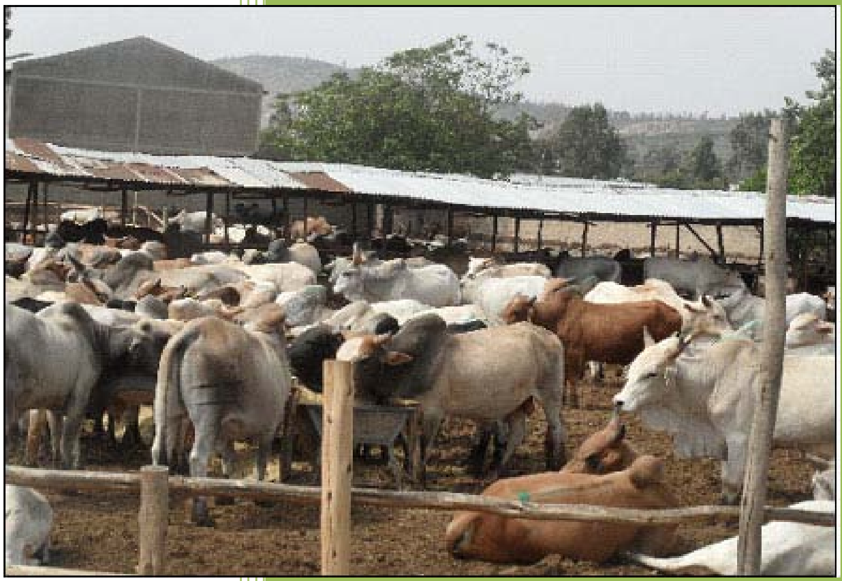
Global Methane Initiative

Ethiopia

Methane Emissions From Agricultural Waste Country Resource Assessment



Prepared for
Global Methane Initiative

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EXECUTIVE SUMMARY

The Global Methane Initiative is a partnership set up to reduce global methane emissions along with enhancing economic growth and energy security. The Initiative works in five sectors: agriculture, landfills, oil and gas, waste water and coal mining. The Agricultural subsector was created in 2005 with the purpose of promoting anaerobic digestion of livestock waste. As part of the Initiative, the U.S. Environmental Protection Agency has funded a resource assessment in Ethiopia. This resource assessment summarizes the findings from the study.

The agricultural sector in Ethiopia has strong dominance in the economic performance of the country. The sector accounts for 45% of the GDP and employ 85% of the labor force. Within the agricultural sector, livestock has the largest production monetary value. Ethiopia also has one of the largest livestock populations in Africa. Livestock in Ethiopia provides income for farming communities and a means of saving. It is also an important source of foreign exchange earning to the nation. Livestock provides 16% of the total GDP and generates 14% of the country's foreign exchange earnings. On a national level, livestock contributes a significant amount to export earnings in the formal market (10 percent of all formal export earnings, or US$150 million per annum) and the informal market an estimated US$300 million per annum.

The livestock sector in Ethiopia makes a significant contribution to the greenhouse gas emission of the country. Based on the most recent international data from The World Bank, Ethiopia's methane emissions are about 52MT CO2 equivalent and the livestock sector contributes 45% of these methane emissions. The livestock sector has one of the highest potentials for methane reduction in Ethiopia.

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List of Abbreviations

ADLI	Agriculture Development-Led Industrialization
AGP	Agricultural Growth Programme
AMIP	Agricultural Marketing Improvement Programme
ARDPLAC	Agriculture and Rural Development Partners Linkage Advisory Council
ATVET	Agriculture Technical and Vocational Education and Training
BoARD	Bureau of Agriculture and Rural Development
BoFED	Bureau of Finance and Economic Development
CAADP	Comprehensive Africa Agriculture Development Program
CBO	Community Based Organization
COMESA	Common Market for Eastern and Southern Africa
CSA	Central Statistical Authority
CSO	Civil Society Organisation
DA/SMS	Development Agent/Subject Matter Specialist
DAG	Development Assistance Group
DRMFS	Disaster Risk Management and Food Security
ECX	Ethiopian Commodity Exchange
EDRI	Ethiopian Development Research Institute
EIAR E	Ethiopian Institute of Agricultural Research
ELALUDEP	Ethiopia Land Administration and Land Use Development Project
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
FDRE	Federal Democratic Republic of Ethiopia
FSP	Food Security Programme
FTC	Farmers Training Centre
FY	Fiscal Year
FYGTP	Five-Year Growth and Transformation Plan
GDP	Growth Domestic Product
GoE	Government of Ethiopia
MDG	Millennium Development Goal
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MoTI	Ministry of Trade and Industry
MoWR	Ministry of Water Resources
NARS	National Agricultural Research System
PAP	Pastoral and Agro-Pastoral
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PBS	Protection of Basic Services Programme
PSNP	Productive Safety Net Programme
RARI	Regional Agriculture Research Institute
RDPS	Rural Development Policy and Strategy
RED&FS	Rural Economic Development and Food Security
SLMP	Sustainable Land Management Programme
SO	Strategic Objective
UNDP	United Nations Development Programme
USD	United States Dollar

1. INTRODUCTION

The Global Methane Initiative is a collaborative effort between national governments, multilateral organizations and the private sector set up to capture methane emission and use them as a clean energy source. The partnership was launched in 2004 as Methane to Markets and in 2010, it expanded into the Global Methane Initiative. Countries that have joined the partnership have made formal declarations to minimize methane emissions from key sources of methane, including agriculture, coal mining, landfills, and waste water and oil and gas systems. There are currently forty-one member countries in the partnership.

The role of the partnership is to bring divers organizations together with national governments to catalyze the development of methane projects. Organizations include the private sector, the research community, development banks, and other governmental as non-governmental organizations, Facilitating the development of methane projects will decrease greenhouse gas (GHG) emissions, increase energy security, enhance economic growth, improve local air quality, and industrial safety.

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

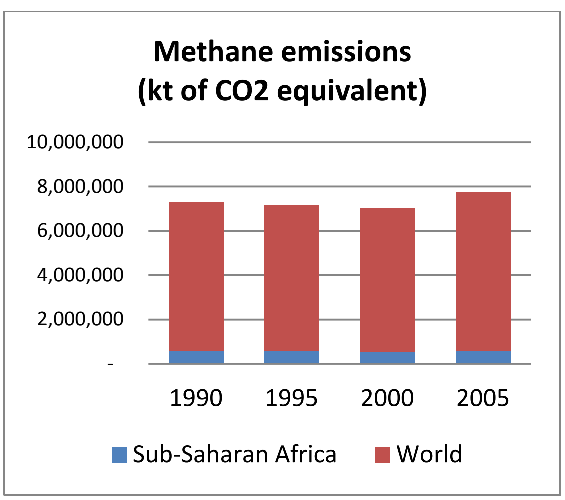
The main objective of this resources assessment is to identify the potential for incorporating anaerobic digestion into the livestock manure and agro-industrial sectors to reduce methane emissions and provide a renewable source of energy in Ethiopia. The related objectives of this resource assessment study are to:

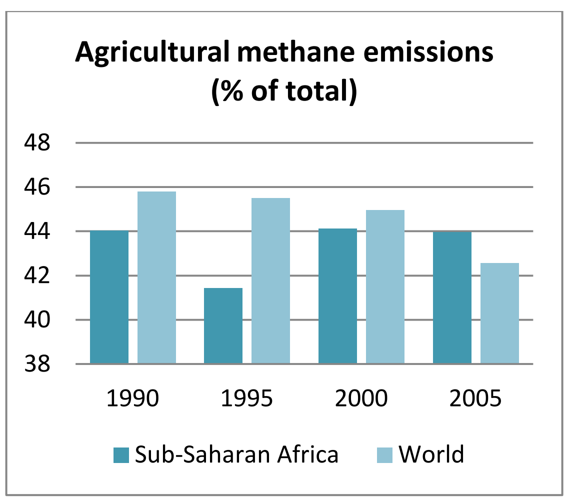
- Identify and characterize methane reduction potential in the agricultural sector in Ethiopia.
- Develop country market opportunities.
- Provide the location of resources.

The report summarizes the findings of the study and point out the most feasible and practical areas of investment in potential methane emission reductions. The study was conducted using primary and secondary data. Data collectors visited selected feeding lots, dairy farms and agro-industries to gather data and conduct observations. Secondary data from the Ethiopian Central Statistics Agency, Environmental Protection Authority, Ministry of Agriculture and Ministry of Water and Energy was used. Additional data from previous studies are also incorporated in the study.

1.1 METHANE EMISSION FROM LIVESTOCK WASTES

Methane is emitted from a variety of both anthropogenic (human-induced) and natural sources and account for 16% of global GHG emissions. According to the International Energy Agency, in 2007 global GHG emissions amounted to 30,000,000Kt CO_2 equivalent (CO_2-eq), with methane accounting for 7.7Gt CO_2-eq. The methane emissions include those stemming from human activities such as agriculture and from industrial methane production. The IEA data also indicates that in 2005 about 42% of methane emission came from agricultural sources. Agricultural methane emissions are emissions from animals, animal waste, rice production, agricultural waste burning (non energy, on-site), and savannah burning, Sub-Sahara, however, has slightly higher agricultural methane emissions with about 46% of CO_2-eq coming from agricultural sector.





Data from World Bank – World Development Indicator - International Energy Agency (IEA Statistics © OECD/IEA)

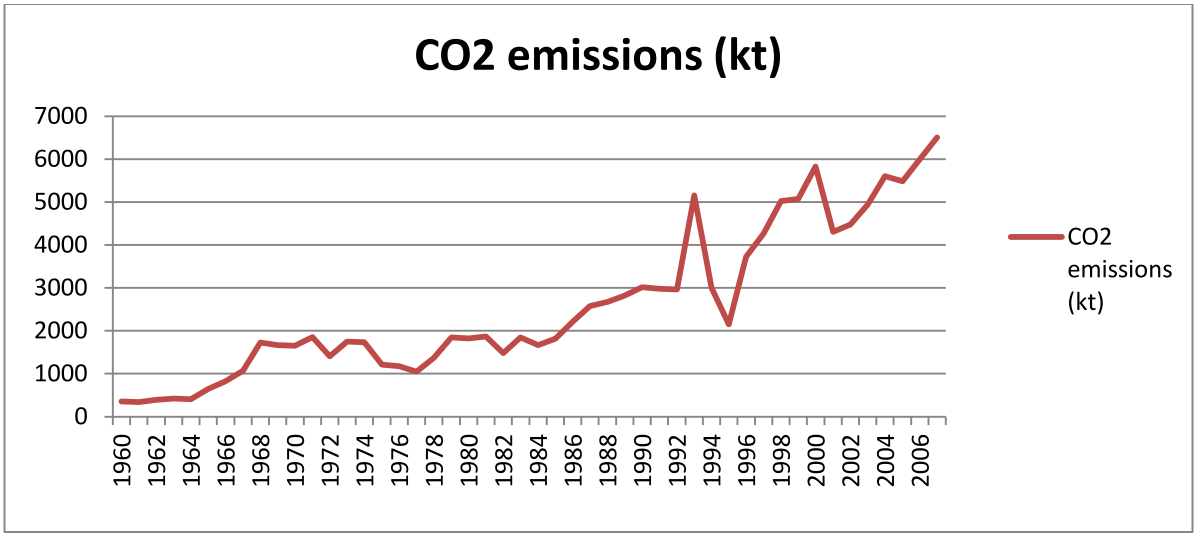
Human related sources create the majority of methane emission and the three main sources are fossil fuel mining/distribution, livestock and landfills. Methane emissions from livestock come in two ways. Animals like cows, sheep and goats are examples of ruminant animals and these animals create methane during their normal digestion process. This process, also called enteric fermentation, occurs in the stomach of these animals and produces methane as a by-product. The other process that creates methane emissions from livestock is from their manure. When manure produced from livestock decomposes anaerobically, it produces methane.

1.2 METHANE EMISSIONS FROM AGRO-INDUSTRIAL WASTES

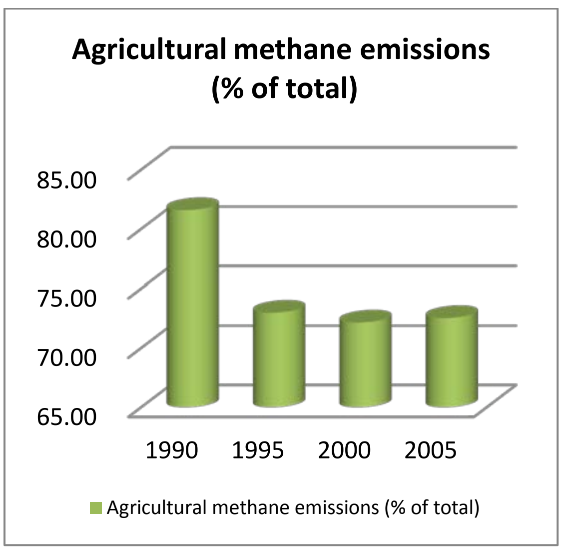
Waste from agro-industrial activities is an important source of methane emissions. The organic factor of agro-industrial waste typically is more readily biodegradable than the organic fraction of manure. Thus, greater reduction in biochemical oxygen demand (COD) and volatile solids (VS) during anaerobic digestion can be realized. In addition, the higher readily biodegradable fraction of agro-industrial wastes translates directly into higher methane production potential than from manure. The majority of agro-industrial wastes in developing countries are not treated before discharge and only a minority are treated anaerobically. As a result, agro-industrial wastes represent a significant opportunity for methane emission reductions through the addition of appropriate anaerobic digestion system.

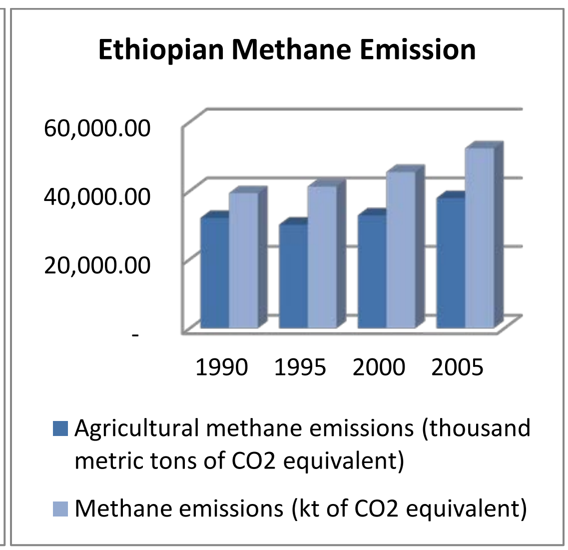
1.3 METHANE EMISSION IN ETHIOPIA

Ethiopian CO_2 and methane emissions have been insignificant; however, its CO_2 emissions have been growing in the last fifteen years. After the change of government and slight decline in the economy in the early 1990's, Ethiopia's CO_2 emissions have been growing parallel to its economic growth. Based on its 2010 World Development Indicator, the country's CO_2 emissions stand at 6,000 Kt/year.



Ethiopia's methane emissions have also been growing in the last fifteen years. Based on the most recent international data from The World Bank, Ethiopia's methane emissions are about 52MT CO_2-eq. It has increased by 25% in the last fifteen years from 39MT CO_2-eq. The agricultural sector has been the largest methane emitter in Ethiopia. Even thought a portion of agricultural methane emissions have been declining; it remains a significant source of methane emissions. Livestock and forestry account for the largest portion of methane emissions under agriculture.





Data from World Bank – World Development Indicator - International Energy Agency (IEA Statistics © OECD/IEA)

1.4 ETHIOPIA'S VULNERABILITY TO CLIMATE CHANGE

Though Ethiopian is not considered a significant CO_2 emitter, it has been impacted by GHG emission and climate change. Climate change impacts on Ethiopia have been visible in terms of water shortage and food security. Ethiopia remains vulnerable to drought as well as climate driven health impacts. Studies have shown that climate change over the coming decades presents a serious threat to various economic and social sectors in the country as the frequency and intensity of drought will likely increases. The impact of climate change in Ethiopia is also seen on the increasing temperature and declining rainfall in country, particularly in northern parts. Such changes affect agricultural production, deteriorate infrastructure and worsen the livelihoods of the rural poor.

Climate change vulnerability analysis for Ethiopia suggest that climate change over the coming decades presents a serious threat to various economic and social sectors (on a natural resources basis, particularly for biodiversity, ecosystems, water, agricultural and human health) as the frequency and intensity of drought is likely to increase.[1] Due to the strategic importance of agriculture to the national economy, and its sensitivity to water availability, this sector has been given priority by the government.

Community-level vulnerability is understood as a function of exposure to (climate and non-climate) hazards, sensitivity to hazards, and adaptive capacity.[2] Exposure is defined by the magnitude, character and rate of climate change in a given geographical area. Sensitivity to climate change is the degree to which a community is adversely or beneficially affected by climate-related stimuli. A nationwide comparative vulnerability trend analysis study, undertaken by the CVI Core Group of EWWG/DPPC (WFP-VAM, 2004) (1994-1998 to 1999-2002) on 418 crop-dependent woredas, showed that the vulnerability status of 161 woredas had worsened over the study period. The reduced, limited and erratic natures of rainfall as well as the recurrent

[1] EPA and MEDaC, 1997: Conservation Strategy of Ethiopia, Vol. I, II, III & IV, Addis Ababa, Ethiopia.
[2] IPCC. 2001. *Climate Change 2001: Impacts, adaption, and vulnerability. Summary for Policy Makers*. A report of the Working Group II of the Intergovernmental Panel on Climate Change.

droughts are acknowledged as major factors contributing to increased vulnerability and destitution.[3]

Of some concern is the possible effect of rising temperatures and falling rainfall trends in the near future, which may cause drops in crop yields, migration of wildlife, reduction of forest area and change in species combination, and spread of malaria and other vector borne diseases.[4] In light of the occurring frequent droughts and the prevailing scenario of climate variability and change, the livelihood of subsistent small-holding rain-fed agriculture farmers, who make up 85% of the agricultural sector, will worsen if community resilience is not built to cope with future climate variability but left to continue with existing drought coping mechanisms.

Erratic and a shortage of rainfall, degraded land, eroded ecosystems, and a deteriorated environment will remain the main basis for drought vulnerability of many rural areas in Ethiopia. Environmental degradation is aggravated by open-access grazing, poor soil and water conservation practices, and prolonged dry periods also create vulnerability in many parts of Ethiopia.

A study was conducted to examine vulnerability across 7 of the 11 regions of Ethiopia: Afar; Amhara; Beneshangul Gumuz; Oromia; the Southern Nations, Nationalities, and People's Region (SNNPR); Somali; and Tigray indicated that the Afar and Somali region are the most vulnerable. The study calculated vulnerability to climate change by region as the net effect of sensitivity, exposure, and adaptive capacity. Results indicate that Afar, Somali, Oromia, and Tigray are relatively more vulnerable to climate change than the other regions. The vulnerability of Afar and Somali is attributed to their low level of rural service provision and infrastructure development. Tigray and Oromia's vulnerability to climate change can be attributed to the regions' higher frequencies of droughts and floods, lower access to technology, fewer institutions, and lack of infrastructure. SNNPR's lower vulnerability is associated with the

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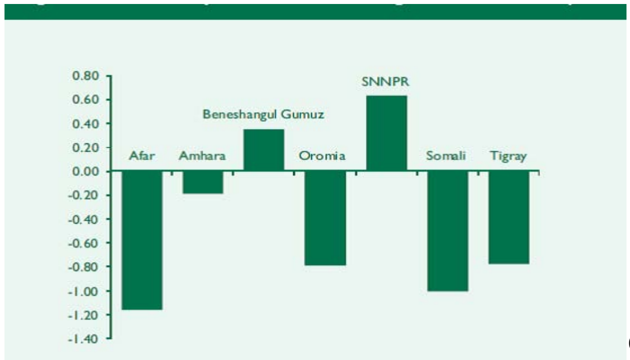
[3] Bureau of Rural Development. 2003: Rural household socio-economic baseline survey of 56 woredas in the Amhara region. Vol. IX: Food security, Bahir Dar.
[4] EPA and MEDaC, 1997: Conservation Strategy of Ethiopia, Vol. I, II, III & IV, Addis Ababa, Ethiopia.

region's relatively greater access to technology and markets, larger irrigation potential, and higher literacy rate.[5]



[6]

5 Measuring Ethiopian Farmers' Vulnerability to Climate Change Across Regional States. Temesgen T. Deressa, Rashid M. Hassan and Claudia Ringler. IFPRI Research Brief 15-5

6 Source: Deressa, T. T., R. M. Hassan, and C. Ringler, Measuring Vulnerability of Ethiopian Farmers to Climate Change across Regional States, IFPRI Discussion Paper

2. BACKGROUND AND CRITERIA FOR

2.1 METHODOLOGY USED

For this study, we used a combination of primary and secondary data to calculate methane emissions as well as identify sectors for priority. For primary data we conducted field visits, data collection, and interviews and for secondary data we used information from the Central Statistics Authority of Ethiopia, Ministry of Agriculture, Environmental Protection Authority, Ministry of Energy and Water, Oromia and Addis Ababa Health Bureaus as well as FAO and the World Bank.

Primary Data Collection

In order to assess the livestock and agro-industrial sectors, our field researchers made the following field visits.

Field Visits

- Dairy farms: Total of 22 in Addis Ababa, Debre Ziet, Nazret/Adama, Mojo, Sendefa and Sebeta.
- Feedlots: Total of 38 in Addis Ababa, Debre Ziet, Nazret/Adama, Mojo, Sendefa and Sebeta.
- Ranches: 1 in Awassa
- Agro-Industry/ Abattoirs: Total of 3 in Addis Ababa, Debre Ziet and Nazret

Data Collection

In order to collect data and assess the livestock sector in dairy farms and feedlots, researchers used the form attached in Annex I. Once the data had been collected, it was entered into a software application developed using MS Access.

Interviews

In addition to primary data collection, researchers also visited several federal, regional and sub-regional agencies and conducted interviews. Office visited includes: Ministry of Agriculture, Environmental Protection Authority, Ministry of Energy and Water, Oromia and Addis Ababa Health Bureaus, Ethiopian Meat and Dairy Institute and several wordea officials of MOA in Sebeta and Debre Ziet.

Secondary Data

Out calculation of methane emissions for enteric fermentation from livestock category is largely done using secondary data. This data includes national and international data from the Central Statistics Authority of Ethiopia, Ministry of Agriculture, Environmental Protection Authority, Ministry of Energy and Water, Oromia and Addis Ababa Health Bureaus as well as FAO and the World Bank.

2.2 ESTIMATION OF METHANE EMISSIONS IN THE LIVESTOCK SECTOR

This section describes the generally accepted methods for estimating methane emissions from livestock manure along with the data used to estimate the methane emissions from the sector. The livestock population which this estimation uses is listed in table 2.1. For the estimation, we have divided the livestock population into three categories: dairy cows, other cattle (growing cattle) and mature cattle. This separation is done in line with the IPCC recommendation which has stated "it is good practice to classify livestock population into subcategories for each species according to age, type of production, and sex."[7]

[7] 2006 IPCC Guideline for National Greenhouse Gas Inventories. P 10

Table 2.1 – The total number of livestock by category in Ethiopia

Livestock Category	Number of Population	Total Number of Livestock
Dairy cows	9,627,745	50,884,005
Growing cattle	14,845,777	
Mature cattle	26,520,203	

Table 2.2 Representative Livestock Categories
(From 2006 IPCC Guideline for National Greenhouse Gas Inventories)

Representative Livestock Categories	
Dairy cows	• High-producing cows that have calved at least once and are used principally for milk production • Low-producing cows that have calved at least once and are used principally for milk production
Growing Cattle	• Calves pre-weaning • Replacement dairy heifers • Growing / fattening cattle or buffalo post-weaning • Feedlot-fed cattle on diets containing > 90 % concentrates
Other Mature Cattle	Females: • Cows used to produce offspring for meat • Cows used for more than one production purpose: milk, meat, draft Males: • Bulls used principally for breeding purposes • Bullocks used principally for draft power

2.3 CALCULATION OF METHANE EMISSION FOR ENTERIC FERMENTATION FROM A LIVESTOCK CATEGORY

The 2006 IPCC guidelines for national greenhouse gas inventories are used for estimating methane emission from enteric fermentation of livestock as calculated below using Tire 2 methods. The general formula for enteric fermentation is given below.

$$\boldsymbol{EF = \left[\frac{GE \cdot \left(\frac{Ym}{100}\right) . 150}{55.65}\right]} \qquad \textbf{\textit{1.1}}$$

Where
EF = emission factor, kg CH4 head^{-1} yr^{-1}
GE = gross energy intake, MJ/ head^{-1} day^{-1}
Ym = methane conversion factor, percent of gross energy in feed converted to methane
The factor 55.65 (MJ/kg CH4) is the energy content of methane

The total selected emission factors are being developed for an animal category for the dry season of the year. In order to calculate the emissions, we first need to find the value of GE (gross energy) using equation 1.2.

$$GE = \left[\frac{\left(\frac{NEm+NEa+NEl+NEwork+NEp}{REM}\right) + \frac{NEg}{REG}}{\frac{DE\%}{100}} \right] \qquad 1.2$$

GE = gross energy, MJ/ day
NE_m = net energy required by the animal for maintenance, MJ/ day
NE_a = net energy for animal activity, MJ/ day
NE_l= net energy for lactation, MJ/ day
NE_{work} = net energy for work, MJ/ day
NE_p = net energy required for pregnancy, MJ day-1
REM = ratio of net energy available in a diet for maintenance to digestible energy consumed
NE_g = net energy needed for growth**,** MJ/ day
REG = ratio of net energy available for growth in a diet to digestible energy consumed
DE%= digestible energy expressed as a percentage of gross energy

Once the values for GE are calculated for each animal subcategory the next step will be substituting it in equation 1.1.

As we can see in equation 1.2 we are expected to calculate the net energy required for maintenance, activities, growth, lactation, work and pregnancy. Therefore we started with the maintenance calculation as shown below.

Calculating NE_m (net energy for maintenance)

$$NEm = \text{Cfi}\,.(weight)^{0.75} \qquad 1.3$$

NE_m= net energy required by the animal for maintenance, MJ day^{-1}
Cf_i= a coefficient which varies for each animal category (Coefficients for calculating NE_m), MJ/ day kg
Weight = live-weight of animal, kg.

Table 2.3 - Live-weight of livestock category in this case dairy cows, growing cattle and mature cattle.

Livestock category	***Live weight in Kg***
Dairy cows	350
Growing cattle	200
Mature cattle	280

From the given input values of weight and coefficients for energy maintenance from 2006 IPCC guidelines we can calculate NE_m as shown below in table 2.4.

Table 2.4- Coefficients for calculating net energy for maintenance (NE_m)

Animal category	**Cf_i (MJ/Kg day)**	**Net energy for maintenance (NE_m) in MJ/day**
Dairy cows	0.386	31.23
Growing cattle	0.322	17.13
Mature cattle	0.370	25.33

<u>Calculating NE_a (net energy for activity)</u>

$$NEa = Ca \,.\, NEm \qquad \textbf{1.4}$$

Table 2.5 - Activity Coefficients corresponding to animal feeding situation is given from 2006 IPCC guidelines.

Animal category	**C_a is dimensionless**	**Net energy for activity (NE_a) in MJ/day**
Dairy cows	0.17	5.31
Growing cattle	0.00	0
Mature cattle	0.36	9.12

<u>Calculating NE_g (net energy for growth)</u>

$$NEg = 22.02 \,.\, \left(\frac{BW}{C.MW}\right)^{0.75} .\, WG^{1.097} \qquad \textbf{1.5}$$

NE_g = net energy needed for growth, MJ/ day
BW = the average live body weight (BW) of the animals in the population, kg

C = a coefficient of growth
MW = the mature live body weight of an adult female in moderate body condition, kg
WG = the average daily weight gain of the animals in the population, kg /day

MW is given as 350Kg and WG 0.5 Kg/day

Table 2.6 - Growth Coefficients to calculate net energy for growth

Animal category	C	Net energy for growth (NE_g) in MJ/day
Dairy cows	0.8	12.17
Growing cattle	1.0	6.77
Mature cattle	1.2	7.59

Calculating NE_l (net energy for lactation)

$$NEl = milk\,.\,(1.47 + 0.4 * fat) \qquad 1.6$$

NE_l = net energy for lactation, MJ/ day
Milk = amount of milk produced, kg of milk/ day
Fat = fat content of milk, % by weight.

Table 2.7 - Calculating net energy for lactation

Animal category	Milk in Kg/day	Fat content by %	NE_l in MJ/day
Dairy cows	8.00	4.0 %	11.89
Growing cattle	0.00	0%	0.00
Mature cattle	0.00	0%	0.00

Calculating NE_{work} (Net energy for work)

$$NEwork = 0.10\,.\,NEm\,.\,hours \qquad 1.7$$

NE_{work} = net energy for work, MJ/ day
NE_m = net energy required by the animal for maintenance MJ/ day
Hours = number of hours of work per day

Table 2.8 - Calculating net energy for work

Animal category	Hours/Days	NE_m in MJ/day	NE_{work} in MJ/day
Dairy cows	3	31.23	9.37
Growing cattle	8	17.13	13.7
Mature cattle	8	25.33	20.26

Calculating NE_p (Net energy for pregnancy)

$$NEp = Cpregnancy \, . \, NEm \quad \textbf{1.8}$$

NE_p = net energy required for pregnancy, MJ/ day
$C_{pregnancy}$ = pregnancy coefficient
NE_m= net energy required by the animal for maintenance MJ /day

Table 2.9 - Constants for calculating Net energy for pregnancy

Animal category	$C_{pregnancy}$	NE_m in MJ/day	$NE_{pregnancy}$ in MJ/day
Dairy cows	0.1	31.23	3.123
Growing cattle	0.1	17.13	1.713
Mature cattle	0.1	25.33	2.533

DE % = 48.3 % calculated using the input from 2006 IPCC but usually in the range of 45 – 55 %.

Using equation 1.9 we can calculate the ratio of net energy available in diet for maintenance to digestible energy consumed.

$$REM = \left[1.123 - (4.092 \, . \, 10^{-3} \, . \, DE\%) + \left(1.126 \, . \, 10^{-5} \, . \, (DE\%)^{2}\right)\right] \quad \textbf{1.9}$$

REM = ratio of net energy available in a diet for maintenance to digestible energy consumed
DE% = digestible energy expressed as a percentage of gross energy

$$REM = 1.121$$

Using equation 1.10 we can calculate the ratio of net energy available for growth in a diet to digestible energy consumed.

$$REG = [1.164 - (5.160 \, . \, 10^{-3} \, . \, DE\%) + \left(1.308 . 10^{-5} \, . \, (DE\%)\right] \quad \textbf{1.10}$$

REG = ratio of net energy available for growth in a diet to digestible energy consumed
DE% = digestible energy expressed as a percentage of gross energy

$$REG = 1.162$$

Next we referred to equation 1.2 and substituted all the above calculated energies to find the value of GE.

Table 2.10 - Calculating GE for each livestock subcategory

Livestock category	***GE (gross energy) in MJ/day***
Dairy cows	13420.0
Growing cattle	7216.56
Mature cattle	11924.63

Now, all the inputs needed to find the value of emission factor as given in equation 1.1 are fulfilled. We substituted and calculated CH_4 emission factors for each livestock subcategory.

Table 2.11 - 2006 IPCC methane conversion factor in percent of gross energy

Livestock category	***Ym***
Dairy cows	6.5 % ± 1.0 %
Growing cattle	3.0 % ± 1.0 %
Mature cattle	4.5 % ± 1.0 %

Due to the importance of Ym in driving emissions we need to be careful in selecting the boundaries - when good feed is available the lower bound should be used and when poor feed is available the higher bounds are more appropriate. Taking this and the Ethiopian livestock feeding system into consideration, we took the higher bound in our calculation and substituted it into equation 1.1.

Table 2.12 - Calculating emission factor in each subcategory of livestock

Livestock category	***CH_4 emission factor in Kg/days***
Dairy cows	271,294
Growing cattle	778,801
Mature cattle	176,771

To estimate the total emissions, the selected emission factors are multiplied by the subcategory of animal population.

Table 2.13 - Calculating total emissions in each subcategory of livestock

Livestock category	***Total CH_4 emissions in gigagram (Gg)***
Dairy cows	2,611,949
Growing cattle	1,155,016
Mature cattle	4,688,003

To complete our calculation we summed the emissions from each livestock category and calculated a total of ***8,454,968 Gg*** of methane emissions from the livestock subcategory of categories of dairy cows, growing cattle and mature cattle in dry seasons of Ethiopia, specifically, for 150 days. 8,454,968Gg of methane emissions for 150 days (during dry seasons) is equivalent to 36,400Kt per year.

2.4 CALCULATION OF METHANE EMISSION FROM MANURE MANAGEMENT OF LIVESTOCK CATEGORY

The general accepted methods for estimating methane emissions produced during the storage and treatment of manure and also manure deposited on pasture are first discussed here. The main factors affecting methane emissions are the amount of manure produced and the portion of the manure that decomposes an aerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed.

When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it decomposes an aerobically and can produce a significant quantity of methane. The temperature and the retention time of the storage unit greatly affect the amount of methane produced. When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less methane is produced.

In Ethiopia most livestock manure is managed as a solid on pastures and ranges, a smaller fraction is burned as a fuel. The 2006 IPCC guidelines for national greenhouse gas inventories were used for estimating methane emission from a group of livestock production sector. Using tire 2 methods, methane emissions for a livestock group (T), existing manure management system (S) and climate (K) combination are estimated. Considering the climate condition as warm with an average temperature of 28^0c and manure management system of pasture and ranges the emission factors can be found as shown below using equation 1.11.

$$EF(t) = (VS(t)\ .365).[B_{o(T)}.0.67kg/m^3.\sum_{s,k}\frac{MCFs,k}{100}.MS_{(T,S,K)}]\ldots\ldots\ldots\ldots\ 1.11$$

Where:-
$EF_{(T)}$ = annual CH_4 emission factor for livestock category (T), kg CH_4 /animal /yr
$VS_{(T)}$ = daily volatile solid excreted for livestock category (T), kg dry matter / animal/ day
365 = basis for calculating annual VS producing capacity for manure produced by livestock category T, m^3 CH_4/kg of VS excreted
0.67 = conversion factor of m^3 CH_4 to kg CH_4
$MCF_{(T,S,K)}$ = fraction of livestock category T's manure handled using manure management system 'S' in climate region k, dimensionless

From the equation, an estimate of the average daily VS excretion rate for the livestock category is required. Using equation 1.12 we get the value of VS (volatile solid) excretion factor and comparing it with the default values of IPCC for dairy cows, growing cattle and mature cattle is given below on table 1.12.

$$VS = \left[GE.\left(1 - \frac{DE\%}{100}\right) + (UE.GE)\right].\left[\frac{1-ash}{18.45}\right]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..1.12$$

Where:-
VS = volatile solid excretion per day on a dry-organic matter basis, kg VS/ day
GE = gross energy intake, M/J day
DE% = digestibility of the feed in percent (60%)
(UE • GE) = urinary energy expressed as fraction of GE. Typically 0.04GE can be considered urinary energy excretion by most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in their diet).
ASH = the ash content of manure calculated as a fraction of the dry matter feed intake (e.g.,0.08 for cattle).
18.45 = conversion factor for dietary GE per kg of dry matter (M/J kg), this value is relatively constant

Table 2.14 Average volatile solid compared with IPCC guidelines

Livestock category	***Volatile Solid waste***
Dairy cows	2.28
Growing cattle	1.50
Mature cattle	2.03

Estimation of methane emission using equation 1.12 also requires identification of the appropriate MCF, which is a function of the current manure management system and climate.

Depending on Ethiopia's livestock categories of cattle and their manure management system, MCF is given for average annual ambient temperatures ranging from (cool) $\leq 10^{0}$C to 28^{0}C (warm climate) in table 2.15.

Table 2.15 MCF values for livestock category of cattle manure management systems

Climate	***Manure management system methane emission factor in %***	
	Temperature	***MCF for Pasture/ Range/ Paddock***
Cool	5 - 14	2%
Temperate	15 - 25	2%
Warm	≥ 26	2%

The final requirements in order to determine emission factor using equation 1.11 are the methane production potential (Bo) for the type of manure under consideration and MS which is the average VS production per head per day for an average dairy cow, growing cattle and mature cattle. Default values from 2006 IPCC guidelines can be in use.

Table 2.16 production potential and manure management system of dairy cows, growing cattle and mature cattle

Livestock category	***Production potential (B_o) in m^3/kg VS***	***Manure Management system (MS) in %***
Dairy cows	0.13	83%
Growing cattle	0.1	95%
Mature cattle	0.1	95%

Now, from all the above calculated values we can determine the emission factors for each sub category of cattle by substituting the values in equation 1.11 as follows.

Table 2.17 methane emission factors from manure management system of cattle.

Livestock category	***Emission Factors in kg/animal/year***
Dairy cows	1
Growing cattle	1
Mature cattle	1

To complete the estimation of methane emission from cattle's manure management system we need to multiply the factor with the total number of livestock group using equation 1.13.

$$\textbf{CH4 manure} = \sum_T \frac{EF(t).N(t)}{10^6} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{1.13}$$

Where:-

CH_4 Manure = CH_4 emissions from manure management, for a defined population, Gg CH_4/ yr
$EF_{(T)}$ = emission factor for the defined livestock population, kg CH4 head/yr
$N_{(T)}$ = the number of head of livestock species/category T in the country
T = species/category of livestock

Table 2.18 total emissions of methane from each sub category of cattle manure management.

Livestock category	***Number of population***	***Total Emission of Methane in Gg/year***
Dairy cows	9,627,745	9.6
Growing cattle	14,845,777	14.8
Mature cattle	26,520,203	26.5

From this we can conclude that the total methane emission from manure management of cattle is 50.9Gg/year.

3. SECTOR CHARACTERIZATION

3.1 INTRODUCTION - AGRICULTURE AND AGRO-INDUSTRY IN ETHIOPIA

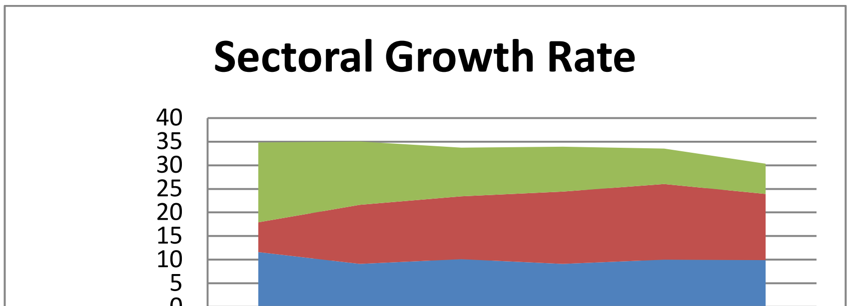
The agricultural sector in Ethiopia has strong influence on economic performance of the country. The sector accounts for 45% of the GDP and employs 85 % of the labor force. Ethiopia has a total area of about 1.13 million km2 and about 51.3 million hectares of arable land; however, only about 11.7 million hectares of land are currently being cultivated. This is about 20% of the total arable area. The agricultural sector also accounts for 90 % of the country's exports. Of this, livestock production accounts for about 32 % of agricultural GDP and draught animal power is critical for all farming systems.

The agricultural landscape of Ethiopia is divided into two major parts. The highland crop-livestock mixed farming covers around 40 % of the total land surface and is situated in the Northern, North-eastern and Central part of the country. It is featured by a mixed farming system where crop cultivation and livestock production are undertaken side-by-side, complementing each other. Livestock in this area are primarily kept on small holdings where they provides draught power for crop production, manure for soil fertility and fuel, and serves as a source of family diet and source of cash income (from the sale of livestock and livestock products) particularly when markets for crops are not favorable. The highlands are a major source of sheep for slaughter in the cities.

The lowland pastoral and agro-pastoral production systems cover around 60 % of the land area and are situated in the Eastern, Southern and Western part of the central highlands. Livestock are the principal source of subsistence providing milk and cash income to cover family expenses for food grains and other essential household requirements (mostly consumer goods). The pastoral lowlands are a major source of goats and sheep for export. Cattle from the area are sold for fattening in areas close to Addis Ababa. Although the majority of Ethiopia's livestock is found in the highlands, 95 percent of the livestock supplied for export is supplied by the pastoral and agro-pastoral areas of the lowland regions of Afar, Somali and Borena.

Ethiopian agriculture is dominated by a subsistence, low input-low output, rain-fed farming system. The use of chemical fertilizer and improved seeds is limited. Low agricultural productivity can be attributed to limited access by smallholder farmers to agricultural inputs, financial services, improved production technologies, irrigation and agricultural markets; and, more importantly, to poor land management practices that have led to severe land degradation. The country has one of the highest rates of soil nutrient depletion in sub-Saharan Africa. Land degradation is further exacerbated by overgrazing, deforestation, population pressure and inadequate land use planning.

Since 1996/97 the average growth rate of the agricultural GDP has been about 10 % per annum, and since 2004-05 the sector has been reported to have expanded at around 13 % per annum. Agricultural growth has declined since then. Despite the growth the in agricultural sector, the share of agriculture in GDP declined from 53% to 43 % between 1995/96 and 2008/09. The decline has been largely because of rapid economic growth occurring in the non-agriculture sector, mainly the service and industry sectors.

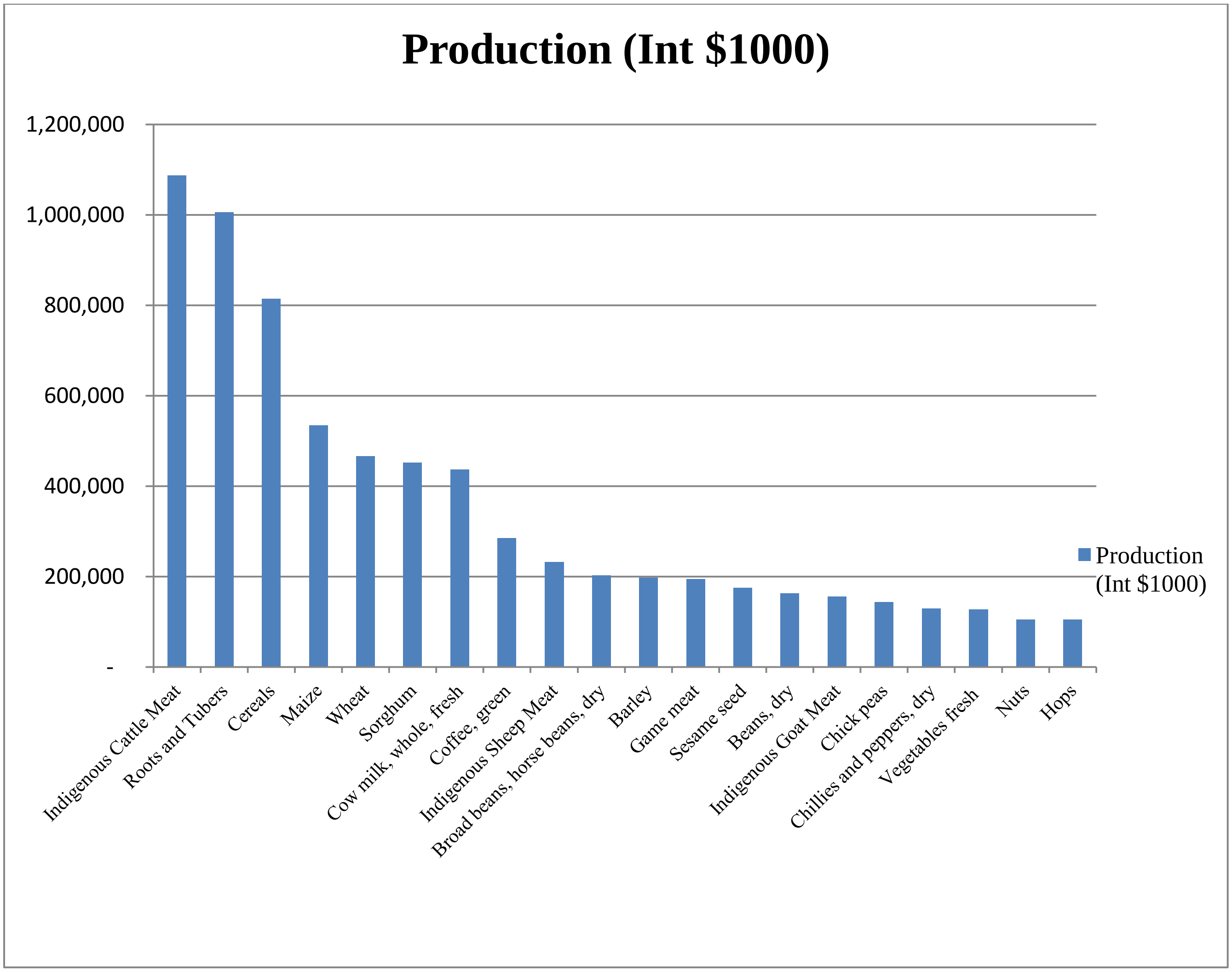


	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Agriculture	16.9	13.4	10.3	9.5	7.5	6.4
Service	6.3	12.5	13.3	15.3	16	14
Industry	11.6	9.1	10.1	9.1	10	9.9

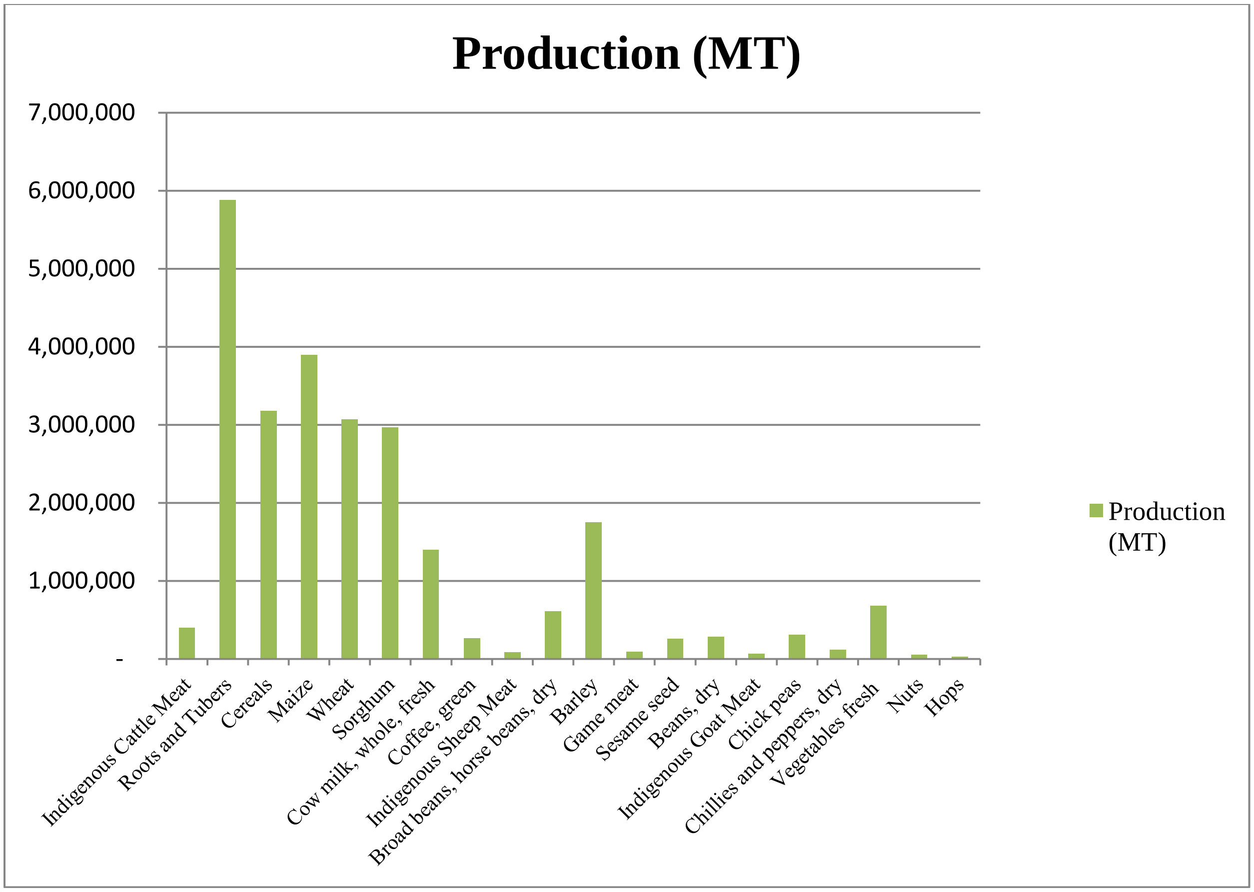
Another major of the decline in the agricultural sector which has also affected the livestock population is the worsening climate change as it relates to land suitable for farming and grazing. A review of drought history based on work carried out by NMSA, EWWG, WB, WFP, FEWS-Net, SCF-UK, CSA, and others indicates that drought occurs every 3-5 years in some parts of the country and every 6-8 years all over Ethiopia. Drought is commonly expressed as shortage or absence of rainfall causing a loss in rain-fed agriculture. For example, the decline in the level of rainfall during severe drought years in Ethiopia (ie 1984/85, 1991/92, 1993/94, and 1999/2000) was accompanied by serious reductions in rain-fed agricultural outputs; this is because a 10% drop in rainfall (below the long term national average) results in an average drop of 4.2% in cereal yields. Hence, climate variability/droughts have impacted the country seriously over the past ten years, resulting in increasing agricultural losses and human suffering, placing the country in a situation of critical food insecurity and water shortages. Output failure often occurs and the farming communities sink further into poverty, with four to five million rural people (5.7%-7.1% of the population) left chronically food insecure each year. An additional six to seven million people (8.5% to 10%) are transitionally food insecure and require food aid when they produce less as a result of the impact of climate variability.

Agricultural production in Ethiopia is dominated by roots and tubers such as potatoes and cassava, followed by maize and cereals. Over the past decade, cereal production has more than doubled to nearly 15 million tonnes, as a result of horizontal expansion and increased yields. Though livestock is of the lowest in production, it has the highest production in monetary value. In 2008, livestock accounted for approximately US$150 million in formal export earning, making up 10 percent of export. Roughly half of this value comes from live animal and meat export, the remaining being from hides and skins. Formal live animal exports are predominantly cattle (70%), meat exports are almost entirely from sheep and goats, and hides and skins are primarily from cattle. Trends over the last 10-20 years show meat and live animals becoming increasingly important to livestock exports relative to hides and skins. Beyond formal sector trade, there is a significant informal cross-border trade in live animals, which substantially increases livestock's export importance. Estimated of informal trade volume vary widely (e.g., between 250,000 and 500,000 head of cattle per year), but appear to dwarf formal export (84,000 head in 2008).

Hides, skins and leather products are the 2nd major export product in value from Ethiopia (after coffee). In 2000/2001, this sector accounted for 17% of total foreign exchange earnings. By far the major part of the export is in the form of semi-processed hides and skins (e.g. pickled, wet blue or crust). Italy is the main export market; other importing countries are India and Pakistan.



FAO data based on imputation methodology



FAO data based on imputation methodology

3.2 SUB-SECTORS WITH POTENTIAL FOR METHANE EMISSION REDUCTIONS

For the selection of the sectors with the highest potential for methane emission reductions the following criteria were used 1) size of subsector and 2) methane emissions from the sector.

Sub Sector	Size	Geographical Distribution
Feeding lots	65 centers within 150Km of Addis Ababa (Estimate)	Oromia Region: Nazert, Debre Ziet, Mojo, Sebeta and Sendfa
Dairy farms	225 centers	Oromia Region: Sebeta, Sendfa, Mojo, Debre Ziet and Nazert. East and West Shoa zones, West and East Arsi, North Shoa Zone
Slaughterhouses	Large capacity: 6 operational 2 under construction (1 municipality – owned and 7 export)	Addis Ababa, Mojo, Mekele.

3.2.1 LIVESTOCK

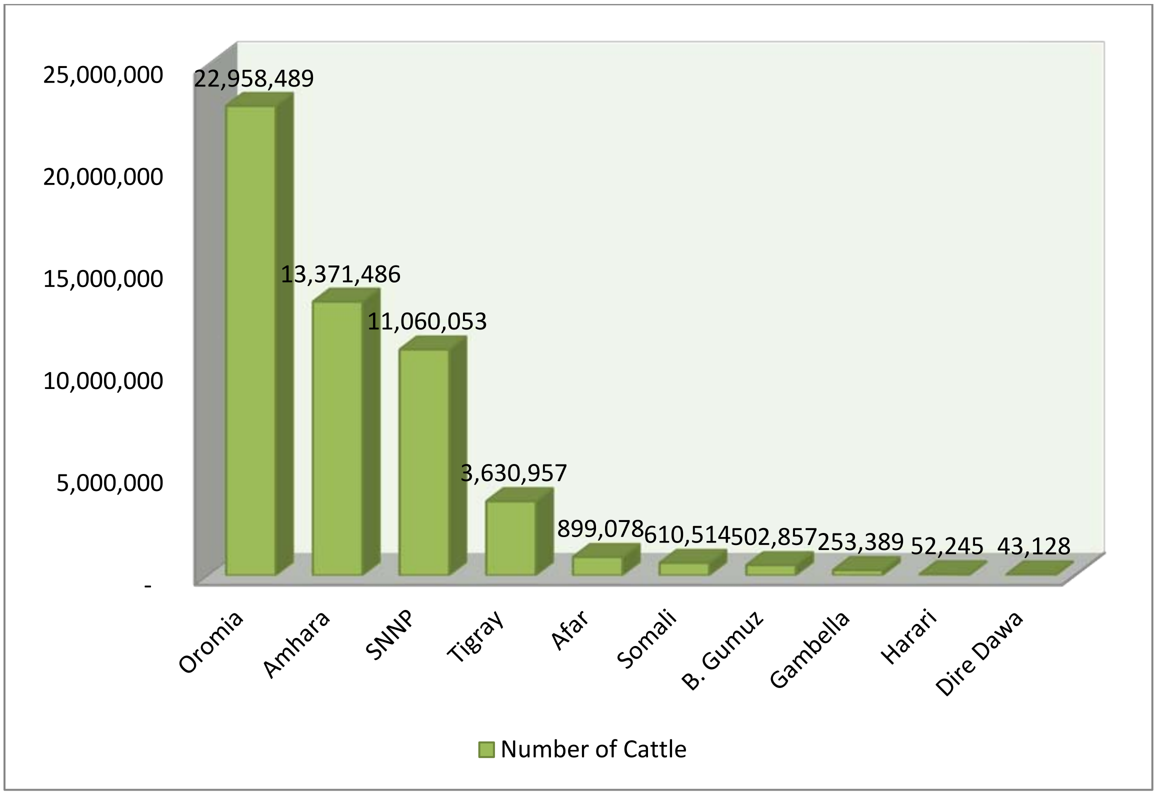
Ethiopia has one of the largest livestock populations in Africa, with approximately 50 million cattle. Livestock in Ethiopia provides income for farming communities and a means of savings. It is also an important source of foreign exchange earnings for the nation. Livestock provides 16 % of the total GDP and generates 14 % of the country's foreign exchange earnings. Livestock also confer a certain degree of security in times of crop failure, as they are a "near-cash" capital stock. Furthermore, livestock provides farmyard manure that is commonly applied to improve soil fertility and used as a source of energy.

Cattle Population

The total cattle population of Ethiopia is estimated to be about 53.4 million. Out of this total cattle population, the female cattle constitute about 55.2 percent and the remaining 44.8 percent are male cattle. The majority of the cattle population (63.63 percent) is between the age of 3 and 10 years, and are largely used for draught purposes, while 15 percent are between the ages of one and three years. Over 99 percent of the total cattle are local breeds while the remaining are hybrid and exotic breeds. Dairy-cows are estimated to be around 7.4 million and milking-cows are about 10.7 million heads. There are about 2 million horses, 6.2 million donkeys, 0.38 million mules, and about 1.1 million camels in the sedentary areas of the country.

The function and purpose for which livestock are reared varies considerably across the two major agro-ecological and socio-economic zones and the two major livestock production systems in the country: the highland and the lowland pastoral and agro-pastoral systems. The highland covers around 40 % of the total land surface and is situated in the Northern, North eastern and central part of the country. Livestock in this area is primarily kept on small-holdings where it provides draught power for crop production, manure for soil fertility and fuel, and serves as a source of family diet and source of cash income (from the sale of livestock and livestock products) particularly when markets for crops are not favorable. The highlands are a major source of sheep for slaughter in the cities.

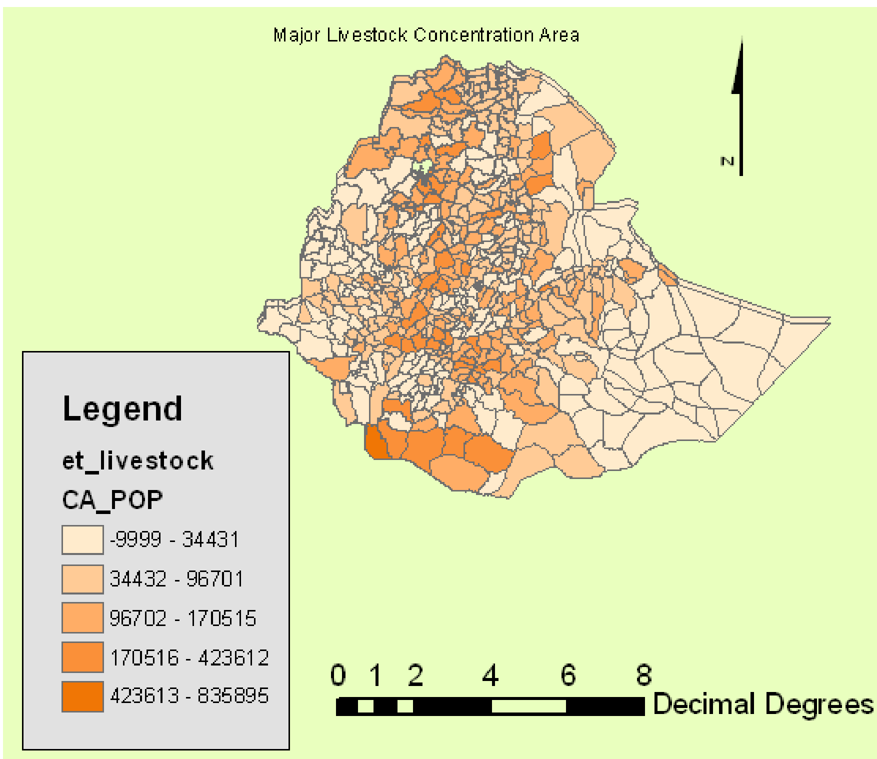
The lowland pastoral and agro-pastoral production system covers around 60 % of the land area and is situated in the Eastern, Southern and Western parts of the central highlands. Livestock are the principal source of subsistence, providing milk and cash income to cover family expenses for food grains and other essential household requirements (mostly consumer goods). The pastoral lowlands are a major source of goats and sheep for export. Cattle from the area are sold for fattening in areas close to Addis Ababa. Although the majority of Ethiopia's livestock is found in the highlands, 95 percent of the livestock supplied for export is supplied by the pastoral and agro-pastoral areas of the lowland regions of Afar, Somali and Borena.



The livestock sector has been contributing to a considerable portion of the country's economy, and still promises to rally round the economic development of the country. It is eminent that livestock products and by-products in the form of meat, milk, honey, eggs, cheese, and butter supply, etc. provide the needed animal protein that contributes to the improvement of the nutritional status of the people. Livestock also plays an important role in providing export commodities, such as live animals, hides, and skins to earn foreign exchanges for the country.

On the other hand, draught animals provide power for the cultivation of the smallholdings and for crop threshing virtually all over the country and are also essential modes of transport to take holders and their families long-distances, to convey their agricultural products to the market places and bring back their domestic necessities. Livestock also offers a certain degree of security in times of crop failure, as they are a "near-cash" capital stock. Furthermore, livestock provides farmyard manure that is commonly applied to improve soil fertility and also is used as a source of energy.

The map below shows the major livestock concentration in Ethiopia. The deep red shows the largest livestock concentration, light red shown the next largest, and the other one shown the lowest livestock concentration in the country.



Despite these benefits from the sector, the problem of environmental pollution from these effluents as a significant contributor of GHG in solid, liquid and gas form are rapidly increasing. The awareness of converting these waste into renewable energy as well as applying the new technology are still the law. Studies have indicated that almost 80% of the wastes from the sector are not properly handled. Current practices of waste disposal in the livestock and agro-industries sectors in Ethiopia are disposal of wastes underground and dumping of wastes into a nearby river.

Poultry Population

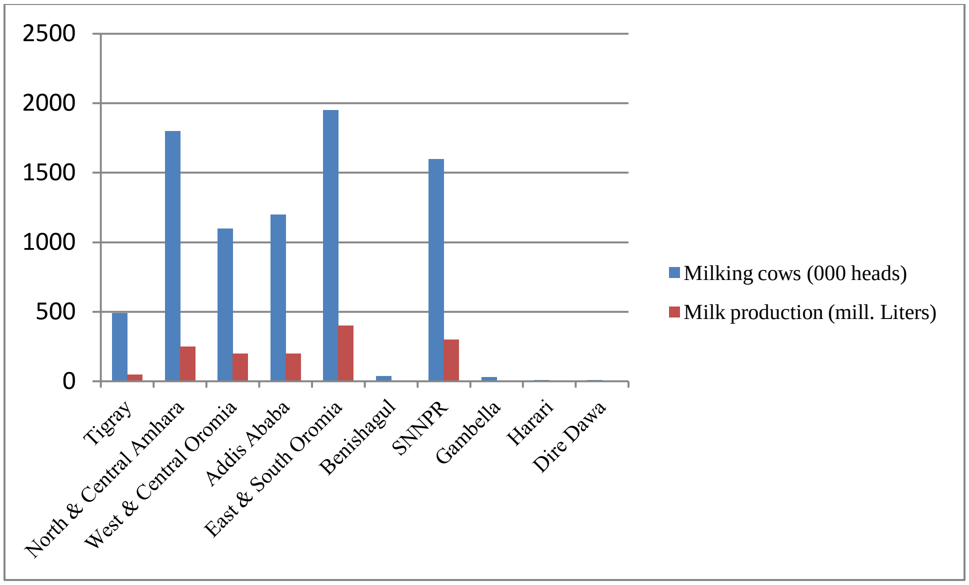
The total poultry population at the country level is estimated to be about 49.3 million. Poultry includes cocks, cockerels, pullets, laying hens, non-laying hens and chicks. Most of the poultry are chicks, 37 percent, followed by laying hens, 32 percent. There are estimated to be about 4.9 million pullets in the country. Cocks and cockerels are also estimated separately, and are 5.6 million and about 2.8 million, respectively. The others are non-laying hens that make up about 3.7 percent (1.83 million) of the total poultry population in the country. With regard to breed, 97.3 percent, 0.38 percent and 2.32 percent of the total poultry were reported to be indigenous, hybrid and exotic, respectively.

3.2.2 LIVESTOCK (FEEDING LOTS AND DAIRY FARMS)

Dairy Farming

There are four major milk production systems in Ethiopia: pastoral and agro-pastoral, smallholder crop-livestock mixed system, urban and peri-urban, and intensive dairy farming. Over 90% of the country's milk production is made by pastoralist and small holder farmers.[8] According to a survey by the CSA (2003), 9.3 million milking cows produced an estimated 2,590 million liters of milk in 2001-2002; giving an average yield of 278 liters per cow per year over 239 lactation days. About 56% of milk in the country is processed into butter, cheese and yogurt and 44% is consumed fresh. Only a small amount of milk is processed into pasteurized milk, butter and cheese by large scale commercial processors. Most of the milk produced in the country is processed by the producers themselves on –farm into butter and soft cheese (ayib) for home consumption and sale.

[8] Central Statistics Authority (CSA) 2008.



Central Statistics Authority (2008)

This study focused on assessing methane emission on urban, peri-urban and intensive commercial systems which have the best prospect for development of anaerobic digesters.

Urban and Peri-Urban

The dairy farms in urban and peri-urban areas primarily have cows to produce milk for housel consumption. There is currently no centralized system of monitoring household dairy farming. Thus, accessing date has been difficult. However, a 2004 study by International Food Policy Research Institute has indicated that there are an estimated 5,167 small, medium and large scale dairy farms producing 35 million liters of milk annually around Addis Ababa.[9] On average, 78% of all milk production in the country is consumed by producing household and only 22% goes to the market. In Dire Dawa and Harar the amount of milk sold in the market is higher and reaches about 40%. In Addis Ababa and surrounding, about 30% of the milk is sold in the market. On average for Ethiopia, 53% of total milk sold by producers is sold as fluid milk while 42% is sold as butter with considerable regional variation in these proportions.

[9] Ahmed, Mohamed AM, Simeon Ehui and Yemersarh Assefa. Dairy Development in Ethiopia. Discussion Paper No. 123. Environmental and Production Technology Division. International Food Policy Research Institute. October. 2004.

Most of the urban and peri-urban dairy farms have from one to ten cows. The number of cows depends on several factors, such as availability of space, need, and food. Dairy cows in this sector are also relatively heavier than cattle in other parts of the country. As studies have shown, cows in Addis Ababa yield significantly higher milk due to the high incidence of crossbred and exotic cattle. While hybrid and exotic cows represent only 1.8% of total milking cows in Ethiopia, 47% of the cows in Addis Ababa are crossbred. Cows in Addis Ababa and surrounding areas also have access to food with higher nutritional quantity. The dairy cattle are normally zero-grazed and fed mainly natural forages and crop residues. Feed concentrates is only given to the dairy cattle. For example, small farms in Sebata have access to fodder with high nutrition value from Meta Abo Brewery. Most of the dairy farmers get the byproduct of the brewery for their cattle free from the factory and are able to feed them well.

Waste Disposal System

There is no scientific study done on the waste disposal systems of the dairy farms in urban and peri-urban areas. However, we conducted an assessment through site visits and interviews of dairy farms in Sebeta, Sendfa, Addis Ababa, Debre Ziet and Mojo. Based on our assessment, most of the dairy farms in these areas do not have any manure collection or waste disposal system. Most of the dairy farmers indicated that they use the dung as firewood in cook stoves or for baking injera. However, before the manure is converted into dung, it is either piled outside or placed in an open pit. The farmers use the manure or dung from the livestock as fuel by preparing it through the following process. They first collect the waste from the bran then store it in open space or in hole dug underground. The manure is separated into small pieces to easily be put in stoves. After it is left in open air for two or more days, and once it is dry, it is used immediately as fuel or placed underground for a longer period of time for storage. Some of the farmers also sell or give away the dung to local residents so that they can also use it as fuel as well.

In addition to use of manure or dung for cooking, some also use the manure as soil enrichment or fertilizer in their farm. Some of the dairy farmers have garden where they grow vegetables and other crops for household consumption or sales. Some of the farmers indicated that they use the manure to enhance the soil. Those that use the manure for this purpose indicated that they dispose it to the garden soon after enough manure is piled for disposal.

Manure dumped outside residential dairy farms in Sebeta

Biogas

Through the National Biogas Program (NBP), use of biogas at a household level is being promoted now. The NBP has started a pilot program to construct 14,000 biogas plants in four regions: Oromia, Amhara, Southern Region and Tigray and develop commercially viable biogas sector. The program eventually plan to up-scale biogas development and construct 100,000 biogas plants in subsequent phases.

The National Biogas Program, in the past two years, has constructed over eight hundred biogas plants. We visited two household biogas operations in the town of Sebeta to study. Biogas owners have indicated that though they have benefited greatly from the biogas the cost of construction and construction time it took was excessive. The current biogas plant takes five to six months to construct and costs close to $16,000 birr or US$900.

Household level biogas in Sebeta

Intensive Commercial Systems

Commercial dairy farming started in the early 1950s when Ethiopia received the first batch of dairy cattle from the United Nations Relief and Rehabilitation Administration (UNRRA). The government in 1966 then established the Addis Ababa Dairy Industry (AADI) to control and organize the collection, processing and distribution of locally produced milk. In the early 1970's the Dairy Development Agency (DDA) was created as an autonomous body to provide guidance and assistance to farmers to establish commercial dairy farms in areas serving the cities and townships and improve the quality and increase the quantity of milk and milk products. The agency also took over the AADI. After the change of government in 1973, the Dairy Development Enterprise (DDE) was established to operate the nationalized state farms, establish a milk collection network, process and market dairy products, provide advisory and limited technical service to farmers, and sell veterinary medications and feed to farmers. The DDE also took over the Dairy Development Agency.

In 1993, the DDE was taken back under government control but was given more management autonomy to make it more efficient, profitable and financially self-supporting. Of the fourteen large dairy farms run by DDE, twelve were returned to their previous owners or sold. These farms have now expanded their activities, including self-processing of milk. As a result of policy changes to allow private sector investment in dairy production, processing and marketing, several small and medium scale dairy processing industries have been established around Addis Ababa and other urban areas. These firms use milk from their own production as well as collect milk from producers.

Commercial Dairy Farms in Nazret/ Adama, Mojo and Deber Ziet

There is currently no centralized system of monitoring or supporting dairy farms in Ethiopia at a federal level. Thus, there is no national or federal level data available on the number of dairy farms in Ethiopia. The Ethiopian Meat and Dairy Technology Institute (EMDTI), thought it doesn't have full mandate to monitor dairy farms, it provides capacity building; training and consultancy services on a voluntarily base for dairy farms. Its activities include practical training for stakeholders in meat and dairy industries; short term training and demonstrations; consultancy on livestock production; establishment of standards for both meant and dairy products; promotion of investments in livestock sector; and market promotions, including linking of livestock producers with both domestic and external markets. The agency was established in 2008 and its clients include meat and live animal exporters, slaughterhouse operators, butchers, supermarkets, dairy cooperatives and processors, feedlot operators, and pastoralists' farmers.

Feedlots

The feedlots buy cattle from primary and secondary markets and feed them on concentrates consisting of wheat bran, oil seed cake, molasses, salt and essential minerals. Finished animals are sold direct to butchery owners and traders. Numerous primary markets converge into secondary markets within a radius of some 300 Kms from Addis terminal markets. Animals from such distant places as Borana, Wolaita and Harar are also brought direct to Addis. Most butchery owners also buy livestock from private feedlot centers around Nazareth and Modjo and from small-scale fatteners elsewhere and transport the animals directly to the abattoir; bypassing the terminal markets in Addis. Several households in these towns are also engaged in small-scale fattening activities, consisting of 1-3 head of cattle. Most of these households sell their cattle to traders or in open market during holidays.

Feedlots in Nazaret/ Adama & Quarantine office

Even though the Ministry of Agriculture has the mandate to monitor and regulate feedlots, responsibilities or tasks have been relegated to sub-regional offices of the MOA. Thus, there is currently no centralized system of monitoring feedlots at a federal level. During our assessment and site visits, we have seen that feedlots in Adama or Nazert area, which has one of the largest concentrations of feedlots, are monitored by MOA Nazerth Animal & Plant Quarantine office. The office monitors animals that go in and out of the feedlot and provide vaccinations as well as certifications that feedlot owners can use during export.

Description of Waste Handling System

To assess the methane emissions from feedlot manure, we conducted site visit and looked at feeding lots in the Oromia Region (Adama, DebreZeit, Sebeta, Suluta and Mojo). Based on the site visits and data collected, it is believed that close to 90% of the farms indicated that they do not have any waste management and disposal system in place. Almost all of the feedlots use an open space to store and feed the cattle. The cattle dispose their waste throughout the compound.

Feedlot owners have indicated that such practices and lack of waste handling systems severely limits the full utilization of the compound as neither the cattle nor the caretakers can freely move within the compound. Furthermore, during the summer season or when it rains, the compound becomes inhospitable as the manure is mixed with runoff. The current system has a negative health and environmental impact on the community. As cattle are sold and leave the compound, the manure is collected and piled up around the fences or outside of the compound. However, while the cattle are around and before the manure is taken, it is left to dry in an open space. In some areas, local residents take the manure to use as fuel. The manure is usually placed in bags “madeberia” and transported by carriages or donkeys. Some feedlot owners in Modjo have indicated that they dump the manure into the nearby river.

Feedlots covered with manure

Manure left inside a compound (Nazret)

Manure left outside of compound (Mojo)

Manure taken by local residents for fuel

3.4 ABATTOIRS

Large municipalities throughout Ethiopia operate abattoirs for the local consumers. The largest municipality-owned abattoir is located in Addis Ababa. Owned by the city government, the main slaughterhouse of Addis Ababa is located in the centre of the city and it is around 50 years old. Even though the Kera abattoir is the largest abattoir serving the Addis Ababa market, it is estimated that approximately half of all cattle and the vast majority of sheep are slaughtered outside of the abattoirs in small butcheries or, for sheep and goats, at the household. Christian butcheries cater to the Orthodox Christian population and are closed during Orthodox fasting periods. Muslim butcheries offer halal meat, operating throughout the year, including Ramadan, during which meat consumption is high. The city also owns and operates another abattoir at Kalitti, located about 10Km from the city.

The Kera Abattoir slaughters an average of 1,300 cattle per day and the animals provide many by-products. Among these inedible parts, bones, jaws, horns, hoofs and brains are the major parts. In addition, it has a by-product of an estimated 20 tons of intestinal matter alone and 7,000 liters of blood per day. The abattoir has no waste management system and the by-products, except intestinal, used to be left on the compound, creating smell and other negative environmental and health impacts. In 2010, the abattoir removed the by-products and started to sell them for producers of fertilizers and dog food. The smell and other hazards have been substantially reduced. However, the daily waste of 20 tons of intestinal matter and 7,000 liters of blood has remained a major problem. These wastes are left to flow into the nearby river. This has a negative externality for downstream dwellers and water users from the river. Though no calculation has been done, this waste is also believed to have methane emissions.

An estimated 1,085 butcheries operate in Addis, of which 835 are licensed. All butcheries serve traditional cuts to customers. Some of these butcheries also double as ‘beef restaurants’ serving raw and fried meat to customers. Almost all butcheries operate as ‘meat kiosks’ with no cold storage facilities on the pretext of customers’ preference for fresh meat (with the exception of few grocers where European cuts are served).

There are currently six export abattoirs under operation (Helimex Export Abattoir, Elfora Agro-Processing, Modjo Modern Export Abattoir, Luna Export Abattoir, Abegrelle, Ashraf and Organic Export- Not operational yet). These abattoirs have an annual slaughter capacity of 2.5 million shoats with a possibility of expansion to 4.5 million shoats in the near future. This is equivalent to a meat production capacity of 24,000 MT per year, with expansion to 40,000 MT per year.

Liquid waste (blood) disposed into river from Nazart Abettor and residentially buildings nearby
The Nazart Abettor only server the city and slaughters about 100 cattle per day

ELFORA is a private agro-industrial company established 1997 through the acquisition of eight livestock and meat processing plants that were previously owned by the government. The company has three major operations: Food Processing and Crop Production, which manages five meat processing plants; Livestock Operations, which is engaged in live animal supply, purchasing centers, ranches and quarantine stations; and the Poultry Operations, which have modern broiler processing and packing units. The Company's Meat Plants at Melge Wondo, Dire Dawa, Kombolcha, Gondar, Metehara, and DebreZeit are engaged in the production of meat either in canned form or carcass for both domestic and export markets. The company is currently one of the livestock and meat products exporters. The MelgeWondo Meat Plant is utilized exclusively for beef carcass export to the Egyptian Market, and the DebreZeit & Metehara Abattoirs for export of mutton and goat carcass to the Middle East.

ELFORA possesses the complete chain of livestock facilities from the purchasing of the animals through holding, ranching, and quarantine, in which the necessary animal health care is provided. Strict control on quality is practiced, supported by health certificate. ELFORA ranches have yearly capacity to accommodate 65,000 heads of cattle and 400,000 heads of sheep & goats per year. Likewise, the holding grounds can accommodate 65,000 heads of cattle and 400,000 heads of sheep & goats per year. ELFORA feedlots have the capacity of holding 16,500 heads of cattle per year.

Two ELFORA abattoirs have fulfilled hygienic standards and are approved and registered by the Ministry of Agriculture and Rural Development as "Export Standard" abattoirs. One of ELFORA's abattoirs is pioneering the implementation of the Hazard Analysis Critical Control Point (HACCP) system, following the institution of Good Manufacturing and Good Hygienic Practices.

Even though the plants have good manufacturing and hygienic practices, they face major problem s with solid and liquid waste disposal. Based on a visit we conducted to the Debre Ziet abattoir and observations we made, the abattoir is currently disposing the waste into a lagoon and into the ground. Current waste disposal at the abattoir clearly reflects methane emissions which has negative environmental and health impacts in the community.

Waste disposal system of ELFORA Abattori in DebreZiet. Pond, man-made lake, and solid waste pile

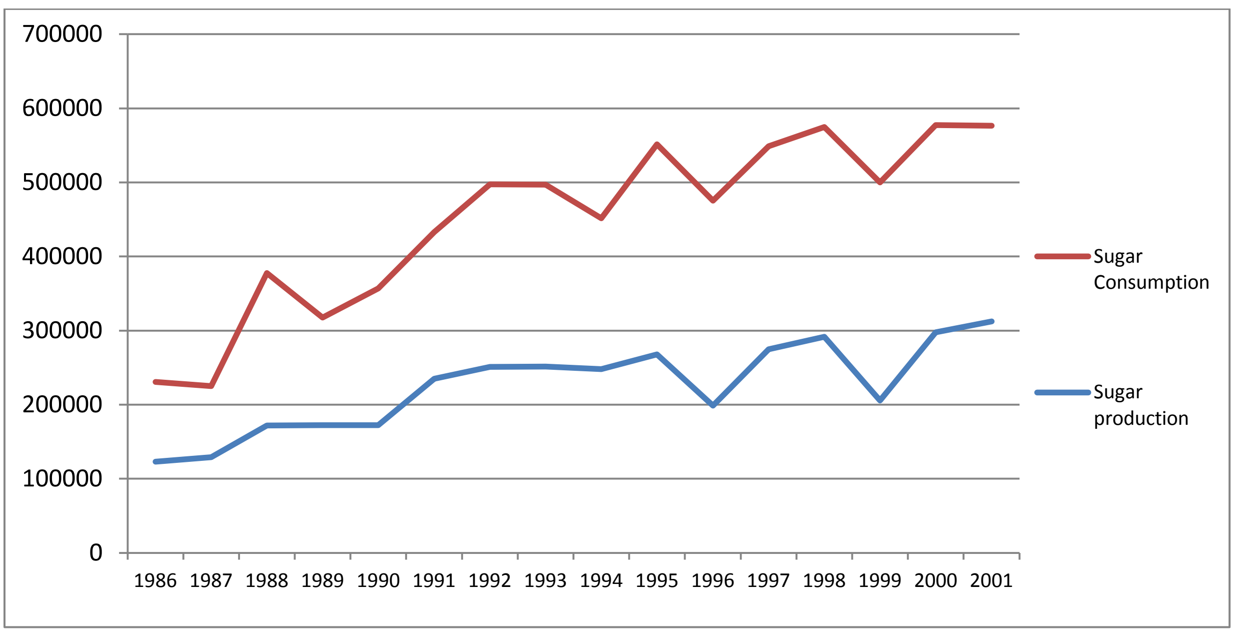
Name of Abattoir	Location	Design Capacity	Actual	Wastewater Treatment Practice
Addis Ababa Kera	Addis Ababa	3,200/ day – sheep & cattle	1,200 – 2,000/day. Depending on season	Solid waste – sold Liquid waste - none
Elfora Agro Industries	Debre Ziet	1,500/ day – sheep & cattle		Lagoon
Modjo Modern Abattoir	Modjo	3000 small stock	Based on order but vary from 250 – 1000/ day	Solid & liquid waste low costs energy & small boiler through biogas
Helemix PLC	Addis Ababa/Akaki			None
Organic Export Abattoir	Modjo			None
Luna Modern Slaughterhouse	Modjo	3,000 sheep & goats; or 100 cattle or 150 camels	Based on order but vary from 250 – 1000/ day	Produces Biogas from solid waste
Abergelle Export Abattoir	Mekele	3,000 sheep & goats; or 100 cattle or 150 camels		N/A
Ashraf export Abattoir (Not operational yet)	Bahir Dar	3,000 sheep & goats; or 100 cattle or 150 camels		N/A

3.5 AGRO- INDUSTRY

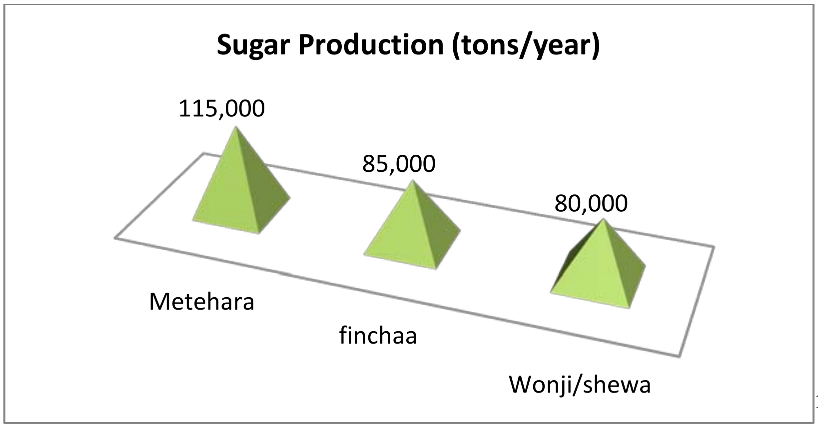
Sugar agro-industrial development in Ethiopia initially started in the so-called Wonji plains in the early 1950s. Nearly 60 years after its introduction merely 35,000 ha has been cultivated to sugarcane and 4 small to medium sized sugar factories with a combined daily crushing capacity of 12,500 tons were installed in 3 separate locations across the country.

At present there are four operating sugar factories in Ethiopia at three separate locations, namely Wonji/Shoa, Metahara and Finchaa, on order of their periods of establishment. The oldest two sugar factories, Wonji/Shoa was scraped and replaced in 2011 by newly constructed plant which has a capacity of producing 6,250 TCD. The ongoing expansion of Finchaa sugar Factory from 5,000 TCD to 12,000 TCD will be completed at the end of 2011.

The largest green field sugar factory is at Tendaho, with daily crushing capacity of 26,000 TCD, is currently under construction and its first phase of 13,000 TCD capacity is planned to be completed before the end of 2012. Three sugar factories each with 10,000 TCD capacities also are currently at design and site investigation stage. Contractors are already engaged and all factories shall be ready for operation at the beginning of 2013. Irrigation system development and cane plantation activities along with public facilities for the above sugar factories are currently going on at a full scale to meet the sugarcane demand of the sugar factories immediately after their completion.



Ethiopia's total annual sugar production is about 300,000 tons, which only covers 60% of the annual demand for domestic consumption. The difference has to be bridged through importation from abroad. As a result, per-capita consumption of sugar in Ethiopia is one of the lowest in the world at about 5 to 6 kg.



[10]

Name of Factory	Area occupied with Sugarcane (hectare)		Production of sugarcane (tons)	
	2001	2002	2001	2002
Finicha	9,730	9,759	872,796	957,933
Wonji	7,050	7,050	80,000	80,000
Tendaho	64,000	64,000	600,000	600,000

Area under cultivation, yield and production sugar in 2000-2002 by private sugar factory

	2001	2002
Cultivated land(ha)	15,601.73	18,908.73
Production per ha(quntal)	358.6	355.63
Total Production	5,594,040.80	6,724,393.51

[10] Source: Investment Opportunity profile for sugar cane plantation and processing in Ethiopia, May 2008

4. POTENTIAL FOR METHANE EMISSION REDUCTION

This section outlines the potential for reducing GHG emissions from livestock manure through use of anaerobic digestion. Anaerobic digestion is the breakdown of organic material by a microbial population that lives in an oxygen free environment. When organic matter is decomposed in an anaerobic environment the bacteria produce a mixture of methane and carbon dioxide gas. Anaerobic digestion treats waste by converting putrid organic materials to carbon dioxide and methane gas. This gas is referred to as biogas. The biogas can be used to produce both electrical power and heat.

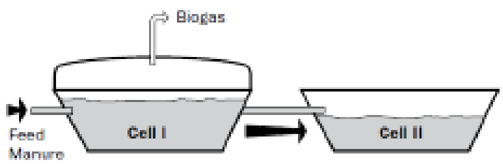
Another end product of anaerobic digestion is nutrient rich organic slurry, as well as other marketable inorganic products. The effluent containing particulate and soluble organic and inorganic materials can be separated into its particulate and soluble constituents. The particulate solids can be sold or exported from the dairy while the nutrient rich liquids are applied to the land. Other environmental benefits of anaerobic digestion include odors reduction.

4.1 TECHNOLOGY OPTIONS

General categories of AD technology for dairy or feedlot manure include anaerobic lagoons, plug flow digesters and complete mix reactors (mesophilic or thermophilic).

Anaerobic Lagoons

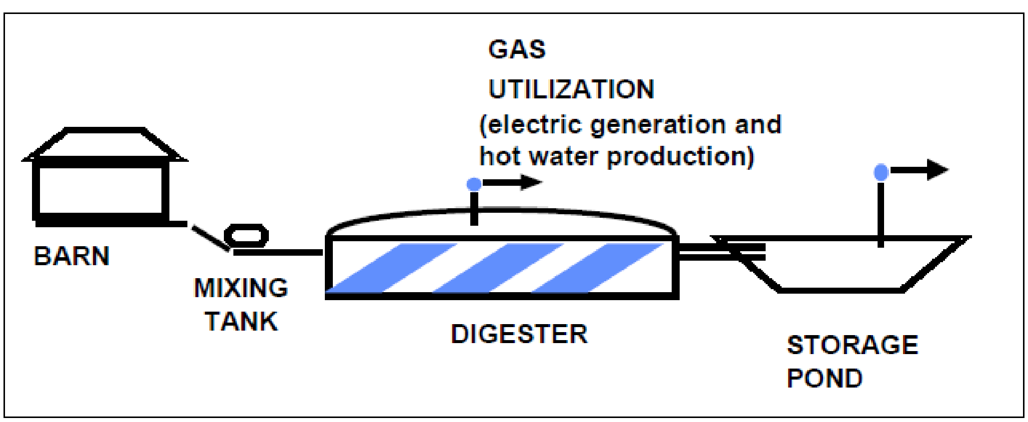
Anaerobic lagoons are essentially covered ponds which can be mixed or not mixed. Manure enters at one end and the effluent is removed at the other. Lagoons operate at a psychrophilic temperature which leads to seasonal production variability. They generally have poor bacteria to substrate contact; hence a very low processing rate (high HRT) and large footprint are required. Covered lagoons are a low capital investment for production of biogas, but tend to underperform other technologies for biogas production, electricity generation, and weed seed and pathogen reduction. Covered lagoons are largely used for odor control instead of biomethane production.



Plug flow digesters

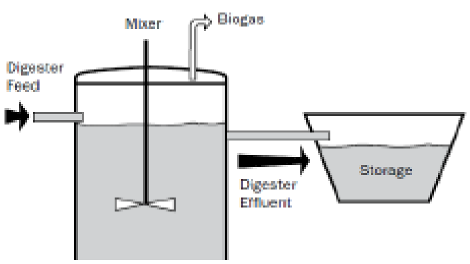
Plug flow digesters are linear (horizontal or vertical) shaped reactors - influent enters on one end and effluent exits on the other. They are typically not mixed; substrate moves through the reactor in a "slug" and HRT = SRT. Plug flow digesters have a narrow solids range to avoid stratification or obstruction. They have moderate capital and operational costs, and require periodic cleaning of the system which incurs downtime.

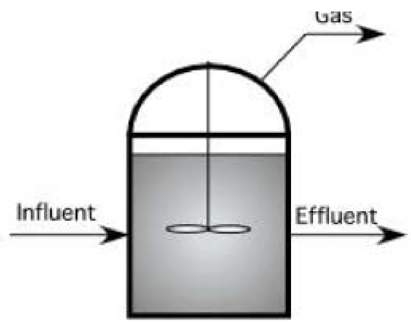
These digesters were designed to handle feedstock at high percent solids with a simple push-through technique. As feedstock is added at one end and an equal proportion is removed from the other side. Although other designs exist, a typical design is a heated below-grade rectangular tank covered with an air tight expandable membrane. Limitations associated with plug-flow digesters include sands and silt settling out, stratification of dilute wastes, unsuitability for dilute milking wastes, and lower methane production. Periodically, solids must be removed from the plug flow reactor. Since there is no easy way of removing the solids, the reactor must be shut down during the cleaning period.



Complete Mix or Continuous Stirred Tank Reactor

The completely mixed reactor a tank that is heated and mixed. Complete Mix or Continuous Stirred Tank Reactors (CSTR) are typically concrete or metal cylinder with a low height to diameter ratio. They can operate at mesophilic or thermophilic temperatures; mixing can be mechanical, hydraulic or via gas injection. Complete mix reactors can accommodate a wide range of solids and generally, HRT = SRT. Higher capital and operational costs are balanced against the stability of the system and reliability of energy production. Additionally, the CSTR accepts multiple co-digestion feedstocks.





Induced Blanked Reactor (IBR)

An induced blanked reactor is a modified version of UASB digester designed for HRT of 5 to 8 days. With a sludge blanket maintained within the bioreactor, slow growing bacteria are retained in the tank which accelerates digestion of slurry. The technology consists of multiple above ground tanks with high height to diameter ratio. Modular design allows for isolation and repair of failed tanks. Tanks are designed as flow through systems with influent entering at the bottom and effluent exiting through the top. Solids and slow growing bacteria are retained on a septum with a plugging control mechanism. Formation of a sludge blanket, consisting primarily of bacteria, occurs in the lower portion of the tank. As methane bubbles up, bacterial aggregates of methanogens float up to the septum, the septum separates the methanogens from the gas, bacteria return to the bottom of the tank and gas exits via the septum. Additional recirculation of the effluent helps retain any bacteria that got past the septum.

Factors Controlling the Conversion of Waste to Gas

The rate and efficiency of the anaerobic digestion process is controlled by:

- The type of waste being digested,
- Its concentration,
- Its temperature,
- The presence of toxic materials,
- The pH and alkalinity,
- The hydraulic retention time,
- The solids retention time,
- The ratio of food to microorganisms,
- The rate of digester loading, and
- The rate at which toxic end products of digestion are removed.

Waste Characteristics

All waste constituents are not equally degraded or converted to gas through anaerobic digestion. Anaerobic bacteria do not degrade lignin and some other hydrocarbons. The digestion of waste containing high nitrogen and sulfur concentrations can produce toxic concentrations of ammonia and hydrogen sulfide. Wastes that are not particularly water-soluble will break down slowly.

Dilution of Waste

The waste characteristics can be altered by simple dilution. Water will reduce the concentration of certain constituents such as nitrogen and sulfur that produce products (ammonia and hydrogen sulfide) that are inhibitory to the anaerobic digestion process. High solids digestion creates high concentrations of end products that inhibit anaerobic decomposition. Therefore, some dilution can have positive effects.

Foreign Materials

Addition of foreign materials such as animal bedding, sand and silt can have a significant impact on the anaerobic digestion process. The quantity and quality of the bedding material added to the manure will have a significant impact on the anaerobic digestion of dairy waste. Sand and silt must be removed before anaerobic digestion. If it is not removed before digestion it must be suspended during the digestion process.

Toxic Materials

Toxic materials such as fungicides and antibacterial agents can have an adverse effect on anaerobic digestion. The anaerobic process can handle small quantities of toxic materials without difficulty. Storage containers for fungicides and antibacterial agents should be placed at locations that will not discharge to the anaerobic digester.

Nutrients

Bacteria require a sufficient concentration of nutrients to achieve optimum growth. The carbon to nitrogen ratio in the waste should be less than 43. The carbon to phosphorus ratio should be less than 187.

Temperature

The anaerobic bacterial consortia function under three temperature ranges.

- Psychrophilic temperatures of less than 68 degrees Fahrenheit produce the least amount of bacterial action.
- Mesophilic digestion occurs between 68 and105 degrees Fahrenheit.
- Thermophilic digestion occurs between 110 and 160 degrees Fahrenheit.

The optimum mesophilic temperature is between 95 and 98 degrees Fahrenheit. The optimum thermophilic temperature is between 140 and 145 degrees Fahrenheit. The rate of bacterial growth and waste degradation is faster under thermophilic conditions. On the other hand, thermophilic digestion produces an odorous effluent when compared to mesophilic digestion. Thermophilic digestion substantially increases the heat energy required for the process.

Seasonal and diurnal temperature fluctuations significantly affect anaerobic digestion and the quantities of gas produced. Bacterial storage and operational controls must be incorporated in the process design to maintain process stability under a variety of temperature conditions. Temperature is a universal process variable. It influences the rate of bacterial action as well as the quantity of moisture in the biogas. The biogas moisture content increases exponentially with temperature. Temperature also influences the quantity of gas and volatile organic substances dissolved in solution as well as the concentration of ammonia and hydrogen sulfide gas.

pH

Methane producing bacteria require a neutral to slightly alkaline environment (pH 6.8 to 8.5) in order to produce methane. Acid forming bacteria grow much faster than methane forming bacteria. If acid-producing bacteria grow too fast, they may produce more acid than the methane forming bacteria can consume. Excess acid builds up in the system. The pH drops, and the system may become unbalanced, inhibiting the activity of methane forming bacteria. Methane production may stop entirely. Maintenance of a large active quantity of methane producing bacteria prevents pH instability. Retained biomass systems are inherently more stable than bacterial growth based systems such as completely mixed and plug flow digesters.

Hydraulic Retention Time (HRT)

Most anaerobic systems are designed to retain the waste for a fixed number of days. The number of days the materials stays in the tank is called the Hydraulic Retention Time or HRT. The Hydraulic Retention Time equals the volume of the tank divided by the daily flow (HRT=V/Q). The hydraulic retention time is important since it establishes the quantity of time available for bacterial growth and subsequent conversion of the organic material to gas. A direct relationship exists between the hydraulic retention time and the volatile solids converted to gas.

Solids Retention Time (SRT)

The Solids Retention Time (SRT) is the most important factor controlling the conversion of solids to gas. It is also the most important factor in maintaining digester stability. Although the calculation of the solids retention time is often improperly stated, it is the quantity of solids maintained in the digester divided by the quantity of solids wasted each day.

$$SRT = \frac{(V)C(d)}{Q(w)C(w)}$$

Where V is the digester volume;
C(d) is the solids concentration in the digester;
Q(w) is the volume wasted each day and
C(w) is the solids concentration of the waste.

In a conventional completely mixed or plug flow digester, the HRT equals the SRT. However, in a variety of retained biomass reactors the SRT exceeds the HRT. As a result, the retained biomass digesters can be much smaller while achieving the same solids conversion to gas.

The volatile solids conversion to gas is a function of SRT (Solids Retention Time) rather than HRT. At a low SRT sufficient time is not available for the bacteria to grow and replace the bacteria lost in the effluent. If the rate of bacterial loss exceeds the rate of bacteria growth, "wash-out" occurs. The SRT at which “wash-out” begins to occur is the "critical SRT".

Digester Loading (kg / m3 / d)

Neither the hydraulic retention time (HRT), nor the solids retention time (SRT) can tell the full story of the impact that the influent waste concentration has on the anaerobic digester. One waste may be dilute and the other concentrated. The concentrated waste will produce more gas per gallon and affect the digester to a much greater extent than the diluted waste. A more appropriate measure of the waste on the digester’s size and performance is the loading. The loading can be reported in pounds of waste (influent concentration x influent flow) per cubic foot of digester volume. The more common units are kilograms of influent waste per cubic meter of digester volume per day (kg / m3 / d). One kg / m3 / d is equal to 0.0624 lb / ft3 / d. The digester loading can be calculated if the HRT and influent waste concentration are known. The loading (in kg / m3 / d) is simply:

$$L = \frac{1}{HRT}(CI)$$

where CI is the influent waste concentration in grams. Increasing the loading will reduce the digester size but will also reduce the percentage of volatile solids converted to gas.

Food to Microorganism Ratio

The food to microorganism ratio is the key factor controlling anaerobic digestion. At a given temperature, the bacterial consortia can only consume a limited amount of food each day. In order to consume the required number of pounds of waste one must supply the proper number of pounds of bacteria. The ratio of the pounds of waste supplied to the pounds of bacteria available to consume the waste is the food to microorganism ratio (F/M). This ratio is the controlling factor in all biological treatment processes. A lower F/M ratio will result in a greater percentage of the waste being converted to gas.

End Product Removal

The end products of anaerobic digestion can adversely affect the digestion process. Such products of anaerobic digestion include organic acids, ammonia nitrogen, and hydrogen sulfide. For any given volatile solids conversion to gas, the higher the influent waste concentration, the greater the end product concentration. End product inhibition can be reduced by lowering the influent waste concentration or by separately removing the soluble end products from the digester through elutriation. Elutriation is the process of washing the solids (bacteria) with clean water to remove the products of digestion. The contact process provides an efficient means of removing the end products of digestion. End product removal can be enhanced by elutriation, which is easily incorporated into the contact process.

4.2 CENTRALIZED PROJECTS

The only centralized biogas program currently in the Ethiopia is National Biogas Program implemented Ethiopian Rural Energy Promotion and Development Centre (EREDPC) which is under the Ministry of Water and Energy. The NBP envisages a first (pilot) implementation phase with construction of 14,000 biogas plants and development of a commercially viable biogas sector. Up-scaling construction to 100,000 biogas plants is considered for a subsequent phase. The overall goal of the NBP is to improve the livelihoods and quality of life of rural households in Ethiopia through the exploitation of the market and non-market benefits of domestic biogas.

The programme comprises eight major components: promotion and marketing, training, quality management, research and development, monitoring and evaluation, institutional support, extension, and gender mainstreaming. The program implemented the construction of biogas at the household level through microfinance. Microfinance is believed to make domestic biogas affordable by supplying long-term credits to farmers wishing to purchase the technology at a low interest rate. The cost of each biogas is estimated to be about 11,000 Birr or $630 (USD). Households are expected to contribute 5,000 birr or $300 (USD).

The day-to-day coordination of the programme is conducted by semi-autonomous National Biogas Programme Coordination Office (NBPCO) inside the EREDPC. This office initiates, coordinates, and monitors the activities within the biogas sector and it are also responsible for accounting, financial procedures, and staff management. SNV-Ethiopia provides technical assistance through advisory services, resource mobilisation and knowledge brokering.

APPENDIX A: Form

Ethiopian Methane Emission From Agricultural Manure Data Collection

I. Farm Location & General Information

1. Farm Name:____
2. Address:____
3. Woreda:_________________ 4. Zone________________
5. Region ___________________
6. Tel:____
7. Fax:____
8. Email:____
9. Contact Person:___________________________________
10. Contact Person 2:_________________________________

II. Livestock Data

	Average Number			Milk production, Kg per cow-day
Milking Herd	Jan.	June	Sept.	
Lactating				
Dry				
Replacement Herd				**Average weight, Kg**
Calves				
Replacement heifers				
Sheep				
Goat				
Swain				

III. Waste Management System

1. Do you separate manure solids? ☐ No ☐ Yes If so, how?

2. How do you store manure and how often do you remove it?

☐ No system

☐ Anaerobic lagoon with secondary storage _______

☐ Combined storage and treatment lagoon ______

☐ Storage tank or pond _________

☐ Solid storage _________

APPENDIX B:

Feeding Centers and Dairy Farms visited

NAME OF FARM	REGION/ ZONE	TYPE OF FARM	NO.CATTLE /AVER AGE WEIGHT EACH	MANURE COLLECTION AND DISPOSAL SYSTEM	IS THERE TECHNOLOGY TO CONVERTING WASTE IN TO RENEWABLE ENERGY(biogas).	Operational/ functional status now
Ato Mohamed Amin	Adama	Fattening	100/400kg	Manuel scraping.	Biogas	Functional
Ato Abu Dqbo	Adama	Fattening and Export	800/320kg	Manuel scraping.	No Technology	-
AtoAsrse Farm	Adama	Fattening and export	700/380kg	Manuel scraping.	No Technology	-
SentayewMu latu	Adama	Fattening and export	440/340kg	Manuel scraping.	No Technology	-
AtoDemseGe zhage	Adama	Fattening and export	500/350kg	Manuel scraping.	No Technology	-
Atomekonne nzewode	Adama	Fattening and export	100/250kg	Manuel scraping.	No Technology	--
Atoalemayeh Bekele	Adama	Fattening and export	150/400kg	Manuel scraping.	No Technology	-
AtoHayeleTa kele	Adama	Fattening and export	165/350kg	Manuel scraping.	No Technology	-
AtoSetotawo Abebe	Adana	Fattening and export	154/270kg	Manuel scraping.	No Technology	-
RezeAgrovte Trading	Adana	Fattening and export	20/250kg	Manuel scraping.	No Technology	-
Paineer Agro industry	Adama	Fattening and export	880/250kg	Manuel scraping.	No Technology	-
ShetayeKelta	Adama	Fattening export	206/310kg	Manuel scraping.	No Technology	-
Emru Farm	Adama	Fattening and export	160/320kg	Manuel scraping.	No Technology	-
Writu	Adama	Fattening	130/310kg	Manuel scraping.	No Technology	-

General Business Group		and export				
Daniel Nigusse	Adama	Fattening and export	100/300kg	Manuel scraping.	No Technology	-
NigusseAsefa	Adama	Fattening and export	100/250kg	Manuel scraping.	No Technology	-
AbraZegye	Adama	Fattening and export	100/350kg	Manuel scraping.	No Technology	-
G/ezaber G/Michel	Suluta	Dairy Farm	100/300kg	Manuel scraping.	Household biogas	functional
AtoAbiyMamo	Suluta	Dairy Farm	100/400kg	Manuel scraping.	Household biogas under construction	-
Nhardel Dairy Farm	Debrezeit	Dairy Farm	90/150kg	Manuel scraping.	Biogas	Not functional
Tesdaye Dairy Farm	DebreZeit	Dairy Farm	75/150kg	Manuel scraping.	No Technology	-
Genesis Farm	DebreZeit	Dairy and Processing	106/600kg	Manuel scraping.	Biogas	Functional
AtoBezhahe/Brhane	Mojo	Dairy Farm	170/300kg	Manuel scraping.	No Technology	-
AtoAkiluMoges	Sebta	Dairy Farm	33/350kg	Manuel scraping.	Household biogas	Functional
AtoAlemu Tulu	Sebta	Dairy Farm	60/400kg	Manuel scraping.	Household biogas	Functional
TadeleBiru	Derbachancho	Dairy Farm	7/400kg	Manuel scraping.	No Technology	-
AtoZewdulegasa	chancho	Dairy farm and milk processing	15/450kg	Manuel scraping.	Household biogas	Functional
AtoGirmaAlemu	Sendaf	Dairy Farm	18/400kg	Manuel scraping.	Household biogas under construction	-