 2001 agricultural census from Turkstat, milk production took place in 1,746,927 cattle and buffalo holdings (Bollen, 2006) and 530,151 sheep and goat holdings (Schank, 2006). The "small and dispersed structure of milk holdings" and "lack of efficient farmer organizations" are the main problems of the dairy sector in Turkey (Petel, 2006).

According to the Ministry of Agriculture and Rural Affairs, the milk is distributed between medium-size establishments and dairies (33 percent), modern dairy factories (27 percent), direct sales (20 percent), and milk consumed by farmers (20 percent). The main milk products in 2004 were cheese (44 percent), yogurt (20 percent), butter and milk powders (19 percent), and liquid milk (14 percent) (Petel, 2006).

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

As noted in Section 2.1, little published data is available to characterize waste handling and management across Turkey's livestock and agro-industrial sectors. Since the majority of dairy farms in Turkey are small farms, which typically use dry manure management systems, it was assumed that only 2.5 percent of dairy cows are fully confined and live in farms that use open anaerobic lagoons to treat their wastewaters. IPCC default values were used to estimate volatile solids production and the maximum methane production capacity of the manure.

3.4 AGRO-INDUSTRIAL SECTORS

This section focuses on slaughterhouses, sugar beet, olive oil, fruit processing, beverages, fish processing, and starch—the sectors with the greatest potential for methane emissions or capture and use.

3.4.1 Slaughterhouses

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

Turkish meat production is composed mainly of chicken, with more than 1 million metric tons produced in 2008, followed by bovines (beef) and and ovines (lamb and goat). The quantity of pork produced in Turkey is negligible. The number of slaughtered animals and meat production in 2008 are shown in Table 3.6.

Table 3.6 – Number of Animals Slaughtered and Meat Production in 2008

Animal Category	Animals Slaughtered (head)	Meat Production (MT)
	617,986,000	1,087,680
	1,736,107	370,619
	5,588,906	96,738
	767,522	13,753
	6,100,000	12,200
	7,251	1,334
Total	632,185,786	1,582,324

Sources: [1] Turkstat, 2010; [2] FAOSTAT

According to the Ministry of Agriculture and Rural Affairs (Bollen, 2006), there were 10.1 million bovine animals in Turkey in 2004, including 4.3 million crossbred cattle (43 percent), 3.5 million domestic breed cattle (35 percent), 2.1 million purebred cattle (21 percent), and 0.1 million buffalo (1 percent). Out of this total, 2.6 million bovine animals (498,362 MT) were slaughtered in 2004. In 2005, slaughtering took place in 627 slaughterhouses for bovine animals, including 150 private and 477 public facilities. In 2001, cattle fattening took place in more than 70,000 holdings for a total of nearly 1.2 million cattle (Table 3.7).

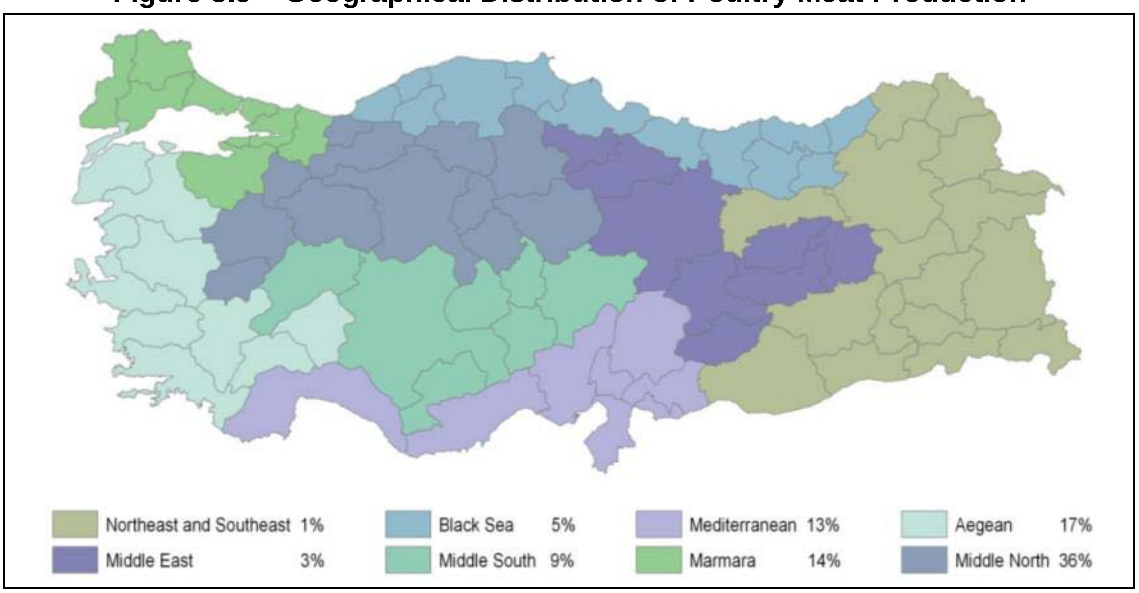
Table 3.7 – Number of   and Cattle Fattening Holdings

Size of Holding (number of cattle)	Number of Holdings Engaged in Cattle Fattening	Number of Cattle
1-4	33,205	89,816
5-9	15,151	101,762
10-19	13,246	156,082
20-49	6,684	195,082
50-149	2,067	118,986
150-299	240	60,417
300+	623	449,828
Total	71,216	1,172,753

[a] **Includes buffalo**
Source: Turkstat 2001 Agricultural Census in Bollen, 2006

According to the Ministry of Agriculture and Rural Affairs (Schank, 2006), there were 25.2 million sheep and 6.6 million goats in Turkey in 2004. The highest concentration of sheep (26 percent) was located in the southeastern region of Turkey, while the rest were dispersed throughout the country. In 2001, fattening of sheep and goats took place in 40,428 holdings with a total of 2.8 million animals. The remaining animals (about 24.8 million) were raised for milk production. Slaughtering was carried out in 564 slaughterhouses for ovine animals, including 96 private and 468 public facilities. Total ovine meat production was 276,557 MT in 2004. Poultry production is concentrated in the Middle North (36 percent), Aegean (17 percent), Marmara (14 percent), and Mediterranean (13 percent) regions (Figure 3.5). Poultry production accounted for 15 percent of total livestock production value in 2005 and 3.7 percent of total gross agricultural output (Cinar, 2006).

Figure 3.5 – Geographical Distribution of Poultry Meat Production



Source: Created by the authors based on data from Cinar, 2006

According to the White Meat Processors and Breeders Association (BESD-BIR), there were 16 poultry slaughterhouses in Turkey in 2010. These slaughterhouses had a combined hourly capacity of 10,250 chickens, 100 turkeys, 1,300 ducks, and 2,062 quail. According to BESD-BIR, total poultry production in Turkey in 2009 was 1.3 million MT (Table 3.8).

Table 3.8 – Poultry Meat Production in Turkey in 2009 and 2010

Year	Broiler Meat Production (MT/yr)	Turkey Meat Production (MT/yr)	Layer Hen Meat Production (MT/yr)	Total (broiler + turkey + layer hen) (MT/yr)
2009	1,250,000	35,000	60,000	1,345,000
2010 (estimation)	1,470,000	30,000	60,000	1,560,000

Source: BESD-BIR, personal contact

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

The COD of the wastewater from a cattle slaughterhouse in Turkey was reported to be between 2,100 and 2,425 mg/L (Kabdasli et al, 2003). This is within the range of the IPCC default values, therefore the IPCC default COD value was used for this sector.

As with other subsectors in Turkey, there are very little published data on waste characteristics, handling, and management. Based on consultations with local experts and site visits, we assumed that 30 percent of the slaughterhouses use open anaerobic lagoons. IPCC default values for the wastewater generation rate and COD level were used for the entire sector.

3.4.2 Sugar Beet Industry

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

Turkey was the fifth largest sugar beet producer in the world in 2008 and the third largest producer in Europe[6]. Sugar beet is the second main agricultural product by volume in Turkey (Table 3.1) with an estimated 15.4 million MT in 2008. Of this total, Pankobirlik, a sugar beet producers association, is estimated to produce approximately 6.4 million MT, while the rest is produced by farmers contracted by the state-owned refineries and private factories.

The Turkish Sugar Board's official count of sugar-beet-producing farms was 459,571 farms in 2003 and 209,000 farms in 2008. However, both figures are distorted,[7] and it is estimated that there are about 350,000 farms growing sugar beets in Turkey (Cakiroglu, 2010).

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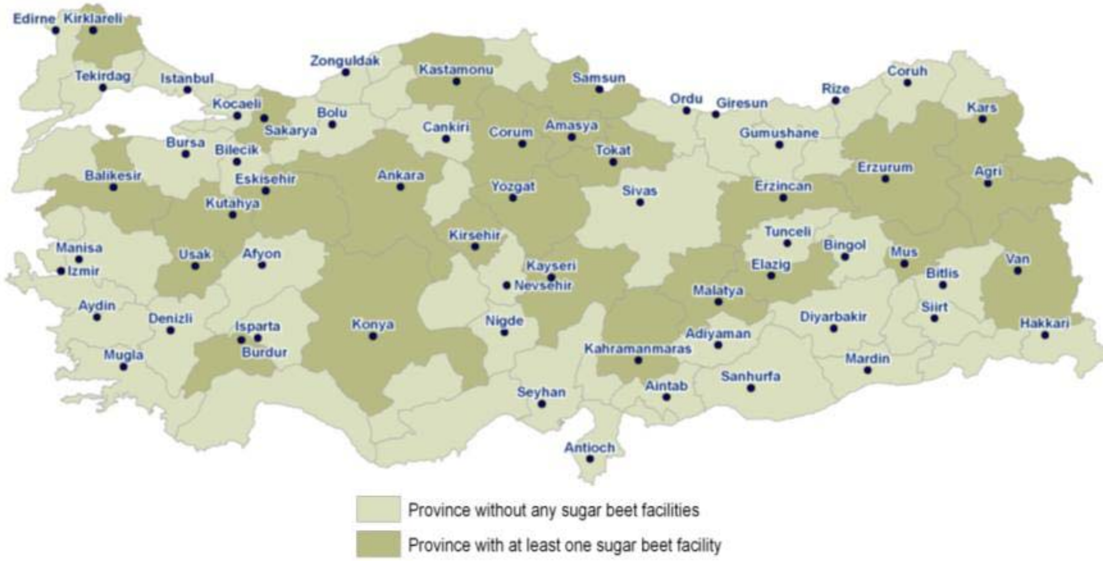
[6] http://faostat.fao.org/site/339/default.aspx

[7] Previously, in order to take advantage of advance payments, farmers registered multiple family members as individual producers, which inflated the farm numbers. More recently, beet procurement firms have demanded "farmers' documents before making advance payments," which are issued by agricultural chambers for an annual fee. Consequently producers pool production to avoid these fees, artificially deflating the number of farms (Cakiroglu, 2010).

In Turkey, sugar beets are used in the production of sugar, centrifugal sugar (crystallized sugar separated from molasses by centrifugation), starch-based sweeteners (SBS), molasses and bio-ethanol. Sugar is produced in 30 sugar beet plants (Figure 3.6 and Table 3.9), including 25 plants belonging to the state-owned Turkish Sugar Corporation (TSC) overseen by the Ministry of Industry and Trade. Total centrifugal sugar production is estimated at 2.36 million MT in 2010. Of this total, the 25 state-owned refineries are projected to produce 1.3 MMT and the 5 private refineries are projected to produce 0.96 MMT (Oztakent 2008). SBS is produced in five factories, which have a total capacity of around 932,000 MT. However, the SBS government controlled quota for 2010 was only 338,000 MT (Cakiroglu, 2010) so the producers were not able to produce as much SBS as they have capacity to produce.[8] Molasses is estimated to consume about 4 percent of the total beet production, for a total molasses production of 640,000 MT in 2010. The molasses is used in animal feed, to produce alcohol and yeast, and for exportation.

Figure 3.6 – Location of Sugar Beet Factories in



Source: Created by the authors based on data from Vuranel, 2008

[8] Turkey's Sugar Law (No: 4634) regulates the production and pricing of sugar. The purpose of the law is to regulate "the sugar industry, procedures and principles in sugar production, and conditions and methods of pricing and marketing" with the goal of increasing Turkey's self sufficiency and ensuring Turkey's demand for sugar can be met by local supply. (http://www.abgs.gov.tr/tarama/tarama_files/11/SC11DET_18_Sugar.pdf)

Table 3.9 – Sugar Beet Factories in Turkey in 2004

Region	Number of Facilities	Status	Capacity			
			Sugar Beets Processed (MT/d)	Total Sugar Production (MT/yr)	Sugar Cubes (MT/d)	Molasses Dried Pulp (MT/d)
Aegean	2	State Owned	8,800	170,000	200	588
Central Anatolia	7		36,200	673,000	213	1,138
Eastern Anatolia	8		19,900	277,000	750	1,153
Marmara	2		10,500	116,000	100	790
Mediterranean	2		9,000	164,000	—	275
Middle Black Sea	3		16,600	282,000	80	300
Western Black Sea	1		3,500	60,000	—	138
Subtotal			104,500	1,742,000	1,343	4,381
Marmara	1	Susbsidary	6,000	67,000	—	300
Aegean	1		2,000	41,000	—	178
Subtotal			8,000	108,000	0	478
Middle Black Sea	1	Private	5,500	112,000	—	200
Central Anatolia	2		14,500	338,000	80	600
Subtotal			20,000	450,000	80	800
Grand total			132,500	2,300,000	1,423	5,659

Source: MoEF, 2004

According to Cakiroglu (2010), there is only one ethanol factory using sugar beets as raw material in Turkey. "The plant has the capacity to process 800,000 MT of sugar beets annually, producing 80,000 of ethanol". In addition, Oruc (2008) mentioned that four state-owned sugar plants have the potential to produce ethanol with a total hypothetical production capacity of 60,000 of ethanol per year. He also identified three private distilleries that could potentially produce ethanol with a total hypothetical production capacity of 150,000 per year.

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

Table 3.10 presents the characteristics of wastewater at a beet molasses alcohol distillery in Turkey.

Table 3.10 – Wastewater Characteristics at a Beet Molasses Alcohol Distillery in Turkey

Parameters	Value
pH	4.98
COD (mg/L)	107,000
Total solids (mg/L)	99,666
Suspended solids (mg/L)	3,294
Volatile suspended solids (mg/L)	2,440

Source: Filik, 2006

GMI evaluated the waste management system and wastewater characteristics at three distilleries in Turkey. Of the three distilleries, two have a wastewater treatment plant with an open lagoon without methane capture prior and one has a wastewater treatment plant without any lagoon or pond. Wastewater characteristics were available for only one of the plants, and for that plant the flow was 150 of wastewater per hour and the COD concentration was 4,000 to 5,000 mg/L.

Case Study: Sugar Factory

- The plant processed 960,000 MT of beets and produced 134,000 MT of sugar in 2007–2008.
- The plant uses about 5 of wastewater per MT of sugar beets processed and generates about 1 of wastewater per MT of beets after internal recycling. Since 100 MT of sugar beets give 12–14 MT of sugar, the wastewater generation rate is equivalent to 7.7 of wastewater per MT of sugar produced.
- The COD of the wastewater is 7,600 mg/L.
- The plant started operations in 1952 and used to collect all its wastewater in conventional anaerobic lagoons before a wastewater treatment plant was installed in 2007. The treatment process consists of anaerobic treatment (hydrolysis tank + anaerobic reactor) and aerobic treatment (aeration tanks + secondary clarifiers).
- Currently, all the biogas is burned via an automatic flare. However, the plant plans to invest in equipment to harness energy from the biogas.

Open anaerobic lagoon at the sugar factory before a wastewater treatment plant was installed.

The anaerobic reactors and flare.

Source: Oztakent, 2008

Once again, due to a lack of published data for the sector, it was assumed that 80 percent of sugar beet plants use open anaerobic lagoons, based on consultations with industry experts and site visits. The wastewater generation rate and COD level of the sample plant were also used for the rest of the sector. Given that there is currently only one ethanol distillery, the emissions from this sector were considered negligible and not significant for this report.

3.4.3 Olive Oil

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

In 2009, Turkey was the third largest olive producer in the world with 1.3 million MT of olives and the sixth largest olive oil producer with 143,600 MT of olive oil (FAOSTAT). Turkey has over 107 million olive trees cultivated on 644,000 hectares (Barzoukas, 2006). The main olive growing areas in Turkey are the Marmara, Aegean, Mediterranean, and Southeastern Anatolia regions. In 2005, there were 1,005 olive oil press facilities (a decrease from 1,141 plants in 1995), with a total olive oil production capacity of 343,000 MT per year (an increase from 266,000 MT in 1995) (Table 3.11). There were also 15 olive oil refining facilities, 100 facilities for olive oil bottling and canning, 18 olive pomace oil producing facilities, and 478 table oil facilities (employing five or more employees) (Barzoukas, 2006). Approximately 55 percent of Turkey's olive oil production is exported and the remaining 45 percent is domestically consumed (Barzoukas, 2006).

Table 3.11 –Number of Olive Oil Plants in Turkey in 1995

City	Number of Plants	Number of Hydraulic Presses	Number of Super Presses	Number of Continuous Presses	Installed Capacity (1,000 MT)
Izmir	213	202	118	19	52
Aydin	173	175	61	28	46
Gaziantep	140	127	46	2	25
Balikesir	135	116	60	26	36
Mugla	133	117	44	11	27
Canakkale	95	81	41	7	20
Manisa	85	82	37	7	20
Hatay	67	51	17	24	21
Bursa	55	50	11	4	10
Icel	13	11	2	1	2
Antalya	8	5	7	1	2
Adana	7	2	4	1	1
Kocaeli	7	3	3	0	1
Kahramanmaras	5	4	2	0	1
Tekirdag	2	2	2	1	1
Digerleri	3	2	2	0	1
Total	1,141	1,030	457	132	266

Source: Tunalioglu and Karahocagil, 2006

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

With a lack of published data on this subsector, we made an assumption regarding wastewater management based on consultations and industry experts. We assumed that the majority of the sector (90 percent) directly discharges its wastewaters into the environment, while the rest of the sector (10 percent) uses open anaerobic lagoons. Average values from the literature (not Turkey-specific) were used to estimate the wastewater generation rate and COD level.

3.4.4 Fruit Processing

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

In 2007, Turkey produced nearly 20 million MT of fruit, of which 737,200 MT were processed into juices (748 million liters), concentrates (81,500 MT), and purees (125,600 MT) (Table 3.12).

Table 3.12 – Production of Major Fruits and Fruit Processed for Fruit Juices in Turkey in 2007

Fruit	Fruit Production (MT)	Fruit Processed Into Juice (MT)
Grape	3,612,000	18,300
Apple	2,450,000	356,800
Orange	1,441,000	53,300
Apricot	570,000	38,200
Peach	543,000	90,100
Cherry	170,000	72,600
Pomegranate	102,000	57,500
Carrots	642,	30,600
Quince	95,	7,500
Strawberry	250,	4,100
Tomatoes	9,945,	3,900
Other	-	4,300
Total	19,820,000	737,200

[a] FAOSTAT
Source: Eks and Akdag 2007

There were 34 active fruit juice, fruit concentrate, and puree factories in Turkey in 2007. The main fruits used for concentrate and puree production and the production quantities are listed in Table 3-13.

Table 3.13 – Main Fruit Concentrates and Purees Produced in Turkey in 2007

Fruit	Fruit Concentrate (MT)	Fruit	Fruit Puree (MT)
Apple	48,900	Peach	85,200
Cherry	14,500	Apricot	34,000
Pomegranate	5,600	Tomatoes	3,500
Grape	4,900	Apple	1,900
Carrot	4,100	Strawberry	400
Orange	1,600	Rosehip	300
Quince	1,400	Zucchini	200
Other	400	Other	100
Total	81,400	Total	125,600

Source: Eks and Akdag 2007

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

Once again, there was a lack of published data on the waste handling and management practices for this sector. Based on consultations with industry experts and site visits, we assumed that the majority of the sector (80 percent) uses open anaerobic lagoons. Default values from IPCC (not Turkey-specific) were used for the wastewater generation rate and COD level.

3.4.5 Alcoholic Beverages

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

The main alcoholic beverage produced in Turkey is beer with more than 1 billion liters produced in 2009, followed by raki (about 69 million liters) and wine (25 million liters) (Turkstat, 2010). Raki, made from raisin and aniseed, is Turkey's national drink and makes up 80 percent of domestic consumption of distilled alcoholic drinks. In 2004, raki was manufactured in six factories of TEKEL, the state-owned tobacco and alcohol company, with a total production capacity of 84.8 million liters. Beer was manufactured by two private firms and TEKEL (SPO, 2004). Table 3.14 presents the geographic location of the main raki factories in Turkey.

Table 3.14 – Geographic Location of the Main Raki Manufacturers in Turkey

City, Region	Production Capacity
Istanbul, Marmara	
Tekirdag, Marmara	
Luleburgaz/Kirklareli, Marmara	4,000,000 liter/year
Nevsehir, Central Anatolia	17,000,000 liter/year
Diyarbakir, Eastern Anatolia	10,000,000 liter/year
Manisa/Alahesir, Aegean	5,000,000 liter/year
Manisa/Aksehir, Aegean	6,000,000 liter/year
Izmir, Aegean	15,000,000 liter/year

Source: Ince et al., 2005

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

Beer: The COD of the wastewater from a local beer production factory in Istanbul was reported to range between 870 and 5,065 mg/L (Oktem and Tufeckci, 2006). The COD of the wastewater at the beer plant was reported to range between 3,000 and 4,000 mg/L (personal contact at the plant).

Raki: Ince et al. (2005) compared the performance of three full-scale upflow anaerobic sludge blanket (UASB) reactors treating alcohol distillery wastewater in Turkey and reported their wastewater characteristics (Table 3.15). The average COD of the two raki distilleries averaged 29,000 mg/L.

Table 3.15 – Wastewater Characteristics at Three Distilleries in Turkey

Parameter	Tekirdag (Raki)	Istanbul (Raki)	Canakkale (Cognac)
(mg/L)	13,000–15,000	12,000–16,000	6,000–12,500
COD (mg/L)	27,000–32,000	25,000–33,000	11,000–23,000
pH	4.0–6.0	5.5–6.0	6.5–7.0

Source: Ince, 2005

With a lack of published data regarding waste management systems employed in this sector, GMI assumed that the majority of the sector (80 percent) uses open anaerobic lagoons. We based this assumption on site visits and consultations with local experts in other sectors. Default values from IPCC (not Turkey-specific) were used for the wastewater generation rate. Average COD level from the plants surveyed was used for the sector.

3.4.6 Starch

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

In 2007, there were six major starch production plants in Turkey producing the vast majority of Turkey's total starch and derivatives. These six plants belonged to five companies: three multinational companies and two national companies (Table 3.16). All six plants use corn as the starch source.

Table 3.16 – Major Starch Companies in Turkey in 2007

Type	City, Region	Number of Plants	Percentage of Total Production
Multinational	Istanbul, Marmara	2	45%
Multinational	Adana, Mediterranean	1	30%
Multinational	Istanbul, Marmara	1	13%
National	Adana, Mediterranean	1	8%
National	Adana, Mediterranean	1	4%

Source: Ataman, 2007

In Turkey, corn starch is mainly used in the production of high-fructose syrups (~50 percent). However, since 2001, the production of SBS is limited to 10 percent (+/-5 percent) of sucrose production from sugar beets by federal laws governing sugar production. Between 2001 and 2007, sucrose production from sugar beets was around 2.3 million MT per year and therefore, SBS production was limited to ~0.35 million MT per year.

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

The waste management system and wastewater characteristics at four starch processing plants in Turkey are summarized below. This information is based on personal communication with the plants.

- Plant 1 had a wastewater treatment plant with (1) equalization pond, (2) anaerobic system with methane capture, (3) aerobic system, (4) chemical treatment, (5) final discharge; the flow was 36,000 of wastewater per month and the COD was 109.73 MT per month.
- Plant 2 had a wastetwater treatment plant with a lagoon prior to treatment; the flow was 150 of wastewater per day and the COD was ~5,000 mg/L.
- Plant 2 had a wastewater treatment plant with (1) aerobic system, (2) discharge into the “General Directorate of State Hydraulics Works” channel.
- Plant 4’s wastewater was treated at a wastewater treatment plant in the industrial zone.

With a lack of published data regarding waste management systems employed by this subsector, we assumed that 50 percent of the sector uses open anaerobic lagoons. This assumption is based on site visits and consultations with local experts in other sectors.

3.4.7 Fish processing

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

The major regions for fish processing industries in Turkey are the Marmara and Black Sea regions. The quantities of selected fish products produced in Turkey are shown in Table 3.17. The main fish processing plants in the Black Sea region are shown in Table 3.18.

Table 3.17 – Quantity of Selected Fish Products in Turkey in 2008

Fish	Quantity (MT)
Filet fish, other fish meat, fish lung and eggs (fresh or cool)	13,368
Fish, filet fish, other fish, fish lung and eggs (frozen)	41,105
Dried, salted fish or pickled fish	7,027
Canned fish, caviar and caviar products	-
Total	61,500

Source: Turkstat

Table 3.18 – Main Fish Processing Plants in the Black Sea Region, by Location

City	Capacity (MT/day)	Number of Facilities	Production Method
Rize	300	1	Fish meal and oil
Trabzon	850	1	
Samsun	1,000	1	
Sinop	1,800	1	
Trabzon	15	1	Frozen fish
Persembe	10	1	
Fatsa	10	1	
Samsun	25	2	Frozen fish, snail
Carsamba	15	1	
Sinop	40	1	

Source: Kutlu, 2007

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

As with other subsectors, published data on waste management practices for this subsector are not available. Consistent with other subsectors, we assumed that the majority of the sector (80 percent) uses open anaerobic lagoons. Default values from IPCC (not Turkey-specific) were used for the wastewater generation rate and COD.

3.4.8 Non-alcoholic Beverages

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

The quantities of selected non-alcoholic beverages produced in Turkey are shown in Table 3.19. Data on the geographic locations of the operations are not available.

Table 3.19 – Quantity of Non-Alcoholic Beverages Produced in Turkey in 2008

Beverage	Quantity ()
Mineral water, aroma, and sweeten water	5,419
Other non-alcoholic beverages	3,149
Total	8,568

Source: Turkstat

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

As above, we assumed that the majority of the sector (80 percent) uses open anaerobic lagoons. Default values from IPCC (not Turkey-specific) were used for the wastewater generation rate and COD. Because IPPC values do not exist for non-alcoholic beverages, the values for juices were used.

4. POTENTIAL FOR METHANE EMISSIONS REDUCTIONS

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 emissions reductions from manure management and agricultural commodity processing systems.

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 on the invested capital.

A number of options exist for anaerobically digesting wastes and utilizing the captured methane. For a specific project, waste characteristics will determine which digestion technology options are applicable. Of the technically feasible options, the optimal approach will be based on cost, subject to possible physical and regulatory constraints. For example, the optimal approach may not be physically feasible 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.

4.1 METHANE EMISSIONS REDUCTIONS

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 emissions reductions from a digester corresponds not to the total methane generated, but rather to the baseline methane emissions from the waste management system prior to installing the digester. The indirect emissions reductions, 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 Emissions Reductions from Digestion of Manure

The methane production potential from manure is estimated as shown in Equation 4.1:

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

where: $_{(M, P)}$ = 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
$_{(M)}$ = Maximum methane production capacity for manure produced by livestock category M (/kg volatile solids excreted)
= Methane conversion factor for anaerobic digestion (decimal)

Table 4.1 shows the estimated GHG emissions reduction potential for dairy operations in Turkey.

Table 4.1 – Methane and Carbon Emissions Reductions from Manure

Parameter	Value	Assumptions
H	104,138	• **Dairy:** Assumed only 2.5% of dairy cattle are in fully confined systems using open lagoons. Used IPCC default values of VS and for dairy cattle in Asia. • **Indirect emissions reductions:** Assumed biogas is used to generate electricity and replace electricity from the grid.
VS (kg/head/day)	2.8	
(/kg VS)	0.13	
MCF	0.8	
(MT/yr)	7,400	
(/yr)	155,700	
Indirect emissions reductions (/yr)	25,000	
Total (/yr)	180,700	

4.1.2 Direct Emissions Reductions from Digestion of Agricultural Commodity Processing Wastes

The methane production potential from agricultural commodity processing wastes is estimated as shown in Equation 4.2 and the emissions factor for the baseline waste management system used at the operation is estimated as shown in Equation 4.3:

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

where: $_{(W)}$ = Annual methane emissions from agricultural commodity processing waste W (kg /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)
$EF_{(W, S)}$ = Emissions factor for waste W and existing treatment system and discharge pathway S (kg /kg COD)

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

$$EF_{(W,S)}=B_{0\,(W)}\times MCF_{(S)} \quad (4.3)$$

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

Table 4.2 summarizes the assumptions used for calculating the methane emissions reduction potential from six agro-industrial subsectors in Turkey.

Table 4.2 – Summary of the Assumptions Used for the Calculations of the Methane Emissions Reduction Potential

Sector	Percentage of Production Using Lagoons	COD and W Values
Slaughterhouses	Assumed 30% use lagoons	IPCC default values
Sugar beet	Assumed 80% use lagoons	Turkey plant values
Olive oil	Assumed 10% use lagoons and the rest directly discharge	Estimated based on IPCC default values and literature values
Starch	Assumed 50% use lagoons	Turkey plant values
Fruit and juices	Assumed 80% use lagoons	IPCC default values
Alcoholic beverages	Assumed 80% use lagoons	Turkey plant values
Non-alcoholic beverages	Assumed 80% use lagoons	IPCC default values (for juices)
Fish processing	Assumed 80% use lagoons	IPCC default values

Table 4.3 shows the estimated GHG emissions reduction potential for six agro-industrial subsectors in Turkey. When indirect emissions are considered, the emissions reduction potential ranges from 28,300 for corn starch to nearly 500,000 for sugar beet. The total emissions reduction potential across all subsectors is over 1 million . Based on limited data and best professional judgment, the values of 0.80 appear to be reasonable estimates for ambient temperature digesters for first-order estimates of methane production potential.

To estimate the potential for indirect emissions reductions through fuel replacement, it was assumed that 50 percent of the biogas would replace natural gas, 29 percent would replace coal, and 4 percent would replace distillate fuel oil in all the subsectors except slaughterhouses. For more information, see Section 4.1.3. For slaughterhouses, it was assumed that the produced biogas would replace distillate fuel oil.

Table 4.3 – Methane and Carbon Emissions Reductions From Agro-Industrial Waste

	Slaughter-houses	Sugar Beet	Olive Oil (lagoon)	Olive Oil (direct discharge)	Corn Starch	Beer	Raki	Fruit	Non-Alcoholic Beverages	Fish Processing
Production (MT or /yr)	2,042,444	2,260,000	143,600		500,000	1,009, 295	68,927	737,200	8,568	61,500
% WMS[9]	0.3	0.8	0.1	0.9	0.5	0.8	0.8	0.8	0.8	0.8
W (/MT)	13	7.7	6	6	8	4.5	4.5	20	20	13
COD (kg/)	4.1	7.6	100	100	3	3	29	5	5	2.5
(kg /kg COD)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
MCF	0.8	0.8	0.8	0.1	0.8	0.8	0.8	0.8	0.8	0.8
(MT /yr)	6,500	21,200	1,700	1,900	1,200	2,200	1,400	11,800	140	320
(/yr)	137,200	444,400	36,200	40,700	25,200	45,800	30,200	247,700	2,900	6,700
Indirect emissions reductions (/yr)	25,800	55,400	4,500	—	3,100	5,700	3,800	30,900	360	840
Total (/yr)	163,000	499,800	40,700	40,700	28,300	51,500	34,000	278,600	3,200	7,600

9 % WMS is the percent of production that occurs in waste management systems that could be replaced by anaerobic digestion systems

4.1.3 Indirect GHG Emissions Reductions

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 replace the use of thermal fuels. Using biogas energy also reduces carbon emissions by displacing fossil fuels. The degree of emissions reductions depends on how the biogas is used. Table 4.4 shows the potential uses of biogas in each of the subsectors.

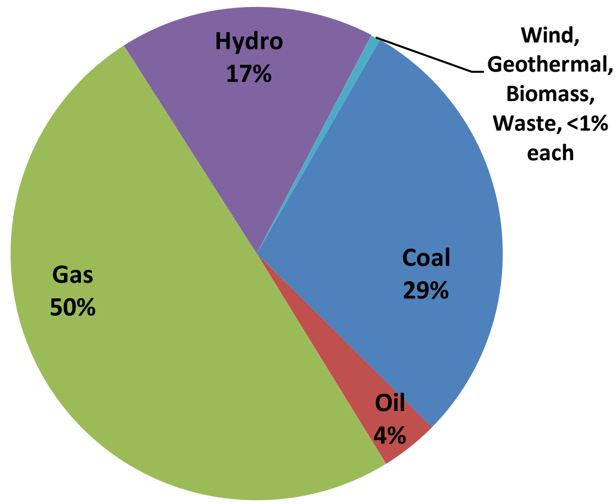
Table 4.4 – Potential Biogas Energy Use by Sector

Sector	Electricity Use	Thermal Energy Replacement
Dairy	Energy-intensive, particularly during milking operations	Liquefied petroleum gas for water heating
Slaughterhouses	Energy-intensive—coolers, freezers, pumps, and general equipment	Natural gas or fuel oil as a boiler fuel
Beverages	Energy-intensive	Natural gas or fuel oil for boiler

When biogas is used to generate electricity, the emissions reductions depends on the energy sources used by the central power company to power the generators. In Turkey, electricity generation is mainly from gas (50 percent) and coal (29 percent), as illustrated in Figure 4.1. Table 4.5 shows the associated carbon emissions reduction rate from the replacement of fossil fuels when biogas is used to generate electricity in Turkey.

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 and 4.2, it was assumed that the collected biogas would be used to generate electricity, replacing fuel oil.

Figure 4.1 – Distribution of Electricity Generation in Turkey (Total = 198,418 Gigawatt Hours in 2008)



Source: International Energy Agency, 2010

Table 4.5 – Reductions in Carbon Dioxide Emissions by Using Biogas to Generate Electricity in Place of Fossil Fuels

Fuel for Generating Electricity Replaced	Emissions Reductions
Hydro and nuclear	0 kg/kWh generated
Coal	1.02 kg/kWh generated
Natural gas	2.01 kg/ used
Liquefied petroleum gas	2.26 kg/ used
Distillate fuel oil	2.65 kg/ used

Source: Hall Associates, 2010

4.1.4 Summary

As illustrated by the equations presented earlier, the principal factor associated with 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,* anaerobic lagoons and landfills 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 reductions 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 4.6 summarizes the findings of the RA in terms of potential methane emissions reductions and carbon offsets in Turkey. The sector with the highest potential for methane reduction and carbon offsets is the sugar beet sector (499,000 /yr).

Table 4.6 – Summary of Total Carbon Emissions Reductions Identified in Turkey

Sector	Methane Emissions Reductions (MT /yr)	Carbon Emissions Reductions (/yr)	Fuel Replacement Offsets (/yr)	Total Carbon Emissions Reductions (/yr)
Dairy	7,400	155,700	25,000	180,700
Slaughterhouses	6,500	137,200	25,800	163,000
Sugar beet	21,200	444,400	55,400	499,800
Olive oil	3,600	76,900	4,500	81,400
Corn starch	1,200	25,200	3,100	28,300
Alcoholic beverages	3,600	76,000	9,500	85,500
Fruit processing	11,800	247,700	30,900	278,600
Fish processing	320	6,700	840	7,600
Non-alcoholic beverages	140	2,900	360	3,200
Total	55,300	1,172,700	155,400	1,328,100

4.2 TECHNOLOGY OPTIONS

4.2.2 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 of particulate matter, 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 Manure: For livestock manure, four anaerobic digestion reactor options exist: 1) plug-flow, 2) mixed, 3) covered lagoon, and 4) attached growth. The appropriate option or options are determined by the concentration of particulate matter, generally measured as total solids (TS) concentration in the collected manure; type of manure; and climate, as shown in Table 4.5. The TS concentration in the collected manure is determined by the method of collection—mechanical (scraping) or hydraulic (flushing)—and the volume of water used for hydraulically collected manure.

Table 4.7 – Overview of Anaerobic Digestion Options for Livestock Manures (Based on EPA, 2004)

	Plug-flow	Mixed	Covered Lagoon	Attached Growth
Influent TS concentration (%)	11–13	3–10	0.5–3	<3
Manure type	Only dairy cattle	Dairy & swine	Dairy & swine	Dairy & 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 & warm	Temperate & warm

Source: U.S. EPA, 2004

As indicated in Table 4.7, use of covered lagoons and attached growth reactors for methane production 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 therefore, 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. Due to wide variation in physical and chemical characteristics, no single treatment process, except for the covered anaerobic lagoon, is suitable for all of these wastewaters. Even the physical and chemical characteristics of wastewater from the processing of a single commodity can vary widely, reflecting differences in processing and sanitation practices. For example, some processing plants prevent solid wastes from entering the wastewater generated to the extent possible, whereas 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 [TSS]) or extremely high concentrations of dissolved organic matter (BOD or COD), alternatives include the complete mix, anaerobic contact, or anaerobic sequencing batch reactor (ASBR) processes. These are typically operated at mesophilic (30 to 35°C) or thermophilic (50 to 55°C) conditions.

As shown in Table 4.8, the anaerobic contact and ASBR processes operate at significantly shorter hydraulic retention times (HRTs) than the complete mix process. A shorter required HRT 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 4.8 – Typical Organic Loading Rates for Anaerobic Suspended Growth Processes at 30°C

Process	Volumetric Organic Loading, kg COD/-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 TSS concentrations or wastewaters with low TSS concentrations after screening or some other form of TSS reduction, such as DAF, one of the anaerobic sludge blanket processes may be applicable. Included are the 1) basic upflow anaerobic sludge blanket (UASB), 2) the anaerobic baffled reactor, and 3) 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 generally is limited to high-carbohydrate wastewaters.

Attached growth anaerobic processes represent another option for agricultural commodity processing wastewaters with low TSS concentrations. Included are the 1) upflow packed-bed attached growth, 2) upflow attached growth anaerobic expanded bed, 3) attached growth anaerobic fluidized bed, and 4) down-flow 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 facilities 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, the addition of nutrients such as nitrogen or phosphorus and a buffering compound to provide alkalinity and control pH may be necessary.

4.2.3 Methane Use Options

In addition to methane, carbon dioxide is also a significant product of the anaerobic microbial decomposition of organic matter. Collectively, the mixture of these two gases commonly 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 kJ/, a typical biogas composition of 60 percent methane and 40 percent carbon dioxide has a lower heating value of 21,453 kJ/. Thus, biogas has a low energy density compared to 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.

Using biogas in place of coal, natural gas, liquefied petroleum gas, or distillate or heavy fuel oil for water or space heating is the most attractive option due to simplicity and the possibility of utilizing existing boilers or furnaces modified to burn a lower energy density fuel. Conversion of a natural gas- or liquefied petroleum gas-fueled boiler or furnace to a biogas furnace generally only requires replacing 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 is an option that 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 to using biogas to generate electricity connected to the grid is the ability to use biogas as it is produced and to use the local electricity grid to dispose of excess electrical energy when generation capacity exceeds onsite demand. The use of biogas to generate electricity not only will reduce farm operating costs, but also will provide a steady revenue stream for the farm.

Given the potential for biogas production in Turkey, there is the potential to produce 31,800 kW of electricity annually from the sectors evaluated in this RA. This estimate assumes a thermal conversion efficiency of methane to electricity of 35 percent and uses the lower heating value of methane.

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 also can be considered an option. However, this can be considered an option only to the degree that replacing the current methane-emitting waste management practice with anaerobic digestion reduces methane emissions. Systems utilizing biogas from anaerobic digestion as a boiler or furnace fuel or for generating electricity should have the ability to flare excess biogas, but flaring should be considered an option only if biogas production greatly exceeds the opportunity for utilization.

4.3 COSTS AND POTENTIAL BENEFITS

The cost of anaerobically digesting livestock manures and agricultural commodity processing wastes and utilizing the methane captured as a fuel depends on the type of digester constructed and the methane utilization option employed. In addition, these costs will vary geographically, reflecting local financing, material, and labor costs. However, it can be assumed that capital costs 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 blanket 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 the 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 biogas hydrogen sulfide removal process.

4.3.2 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 the reduction of methane emissions by the addition of anaerobic digestion. MCFs, and therefore reductions 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 the biogas captured 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, the revenue realized from its use in place of a conventional source of energy is determined by the cost of the conventional source of energy replaced. If low-cost hydropower-generated electricity is available, the revenue derived from using biogas to generate electricity may not justify the required capital investment and operating and maintenance costs. Another factor that must be considered in evaluating the use of biogas to generate electricity 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, the ability to deliver excess generation to the local grid during periods of low onsite demand and the subsequent ability to reclaim it during periods of high onsite demand under some type of a net metering contract should exist.

The third potential source of revenue is from the carbon credits realized from the reduction in the fossil fuel carbon dioxide emissions when using 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. In using biogas 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, due to high capital and operating costs, small livestock production and agricultural commodity processing enterprises are not suitable candidates for anaerobic digestion to reduce methane emissions from their waste streams. The same is true for enterprises that only generate wastes seasonally. If all of the enterprises are located in a reasonably small geographical area, combining compatible wastes from two or more enterprises for anaerobic digestion located at one of the waste sources or a centralized location is a possible option. By increasing project scale, unit capital cost will be reduced. However, operating costs will increase and centralized digestion will not always be a viable option if the ability to generate adequate revenue to at least offset the increased operating costs is lacking.

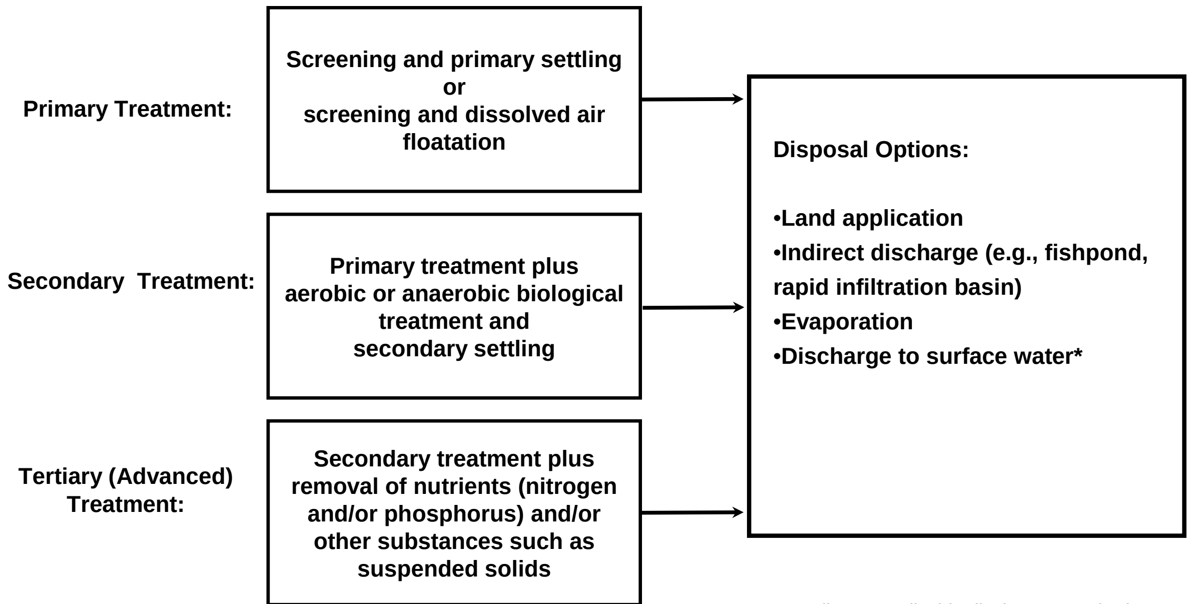
There are two possible models for centralized anaerobic digestion projects. In the first model, digestion occurs at one of the sources of waste, with the waste from the other generators transported to that site. In the model that typically is followed, wastes from one or more agricultural commodity processing 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 would be a more efficient approach. Although obtaining the optimal solution manually is possible, using linear programming should be considered. With this approach, optimal locations with respect to minimizing transportation costs for a number of scenarios can be obtained and compared. 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 carbon credits realized from reducing methane emissions and utilizing 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 onsite 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 onsite 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 costs will be at the waste source with the highest onsite opportunity for methane utilization. Thus, waste transportation costs will be minimized while revenue will be maximized. However, the digester location that minimizes transportation costs may not maximize revenue from methane utilization due to low onsite energy demand. Therefore, alternative digester locations should be evaluated to identify the location that maximizes the difference between revenue generation from methane utilization and transportation costs. 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: TYPICAL WASTEWATER TREATMENT UNIT PROCESS SEQUENCE



*According to applicable discharge standards

APPENDIX B: 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.

Aerated Pond or Lagoon—A wastewater treatment pond or lagoon in which mechanical or diffused aeration is used to supplement the oxygen supplied by diffusion from the atmosphere.

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 example of an aerobic waste treatment process.

Anaerobic—The absence of air or free elemental oxygen.

Anaerobic Contact Process—Any anaerobic process in which biomass is separated from the effluent and returned to a complete mix or contact reactor so that the solids retention time (SRT) is longer than the hydraulic retention time (HRT).

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 the 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.

Bacteria—A group of universally distributed and normally unicellular microorganisms lacking chlorophyll.

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.

Biological Treatment Processes—There are two general types of biological waste treatment processes: suspended and attached growth. Suspended growth processes generally involve mixing to enhance contact between the microbial population and the wastewater constituents. Suspended growth processes can be either aerobic or anaerobic. The activated sludge process is an example of suspended growth wastewater treatment process. Attached growth processes are characterized by the development of a microbial population attached to a natural or artificial media when exposed to wastewater constituents. The trickling filter is an example of an attached growth wastewater treatment process. Attached growth processes also can be either aerobic or anaerobic.

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.

Clarifier—Any large circular or rectangular sedimentation tank used to remove settleable solids from water or wastewater. Special types of clarifiers, called upflow clarifiers, use flotation rather than sedimentation to remove solids.

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

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 Flotation (DAF)—A separation process in which air bubbles emerging from a supersaturated solution become attached to suspended solids in the liquid undergoing treatment and float 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 that is transparent to incoming solar radiation but absorbs the infrared radiation reflected form the earth’s surface. The principal GHGs are carbon dioxide, methane, and chlorofluorocarbons.

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

Hydrolysis—The reduction of insoluble organic and complex soluble organic compounds to simple soluble organic compounds.

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.

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°C to 38°C.

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

Organic Matter—Chemical substances of animal or vegetable origin, or more accurately, 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 anaerobically for the stabilization of organic wastes, including manures, 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) Sometimes used interchangeably with the concept of biological wastewater treatment, particularly the activated sludge process. Commonly applied to treatment that consists chiefly of clarification followed by a biological process, with separate sludge collection and handling.

Solids Retention Time (SRT)—The average time in which solids, including the population of active microbial biomass, remain in a reactor.

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.

Thermophilic Digestion—Digestion carried on at a temperature approaching or within the thermophilic range, generally between 43°C and 60°C.

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 upflow anaerobic reactor in which influent flows upward through a blanket of flocculated sludge that has become granulated.

Volatile Solids (VS)—Materials, generally organic, that can be driven off by heating, usually to 550°C; nonvolatile 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. Typically will include the combination of primary and secondary treatment processes.

*Appendix A illustrates the typical wastewater treatment process.

APPENDIX C: BIBLIOGRAPHY

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