Resource Assessment for Livestock and Agro-Industrial Wastes – Argentina

Prepared for:

U.S. EPA
Methane to Markets Program

Prepared by:

Eastern Research Group, Inc.   PA Consulting Group

July 13, 2009

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Eastern Research Group, Inc.
1600 Perimeter Park Drive
Suite 200
Morrisville, NC 27560

PA Consulting Group
4601 N. Fairfax Drive,
Suite 600
Arlington, VA 22203

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EXECUTIVE SUMMARY

The Methane to Markets Partnership is an initiative to reduce global methane emissions to enhance economic growth, promote energy security, improve the environment, and reduce greenhouse gases. The initiative focuses on cost-effective, near-term methane recovery and use as a clean energy source. It is being done internationally through collaboration between developed countries, developing countries, and countries with economies in transition - together with strong participation from the private sector.

The initiative works in four main sectors: agriculture, landfills, oil and gas, and coal mines. The Agriculture Sub-Committee was created in November 2005 to focus on livestock wastes, and has expanded to include agro-industrial processes. Argentina and United Kingdom are the current co-chairs of the sub-committee.

As part of the Methane to Markets Partnership, USEPA is conducting a livestock and agro-industry resource assessment in Argentina to identify and describe the potential for incorporating anaerobic digestion into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy.

The following table summarizes the findings of the resource assessment in terms of potential methane emission reductions and carbon offsets in Argentina. The sector with the highest potential for methane reduction and carbon offsets is the sugar/distilleries sector, followed by swine, dairy, slaughterhouses, and finally citrus processing. However, it is important to note that the citrus processing sector takes into consideration only one product (lemons) and one geographic area (Tucuman); the total citrus processing sector is expected to be higher than estimated in the resource assessment due to this limitation in the data used.

The following table summarizes the total carbon emission reductions identified in Argentina.

Sector	Methane Emissions Reductions (MT CH_4/yr)	Carbon Emissions Reductions (MT CO_2e/yr)	Fuel Replacement Offsets (MT CO_2e/yr)	Total Carbon Emissions Reductions (MT CO_2e/yr)
Sugar mills + distilleries	41,100	864,600	162,800	1,027,400
Swine	19,600	412,000	77,600	489,600
Dairy	16,800	353,000	66,500	419,500
Slaughterhouses (swine + cattle)	9,300	196,900	37,000	233,900
Citrus	4,100	87,800	16,500	104,300
TOTAL	90,900	1,914,300	360,400	2,274,700

ACKNOWLEDGEMENTS

This work has relied on the support of the National Bioenergy Program of the Instituto Nacional de Tecnología Agropecuaria (INTA) of Argentina. Through the different stages of the project, INTA provided key data, information support, field surveys and technical visits to different sites in Argentina and review and suggestions for the study. We would like to acknowledge the significant contributions of INTA done by the rural engineering institute and Marcos Juarez and Rafaela experimental stations.

We give our special thanks to the Coordinator of the National Bioenergy program of INTA Jorge A. Hilbert; to the Coordinador Regional de Fiscalización Alimentaria Regional Santa Fe of Servicio Nacional de Sanidad y Calidad Agroalimentaria SENASA Victor Di Pascuale; and to the Director of EG-Ingeniería Eduardo Gropelli and their staff for providing us valuable information for the development of this study.

TABLE OF CONTENTS

Appendices

List of Abbreviations

AD	anaerobic digestion
BOD	biochemical oxygen demand
CH_4	methane (chemical formula)
COD	chemical oxygen demand
FAO	United Nations Food and Agriculture Organization
GHG	greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
INDEC	Instituto Nacional de Estadísticas y Censo
INTA	Instituto Nacional de Tecnología Agropecuaria
INTI	Instituto Nacional de Tecnología Industrial
$MMTCO_2e$	million metric tons of carbon dioxide equivalent
ONCCA	Oficina Nacional de Control Comercial Agropecuario
RA	Resource assessment
SAGPyA	Secretaría de Agricultura, Ganadería, Pesca y Alimentación
SAyDS	Secretaría de Ambiente y Desarrollo Sustentable
SECYT	Secretaría de Ciencia, Tecnología e Innovación Productiva
SENASA	Servicio Nacional de Sanidad y Calidad Agroalimentaria
MT	metric tones
USEPA	United States Environmental Protection Agency

1. INTRODUCTION

The main objective of this resource assessment is to identify the potential for incorporating anaerobic digestion into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy in Argentina. This report documents the resource assessment, discusses the most attractive sectors and locations, and prioritizes the sectors in terms of potential methane emissions reductions.

While there are other studies showing methane emissions from the sectors covered in this document, these studies usually take total population or production levels as the baseline for calculating the emissions. This resource assessment, however, uses a different approach, recognizing that not all waste management operations (e.g., pastures) generate methane. It bases its methane emissions reduction estimates 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 sub-sector. For example, methane emissions from swine and dairy sub-sectors only take into account a reasonable fraction of the total population and number of operations in the country. These assumptions provide a better basis for policy development and capital investments.

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

1.1 METHANE EMISSIONS FROM LIVESTOCK WASTES

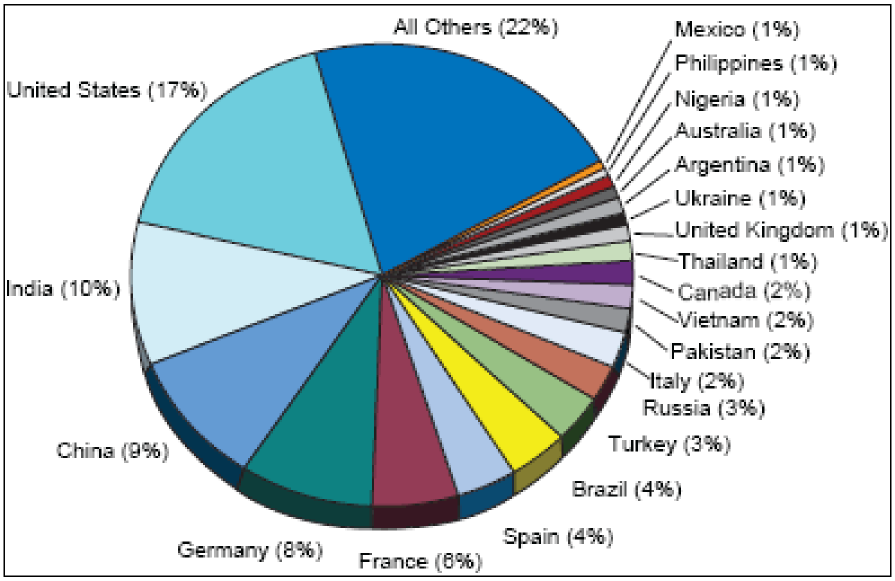
Globally, livestock manure management contributes more than 230 million metric tons of carbon dioxide equivalent ($MMTCO_2E$) of methane emissions, roughly 4 percent of total anthropogenic (human-induced) methane emissions. Three groups of animals account for more than 80 percent of total emissions: swine (40 percent); non-dairy cattle (20 percent); and dairy cattle (20 percent). In certain countries, poultry is also a significant source of methane emissions. Figure 1.1 represents countries with significant methane emissions from livestock manure management.

The Methane to Markets Partnership is conducting resource assessments in several countries to identify the types of livestock and agro-industrial sub-sectors (e.g., dairy, palm oil, sugar cane) with the greatest opportunities for cost-effective implementation of methane recovery systems. The resource assessment objectives are:

- Identify and characterize methane reduction potential in Argentina,
- Develop country market opportunities,
- Provide location of resources and provide a ranking of resources.

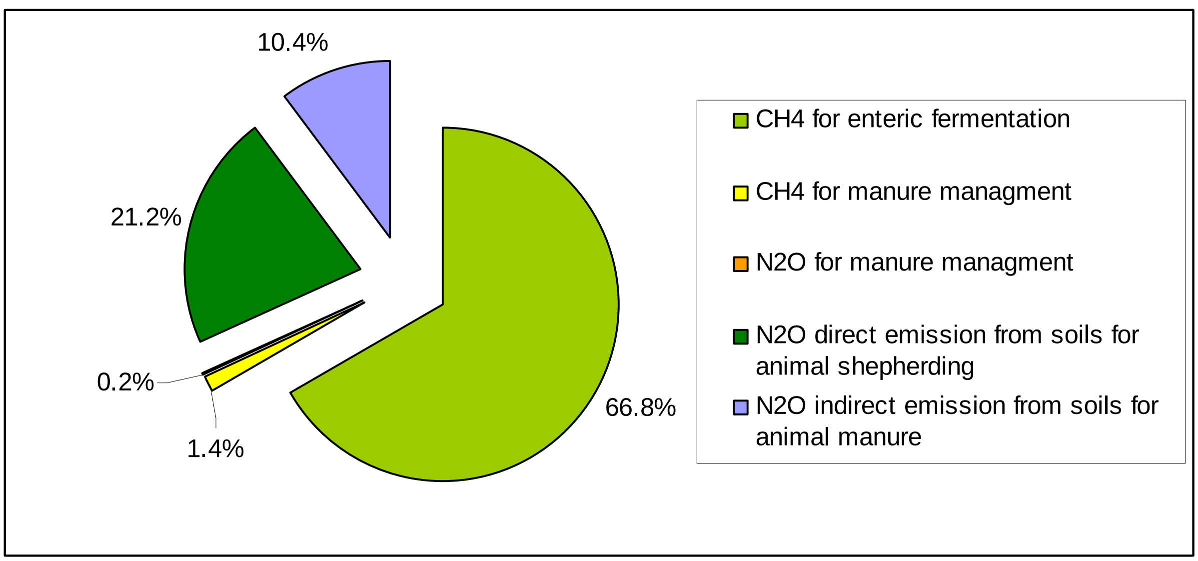
As part of its Partnership activities, Argentina developed a methane emissions country profile on September 2006. This profile estimated the total greenhouse gases (GHG) emissions from the farming sector using the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). As shown in Figure 1.2, methane (CH_4) from enteric fermentation is the principal source of GHG emissions from the farming sector in Argentina followed by nitrous (N_2O) emissions from animal manure excreted on pasture and range soils. The estimated N_2O emissions from soils used for confined animal manure disposal also are significant, but both CH_4 and N_2O emissions from confined livestock manure management systems appear only nominal. However, the CH_4 emissions from confined livestock manure management systems can be reduced though the use of anaerobic digestion under controlled conditions with the capture and combustion of the CH_4 produced.

Figure 1.1 - Estimated Global Methane Emissions From Livestock Manure Management (2005), Total = 234.57 $MMTCO_2E$.



Source: Methane to Markets, Background Information

Figure 1.2 - GHG Farming Emissions Contribution by Categories in Argentina



Source: Berra G. and L. Finster, 2000

Argentine farming GHG emissions by categories are shown in Table 1.1. Appendix A includes emission factors for Argentina's national greenhouse gas inventory.

Table 1.1 – Annual Methane Emissions From Livestock Manure Management by Species in Argentina (2000)

Species	CH4 (MT)	MTCO2eq	Contribution to the category (%)
Dairy cattle	1.99	41.83	3.48
Non-dairy cattle	47	987	82
Sheeps	1.68	35.31	2.93
Goats	0.49	10.26	0.85
Pigs	2.35	49.39	4.1
Horses	2.31	48.42	4.02
Poultry	1.02	21.42	1.78
Buffalos	0	0.02	0
Donkeys and mules	0.17	3.61	0.3
South-American camelids	0.31	6.42	0.53
Total	57.32	1203.7	100

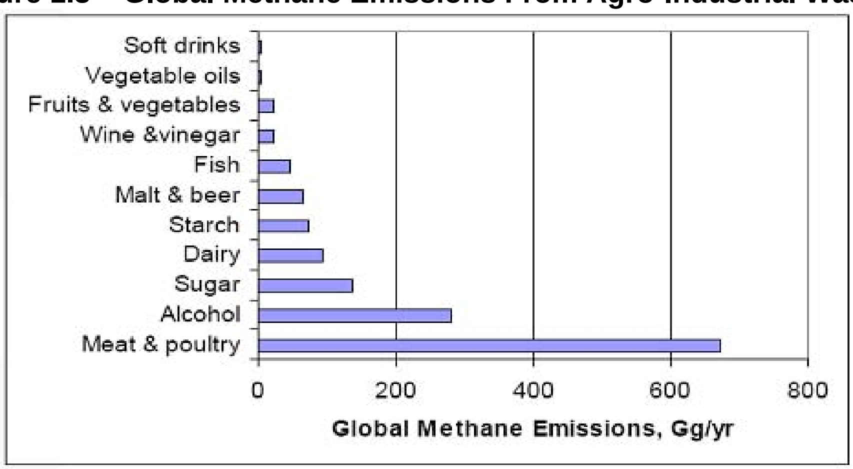
Source: Berra G. and L. Finster, 2000

While methane emissions from animal manure treatment (57 MT CH4/yr) are small compared to enteric fermentation emissions in the sector, they are still an important source of methane; more importantly, these emissions can be captured through anaerobic digestion and used as an energy source. As shown in Table 1.1, more than 85% of the CH_4 emissions are produced by cattle, with non-dairy cattle the main contributor to GHG emissions from farming activities.

1.2 METHANE EMISSIONS FROM AGRO-INDUSTRIAL WASTES

Agro-industry is an important source of methane emissions. The organic fraction of agro-industrial wastes typically is more readily biodegradable than manure. Thus, greater reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), and volatile solids (VS) during anaerobic digestion can be realized. The higher readily biodegradable fraction of agro-industrial wastes translates directly into higher methane production potential. Figure 1.3 shows global CH_4 emissions from agro-industrial wastes.

Figure 1.3 – Global Methane Emissions From Agro-Industrial Wastes



From Doorn et al. 1997

As shown in Table 1.2, the majority of agro-industrial wastes 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 reduction through the installation of appropriate anaerobic digestion systems.

Table 1.2 – Disposal Practices From Agro-Industrial Wastes

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

From Doorn et al. 1997

2. BACKGROUND AND CRITERIA FOR SELECTION

2.1 METHODOLOGY USED

The team used a variety of data sources for conducting the resource assessment including:

Field visits to local sites in various sectors and scales of operations to characterize the waste management systems used and to verify the information collected through other sources.

Interviews with local experts from pertinent ministries (e.g., ministries of agriculture, environment, and energy), local NGOs and engineering/consulting companies working on agriculture and rural development, current users of AD technologies, and other stakeholders. The main government stakeholders at the national level in Argentina include the ministry of environment (SAyDS), specifically the Climate Change Office (DCC), the Ministry of Agriculture (SAGPyA), the Ministry of Energy, the National Institute for Agriculture and Livestock Technology (INTA), and the National Institute for Industrial Technology (INTI).

Secondary data including national and international data (e.g., United Nations Food and Agriculture Organization animal production data sets), specific sub-sector information from business and technical journals, and other documents, reports and statistics.

The team employed the following approach, which will be replicated in future resource assessments in this series:

Step 1: The first step in the development of the Argentina livestock and agro-industry resource assessment was the construction of general profiles of the individual sub-sectors (or commodity groups, e.g., dairies, swine, fruit processing). Each profile includes a list of operations used within the sub-sector 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 average annual standing population, (e.g. number of lactating dairy cows, beef cattle, pigs). For the various commodity groups in the agro-industry sector, the metric is the mass or volume of annual processing capacity or the mass or volume of the commodity processed annually.

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

Step 3: With this information, the team focused initially on those commodity groups in each sector with the greatest potential to emit methane from waste management activities. For example, a country's livestock sector may 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. We initially focused on those commodity groups with higher emissions to most effectively utilize available resources. Ideally, these livestock production and agro-industry sector profiles can be assembled from statistical information published by a government agency. If such information was unavailable or inadequate, a credible secondary source, such as the United Nations Food and Agriculture Organization (FAO), was used.

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 methane emissions. Additionally, the waste management practices employed by the largest producers in each commodity group should be relatively uniform. Unfortunately, in Argentina the information about waste management practices, especially in the livestock production sector, is not always collected and compiled, is incomplete or not readily accessible. Thus, it was necessary to identify and directly contact producer associations, local consultants and business advisors and visit 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 initially receive further analysis. For example, large operations in a livestock commodity group, such as beef or dairy, that relies primarily on a pasture-based production system, where manure is distributed continuously by the grazing animals, will have only nominal methane emissions because manure decomposition will be primarily by aerobic microbial activity. Similarly, an agro-industry sub-sector with large operations that utilize direct discharge of untreated wastewater to a river, lake, or ocean will not be the source of significant methane emissions. Thus, the process of estimating current methane emissions will be sharply focused to most effectively utilize available resources. This profiling exercise will 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 method were used for estimating methane emissions from each commodity group in the livestock production sector. Using the Tier 2 method, methane emissions for each livestock commodity group (M) and existing manure management system (S) and climate (k) combination are estimated as follows using Equation 2.1:

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

where:

- $CH_{4\,(M)}$ = estimated methane emissions from manure for livestock category M, kg CH_4 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
- $B_{o(M)}$ = maximum methane production capacity for manure produced by livestock category M, m^3 CH_4 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 volatile solids 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 requires identification of the appropriate MCF, which is a function of the current manure management system and climate. MCFs for various types of manure management systems for average annual ambient temperatures ranging from ≤ 10 to ≥ 28 °C are summarized in Table 2.2, and can be found in Table 10.17 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

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

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

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

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

Region	Dairy Cows	Breeding Swine	Market Swine
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 raw material not processed or discarded after processing due to spoilage, poor quality, *etc.* One example is the combination of wastewater and the solids removed by screening before wastewater treatment or direct disposal. These solid organic wastes may have relatively high moisture content and are commonly referred to as wet wastes. Appendix B illustrates a typical wastewater treatment unit process sequence. The methods for estimating methane emissions from both are presented below.

a. WASTEWATER

For agricultural commodity processing wastewaters, such as meat and poultry processing wastewaters, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Tier 2 method (Section 6.2.3.1), which utilizes chemical oxygen demand (COD) and wastewater flow data, is an acceptable methodology for estimating methane emissions. Using the Tier 2 method, 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:

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

where:
- $CH_{4\,(W)}$ = annual methane emissions from agricultural commodity processing waste W, kg CH_4 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
- $EF_{(W,S)}$ = emission factor for waste W and existing treatment system and discharge pathway S, kg CH_4 per kg COD
- $R_{(W)}$ = mass of CH_4 recovered, kg per year

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

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

where:
- $B_{o\,(W)}$ = maximum CH_4 production capacity, kg CH_4 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 B_o are not available, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories default value of 0.25 kg CH_4 per kg COD, based on stoichiometry, 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	MCF[1]	Range
Untreated			
Sea, river, or lake discharge	Rivers with high organic loadings my 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

[1] Based on IPCC expert judgment

If the annual mass of COD generated per year (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.

$$TOW_{(W)} = P_{(W)} \quad W_{(W)} \quad COD_{(W)} \qquad (2.4)$$

where: $P_{(W)}$ = product production rate, metric tons per year
$W_{(W)}$ = wastewater generation rate, m^3 per metric ton of product
$COD_{(W)}$ = wastewater COD concentration, kg per m^3

Table 2.5 – Examples of Industrial Wastewater Data, Doorn et al. (1997)

Industry	Typical Wastewater Generation Rate, m^3/metric ton	Range of Wastewater Generation Rates, m^3/metric ton	Typical COD Concentration, kg/m^3	Range of COD Concentrations, kg/m^3
Alcohol	24	16—32	11	5—22
Beer	6.3	5.0—9.0	2.9	2—7
Coffee	NA	NA	9	3—15
Dairy products	7	3—10	2.7	1.5—5.2
Fish processing	NA	8—18	2.5	—
Meat & 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

b. SOLID WASTES

A variety of methods are possible for the disposal of solids wastes generated during the processing of agricultural commodities. Included are: 1) land application, 2) composting, 3) placement in a landfill, and 4) open burning. In addition, disposal of solid wastes from meat and poultry processing, such as solids separated from wastewater by screening and dissolved air flotation, may be disposed of by rendering.

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

Because the mechanisms responsible for the degradation of these wastes are similar to those of livestock manure following land application, the appropriate MCF value for manure disposal by daily spreading listed in Table 10.17 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories should be used. For composting, the IPCC default value of 4 g CH_4 per kg of wet waste, should be used. When agricultural commodity processing wastes are disposed of in landfills, the applicable MCF depends on the type of landfill as shown in Table 2.6.

Table 2.6 – Types of Solid Waste Landfills and Methane Conversion Factors

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

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

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

For all four disposal options, the commodity specific rate of solid waste generation must be known. In addition, information about the concentration of COD in the solid waste, on a wet weight basis, is necessary for all but the composting disposal option. However, COD concentration generally has not been used as a parameter for agricultural commodity processing solid waste characterization. The alternative is to use published values from studies of methane production potential on a volume or mass of methane produced per unit mass of wet waste, or volatile solids added basis as a first-order estimate for B_o for the waste under consideration. If the COD concentration in the solid waste is known, the methane emissions resulting from land application and landfill disposal with the appropriate MCF is calculated using Equation 2.6:

$$CH_{4\,(SW)} = TOW_{(SW)} \quad B_o \quad MCF_{(SW,\,D)}] \qquad (2.6)$$

where: $CH_{4(SW)}$ = annual methane emissions from agricultural commodity processing waste SW, kg CH_4 per year

$TOW_{(SW)}$ = annual mass of solid waste SW COD generated, kg per year

$MCF_{(SW,\,D)}$ = methane conversion factor for solid waste W and existing disposal practice S, decimal

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 are the following:

Large sector/sub-sector: The category is one of the major livestock production or agro-industries in the country.

High volumes of wastes going to lagoons: The livestock production or agro-industry generates high volume of wastewater.

Wastes with high organic content: The wastewater generated has a high organic load as measured in terms of its BOD and COD.

Geographic distribution: There is a concentration of priority sectors in specific regions of the country, making centralized or co-mingling projects potentially feasible.

Energy intensive: There is sufficient energy consumption to absorb the generation from recovered methane.

The top industries that meet all of the above criteria are swine production, dairies, slaughterhouses, sugar distilleries, and fruit processing. The wine and milk processing sectors were also identified as having potential methane emissions, but the information gathered was not sufficient to characterize their waste management systems and volumes/flows of wastes, therefore these sectors are not included as part of the main report; more information on these sectors can be found in Appendix C.

Other livestock sub-sectors such as feedlots and poultry were not considered because the methane emissions generated from those sectors are low. More information about these two sectors can be found in the study conducted under World Bank funding, entitled “Evaluación, diagnóstico y propuestas de acción para la mejora de las problemáticas ambientales y mitigación de gases de efecto invernadero vinculados a la producción porcina, avícola y bovina (feedlots y tambos).” The World Bank study and this resource assessment contain similar baselines in terms of numbers of animals for the dairy and swine sub-sectors. Both studies found that written comprehensive data do not exist on how wastes are managed in the swine and dairy sectors, but that sufficient information is available through in-country experts to use for generating reasonable estimates of the market potential for anaerobic digesters.

2.4 EXAMPLES OF METHANE EMISSIONS REDUCTION PROJECTS IN ARGENTINA

According to the Argentina country profile, there have been very few anaerobic digestion/methane recovery initiatives in Argentina. Several projects using different types of anaerobic digesters (e.g., Hindu type, batch, plug flow) to handle various types of wastes (*e.g*., animal manure, urban organic solid wastes) were implemented mainly in the 1980s.

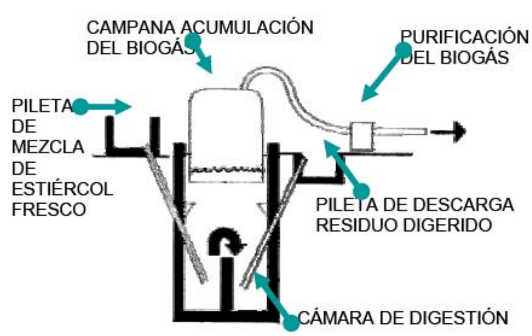
An example in the agro-industrial sector is the upflow anaerobic sludge blanket (UASB) digester used at SANCOR in Charlone (Bs.As.), one of the most important milk processing companies in Argentina. SANCOR operates a plant receiving 180,000 liters of milk per day and is entirely dedicated to cheese production, processing 150 m^3 of whey per day. Due to the high organic load (COD ranging between 55,000 to 60,000 ppm), it was decided to adopt a UASB with a total volume of 2250 m^3, residence hydraulic time of 13.6 hours and a biogas conversion of 26 m^3 biogas/m^3 of whey.

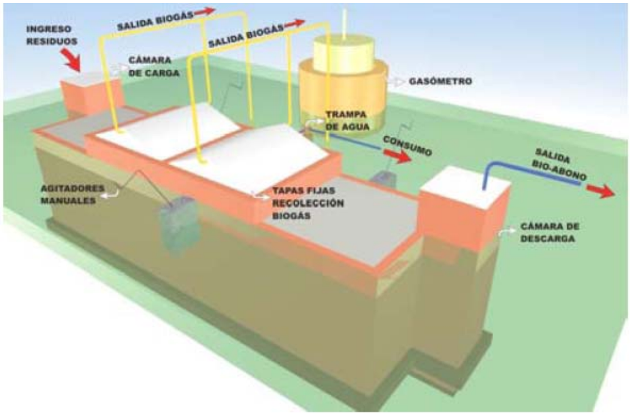
Another case is a company producing juices and essential oils, generating 27,000 t/year of organic wastes. An AD system was installed and generates ~2.7 million m^3/year of biogas, and provides over 60% of the plant's steam consumption. More information can be found in Appendix C.

Anaerobic digestion also is being used by the Krugger Company to produce methane from an integrated livestock feed manufacturing and 600,000-layer table egg production operation. The feed manufacturing component of the operation mainly produces soybean and sunflower oils using solvent extraction, with the remaining meal used in the formulation of the feed for the laying hens. The biogas produced from the combination of the feed manufacturing wastes and the laying hen manure supplies about 50 percent of the 23,000 kWh/day electricity required for the soybean and sunflower oil extraction and refining.

A regional plan for digester construction was developed for integrated farms in the province of Misiones (north east of the country, with tropical climate). The digesters were Hindu type with volumes of six m^3 (Hilbert J. 2006). Overall, 26 digesters of different types were constructed. Also, a group from the Chemical Engineering Faculty of the Universidad Nacional del Litoral has carried out several studies for management of residential organic garbage and rural wastes by anaerobic digestion with gas and fertilizer production. These investigations were performed at different scales, as it can be seen in Table 2.7.

Table 2.7 – Examples of Methane Emissions Reduction Projects in Argentina

AD System at Small Dairy	
	

<table>
<tr><th colspan="2">AD System for Small Community – Santa Fe</th></tr>
<tr><td>
</td><td>Plug flow AD system for a community in Santa Fe (1,000 people). The system was built by Escuela Agrotécnica Particular Incorporada Nº 2.050 “Monseñor Zaspe”. The system captures biogas from the waste and generates energy.</td></tr>
<tr><th colspan="2">Waste Treatment Plant at Gobernador Crespo, Santa Fe</th></tr>
<tr><td></td><td>Prefabricated AD system as part of a plant for treating urban solid wastes for a population of 5,000. This was a World Bank funded project and developed by PROMUDI. The AD system volume is 150 m^3 and operates at 35°C.</td></tr>
</table>

Source: Seminario Desafíos y Estrategias para implementar la digestión anaeróbica en los agrosistemas, Buenos Aires, Mayo 2007

A more recent case is the one showed below from Cabañas Argentinas del Sol, a 1,200 sows, farrow-to-finish swine farm located in Marcos Paz, Buenos Aires with one 1,750 m^3 and two 250 m^3 covered lagoons. The captured methane is being used for soybean processing, confinement facility heating, and generating of electricity using a 50 KVA generator set.

3. SECTOR CHARACTERIZATION

The Argentine economy is traditionally based on agriculture and livestock production; Argentina is one of the main producers of meat, cereals, and vegetable oils worldwide. In the industrial sector, the main companies are producers of food and beverages, including livestock slaughtering and meat processing..

Of the total surface of the country (near 280 million ha), more than 50% is used for shepherding (pasture and rangeland) and 12.8% is cultivated. Figure 3-1 shows the different regions: Pampeana (Buenos Aires, South and Center of Santa Fe, West of Córdoba and La Pampa, South of Entre Ríos) is the main agriculture zone of the country, with an important production of wheat and other cereals. Provinces like Río Negro, Neuquén, Mendoza, San Juan and those of the North Andean region are major fruit and wine regions. Tucumán, Salta and Jujuy specialize in sugar cane production.

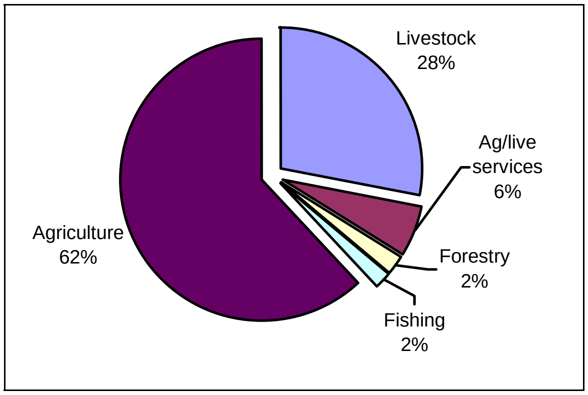
Figure 3.1 – Regions of Argentina

Source: Anaerobic Digestion in Argentina, INTA, 2006

According to the Secretary of Agriculture, Livestock, Fisheries and Food[1], the agriculture and livestock sector and the agro-industrial sector are important cornerstones of the Argentine economy's recovery. As shown in Figure 3.2, the most important part of the Argentine agricultural sector of the economy, which also includes forestry and fishing, was crop production, responsible for 62 percent of the GDP for the sector. Livestock production, at 28% of sector GDP, was also a substantial contributor. As shown in Figure 3.3, the majority of agricultural commodity processing involves the production of food and beverages.

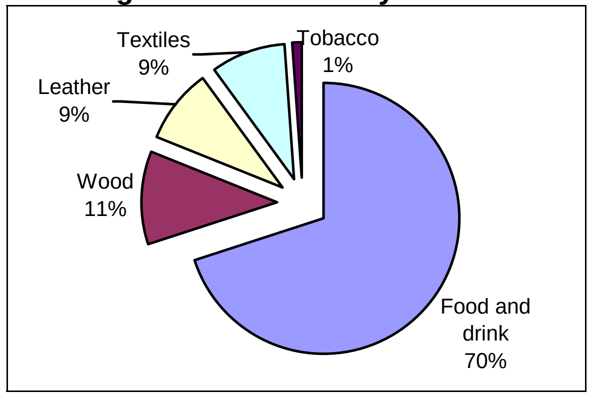
[1] "El desempeño del sector agropecuario y agroindustrial en el nuevo milenio," July 2006

Figure 3.2 – Distribution of GDP Generated in the Agricultural Sector of the Argentinean Economy in 2005



Source: Dirección Nacional de Cuentas Nacionales, INDEC

Figure 3.3 – Distribution of GDP Generated in the Agricultural Commodity Processing Sector of the Argentinean Economy in 2005



Source: Secretary of Agriculture, Livestock, Fisheries and Food and Ministry of Economy

Information regarding the regulatory framework governing livestock waste management and environmental regulations can be found in the study conducted by the Universidad Nacional del Centro de la Provincia de Buenos Aires: "Evaluación, diagnóstico y propuestas de acción para la mejora de las problemáticas ambientales y mitigación de gases de efecto invernadero vinculados a la producción porcina, avícola y bovina (feedlots y tambos)". The objective of this study was to identify short-term mitigation actions that could be included into the CDM through the Argentinean Carbon Fund (FAC).

3.1 POTENTIALLY SIGNIFICANT LIVESTOCK AND AGRO-INDUSTRIAL SECTORS AND SUBSECTORS

In a first stage of the analysis for assessing methane emission reduction potential, some of the previously mentioned criteria will be considered: 1) large sector/sub-sector, and 2) geographic concentration (particularly for centralized AD systems)

The significant Argentine sub-sectors are detailed in Table 3.1 for the purposes of continuing with a deeper analysis.

Table 3.1 – Identified Potential Sectors in Argentina

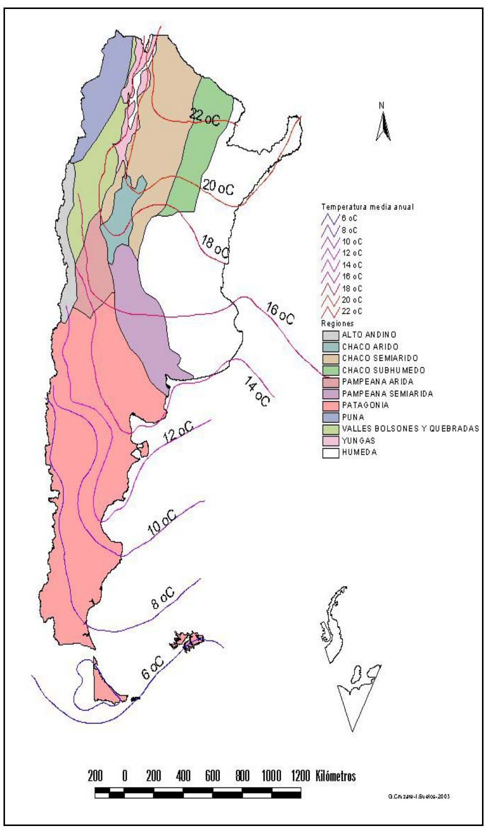
Sub-sector	Size of Sector	Geographic Distribution
Swine	~3 Mill. animals, <2% confined	Santa Fe, Córdoba, Buenos Aires, Entre Ríos
Dairy primary	~11,500 dairy farms by March 2008 ~9500 Mill. L of milk in 2007	Santa Fe, Córdoba, Buenos Aires, Entre Ríos
Dairy industrial	~1700 Mill L of fluid milks ~1,391,000 Tn of dairy products	
Slaughterhouse	38,000 animals per day	Buenos Aires, Santa Fe, Córdoba, Entre Ríos
Sugar mills and distilleries	~2,200,000 TMVC in 2007 23 refineries 11 of the 15 Tucuman refineries have a	Tucumán, Salta, Jujuy

Sub-sector	Size of Sector	Geographic Distribution
	distillery	
Wine processing	~1,500 million L/year 1,322 wineries	Mendoza and San Juan
Juice processing	86,500 Tn of citrus juice in 2006 16 industries of juices and derivatives Argentina is the main worldwide producer of lemon juice	Northwest and Mesopotamia

From the information presented in this table, it can be seen that the center region, containing the provinces of Buenos Aires, Santa Fe, Córdoba and Entre Ríos, has the largest concentration of sub-sectors of interest, such as confined swine production and milk processing and meat-packing plants.

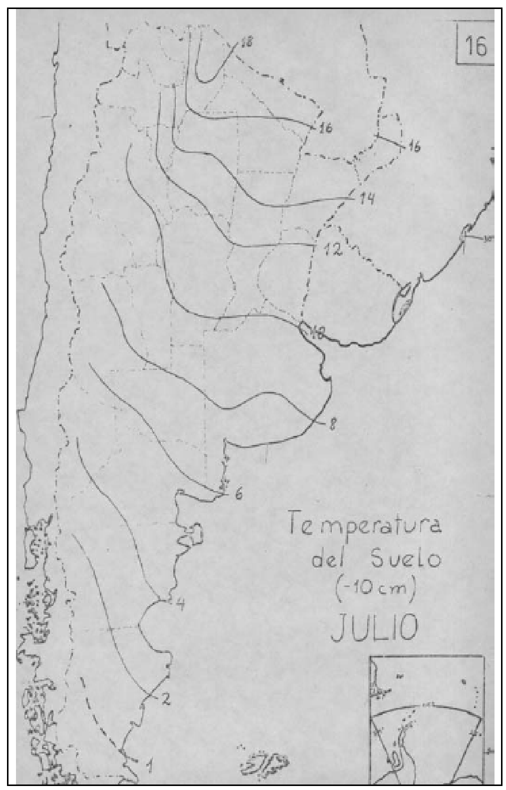
Temperature is also an important factor to consider when estimating methane emissions. Figure 3.4 depicts the average temperatures in the different regions of the country, while Figure 3.5 shows the average temperature value of the soil during the month of July, winter, at a 10 cm depth.

Figure 3.4 – Air Temperature Isobars



Source: FAO

Figure 3.5 – Soil Temperature Isobars



Source: Argentina Profile, 2006

In these figures, the center region (swine, dairy, slaughterhouses) is in the average air temperature range between 14°C and 18°C and the average soil temperature in July is between 8°C and 12°C. The Cuyo region, that leads wine production, is in average temperature values of 10°C to 12°C and soil temperature in July between 6°C and 8°C. The sugar region between 16°C and 20°C of average temperature and soil temperature in July between 12°C and 18°C. Meanwhile, the citrus producer region is between 16°C and 22°C of average temperature and 10°C and 16°C soil temperature in July.

In the following sections of this chapter, each of the sectors listed in Table 3-1 will be discussed. It is also important to note that the wine sector was also studied and analyzed, but it was determined that it was not a priority sector and had low potential for methane emissions reductions due to seasonality and BOD/COD levels. The information on the wine sector is included in Appendix C.

3.2 SWINE

3.2.1 Description of Size, Scale of Operations, and Geographic Location

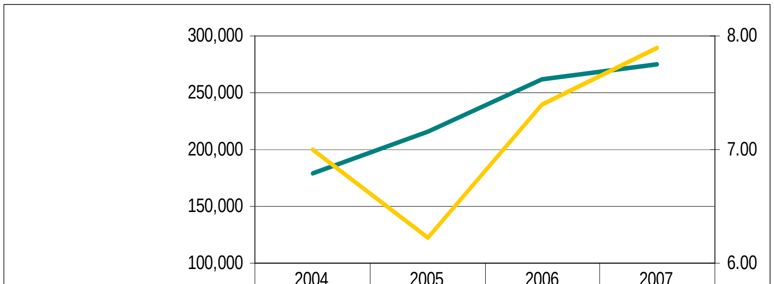
Although the Argentinean swine industry is small, there has been significant growth in recent years in herd size and slaughter rate (Figure 3.6) as well as domestic consumption with consumption exceeding production in 2007 (Figure 3.7).

Figure 3.6 – Evolution of Swine Industry

	2004	2005	2006	2007
Inventory (heads)	2,400,000	2,080,136	2,427,130	3,028,795
Slaughtered (heads)	2,070,864	2,467,978	3,023,388	3,200,115

Source: Anuario 2007 GITEP

Figure 3.7 – Swine Production and Consumption



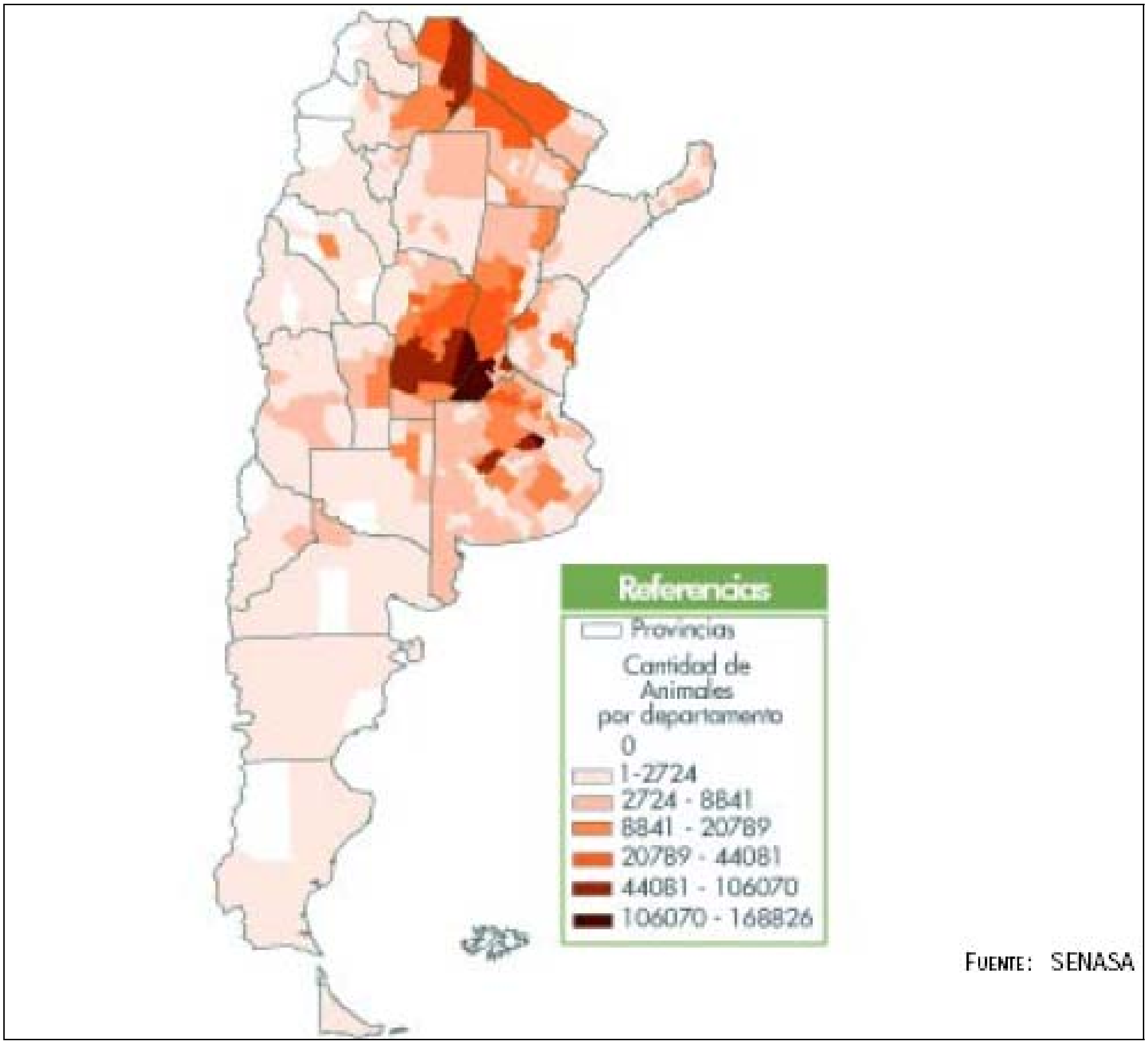
	2004	2005	2006	2007
Production (Tn)	178,700	215,600	262,173	274,407
Consumption (Kg/per./year)	7.00	6.23	7.40	7.89

Production (Tn) Consumption (Kg/per./year)

Source: Anuario 2007 GITEP

Since swine rearing started in the country, it has been concentrated in the Pampeana region and coincides with the production of coarse grains cereals (maize and milo). According to the surveys performed by SENASA, the geographical distribution of swine by province in 2007 is shown in the Figure 3.8.

Figure 3.8 – Distribution of Swine Population by Province



Source: SENASA

As shown in this figure, swine production in Argentina is concentrated in the Buenos Aires, Córdoba, and Santa Fe provinces with herds of 860,546, 714,903, and 631,831 swine, respectively in 2007. The number of swine in these three provinces represented almost 73 percent of the 3,038,795 pigs in Argentina in 2007. Table 3.2 shows the distribution of swine production establishments and swine population by province.

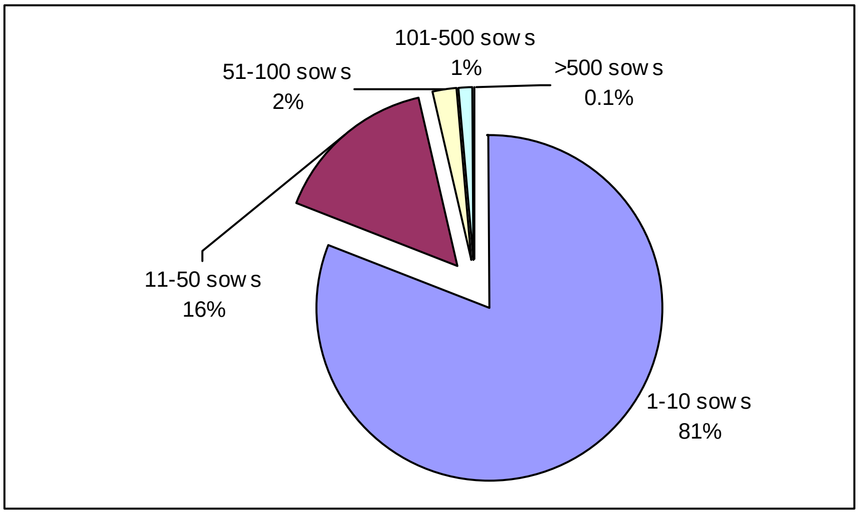
Table 3.2 – Distribution of Swine Farms by Province

Province	Farms	Sows	Total swine
Buenos Aires	11,598	175,408	860,546
Catamarca	594	3,682	7,317
Córdoba	8,206	124,772	714,903
Corrientes	2,963	10,470	22,952
Chaco	5,835	40,923	110,847
Chubut	260	3,299	9,911
Entre Ríos	2,822	18,322	105,491
Formosa	3,896	44,047	98,079
Jujuy	240	3,090	13,503
La Pampa	1,704	24,395	83,768
La Rioja	193	3,254	13,306
Mendoza	539	5,298	25,909
Misiones	2,392	14,408	35,338
Neuquén	213	2,769	10,228
Río Negro	466	3,615	8,903
Salta	2,510	41,220	139,040
San Juan	169	2,260	12,101
San Luis	1,845	16,470	54,714
Santa Cruz	20	246	733
Santa Fe	4,400	107,212	631,831
Santiago del Estero	4,232	22,034	56,539
Tierra del Fuego	19	194	726
Tucumán	979	6,483	22,110
Total	56,095	673,871	3,038,795

Source: Anuario 2007 GITEP

As shown in Figure 3.9, the Argentinean swine industry is characterized by a large number of small farms; operations with more than 50 sows constitute less than 4% of the total of 56,179 swine operations in the country, but these 2,054 operations account for more than 55% of total pork production and the majority of methane emissions from the sector.

Figure 3.9 – Distribution of Swine Population by Farm Size



Source: EEA INTA Marcos Juárez

The largest part of the production is carried out in extensive systems. Only 2-4% of production is carried out in confined intensive systems, which are the main focus of this assessment since these are the farms using lagoons and therefore generating methane emissions. Figure 3.10 shows images of these production systems.

Figure 3.10 – Swine Production Systems

Extensive Swine Production

Confined Swine Production

Source: Argentina Trip October 2008

In recent years, the productivity of intensive swine production in Argentina has increased significantly with the introduction of improved genetic lines and advanced nutrition, housing, and management practices. On-site feed manufacturing and controlled environment housing is common in this segment of the industry. The principal ingredients in formulated diets are corn and soybean meal.

3.2.2 Description of Waste Characteristics, Handling and Management

Currently, there is a little available information about Argentine swine manure excretion rates or physical and chemical characteristics. Typically, data from other countries with similar intensive production practices, such as Brazil or Mexico, are used. At the seminar

"Challenges and Strategies for implementing Anaerobic Digestion in Agro-systems", manure excretion rates and primary plant nutrient content were presented (Patricia Millares from SAGPyA), and are shown in Table 3.3 and Table 3.4.

Table 3.3 – Wastes from Swine Production

Stage	Feces	Urine
Piglets, weaners (8-20 kg) and lactating females	8% of live weight/day	6.17 L urine/animal/day + cleaning water = 8 to 18 Lt water/animal/day
Growth (starting at 20 kg) and finalization (105 to 110 kg)	7% of live weight/day	
Pregnant and not pregnant females	3% of live weight/day	

Table 3.4 – Excreted Nutrients (grams)

Type	kg wastes	N	P	K
Lactating sow	170	133	30	65
Sow	170	52	14	28
Piglet	3	16	5	10
Rebreeding	16	7	3	5
Termination	80	36	12	23

Based on talks held in INTA with sector's experts (Prof. Agr. Naum Spiner and Eng. Darío Panichelli), farms with more than 100 sows typically have a confinement system, and a lagoon system to manage manure. As the number of larger farms with intensive production practices increases, the number of lagoons for manure management also can be expected to increase. Currently, about 2% of the swine farms in Argentina have confined production systems, but these are responsible for the majority of the methane generated in the sector. According to information published by Trateco S.A., these operations typically are using pull-plug pits in combination with anaerobic lagoons, followed by facultative lagoons. The addition of specialized bacterial cultures (bioaugmentation) to pull-plug pits and conventional anaerobic lagoons for odor control and solids removal is common.

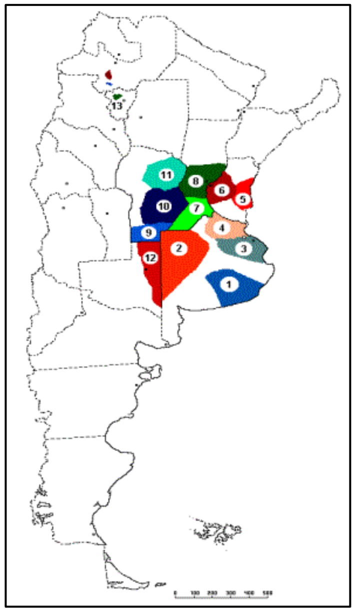
3.3 DAIRY

3.3.1 Description of Size, Scale of Operations and Geographic Location

Argentina's dairy production is concentrated in the provinces of: Buenos Aires, Santa Fe, Córdoba, Entre Ríos, and to a lesser extent in La Pampa and Tucumán (Figure 3.11). Santa Fe is the leading milk producing province in Argentina (>4,500 dairy farms) followed by Córdoba (>3,000 dairy farms), Buenos Aires (>2,000 dairy farms), Entre Ríos, La Pampa and Tucumán. As shown in Figure 3.12, approximately 57 percent of the dairy farms in Santa Fe province have less than 351 cows. The distribution is similar in other provinces. In each province, production practices range from the least capital intensive 100 percent pasture to the most capital intensive 100 percent confinement with a shift from pasture to confinement occurring with increase in herd size.

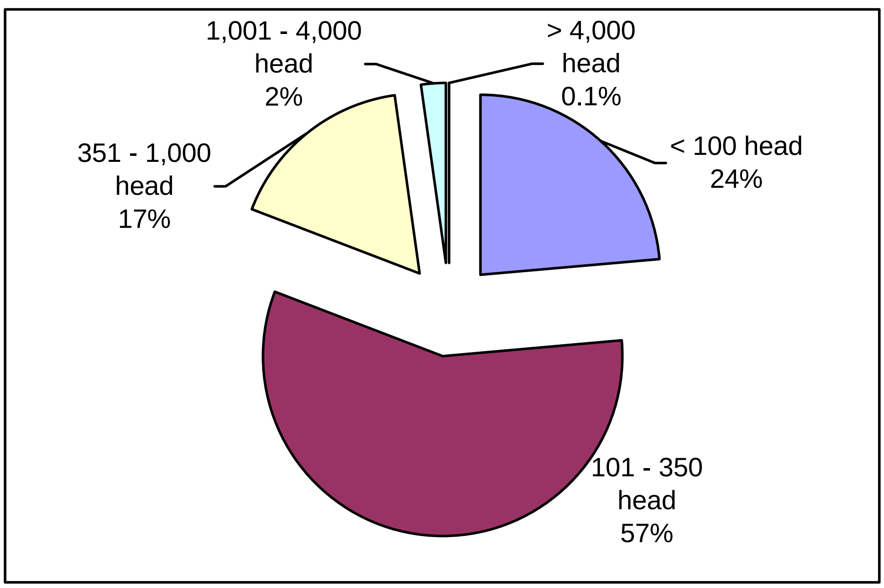
Beginning in the latter years of the last decade, the number of Argentinean dairy farms has decreased sharply with a loss of almost 4,000 operations since 1998. Most of the farms that ceased producing milk where unable to make the necessary capital investments to lower production costs and remain profitable. For the less profitable dairy operations, the alternative of soya production is attractive[2].

Figure 3.11 – Argentine Milk Producing Provinces



Source: SAGPyA, 2003

Figure 3.12 – Dairy Distribution by Size in Santa Fe



Source: INDEC, Censo Nacional Agropecuario 2002.

However, milk production has remained relatively constant at between 9,500 and 10,000 million liters per year reflecting improved genetics and management practices, and it is

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[2] (Schneider; G., E., Comerón from the Program Rural Change central zone of Santa Fe - INTA Rafaela in 2002)

expected to reach 10,400 million liters in 2009, practically the same as the record of 1999. Despite a very dry season in 2008, the dairy herd is in good condition and most farmers' returns are still positive. Also, although production costs increased significantly in the first nine months of 2008, they are expected to be lower in 2009 as feed costs should reflect lower world grain prices. Production of milk in Argentina will continue to concentrate in the hands of medium to large producers who are efficient, use more technology, and are intensifying their production schemes.

3.3.2 Description of Waste Characteristics, Handling and Management

Most small and medium dairy farms in Argentina use pastures extensively, with animal confinement limited to twice a day during milking. On these farms, the manure excreted during the milking process along with the wastewater resulting from the cleaning and sanitizing of milking equipment usually is disposed of in a poorly maintained lagoon or ditch, creating the potential for groundwater contamination. According to the study conducted by the Universidad Nacional del Centro de la Provincia de Buenos Aires, as dairies merge and become larger, the use of lagoons to store wastes is more common. However, these lagoons are not designed appropriately to treat the wastes.

The study "Cuantificación y caracterización de agua y efluentes en establecimientos lecheros. I. Demanda de agua y manejo de efluentes, 2002" by the Instituto Nacional de Tecnología Agropecuaria (INTA) and Escuela Superior Integral de Lechería (ESIL) in the milk producing region of Villa María found that water supplies frequently contained nitrite, nitrate, sodium, arsenic, total soluble salts, and bacteria concentrations that exceeded both national and international standards.

In addition, in 2002 another research study[3] was conducted to determine water demand and effluent management at dairies in Argentina. The objective of the study was to quantify water demand in the different operations carried out during milking and to characterize effluent management practices (Figure 3.13) in order to establish management criteria in dairy farms in Buenos Aires. The study used a sample of 65 representative dairy farms in three milk producing regions.

The study also showed that there is a direct relationship between the use of lagoons and the size of the dairy – above a certain size range (200-300 cows) all dairies have lagoons. However, it was also found that lagoons were not constructed to comply with effluent treatment norms, but just as a containment structure. Finally, the study also quantified the water used in dairies by activity, as shown in Table 3.5.

[3] Nosetti, L., Herrero, M.A., Pol, M., Maldonado May, V., Iramain, M.S., and Flores, M.

Figure 3.13 – Final Effluent Destination at Dairy Farms of Buenos Aires Province

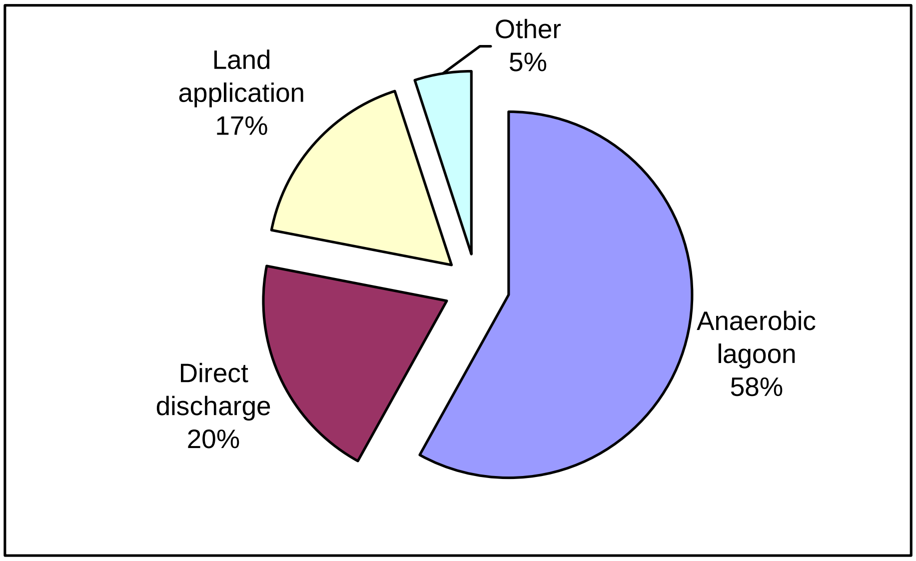


Table 3.5 – Water Consumption in Dairy Farms, Buenos Aires Province

Activity	Median	Mín.	Max.
Rinsing (L water/L milk)	7.31	4.65	9.20
Machine washing (L/day)	308.33	180.00	400.00
Cooling tank washing (L/day)	126.67	60.00	260.00
Milking parlor washing (L/cow/day)	5.59	3.58	8.33
Pen washing (L/cow/day)	16.49	8.28	22.81
Nipple washing (L/cow/day)	1.16	0.00	3.11
Total water consumption (L/day)	32,144	14,368	46,036

3.4 SLAUGHTERHOUSES

3.4.1 Description of Size, Scale of Operations and Geographic Location

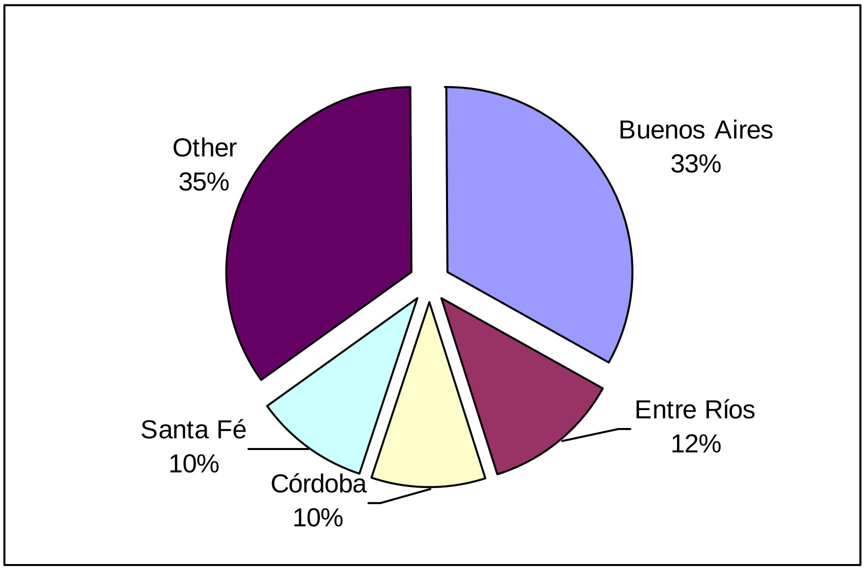
The Argentine legislation recognizes the following two types of establishments in this sector:

Slaughterhouse – meat-packing plant. A facility where animals are slaughtered, that has a cold storage chamber on site, and which may or may not carry out manufacturing and/or industrialization tasks.
Local butcher. A person that slaughters animals of his property for his own supply and/or for third parties.

a. CATTLE SLAUGHTERHOUSES

The following figure shows the distribution of cattle slaughterhouses by Province.

Figure 3.14 – Distribution of Bovine Slaughterhouses by Province

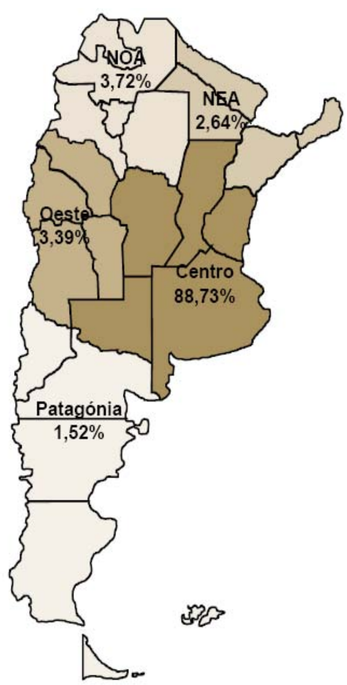


Source: ONCCA

During the month of October 2008, over 1.3 million head were slaughtered. The distribution by province is shown in Figure 3.15.

Figure 3.15 – Distribution of Bovine Slaughtered by Province, October 2008

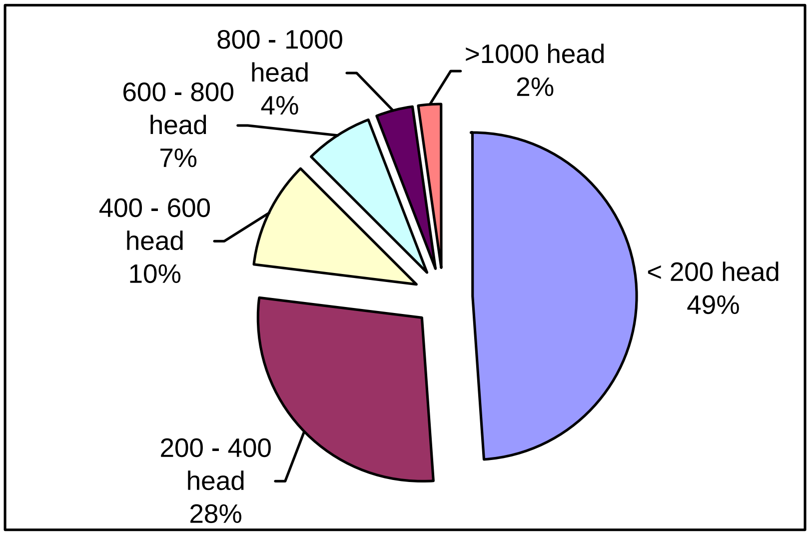
Región Centro	88,73%
Buenos Aires	54,83%
Córdoba	10,48%
Entre Rios	4,23%
La Pampa	2,52%
Santa Fe	16,67%
Región NEA	2,64%
Chaco	1,19%
Corrientes	0,48%
Formosa	0,46%
Misiones	0,51%
Región NOA	3,72%
Salta	0,73%
Santiago del Estero	0,46%
Tucuman	1,76%
Jujuy	0,30%
Catamarca	0,47%
Región Oeste	3,39%
San Juan	0,11%
La Rioja	0,18%
Mendoza	1,77%
San Luis	1,33%
Región Patagónia	1,52%
Chubut	0,27%
Neuquén	0,48%
Rio Negro	0,72%
Santa Cruz	0,03%
Tierra del Fuego	0,01%



Source: ONCCA

Figure 3.16 shows distribution of slaughterhouses by number of animals slaughtered during November 2008.

Figure 3.16 – Distribution of Bovine Slaughterhouses by Throughput in Argentina

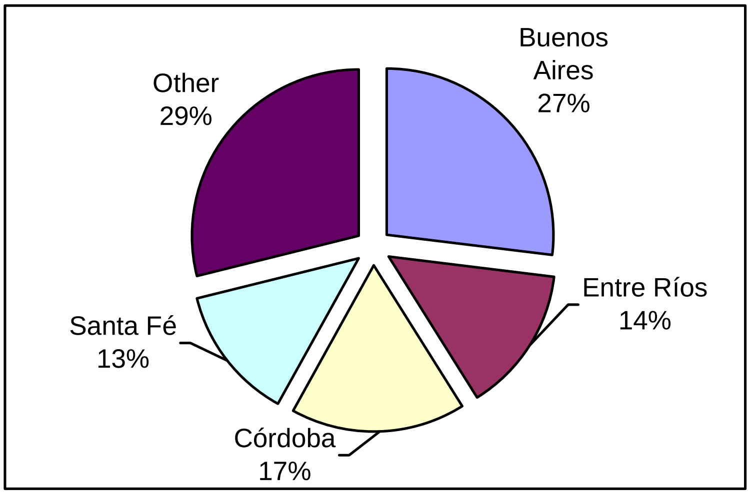


Source: ONCCA

b. SWINE SLAUGHTERHOUSES

There are approximately 160 registered swine slaughterhouses in Argentina (October 2008). The facilities are concentrated in Buenos Aires, Córdoba, and Entre Ríos, as shown in the following figure.

Figure 3.17 – Distribution of Swine Slaughterhouses in Argentina



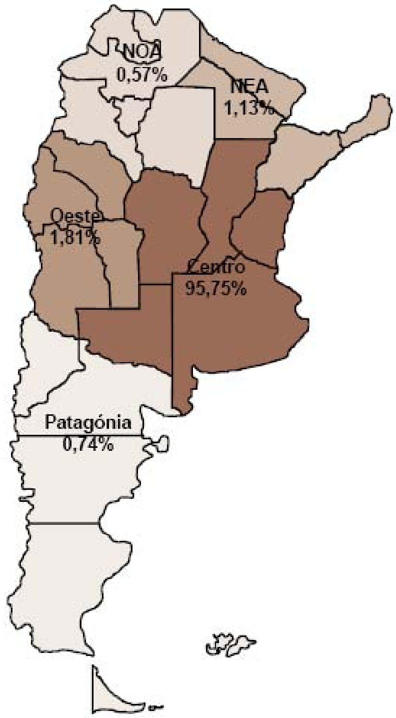
Source: ONCCA

During the month of October 2008, almost 300,000 hogs were slaughtered. The distribution by province is shown in the table below.

Figure 3.18 – Distribution of Swine Slaughtered by Province, October 2008

Región Centro	95,75%
Buenos Aires	62,34%
Córdoba	10,05%
Entre Ríos	1,54%
La Pampa	0,18%
Santa Fe	21,64%
Región NEA	1,13%
Chaco	0,30%
Corrientes	0,03%
Formosa	0,00%
Misiones	0,80%
Región NOA	0,57%
Salta	0,23%
Santiago del Estero	0,05%
Tucuman	0,17%
Jujuy	0,13%
Catamarca	0,00%
Región Oeste	1,81%
San Juan	0,00%
La Rioja	0,01%
Mendoza	1,73%
San Luis	0,06%
Región Patagónia	0,74%
Chubut	0,12%
Neuquén	0,46%
Río Negro	0,12%
Santa Cruz	0,02%
Tierra del Fuego	0,02%

Fuente: Gestión Estratégica de la Información - ONCCA



Source: ONCCA

Four companies in Argentina comprise about 50% of the slaughter: Frigorífico Pompeya (24%), Minguillón (11%), Pork Industries (9%), and Paladini (5.5%).

3.4.2 Description of Waste Characteristics, Handling and Management

In Argentina, waste management practices in this sector are not homogeneous due mainly to differences in size, location, and environmental regulations at the Province level. In many cases, slaughterhouses are located in urban areas (due to city growth), which makes it difficult for them to use lagoons.

Also, in some cases, the slaughterhouses conduct primary treatment only (e.g., fat, solids and fibers separation) and pay a fee to the municipality to discharge effluents into the municipal sewage system.

Appendix C shows the slaughterhouse operations and the wastes generated at each one of them. In general, slaughterhouse effluents have the following properties:

- High organic load, due to the presence of blood (in the slaughter, approximately 3% of the weight is obtained in form of blood), fat, feces, and undigested stomach content
- High levels of oils and fats
- pH fluctuations due to the presence of acid or caustic cleaning agents
- High levels of nitrogen, phosphorus, and salt

High temperature

Effluents produced by the slaughterhouse industry can be classified in three types according to their nature:

Those coming from pens and pre-slaughter washers, composed mainly of urine and feces of the stabled animals.

Those containing blood, coming from the slaughter areas in the slaughterhouse.

Fats, oils, and grease, coming mainly from the slaughter and cutting sections.

The following data comes from a 640 head per day cattle slaughterhouse in Santa Fe. The data is important because it shows the BOD and COD levels from the different effluent streams coming out of the process.

Facility: Cattle Slaughterhouse

Capacity: 640 animals/day

Products: Frozen hamburgers and treatment of cattle blood for plasma and powdered hemoglobin.

Treatment process: Primary and secondary treatment. Anaerobic and aerobic lagoons used.

Residence time: 15 days

Average effluent flow: 2000 m^3/day.

Effluent analysis: Composite samples were taken of the raw effluent over 24 hours in a typical day. The laboratory data showed the following values:

<u>Effluent with blood</u>
pH: 7.8 average. Peaks from 2 to 11.5.
Average temperature 29ºC
BOD: 10000 mg/l; COD: 38000 mg/l; SSEE (soluble solids in ethyl ether - fats): low

<u>Effluent with fat</u>
pH and temp. More stable.
BOD: 3500mg/l; COD: 10000 mg/l; SSEE: 1500 mg/l

<u>Green effluent</u>
pH: moderately alkaline (8)
Average temperature 28ºC.
BOD: 1600 mg/l; COD: 5400 mg/l; SSEE: 740 mg/l

3.5 SUGAR AND DISTILLERIES

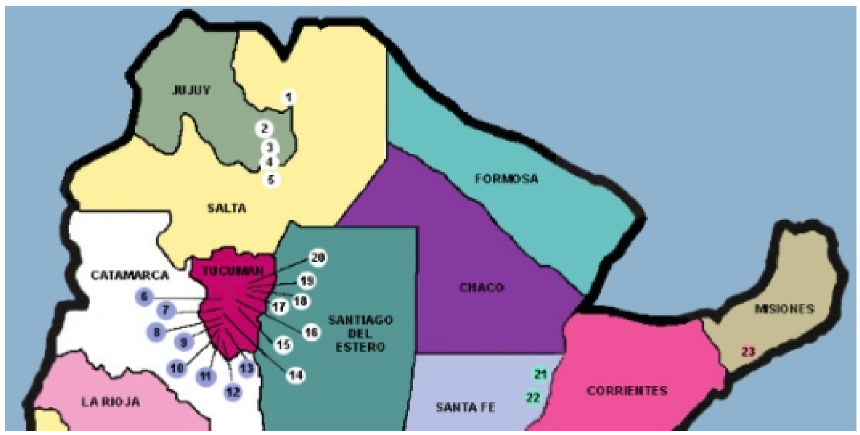
3.5.1 Description of Size, Scale of Operations, and Geographic Location

Sugar production in Argentina is concentrated in the provinces of Tucumán, which produces 62% of the volume, and in Salta and Jujuy, that together process 37%. In Tucumán, the cane is cultivated by independent cane farmers who produce most of the cane. In Salta and Jujuy, the largest proportion the cane is grown by the sugar refineries. The remaining production occurs in Santa Fe and Misiones, which mainly cultivate cane for organic sugar production.

There are 23 sugar refineries in Argentina with 15 of the 23 located in Tucumán, three in Jujuy, two in Salta, two in Santa Fe, and one in Misiones. As shown in Figure 3.19, all of the sugar refineries are located in the northern Argentinean provinces where cane production is concentrated.

Figure 3.19 – Location of Sugar Refineries in Argentina

1	S. M. del Tabacal
2	Ledesma
3	La Esperanza
4	Río Grande
5	San Isidro
6	La Fronterita
7	Ñuñorco
8	La Providencia
9	La Corona
10	Aguilares
11	Santa Bárbara
12	Marapa
13	La Trinidad
14	Santa Rosa
15	Leales
16	Bella Vista
17	San Juan
18	Cruz Alta
19	Concepción
20	La Florida
21	Las Toscas
22	Arno
23	San Javier



Source: Centro Azucarero Argentino

The sugar sector of the provinces of Salta and Jujuy has a very different structure from the one of Tucumán. The main difference is the larger scale of the operations in Salta and Jujuy, because 85% of the cane belongs to the four largest sugar refineries. Integrated operations realize higher yields due to greater investment in mechanization and superior management. The average yield for an integrated operation is 93.5 tons per hectare versus 75.4 tons per hectare for independent cane producers. This situation favors a better crop management and important investments in genetics and more advanced machinery–factors derived from greater capital availability by these companies than by the independent cane farmers.

Crop mechanization is generalized in the entire region. Almost all sugar refineries apply an integral mechanization system, while 40% of the independent cane farmers have complete mechanization and the remaining 60% use a semi-mechanized system. Since rainfall is less than that required for adequate cane yield, use of irrigation is necessary in both Salta and Jujuy, but not in Tucumán.

Cane grows in spring and summer taking advantage of heat and humidity, and is harvested from May through October. Sugar refineries operate between May and November (7 months) and alcohol distilleries operate between March and December. It is estimated that for each liter of alcohol nearly 10 to 14 liters of vinasse[4] is produced, depending on the type of cane and process used.

Currently, 11 of the 15 Tucuman sugar refineries have distilleries, producing a province total of around 940,000 annual liters of alcohol. This product is used as raw material in the chemical industry, manufacturing of herbicides, and some fuels (Flexfuel).

During the 2007 harvest, a total of 2,197,952 metric tons raw value (MTRV) were produced in the country, with the region distribution as follows: Tucuman (62%), Norte (36%), and Litoral (2%). Appendix C presents sugar production per sugar refinery as well as the obtained yield as function of the milled cane.

3.5.2 Description of Waste Characteristics, Handling and Management

The wastes associated with the processing of sugar cane are as follows:

Wastewater is generated during the cleaning and sanitizing of plant and equipment. On average, 10 m^3 of wastewater is generated for every m^3 of cane processed, although there is some reuse of wastewater in some processing facilities. Wastewater from the sugar mill La Florida (~143,800 Tons/yr of sugar) was analyzed and the following was found: BOD: 1,650 mg/L; COD 1,764 mg/L.

Cachaza is the solid residue remaining after cane juice filtering. It has a moisture content of about 40 percent and is a spongy, amorphous material that can absorb a large amount of water. Cachaza generally is rich in nitrogen, phosphorus, and calcium. About 40 kg is generated per metric ton of cane processed.

Bottom ash and fly ash are generated from the use of bagasse as a fuel. Bagasse is the cane fiber remaining after juice extraction.

According to the “Programa de Reconversión Industrial, Cuenca Río Salí, Secretaría de Ambiente y Desarrollo Sustentable, Diciembre 2007”, when alcohol production is associated with sugar refining, vinasse is another waste with BOD and COD concentrations ranging from 40 to 100 g per L. About 12 to 15 L of vinasse is generated per L of alcohol or 120 L per metric ton of cane processed. If alcohol is produced directly from cane juice, the rate increases to 1,020 L of vinasse per metric ton of cane processed. However, the BOD and COD concentrations are lower.

Depending of the source and process stage, Table 3.6 summarizes the wastes and by-products generated.

[4] Vinasse is a liquid residue left in the distillation of ethanol from sugar cane derivates.

Table 3.6 – Source and Process Stage, and Characteristic of Wastes Generated

Source	Process Stage	Wastes/By-Products
Sugar Cane	Harvest	Ashes and gases due to burning
Sugar Cane	Milling	Waste water from cane wash, soil wash, and oils from lubrication systems. Bagasse is a by-product, containing 50% humidity, and that is sent to the boilers where it is burned as a fuel.
Cane juice	Process	Wash waters from floors and from the different components, like evaporators, heaters, buckets, etc. Here 'cachaza' is produced as filtration residue and molasses as by-product
Bagasse	Boilers	Smoke, gases and particulate material from chimneys, ashes from combustions chambers and waste water from scrubbers
Water and chemicals	Cooling lagoon	Waste waters
Molasses	Distillery	Vinasses and wash waters from barrels

Source: Programa de Reconversión Industrial, Cuenca Río Salí, Secretaría de Ambiente y Desarrollo Sustentable, Diciembre 2007

A 2005 survey by the Water Resources Directorate of the province of Tucumán found that most sugar refineries discharge their wastes to surface waters flowing into the Rio Hondo dam without adequate treatment.

According to the Monitoring Program of the Río Hondo Embalse, issued by the Sub-Secretariat of Water Resources for the Nation in December 2007, the situation has not improved. In this report, it was stated that only two of the refineries with distilleries provided adequate wastewater treatment before discharge. Table 3.7 shows production and vinasse generation for all sugar mills and distilleries in Tucumán.

Table 3.7 – Sugar Production and Vinasse Generation by Sugar Refineries, Tucumán

Sugar Mills	Sugar Cane (MT/yr)	Sugar (MT/yr)	Cachaza (MT/yr)	Alcohol (m^3/day)	Vinaza (m^3/yr)
La Florida	1,265,000	143,800	63,250	30,000	360,000
Concepción	2,667,000	25,000	106,680	21,000	252,000
La Corona	800,000	80,000	32,000	16,000	192,000
Marapa	650,000	65,000	26,000	16,000	192,000
La Trinidad	1,200,000	140,000	48,000	17,000	204,000
Santa Bárbara	1,000,000	110,000	55,000	12,000	144,000
La Fronterita	1,200,000	120,000	48,000	8,000	96,000
Santa Rosa	800,000	60,000	32,000	8,000	96,000
San Juan	450,000	40,000	18,000	5,000	60,000
Leales	500,000	55,000	20,000	7,500	90,000
Bella Vista	860,000	86,000	28,380	6,845	82,140
La Providencia	1,290,000	130,000	30,950	0	0
Ñuñorco	850,000	85,000	46,750	0	0
Aguilares	700,000	70,000	28,000	0	0
Cruz Alta	380,000	38,000	13,300	0	0
TOTAL	14,612,000	1,247,800	596,310	147,345	1,768,140

Source: Provincia de Tucumán, 2006

The report also provides information and data on flow and organic loading (i.e., BOD_5) before final discharge. For sugar mills, the study found that average wastewater flows were ~28.6 m^3/metric ton of final product and a BOD_5 of 2,600 g/metric ton of final product. For distilleries, the study found that average wastewater flow was ~22 m^3/day and a BOD_5 of 60,000 g/m^3.

Finally, SAyDS is implementing the Plan de Reconversión Industrial en la Provincia de Tucumán to reduce organic loadings from the citrus processing and sugar mills/distilleries. In 2007, the project reduced ~550,000 kg BOD/day.

3.6 CITRUS PROCESSING

3.6.1 Description of Size, Scale of Operations and Geographic Location

In Argentina, there are approximately 5,300 citrus growers with 147,466 hectares of groves producing 2.7 million tons of fruit annually. In addition, there are 16 companies engaged in various aspects of citrus fruit processing, such as juice and derivatives production.

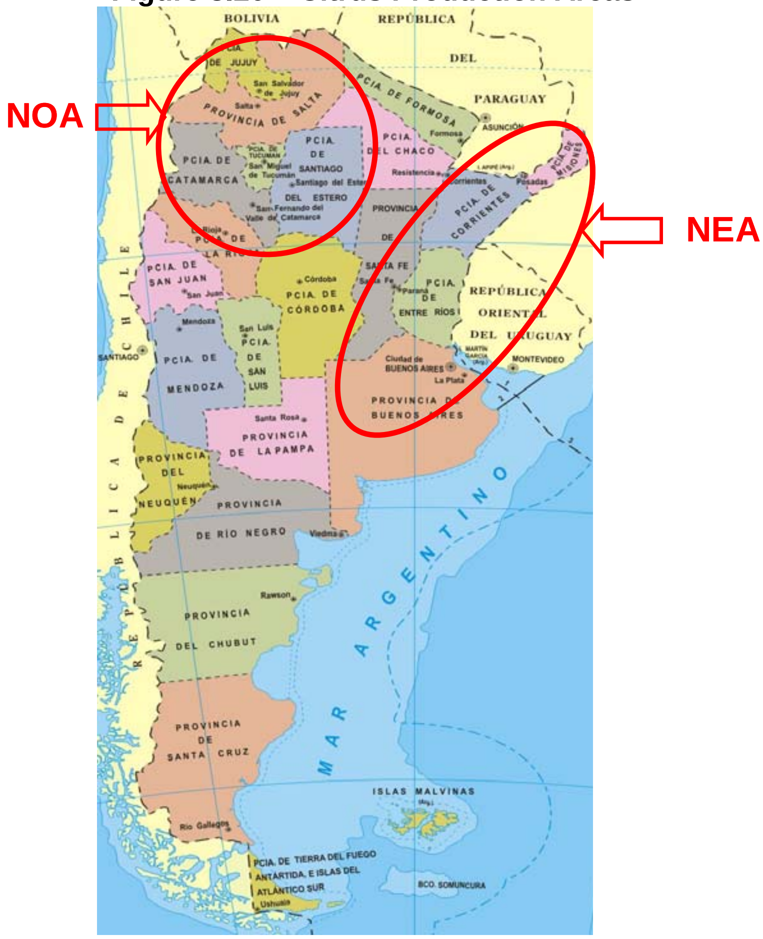
Nearly 120,000 individuals are employed in this industry, which generates the equivalent of approximately 528 million USD annually. Approximately 64 percent of this sum is derived from export of fresh fruit, concentrated juices, and derivatives.

There are two principal zones of citrus production: 1) NOA (Tucumán, Jujuy, Salta, Catamarca and Santiago del Estero) with 64,088 hectares of groves and about 61% of the national production and 2) NEA (Entre Ríos, Corrientes, Misiones and Buenos Aires) with 83,378 hectares and about 39% of the national production (Figure 3.20).

Lemon and grapefruit production is concentrated in NOA while orange and tangerine production is concentrated in NEA. See Appendix C for the distribution of production by province. It has been estimated that citrus production may reach 3 million tons in a few years.

The citrus harvest in Argentina occurs from March through December but occurs mainly between May and September. Lemons are the principal crop (49%) followed by oranges (27%), tangerines (18%), and grapefruit (6%). Forty-seven percent of the citrus crop is processed, 32 percent directly consumed domestically, and the remainder exported. Ninety-two percent of the exports occur between May and September principally to the European Union.

Figure 3.20 – Citrus Production Areas



Source: Figured prepared during RA development

Table 3.8 shows the citrus fruit production of Argentina in relation to worldwide production and to southern hemisphere production. As shown in this table, Argentina is the leading producer of lemons in the world. Fourteen percent of lemon production is directly consumed domestically, 18 percent exported for direct consumption and the remaining 68 percent processed into juice concentrate and essential oils for both domestic consumption, and export. After the sugar industry, the lemon industry is of major economic and social importance in Tucumán, which accounts for 75.4% of national production. The remaining production comes from Corrientes (7.5%), Misiones (5%), Entre Ríos (4.8%), Jujuy (3.7%), Salta (2%) and Buenos Aires (1.6%).

Table 3.8 – Argentina's Citrus Production in Relation to Worldwide Production

Citrus	Argentina / World	Argentina / Southern Hemisphere
Lemon	49.00%	93.26%
Mandarin	2.69%	s/d
Orange	0.63%	1.08%
Grapefruit	8.19%	40.00%

Source: World Horticultural Trade & U.S. Department of Agriculture, February 2007

There are different types of lemon concentrate juices: clarified and different acidity grades. Special products are also produced, due to clients' preferences. Industry uses approximately

17 kg of lemon to obtain 1 kg of juice concentrate. This rate varies as a function of the prevailing climate conditions during the production cycle.

Seventy percent of lemon production in Argentina, averaging 1.2 million tons/yr, is used to produce lemon concentrate, while the remaining 30% is used to produce essential oils, dehydrated peel, and frozen pulp. Lemon concentrate represents almost 75% of the total citrus fruit juice produced in Argentina.

3.6.2 Description of Waste Characteristics, Handling, and Management

Liquid wastes come mainly from large-scale industrialization of lemon-derived products. As seen in the table below, anaerobic lagoons are the preferred method for treating/disposing of effluents from the citrus processing plant. Effluents are then usually discharged to rivers or other bodies of water. The sector has been targeted by nearby communities due to unpleasant odors coming from their facilities. A typical effluent composition from a citrus processing plant has the following makeup:

Solids: Citrus pulp and peel residuals (biodegradable)
Liquids: Sugars (biodegradable)
Citric acid (biodegradable)
Pectins (biodegradable carbohydrates)
Residuals of citrus fruit essential oils

According to the Monitoring Program of the Río Hondo Embalse, a citrus processing industry has an average flow of 250 m^3/day and generates high organic loadings (BOD ~10,000 gr/m^3). The same report also provides production and wastewater flow for each of the main citrus processing plants in Tucumán, as shown in Table 3.9.

Table 3.9 – Production, Wastewater Flow, and Treatment Method of Main Citrus Processing Plants

Name of Citrus Processing Plant	Processed lemons (metric tons/yr)	Wastewater Volume (m^3/yr)	Treatment Method
Trapani	960,000	90,000	Lagoons
Citromax	720,000	80,000	Lagoons
Cota	600,000	60,000	NA
Citrusvil	840,000	100,000	Lagoons
San Miguel	1,080,000	140,000	Dissolved Air Flotation
Litoral Citrus	600,000	70,000	Lagoons
Acheral Citrus	NA	NA	Lagoons
Trade	720,000	80,000	NA
TOTAL	5,520,000	620,000	

Source: Programa de Monitoreo del Embalse Río Hondo, Diciembre 2007

The Universidad Nacional del Litoral conducted an analysis of process effluent from one of the main citrus processing plants in Argentina. The results are shown below and more information can be found in Appendix C in the citrus processing section.

Total solids: 26.3 gr/L
pH: 3.64
COD: 30,000 – 35,000 p.p.m.

4. POTENTIAL FOR METHANE EMISSIONS REDUCTION

This section explains the potential for reducing greenhouse gases though the use of anaerobic digesters. Anaerobic digesters reduce greenhouse gas emission reductions in two ways. First is the direct methane emission reduction from the capture and burning of biogas that otherwise would escape into the atmosphere from the waste management system. Second is the indirect reduction of CO_2, methane, and nitrous oxide from the use of biogas to displace fossil fuels that would otherwise be used to provide thermal energy or electricity to the agricultural operation. Section 4.1 explains the potential methane emissions reduction from manure management systems and agricultural commodity processing waste.

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

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

4.1 METHANE EMISSIONS REDUCTION

Anaerobic digestion projects for both manure and agricultural commodity processing wastes may produce more methane than currently is being emitted from 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 reduction from a digester corresponds not to the total methane generated, but rather the baseline methane emissions from the waste management system prior to installation of the digester. The indirect emissions reduction, as explained in section 4.1.3, is based on the maximum methane production potential of the digester and how the biogas is used.

4.1.1 Direct Emission Reductions from Digestion of Manure

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

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

where: $CH_{4\,(M,\,P)}$ = estimated methane production potential from manure, kg/year

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

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

$B_{o(M)}$ = maximum methane production capacity for manure produced by livestock category M, m^3 CH_4 per kg volatile solids excreted

MCF_{AD} = methane conversion factor for anaerobic digestion, decimal

Table 4.1 shows the estimated GHG emission reduction potential for pig and dairy operations in Argentina. In both sectors, when the indirect emissions reductions are considered, the potential reductions are more than 400,000 metric tons CO_2e per year.

Table 4.1 – Methane and Carbon Emission Reductions From Manure

	Swine	Dairy	Assumptions
VS (kg/head-day)	0.30	2.90	Only swine farms with over 100 sows were considered to have confined systems and lagoons. Dairy farms with >4000 head were considered to have confined systems and lagoons Dairy farms between 400-4000 heads were considered at 10% of total manure. Assumes biogas is used to generate electricity. Based on Argentina's base and peak load profile, fuel oil was selected as the fossil fuel being replaced, per Table 4.4.
H (#)	1,230,219	243,076	
Bo (m^3 CH_4/kg VS)	0.29	0.13	
MCF	0.75	0.75	
CH_4 (kg/yr)	19,630,466	16,807,902	
CH_4 (MT/yr)	19,630	16,808	
CO_2 (MT CO_2e/yr)	412,240	352,966	
Indirect emission reduction (MT CO_2e/yr)	77,643	66,479	
Total CO_2 (MT CO_2e/yr)	489,883	419,445	

4.1.2 Direct Emission Reduction from Digestion of Agricultural Commodity Processing Wastes

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

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

where: $CH_{4\ (W)}$ = annual methane emissions from agricultural commodity processing waste W, kg CH_4 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

$EF_{(W,\ S)}$ = emission factor for waste W and existing treatment system and discharge pathway S, kg CH_4 per kg COD

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

$$EF_{(W,S)} = B_{o\,(W)} \quad MCF_{(S)} \tag{4.3}$$

where: $B_{o\,(W)}$ = maximum CH_4 production capacity, kg CH_4 per kg COD

$MCF_{(S)}$ = methane conversion factor for the existing treatment system and discharge pathway, decimal.

Table 4.2 shows the estimated GHG emission reduction potential for five sectors in Argentina. When the indirect emissions reductions are considered, the potential GHG reductions range from 29,207 metric tons CO_2e per year for swine slaughterhouses to 785,986 metric tons CO_2e per year for distilleries. Total emissions reduction potential across all sectors is 1.3 million metric tons CO_2e per year. Based on limited data and best professional judgment, the MCF_{AD} values of 0.90 and 0.80 appear to be reasonable estimates for heated and ambient temperature digesters, respectively, for first-order estimates of methane production potential.

Table 4.2 – Methane and Carbon Emission Reductions From Agro-Industrial Waste

	Slaughterhouses - Swine	Slaughterhouses - Cattle	Sugar Mills	Distilleries	Citrus Processing	Assumptions
P (MT/year)	98,617	683,205	2,197,952	147,345	5,520,000	Biogas use: Assumes biogas is used to generate electricity.. Based on Argentina's base and peak loads profile, fuel oil was selected as the fossil fuel being replaced, per Table 4.4. Slaughterhouses: with capacity of >400 animals/day were considered. 50% of slaughterhouses have lagoons. Sugar and distilleries: values shown in RA for wastewater flow and COD levels were used. Citrus processing: Assumed 80% of major plants use lagoons. Only considered lemon production in Tucuman. Values shown in RA for wastewater flows and COD levels were used.
W (m^3/MT)	13	13	10.5	12	0.112318841	
COD (kg/m^3)	4.1	4.1	1.8	80	30	
TOW (kg COD/year)	5,256,262	36,414,850	41,541,293	141,451,200	18,600,000	
B_0 (kg CH_4/kgCOD)	0.25	0.25	0.25	0.25	0.25	
MCF	0.9	0.9	0.9	0.9	0.9	
EF (kg CH_4/kg COD)	0.225	0.225	0.225	0.225	0.225	
CH_4 (kg CH_4/year)	1,182,659	8,193,341	9,346,791	31,826,520	4,185,000	
CH_4 (MT CH_4/year)	1,183	8,193	9,347	31,827	4,185	
CO_2 (MT CO_2e/year)	24,836	172,060	196,283	668,357	87,885	
Indirect emission reduction (MT CO_2e/yr)	4,678	32,406	36,969	125,881	16,553	
Total CO_2 (MT CO_2e/yr)	29,514	204,467	233,251	794,238	104,438	

4.1.3 Indirect GHG Emissions Reductions

The use of anaerobic digestion systems has the financial advantage of offsetting energy costs at the production facility. Biogas can be used to generate electricity or to supplant the use of thermal fuels. Using biogas energy also reduces carbon emissions from the fossil fuels that are displaced by use of the recovered biogas. The degree of emission reduction depends on how the biogas is used. The following table shows the potential uses of the biogas in each of the sectors.

Table 4.3 – Potential Biogas Energy Use by Sector

Sector	Electricity Use	Thermal Energy Replacement
Swine	Feed mills	LPG to heat pig pens and piglets
Dairy	Energy intensive, particularly during milking operations	LPG
Milk processing	Energy intensive – chillers, pumps and engines, compressors.	Natural gas/LPG for boiler
Slaughterhouses	Energy intensive – cold chambers, pumps and general equipment.	Natural gas for boiler
Sugar/distilleries	Energy intensive. Sugar mills don't require electricity from the grid during harvest since they burn bagasse. However, they could sell the energy generated in an AD system.	Natural gas for boiler. Large user of steam in the process, particularly for evaporation and crystallization operations.
Citrus	Energy intensive	Natural gas for boiler, rotary and other driers

When biogas is used to generate electricity, the emission reduction depends on the energy sources used by the central power company to power the generators. In Argentina, the generation sector is comprised of thermal plants (60%), hydroelectric plants (34%), and nuclear plants (6%), as illustrated in Figure 4.1. The fuels used by the thermal plants are natural gas, diesel, and fuel oil. Many thermal plants in Argentina are dual fuel, which allows them to use either natural gas or fuel oil. Currently, fuel oil is used most often for both the base and peak loads. Table 4.4 shows the associated carbon emissions reduction rate from the replacement of fossil fuels when biogas is used to generate electricity in Argentina.

Figure 4.1 – Distribution of Electricity Generation

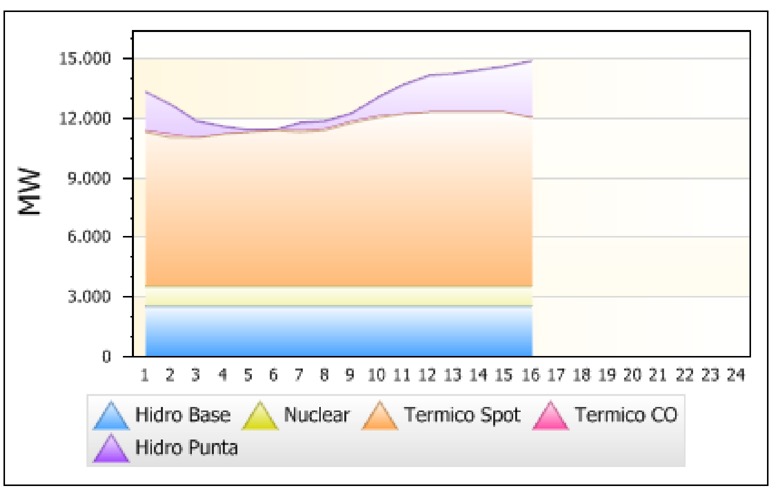


Table 4.4 – Carbon Emissions by Type of Fuel

Fuel Replaced	CO_2 Emissions Factors
Generating electricity - depends on fuel mix 100 % coal 100 % hydro or nuclear	 1.02 kg/kWh from CH_4 0 kg/kWh from CH_4
Natural gas	2.01 kg/m^3 CH_4
LPG	2.26 kg/m^3 CH_4
Distillate fuel oil	2.65 kg/m^3 CH_4

Source: Developed by Hall Associates, Georgetown, Delaware USA.

Indirect emissions are estimated by first estimating 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.

4.1.4 Summary

As illustrated by the equations presented above, the principal factor responsible for determining the magnitude of methane emissions from livestock manures and agricultural commodity processing wastes is the waste management practice employed, which determines the methane conversion factor (MCF). As shown in Table 10.17 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and in Tables 2.2 and 2.6 of this document, anaerobic lagoons and landfills have the highest potential for emitting methane from these wastes. Thus, replacing these waste management practices with anaerobic digestion has the greatest potential for reducing methane emissions. While the reduction in methane emissions realized by replacing other waste management practices with anaerobic digestion will not be as significant, the methane captured will be a source of renewable energy with the ability to reduce fossil fuel consumption and the associated greenhouse gas emissions from sequestered carbon.

Table 4-5 summarizes the findings of the resource assessment in terms of potential methane emission reductions and carbon offsets in Argentina. The sector with the highest potential for methane reduction and carbon offsets is the sugar/distilleries sector, followed by swine, dairy, slaughterhouses, and finally citrus processing. Note, however, that the citrus processing sector takes into consideration only one product (lemons) and one geographic area (Tucuman); the total citrus processing sector is expected to be higher than estimated in the resource assessment due to this limitation in the data used.

Table 4.5 – Summary of Total Carbon Emission Reductions Identified in Argentina

Sector	Methane Emissions Reductions (MT CH_4/yr)	Carbon Emissions Reductions (MT CO_2e/yr)	Fuel Replacement Offsets (MT CO_2e/yr)	Total Carbon Emissions Reductions (MT CO_2e/yr)
Sugar mills + distilleries	41,100	864,600	162,800	1,027,400
Swine	19,600	412,000	77,600	489,600
Dairy	16,800	353,000	66,500	419,500
Slaughterhouses (swine + cattle)	9,300	196,900	37,000	233,900
Citrus	4,100	87,800	16,500	104,300
TOTAL	90,900	1,914,300	360,400	2,274,700

4.2 TECHNOLOGY OPTIONS

4.2.1 Methane Production

There are a variety of anaerobic digestion processes, which can be broadly categorized as either suspended or attached growth processes. The applicability of any specific process is determined primarily by physical characteristics of the waste or mixture of wastes that will be anaerobically digested. Attached growth processes are suitable for wastes with low concentrations of particulate matter. For wastes with higher concentrations 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 Manures. For livestock manures, there are four anaerobic digestion reactor options: 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 4.6. 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 manures.

Table 4.6 – Overview of Anaerobic Digestion Options for Livestock Manures (After U.S. Environmental Protection Agency, 2004)

	Plug-flow	Mixed	Covered Lagoon	Attached Growth
Influent total solids 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

U.S. Environmental Protection Agency. 2004. AgSTAR Handbook, 2nd ed., K.F. Roos, J.H. Martin,Jr. and M.A. Moser eds. EPA-430-B-97-015. Office of Air and Radiation, Washington, DC.

As indicated in Table 4.6, 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 thus are only suitable for temperate and warm climates. In temperate climates, there may be seasonal variation in the rate of methane production.

Agricultural Commodity Processing Wastewater. As discussed above, agricultural commodity processing operations may generate either liquid wastewater, solid waste, or both. There is no single treatment process that is suitable for all of these wastewaters, except the covered anaerobic lagoon, due to wide variation in physical and chemical characteristics. 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, to the extent possible, from entering the wastewater generated, 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) or extremely high concentrations of dissolved organic matter (biochemical or chemical oxygen demand), the complete mix, anaerobic contact, or anaerobic sequencing batch reactor (ASBR) processes are alternatives. These are typically operated at mesophilic (30 to 35 °C or thermophilic (50 to 55 °C) temperatures.

As shown in Table 4.7, 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 4.7 – Typical Organic Loading rates for Anaerobic Suspended Growth Processes at 30°C. (Metcalf and Eddy, Inc., 2003)

Process	Volumetric Organic Loading, kg COD/m^3-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

For wastewaters with low total suspended solids (TSS) concentrations or wastewaters with low TSS concentrations after screening or some other form of TSS reduction, such as dissolved air floatation, one of the anaerobic sludge blanket processes may be applicable. Included are the: 1) basic up-flow anaerobic sludge blanket (USAB), 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) up-flow packed-bed attached growth, 2) up-flow 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 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.

4.2.2 Methane Use Options

In addition to methane, carbon dioxide is also 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 per m^3, a typical biogas composition of 60 percent methane and 40 percent carbon dioxide has a lower heating value of 21,453 kJ per m^3. Thus, biogas has a low energy density in comparison 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.

Use of biogas in place of coal, natural gas, liquefied petroleum gas (LPG), or distillate or heavy fuel oil for water or space heating is the most attractive option 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 LPG fueled boiler or furnace to biogas generally only requires replacement of the existing metal combustion assembly with a ceramic burner assembly with larger orifices. If there is seasonal variation in demand for water or space heating, biogas compression and storage 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 will be 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 shut down for maintenance or repairs is necessary. One of the advantages of using biogas to generate electricity connected to the grid is the ability to use biogas as it is produced and use the local electricity grid to dispose of excess electrical energy when generation capacity exceeds on-site demand. Specifically in the case of Argentina, the Ministry of Energy is promoting an initiative that aims to supply at least 8% of the total national energy consumption through renewable energy systems by 2016. Argentina has developed several tariff rates to support new electricity generation projects. The use of biogas to generate electricity not only will reduce farm operating costs, but will also provide a steady revenue stream for the farm.

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

4.3 COSTS AND POTENTIAL BENEFITS

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 cost will increase as the level of technology employed increases. For digestion, the covered anaerobic lagoon generally will require the lowest capital investment, with anaerobic sludge 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 for flaring will be the lowest and generating electricity the will be highest. Based on past projects developed in the United States and Latin America, the cost of an engine-generator set will be at least 25 percent of total project cost, including the anaerobic digester. In addition, while the operating and maintenance costs for flaring are minimal, they can be substantial for generating electricity. For example, using captured biogas to generate electricity requires a continuous engine-generator set maintenance program and may include operation and maintenance of a 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. Methane conversion factors, and therefore reduction in methane emissions and the accompanying carbon credits earned, are determined by the existing waste management system and vary from essentially 0 to 100 percent. Thus, carbon credits will be a significant source of revenue for some projects and nearly nothing for others.

The second potential source of revenue is from the use of 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 needs to 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, there should be the ability to deliver excess generation to the local grid during periods of low on-site demand and the subsequent ability to reclaim it during periods of high on-site demand under some type of a net metering contract.

The third potential source of revenue is from the carbon credits realized from the reduction in the fossil fuel carbon dioxide emissions when use of biogas reduces fossil fuel use. As with the revenue derived directly from using biogas as a fuel, the carbon credits generated depend on the fossil fuel replaced. For 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, small livestock production and agricultural commodity processing enterprises are not suitable candidates for anaerobic digestion to reduce methane emissions from their waste streams due to high capital and operating costs. The same is true for enterprises that only generate wastes seasonally. If all of the enterprises are located in a reasonably small 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. 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 for disposal. The optimal digester location could be determined by trial and error, but constructing and applying a simple transportation model should be a more efficient approach. Although obtaining the optimal solution manually is possible, use of linear programming should be considered. 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 the sale of carbon credits realized from the reduction of methane emissions and from the utilization of the captured methane as a fuel should be estimated. The latter will depend on a number of factors including the location of the digester and opportunities to use the captured methane in place of conventional sources of energy. Generally, captured methane that can be used to meet on-site electricity or heating demand will have the greatest monetary value and produce the most revenue to at least offset and ideally exceed system capital and operation and maintenance costs. Thus, an energy use profile for each source of waste in a possible centralized system should be developed to determine the potential for on-site methane use, the revenue that would be realized, and the allocation of this revenue among the waste sources. .

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

APPENDIX A: ARGENTINA GHG INVENTORY 2000 – EMISSION FACTORS

Quema de Residuos Agrícolas

Cultivo	Fracción de Carbono en los residuos	Relación Nitrógeno/Carbono
Algodón[1]	0,5	0,01
Caña de Azúcar[2]	0,5	0,01
Lino[1]	0,5	0,009
Trigo[1]	0,485	0,012

[1] Manual Revisado del IPCC (1997)

[2] EE Obispo Colombres de Tucumán (Romero et al. 1995)

Factores de emisión de metano procedente del manejo del estiércol

Especies	Region fria		Region templada		Factor de emisión promedio (kg/cab-año)
	Factor de emisión	% Población	Factor de emisión	% Población	
Bovinos lecheros	0	0,4	1	99,6	0,996
Bovinos no lecheros	1	2	1	98	1
Ovinos	0,1	60	0,16	40	0,124
Caprinos	0,11	49	0,17	51	0,14
Porcinos	0	2	1	98	0,98
Equinos	1,1	15	1,6	85	1,52
Búfalos	1	0	1	100	1
Camélidos sudamericanos	1,3	0	1,9	100	1,9
Asnales y Mulares	0,6	13	0,9	87	0,86
Aves de corral	0,012	17	0,018	83	0,017

Elaboración en base a valores por defecto del IPCC

Factores de emisión de N2O y porcentaje del estiércol de cada especie que se trata en cada sistema

Sistema de tratamiento o destino del estiércol	Factor de emisión (kg/cab-año)	Bovinos lecheros	Porcinos	Aves	Otras especies
Praderas o pastizales	0,02	90%	25%		100%
Estanques anaeróbicos	0,001	10%	75%		
Estiércol de aves con cama	0,02			50%	
Estiércol de aves sin cama	0,005			50%	

Elaboración en base a valores por defecto del IPCC

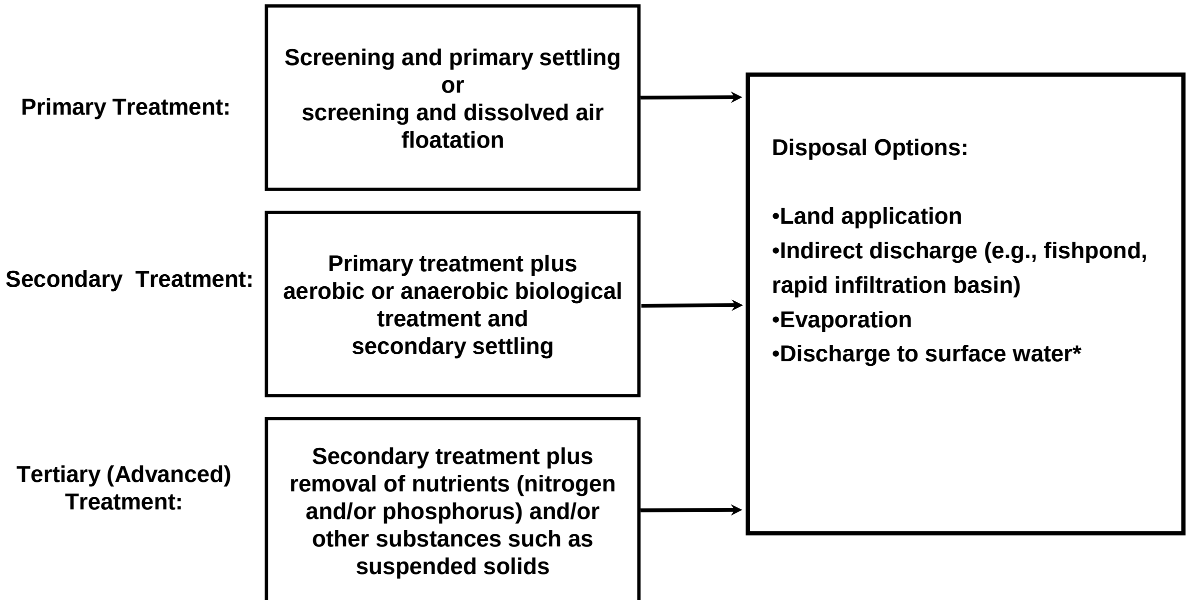
Factores de emisión por fermentación entérica

Categoria	(Kg CH4/cab-año)
Ganado Lechero	**91,79**
Vaca Lechera Lactante y Gestante	111,50
Vaca Lechera Lactante y Vacía	106,72
Vaca Lechera Seca y Gestante	58,42
Vaca Lechera Seca y Vacía	53,82
Ganado no Lechero	**51,78**
Vaca no Lechera Lactante y Gestante	73,17
Vaca no Lechera Lactante y Vacía	68,44
Vaca no Lechera Seca y Gestante	57,74
Vaca no Lechera Seca y Vacía	53,19
Ternero/a no Destetado	0,00
Ternera Feed lot	34,44
Ternero Invernada Corta	42,32
Ternero Invernada Larga	38,78
Ternera Invernada Corta	38,96
Ternera Recría	43,00
Ternero Torito	53,92
Torito	92,89
Novillito Invernada Corta	55,80
Novillito Invernada Larga	52,57
Novillo Invernada Larga	65,23
Vaquillona (1 a 2 años) Invernada Corta	52,81
Vaquillona (1 a 2 años) Recría Vacía	57,21
Vaquillona (Más de 2 años) Recría Vacía	68,30
Vaquillona (Más de 2 años) Recría Gestante	72,52
Toro	82,17

Elaboración en base a las fórmulas establecidas por el IPCC

Source: 2° Comunicación Nacional de la Rep. Argentina a la Convención Marco de las Naciones Unidas para el Cambio Climático, October 2007

APPENDIX B: TYPICAL WASTEWATER TREATMENT UNIT PROCESS SEQUENCE



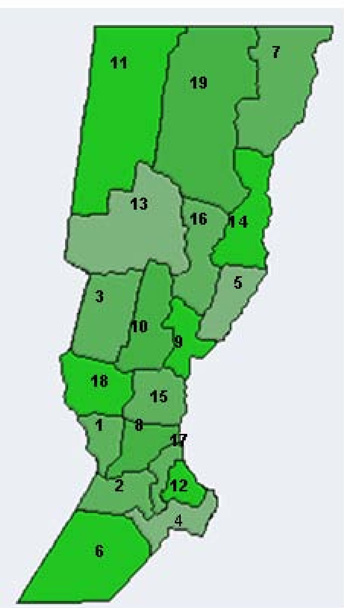
*According to applicable discharge standards

APPENDIX C: ADDITIONAL SECTOR INFORMATION

The following data provides further detail on the sectors included in Chapter 3. It also presents information on other sectors where potential methane emissions were identified: milk processing and wine distilleries. These sectors are not included in the main body of the assessment since there was not enough information on their specific waste management practices. The information found on these sectors can be found in Appendix C.

C.1 DAIRY

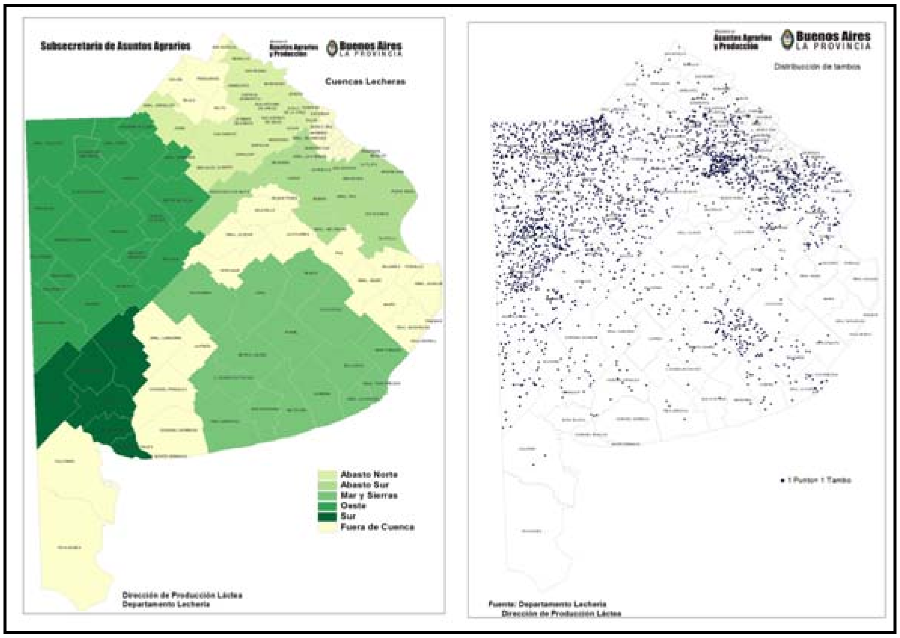
The following figure shows the location of dairies in Santa Fe and Buenos Aires, two of the most important dairy regions in Argentina.



Province of Santa Fe, Dairy Farms by department, 2005

		Farms	Heads
Total Province		4,591	1,068,023
Department			
1	BELGRANO	31	6,760
2	CASEROS	24	4,033
3	CASTELLANOS	1,298	308,862
4	CONSTITUCIÓN	2	168
5	GARAY		
6	GENERAL LÓPEZ	172	87,381
7	GENERAL OBLIGADO	46	3,721
8	IRIONDO	150	40,618
9	LA CAPITAL	124	21,495
10	LAS COLONIAS	1,199	234,015
11	NUEVE DE JULIO	12	4,262
12	ROSARIO	81	6,229
13	SAN CRISTÓBAL	741	182,109
14	SAN JAVIER	18	1,610
15	SAN JERÓNIMO	152	31,604
16	SAN JUSTO	109	27,879
17	SAN LORENZO	60	6,693
18	SAN MARTÌN	354	88,473
19	VERA	18	2,111

Source: Ministerio de la Producción de la Provincia de Santa Fe - Dirección General de Sanidad Animal, Departamento de Lechería



Source: Subsecretaría de Asuntos Agrarios, Dirección de Producción Láctea, Departamento Lechería, Provincia de Buenos Aires

C.2 SLAUGHTERHOUSES

Distribution of Animals Slaughtered by Facility, 2007

Slaughterhouse	Heads	Location	%
Frig. La Pompeya S.a.c.i.f. Y A.	745.232	Marcos Paz	23,29
Coop. De Trab. Ex Empleados Del Frig. Minguillon L	356.493	Moreno	11,14
Pork-ind S.r.l.	291.905	San Andres De Giles	9,12
Frigorifico Paladini S.A.	176.066	Villa Gobernador Galvez	5,50
Coop. De Trabajo De Santa Isabel Ltda.	116.294	Santa Isabel	3,63
Detwiler S.A.	107.038	Gral. Las Heras	3,34
Frig. Guadalupe S.A.	89.670	Colonia Crespo	2,80
Rafaela Alimentos S.A.	87.003	Rafaela	2,72
Establecimiento Don Esteban S.A.	78.275	Totoras	2,45
Industrias Carsigom S.A.	72.002	San Nicolás	2,25
Frigorifico Costanzo S.A.	63.748	San Andres De Giles	1,99
Mattievich S.A.	56.447	Carcaraña	1,76
Alimentos Magros S.A.	47.190	Justiniano Posse	1,47
Agrolucas S.A.	46.906	Gral. Arenales	1,47
La Piamontesa De Averaldo Giacosa Y Cia. S.A.	46.056	Santa Rosa	1,44
Otros	819.830		25,62
Total	**3.200.155**		**100**

Source: ONCCA

Process of a Meat-Packing Establishment, Different Stages and Generated Wastes

Operation	Stage	Wastes
Animal reception	Transport trucks of the farm, unloading ramp, isolation pen, confinement pen, observation pen, necropsy room and digester, access ramp to the slaughter yard, shower	Urine and feces must be cleaned up at least each 24 hours with pressurized water. Duration of animals in pens range from 12 to 72 hours. The drainage system of this sector must be independent of other drainages in the facility. It also must have a mechanical system for separation of the coarse components from feces. Floors from pens and races will drain through channels, drains, drainage inlets and piping, and discharged to the general effluents system. The network formed at the end in the general ductwork will have a siphon or baffled device for achieving a permanent hydraulic closure between both systems. In the case of isolation and observation pens and emergency and necropsy rooms (called sanitary complex of the pens), effluents go to a special decanter where they are hyperchlorinated and disinfected with antiseptics before being sent to the general drainage system.
Slaughter yard	<u>Dirty zone</u> Stunning box, bleeding	The main contaminant is blood, plus other effluents coming from washing the animals and equipment. Blood must be segregated from other effluents.
	<u>Intermediate zone</u> Skinning, cutting of front and rear feet, head cutting, evisceration, removal of green viscera, evisceration, removal of red viscera, sawing	Hides and feet are retired immediately and taken to a storage room. Wastes include blood, hides, green matter, vomit residues and liquids containing FOGs.
	<u>Clean zone</u> Veterinary inspection, washing, classification platform, aerated room, cold rooms, retailing	Wastes include blood, fat, organic matter carried by the wash, and fats coming from cuttings and trimmings at the end of the process.
Rooms annexed to slaughter yard	Head room, guts and tripe room, red viscera room, split and cutting room, flour manufacturing room, meat and bones	Wastes coming from this sector are rich in organic matter. These rooms generate blood residues (e.g., heart wash), green residues coming from the clean up of viscera (guts and tripe), and FOG residues that are left from the different clean up and trimming tasks. Some slaughterhouses conduct the splitting of the different cuts, generating fat and bone residues.

Source: Arturo Shimamoto, Ecosignos Virtual, Año 3, Número 3, 1998

C.3 MILK PROCESSING

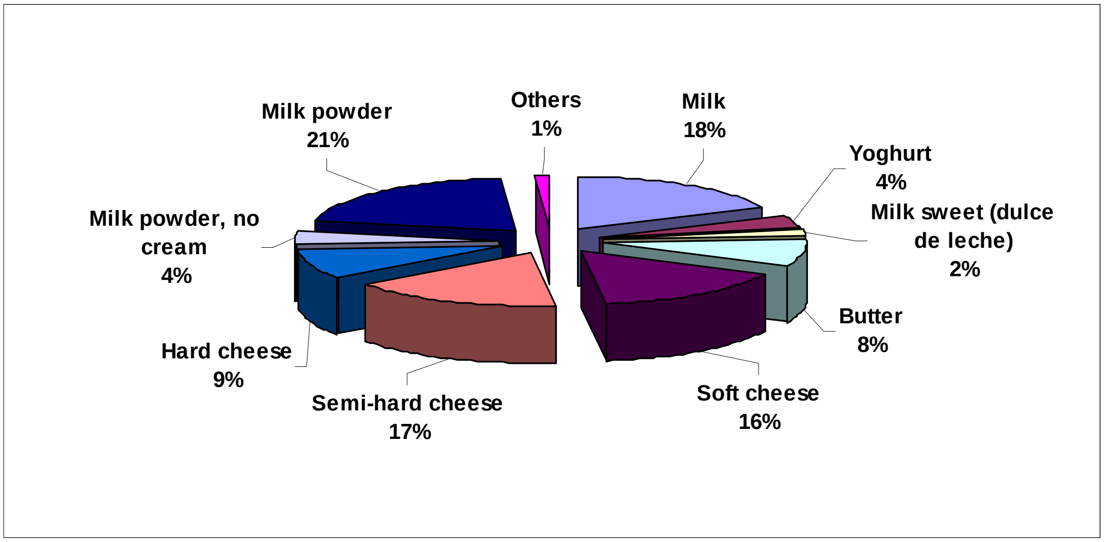
Description of Size, Scale of Operations and Geographic Location

During the last 10 years, the milk processing sector has increased considerably thanks to increased domestic and export consumption, driven by a process of strong restructuring of the industry, the entry of multinational companies in the local market, and large investments in the sector (SAGPyA, 2001). This process was focused on company mergers and acquisitions, product quality improvements, packaging changes, increase in product diversification, markets segmentation, greater industrial specialization (cheeses and types of milk, for example), and export growth.

Of the volume increase expected in 2009, most processors believe that a vast majority of the milk will be turned into whole dry milk, and a smaller portion into cheese. There are no significant new investments in processing capacity projected for the next year since there seems to be production and processing capacity to handle further milk output increases.

According to the information published by Centra de la Industria Lechera (CIL), or Dairy Industry Federation, the distribution of dairy products during the year 2006 is shown in the following figure:

Distribution of Dairy Products Manufacturing (2006)



Source: Centro de la Industria Lechera

Milk processing plants are located near dairies, so their geographic location will follow the dairy sector - Santa Fe, Córdoba, Buenos Aires, Entre Ríos, La Pampa and Tucumán. The industry, as mentioned before, is characterized by a significant concentration (~70%) of the production in 8 large companies. The following table shows the major companies in Argentina, their geographic location, and their main products.

Structure of the Major Milk Companies

Company	Location	Products
Mastellone	Gral Rodríguez, Prov Buenos Aires Longchamps, Prov Buenos Aires Five plants in the country's inland	Fresh milk, cheeses, milk caramel, cream, desserts and yogurts 4.800.000 Lt/day milk
Sancor	Córdoba, Prov Córdoba Chivilcoy, Prov Buenos Aires Sunchales, Prov Santa Fe San Guillermo, Prov Santa Fe Brinkman, Prov Santa Fe Devoto, Prov Córdoba Gálvez, Prov Santa Ge La Carlota, Prov Córdoba Balnearia, Prov Córdoba Centeno, Prov Santa Fe Ceres, Prov Santa Fe Coronel Charlone, Prov Buenos Aires Coronel Moldes, Prov Córdoba Morteros, Prov Córdoba	Industrial plant Córdoba: yogurts, creme caramel, desserts and SanCor Bio Industrial Plant Chivilcoy: milk U.A.T. and refrigerated Industrial Plant Sunchales: powdered milk, sterilized milk U.H.T. (Ultra High Temperature), chocolate milk, special milks and crème caramel Industrial Plant San Guillermo: cheeses Por Salut and Blue Cheese Industrial Plant Brinkmann: soft cheeses and powdered cheese whey Industrial Plant Devoto: butter, powdered milk, cream Maturing cheese depot Gálvez Industrial Plant La Carlota: hard and semi-hard cheeses Industrial Plant Balnearia: special cheeses Industrial Plant Morteros: powdered milk and semi-hard cheeses 6,000,000 Lt/day milk
Milkaut	Frank (concentrates 80% of the production)	Dehydrated: Powdered milk, Powdered Cream, Protein concentrate of Cheese Whey and Protein concentrate of Milk, crème caramel Fresh: pasteurized milk, pasteurized cream, yogurts, desserts and crème caramel. Sterile area: long-life milk (UHT), Natural cheeses: soft paste, semi-hard paste, hard paste and specialties. 500,0000 Lt/day milk in cheeses line 800,000 Lt/day of milk whey 300,000 Lt/day fluid skimmed milk 19,000 Kg/day Lactose 12,000 Kg/day of Powdered Whey Proteins 10,000 Kg/day Milk Proteins 250,000 Lt/day UHT 500,000 Lt/day milk for cheeses
	Colonia Nueva	Hard and semi-hard paste cheeses, with a production capacity of 300,000 Lt/day milk
	Plant Chamical, Province of La Rioja	Grated cheese, using as raw material hard paste cheeses like Sardo and Reggianito. Industrializes dehydrated products
	Plant San Luis, Province of San Luis	Long-life milk (UHT), with a production capacity of 120 thousand liters daily
Nestlé	Magdalena, Prov Buenos Aires El Talar, Prov Buenos Aires Santo Tomé, Prov Santa Fe Firmat, Prov Santa Fe Villa Nueva, Prov Córdoba Lincoln, Prov Buenos Aires	Powdered milks Infant cereals Chocolate beverages Ice creams Yogurts Fresh desserts and Ultrafresh cheeses Mineral water Pets food

Company	Location	Products
Williner		Arrufó: sardo, regianito and trebolgiano cheeses Suardi: regianito, pategrás, fontina and trebolgiano cheeses Rafaela: grated cheese, crème caramel and whey derivatives El Trébol: regianito, sardo and tybo cheeses
Verónica	Clason, Prov Santa Fe Lehmann, Prov Santa Fe, 3 plants Suardi, Prov Santa Fe, 2 plants	Clason: cheeses, butter and cream, crème caramel, UHT Lehmann: cheeses, powdered milk Suardi; cheeses, powdered milk 300 million Lt/year of milk
Manfrey	Freyre, Prov Córdoba	Pasteurizer plant. Creme caramel manufacturing plant. Cheese plant Yogurts, desserts and creme caramel manufacturing plant. Powdered milk dehydrator plant. Pasteurized cream processing plant. Spread cheese manufacturing plant. Pasteurized milk processing plant. Cheese maturing depots 292.000.000 Lt/year milk
Molfino-La Paulina	Rafaela, Prov Santa Fe Villa María, Prov. Córdoba	Rafaela: soft, semi-hard and hard paste cheeses, butter, cream and powdered milk Villa María: cheeses

Description of Waste Characteristics, Handling and Management

The milk processing industry generates three main waste streams:

Solid, semi-solid, and liquid wastes coming from the reception and manufacturing process.

Liquids coming from washing and rinsing of process equipment and devices.

Residuals of plastics, aluminum and corrugated cardboard coming from the packaging process

The solid, semi-solid, and liquid wastes generated during the manufacturing process are comprised mostly of milk whey, casein, caseinates, and wastes from butter manufacturing. These wastes represent 80 to 90 percent of the total wastes. In small processing plants, whey is sold as calf food to dairy or swine farms. In large processing plants, whey residues are generally used to produce fermented beverages, enzymes (beta-galactosidase or lactase, protease), lactic acid, acetic acid, and other potential products.

The following examples illustrate the waste management practices in two of the main milk processing industries in Argentina: Mastellone and Williner.

Mastellone: Mastellone uses stabilization (anaerobic) lagoons in practically all of its industrial plants. The largest treatment system of Mastellone is located at Industrial Complex Gral. Rodríguez, comprised of nine lagoons in series. The first five lagoons are anaerobic and the remaining four are facultative. The lagoons cover 27 hectares with a total volume of 508,000 m^3.

Williner: Williner has two effluent treatment plants: Rafaela and Bella Italia. The processes used at these facilities are not commonly used elsewhere in Argentina.

Rafaela combines physical and biological treatment and uses high purity oxygen in its aerobic process. The main unit operations are: equalization, flocculation and settling of suspended solids and fats, filtering, aerobic digestion, and final separation and polishing. The plant has partial authorization from the municipality of Santa Fe to discharge its effluents to the sewage system.

Bella Italia also combines physical and biological treatment through a series of aerobic lagoons. The wastewater first goes through primary treatment and settling operations, then through a three-lagoon system where forced mechanical aeration takes place. The effluents are then sent to two stabilization lagoons and finally chlorinated before discharging into the sewage.

The following data illustrates typical values of COD in the industry. The data are part of an analysis to simulate organic loading in wastewaters conducted at SANCOR, one of the major milk processing plants in Argentina. The data shows that the levels of BOD and COD would yield high production levels of methane if lagoons were used; more information on WMS is required to determine methane potential.

Results from Laboratory Analysis of Milk Processing By-products

By-product	Dilution	COD (ppm)
Cheese whey (6.2% TS)	20%	11,520
Butter whey (7.4% TS)	20%	17,480
Whole milk	1% on volume	1,860
Chocolate milk	1% on volume	1,935
Dulce de leche	1% on weight	7,680

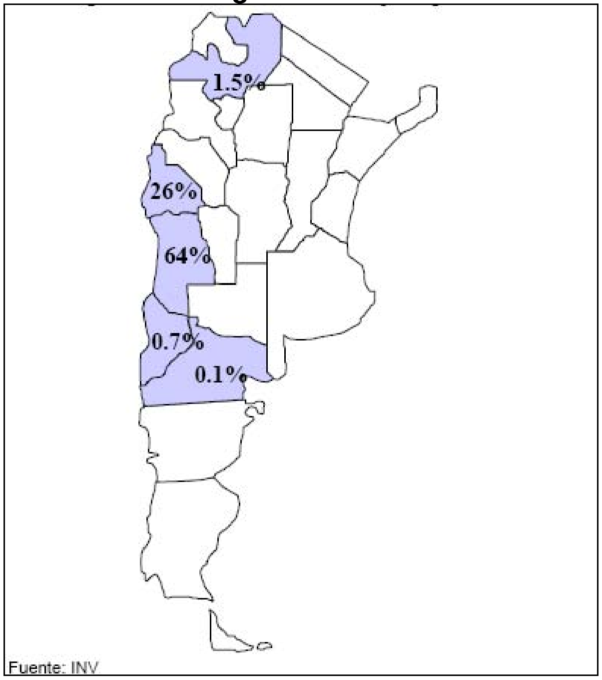
Source: Eduardo Gropelli

C.4 WINE

Description of Size, Scale of Operations and Geographic Location

Argentina has 225,846 hectares of vineyards from which an average of 2,822 million kilograms of grapes is harvested annually. The figure below shows the distribution of grape production in the country as a function of the fraction of cultivated land used for grape production. The most intensive grape production occurs in the Cuyo region, where 64 percent of the cultivated land in the Province of Mendoza is in vineyards and 26 percent in the Province of San Juan.

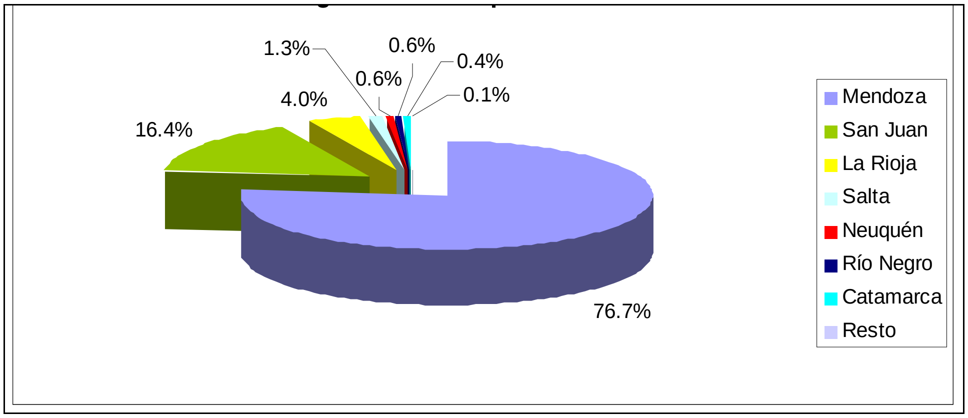
Vineyards as a Percentage of Cultivated Land in Argentina



Source: Instituto Nacional de Vitivinicultura

Wine making is concentrated in Mendoza, San Juan, La Rioja, Río Negro, and Salta provinces as shown in the figure below, with 1.468 million L of wine produced in 1.322 wineries. Although the production of basic wines has decreased in recent years, fine wine production has not fallen.

Argentina Wines Production 2007



Source: Instituto Nacional de Vitivinicultura

Description of Waste Characteristics, Handling and Management

The four important aspects of winery effluents that have to be taken into account are:

Water volume, coming mainly from washing operations. In general, groundwater is used in wineries. Water used for clean up and hygiene is about 1.63 L water/L fabricated wine, the rest of the year consumption of 1.45 L water/L elaborated wine.

Concentration of inorganic salts from groundwater.

Concentration of organic compounds, as reflected by BOD and COD levels.

pH.

Regarding the effluent characteristics, below are included the results of a study conducted by the National University of Cuyo on effluents from Mendoza's wineries that use traditional wine-making systems. Effluent samples of two commercial and representative wineries were taken, identified as A and B. Samples were taken during milling, when effluents come mainly from wash operations. The results of the chemical-biological analysis of the sampling points are shown as follows:

		Salida bodega		Pileta de deposición	
		a	x ± s	a	x ± s
Bodega A	(mg/l)	19/04/01			
	DBO	s/d			
	DQO				
		24/04/01			
	DBO	82 - 53	68 ± 14,526	408 - 94	273,00 ± 161,558
	DQO	107 - 87	95,67 ± 10,263	526 - 163	355,67 ± 182,528
Bodega B		17/04/01			
	DBO	28,5 - 3,1	15,20 ±12,742	88,8 - 46,15	69,52 ± 21,616
	DQO	46 - 8	25,67 ± 19,140	108 - 71	90,33 ± 18,556
		24/04/01			
	DBO	104 - 16	47,67 ± 48,911	64 - 15	32,00 ± 27,731
	DQO	138 - 37	74,33 ± 55,411	76 - 27	47,33 ± 25,541

Source: Caracterización química de efluentes de bodegas Mendoza (Argentina), Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo, 2002

C.5 SUGAR AND DISTILLERIES

Zafra azucarera 2007 En kilogramos (kg) o toneladas métricas valor crudo (TMVC)							
INGENIOS	Azúcares Blancos (kg)	Azúcares Crudos (kg)	Producción total (kg)	Caña Molida (kg)	Rend.	Producción Total (TMVC)	Rend.
Columnas	1	2	3=1+2	4	5=(3/4) %	6*	7=(6/4) %
Aguilares	29310550	6926120	36236670	404273000	8.963	38785	9.594
Bella Vista	72238350	1080900	73319250	754544000	9.717	79600	10.549
Concepción	223530100	63838610	287368710	2851163000	10.079	306805	10.761
Cruz Alta	31116203	357500	31473703	339446000	9.272	34179	10.069
La Corona	47560570	10354900	57915470	635939000	9.107	62051	9.757
La Florida	106739020	23837501	130576521	1336185000	9.772	139857	10.467
La Fronterita	64018550	31506250	95524800	975215000	9.795	101091	10.366
La Providencia	112274000	0	112274000	1278448000	8.782	122036	9.546
La Trinidad	87346450	18895110	106241560	1126497000	9.431	113836	10.105
Leales	45716022	0	45716022	481984000	9.485	49691	10.310
Marapa	59237000	0	59237000	610347000	9.705	64388	10.549
Ñuñorco	51975000	8525000	60500000	653515000	9.258	65019	9.949
San Juan	41099000	0	41099000	442569000	9.286	44673	10.094

Zafra azucarera 2007 En kilogramos (kg) o toneladas métricas valor crudo (TMVC)							
INGENIOS	Azúcares Blancos (kg)	Azúcares Crudos (kg)	Producción total (kg)	Caña Molida (kg)	Rend.	Producción Total (TMVC)	Rend.
Columnas	1	2	3=1+2	4	5=(3/4) %	6*	7=(6/4) %
Santa Bárbara	77980000	11648000	89628000	875124000	10.242	96408	11.017
Santa Rosa	43412370	8608630	52021000	559486000	9.298	55796	9.973
Total Tucumán	1093553185	185578521	1279131706	13324735000	9.600	1374216	10.313
La Esperanza	66947130	0	66947130	676161000	9.901	72768	10.762
Ledesma	225936454	121789709	347726163	3300280873	10.536	367371	11.132
Rio Grande	55871200	13076017	68947217	613722689	11.234	73805	12.026
San Martín del Tabacal	209067000	0	209067000	2043141000	10.233	227245	11.122
San Isidro	41774190	0	41774190	484023170	8.631	45406	9.381
Total Norte	599595974	134865726	734461700	7117328732	10.319	786597	11.052
Arno	16220000	0	16220000	154629000	10.490	17630	11.402
Las Toscas	14917000	0	14917000	145540000	10.249	16214	0.000
San Javier	3030985	0	3030985	41373875	7.326	3295	7.963
Total Litoral	34167985	0	34167985	341542875	10.004	37139	10.874
TOTAL PAIS	1727317144	320444247	2047761391	20783606607	9.853	2197952	10.575

(*)Columna 6=[(Azúcar blanco×1,08695)+Azúcar crudo] / 1000

Source: Centro Azucarero Argentino

C.6 CITRUS PROCESSING

The general process of citrus fruit production can be summarized in the following points:

Fruit reaching the plant is weighed, inspected, and unloaded in water pools to minimize damage when unloading. From the unloading pools it is transported to silos for its storage, or it passes directly for processing.

Fruit from silos or from the unloading pool goes into a channel where the current transports it to an elevator that takes it to the processing building.

Fruit is manually selected and mechanically classified by caliber in a grading machine. At the outlet of this machine there are electronic counters that register the number of fruit units that enter the process. This information is transmitted to a computer automatically regulating the amount of fruit entering the process, modifying the speed of the entry elevator.

Fruit already classified by grade passes to essential oil extraction, which is obtained by scraping the surface of the fruit under a water current, which carries essential oil in emulsion form to the centrifuges for recovery.

With almost all of its essential oil out, the fruit passes to juice extraction. In a single operation, cup extracting machines separate the juice, the peel, the seeds and skins, and an emulsion that contains the remainder of essential oil.

The juice is screened, centrifuged, pasteurized, and concentrated. For special clarified and debittered juices, the juice is passed through ultra-filters and debittering columns.

Juice concentrate is sent to refrigerated batch tanks, where it is homogenized and packed in metal drums with a double polyethylene inner bag to prevent contact with the metal part of the drum. Packed juice is maintained at a temperature of –20°C until shipping.

The solid remainder at the extractor's outlet, formed by peel, seeds, and skin, is transported to the dehydrating section where, previous a three-stage wash, is dehydrated in rotatory drum driers of three stages. The dehydrated product is cooled and pressed in 50 kg packets with a protecting plastic bag. These packets are stowed and are ready for shipping.

The essential oil emulsion is transported to the centrifuges that separate the essential oil from the water.

Essential oil is sent to tanks in cold rooms, where the cold causes the waxes to precipitate. Then, it is centrifuged and filtered for obtaining the final product that is packed in special drums for preservation.

The following table shows Argentina's citrus production by Province.

DISTRIBUTION PER PROVINCE OF THE ARGENTINE CITRUS PRODUCTION (metrics tons) - Year 2006

Provincias	Naranja	Mandarina	Pomelo	Limon	Total
Provinces	*Orange*	*Mandarin*	*Grapefruit*	*Lemon*	*Total*
Entre Rios	435.378	273.537	11.045	19.121	739.081
Tucumán	55.000	8.000	9.000	1.316.300	1.388.300
Misiones	17.796	37.183	8.509	7.713	71.201
Salta	108.250	14.760	199.500	85.550	408.060
Corrientes	130.000	50.000	5.000	35.000	220.000
Buenos Aires	80.000	12.000	1.000	2.000	95.000
Jujuy	88.570	18.500	13.450	36.320	156.840
Catamarca	9.000	7.000	500	400	16.900
Resto del país (1)	14.500	11.400	11.300	1.800	39.000
Rest of the country					
TOTAL	**938.494**	**432.380**	**259.304**	**1.504.204**	**3.134.382**

(1) Estimado a 2001 / *Estimate 2001.*
Fuente/*Source*: Instituto Nacional de Tecnología Agropecuaria (INTA) - Informes Regionales 2006. S.A.G.P.y A.

An example of an AD system in this sector was executed by Eng. Gropelli in a company producing juices and essential oils, generating 27,000 Tn/year of organic wastes. An AD system was installed and generates ~2.7 million m^3/year of biogas, and provides over 60% of the plant's steam consumption. The relevant values are shown in the following table:

Wastes Composition		
Detail	**Amount**	**Units**
Solid organic wastes	27,000,000.00	kg TS/year
Annual operation period	242	days/year
Needed processing capacity	111,570.25	kg TS/day
Total solids concentration	13,60	% TS
Volatile solids concentration	96,60	% VS/TS
Volatile solids amount	3,547,152.00	kg VS/year
Needed processing capacity	14,657.65	kg VS/day
Conversion of Organic Wastes into Combustible Biogas		
Detail	**Amount**	**Units**
Organic matter conversion into biogas	765.00	L/Kg VS
Total biogas generation	2,713,571.28	m^3/year
Specific biogas generation	100,50	m^3/Tn
Percentage Composition of Biogas - Dry		
Detail	**Amount**	**Units**
Methane (CH_4)	48,17	%
Carbon Dioxide (CO_2)	51.83	%
Total components percentage	100.00	%
Heat value of Dry Biogas	4,479.81	Kcal/m^3 Dry
Equivalent generation in PTN Methane	1,307,127.29	m^3/year
PTN Methane density	0.71	kg/m^3
Daily methane production	5,401.35	m^3 CH_4/day
Reduction of Greenhouse Gas Emissions		
Detail	**Amount**	**Units**
Potential reduction CO_2 to environment from wastes (AM0025)	1,958.00	Tn CO_2/year
CO_2 emission by electric energy generation	0.50	kg CO_2/kWh
CO_2 emission by electric energy generation	620.40	kg CO_2/day
System operation period	242.00	days/year
CO_2 annual emission by electric energy consumption	150.14	Tn CO_2/year
Specific reduction by use of Biologic Methane	2.75	Tn CO_2/Tn CH_4
Emissions annual reduction by combustion of Biologic Methane	2,562.17	Tn CO_2/year
Net total potential reduction of CO_2 to the environment	14,630.17	Tn CO_2/year

Source: Eduardo Gropelli, Facultad de Ingeniería Química, Universidad Nacional del Litoral

APPENDIX D: METHANE EMISSIONS FROM SOLID WASTES AND LEAKAGES

Solid Wastes

Estimating the methane production potential for agricultural commodity processing wastes is confounded by the same issue regarding B_o expressed on a mass or volume of methane per unit COD basis discussed above. If the solid waste COD concentration is known, estimating methane production potential is as follows:

$$CH_{4\,(SW,\,P)} = TOW_{(SW)} \quad B_o \quad MCF_{(SW,\,P)}]$$

where: $CH_{4(SW,\,P)}$ = estimated methane production potential from agricultural commodity processing waste SW, kg CH_4 per year

$TOW_{(SW)}$ = annual mass of solid waste SW COD generated, kg per year

$MCF_{(AD)}$ = methane conversion factor for anaerobic digestion, decimal

Again based on limited data and best professional judgment, the MCF_{AD} values of 0.90 and 0.80 appear to be reasonable estimates respectively for heated and ambient temperature digesters for first-order estimates of methane production potential.

Leakage and Combustion Related Emissions

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

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

$$LK_{(P)} = \frac{CH_{4\,(P)}}{0.85} \; CH_{4\,(P)} \quad 0.67\ kg/m^3$$

where: $LK_{(P)}$ = project methane leakage, kg/year

$CH_{4\,(P)}$ = estimated methane production potential from manure or agricultural commodity processing wastes or both, kg/year

0.85 = default methane capture efficiency, decimal

Because no combustion process is 100 percent efficient and all captured methane should be disposed of by combustion, combustion related methane emissions also should be accounted for in estimating a project's net methane emission reduction. Unless higher combustion efficiency values can be justified by supporting documentation, the default values (CCAR, 2008) listed in the table below should be used.

Default Values for Methane Combustion Efficiencies, decimal

COMBUSTION PROCESS	DEFAULT VALUE
OPEN FLARE	0.96
ENCLOSED FLARE	0.995
LEAN BURN INTERNAL COMBUSTION ENGINE	0.936
RICH BURN INTERNAL COMBUSTION ENGINE	0.995
BOILER	0.98

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

$$CE_{(P)} = (CH_{4\,(P)} - LK_{(P)}) \quad 1 - C_{eff}$$

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

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

C_{eff} = Combustion efficiency, decimal

Fossil Fuel Use Related Emissions

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

Default Values for Carbon Dioxide Factors for Gasoline and Diesel Fuel Use for Transportation (Regional Greenhouse Gas Initiative, Inc., 2007)

FUEL	CO_2 EMISSION FACTOR, KG/L
GASOLINE	2.38
DIESEL	2.75

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

$$FF_{(P)} = \frac{FF_{(Use)} \quad C_{factor}}{21}$$

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

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

E_{factor} = Emission factor, kg CO_2/L

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

APPENDIX E: GLOSSARY

Acetogenesis—The formation of acetate (CH3COOH) from carbon dioxide and hydrogen. Many methanogens grow and form methane from acetate.

Acidogenesis—The formation of primarily short-chain volatile acids such as acetic, proprionic, butyric, valeric, and caproic from simple soluble compounds produced during hydrolysis.

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 Bacteria—Bacteria that require free elemental oxygen to sustain life.

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

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

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

Anaerobic Bacteria—Bacteria that grow only in the absence of 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 following four steps: 1) feed, 2) mix, 3) settle, and 4) decant/effluent withdrawal.

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

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

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 if 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.

Cesspool—A lined or partially lined underground pit into which wastewater is discharged and from which the liquid seeps into the surrounding soil. Sometimes called a leaching cesspool.

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.

Chemical Unit Processes—Processes that remove dissolved and suspended wastewater constituents by chemically induced coagulation and precipitation or oxidation. An example is the addition of alum or lime to remove phosphorus by precipitation in tertiary treatment.

Clarifier—Any large circular or rectangular sedimentation tank used to remove settleable solids from water or wastewater. A special type of clarifiers, called upflow clarifiers, use floatation rather than sedimentation to remove solids.

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

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

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

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

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

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

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

Evaporation Pond—A pond or lagoon used for the disposal of wastewater by evaporation.

Facultative—Having the ability to live under different conditions; for example with or without free oxygen.

Facultative Bacteria—Bacteria, which can carry out metabolic activities including reproduction in the presence or absence of free elemental oxygen.

Facultative Pond or Lagoon—A natural or constructed pond or lagoon with an aerobic upper section and an anaerobic bottom section so that both aerobic and anaerobic processes occur simultaneously.

Five Day BOD—That part of oxygen demand usually associated with biochemical oxidation of carbonaceous material with in five days at 20 °C.

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

Human Sewage (Domestic Wastewater) – Human sewage is wastewater that contains human urine and feces. It also usually contains wastewater from bathing and washing of dishes, kitchen utensils, clothing, etc. and may include food preparation wastes. It may be discharged directly, treated on-site prior to discharge, or transported by a collection system for direct discharge or treatment in a centralized wastewater treatment plant followed by discharge. Human sewage also is known as domestic wastewater.

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.

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

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

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

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

Methanogenesis—The formation of methane from CO_2-type, methyl, and acetoclastic type substrates.

Municipal Wastewater—Wastewater treated in a municipal (publicly owned) treatment plant and can contain domestic, commercial and industrial wastewaters.

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

Oxidation Pond—A relatively shallow body of wastewater contained in an earthen basin of controlled shape, in which biological oxidation of organic matter is effected by the natural or artificially accelerated transfer of oxygen.

Physical Unit Processes—Processes that remove particulate matter in wastewater. Screening and gravity separation to remove particulate matter are examples of physical unit processes. These processes are used for primary treatment and following secondary and tertiary treatment processes. A typical example of the use of physical unit processes in a wastewater treatment system is primary settling followed by the activated sludge treatment process, which is then followed by secondary settling before final effluent discharge.

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

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

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

Psychrophilic Digestion—Digestion by biological action below 27 °C.

Raw Wastewater—Wastewater before it receives any treatment.

Secondary Treatment*—(1) Generally, a level of treatment that produces removal efficiencies for BOD and suspended solids of at least 85 %. (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.

Septic Tank—An underground vessel for treating wastewater by a combination of settling and anaerobic digestion. Effluent usually is disposed of by leaching. Settled solids are removed periodically for further treatment or disposal.

Settling Pond—An earthen basin in which wastewater containing settleable solids is retained to remove a part of suspended matter by gravity. Also called a settling or sedimentation basin and settling tanks or basins perform the same function.

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, are in suspension in, water, wastewater, or other liquids. (2) Solid organic or inorganic particles (colloidal, dispersed, coagulated, flocculated) physically held in suspension by agitation or flow. (3) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.

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

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

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

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

*Appendix B illustrates the typical wastewater treatment process.

APPENDIX F: BIBLIOGRAPHY

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