GHG Emission Assessment Guideline

Volume III: Guideline on Data Collection and Estimation of GHG Emission from Livestock and Manure Management

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF AGRICULTURE

ADDIS ABABA
ETHIOPIA

About the authors
Dr. Million Tadessee

Acknowledgements
The authors would like to thank the Ministry of Agriculture – Natural Resources Management Directorate – CRGE unit for providing financial assistance and technical support in the development of this guideline.

Produced by Echnoserve Consulting
April 2015
Front cover photo: Echnoserve
Credit: Bayu Nebsu & Asefa Tadesse

Table of Contents

LIST OF TABLE

I. INTRODUCTION

The livestock production system contributes to global climate change directly through the production of methane (CH_4) from enteric fermentation and manure management and nitrous oxide (N_2O) emission from manure management (Dourmad et al., 2008). Among Ethiopian livestock species the major contributor to GHGs emission are cattle, which are used for meat, dairy products, as draught animals, and are treated as financial assets. Given current practices, the cattle population is likely to increase from today's around 55 million (CSA, 2013) to more than 90 million in 2030 (CRGE, 2011), thereby almost reaching the cattle carrying capacity of the country and doubling emissions from the livestock sector. In a business-as-usual scenario, emissions from livestock are projected to increase as a function of livestock population growth from 55 Mt CO_2e in 2013 to 124 Mt CO_2e in 2030 (CRGE, 2011), mainly driven by an increase in methane from enteric fermentation and manure management (accounting for 112 Mt CO_2e or 90% of emissions in 2030). Emissions from manure left on pasture, range and paddock account for the remaining 10% of livestock emissions in 2030 (CRGE, 2011). Cognizing this fact, Ethiopia set Climate Resilience Green Economy Strategy to protect the country from adverse effect of climate change. As part of the strategy, the government has selected four imitative for fast track implementation. Efficiency improvement in livestock value chain is one of the initiatives selected for fast track implementation to reduce GHG emission from livestock sector. Key to realizing emissions reductions is the ability to measure and track emissions. Development of method and tools for GHG estimation provide this ability and they can be used to quantify emission reduction at farm level, track progress toward reduction goals, and communicate this progress to concerned body or key audiences.

The overall objective of this guideline is to impart the knowledge and skill on GHGs emission measurement and reporting customized guidance to experts, professional, development agent, and producers in Ethiopia on how they should collect data, measure, tracks and report GHG emissions from livestock production customized to the Ethiopian context. Chapter 1 introduce the major GHG emission sources in Livestock, chapter 2 describe the livestock and feed characterization data required for estimation of GHG emission, chapter 3 introduce methodologies for estimation of CH_4 emission from enteric fermentation and manure management in cattle and chapter 4 on methodologies for estimation of nitrous oxide emission from manure management in cattle and the last chapter (chapter 5) deals with GHG emission reporting.

II. LIVESTOCK GREEN HOUSE GAS EMISSION

The green house gas emission from livestock and manure management occurs at different stage along the livestock value chain. However, the relative importance of each source varies considerably. Understanding the qualitative differences amongst them is crucial to many steps in inventory development, including emission calculation, emission reporting and inventory quality control. The green house effect is a natural phenomenon necessary for life on Earth. Greenhouse gases are atmospheric gases that absorb and re-emit long-wave radiation released by the earth back to the surface and as a consequence average global temperatures are predicted to rise (0.5 to 2.5o^C by 2030) (IPCC 2001).

The GHGs that contribute to global warming are CO_2, CH_4, N_2O, SF_6, PFCs, HFCs and NF_3. After carbon dioxide, the most important green house gas is methane which traps over 21 times more heat per molecule compared to CO_2 (EPA 2003). One of the largest biogenic sources of CH_4 is digestive fermentation from ruminant animals (Alan, 2008). CH_4 is emitted through methanogenesis under anaerobic conditions through enteric fermentation, in soils and manure storage, N_2O is primarily emitted as a by-product of nitrification and de-nitrification, while HFCs and PFCs are emitted from refrigeration, air condition equipment.

Enteric fermentation is a natural part of the digestion process which results from the activity of microorganisms in the digestive tract. Digestion in ruminants (e.g. cattle and sheep) differs from that in mono-gastric (e.g. pigs and poultry) in that substantial fermentation occurs in their large stomach called the rumen, resulting in large quantities of CH_4 being produced which are voided through belching (Frank *et al*., 2000). Methane originates from anaerobic microbial fermentation processes in the gastrointestinal tract of ruminant animals particularly in the reticulorumen, or rumen in short. In an adult cow, the rumen occupies a volume of over 100 litres of which usually 85 to 90% is fluid (Moss *et al*., 2000). The high moisture content and temperature that is kept rather constant at around 37o^c makes this an eminently suited environment for microbes to survive and grow, provided the microbes are regularly supplied with a suitable substrate. Substrates needed by the microbes are provided through the ingestion of feed by the host animal. The feed ingested by a ruminant is attacked by the microbes and degraded in a wide range of end products including CH_4.

III. LIVESTOCK FEED CHARACTERIZATION AND GHG EMISSION CALCULATION APPROACH

Estimation of GHG emission can be the most challenging. The general approach is first to identify the management practices and emissions sources that would need to be estimated, before selecting a calculation approach and collecting input data. The selection of a calculation approach is a key step, because the likely accuracy of GHG estimate and the types of input data required vary widely amongst approaches, affecting the ability to realize GHG emission reporting. This chapter: - Describes the livestock population and feed characterization applicable to GHG emission source categories, the level of characterization and input data required for estimation of GHG emission from livestock and the general types of approaches for data collection

3.1. Livestock population and feed characterization

The methods for estimating CH_4 emission from enteric fermentation and manure management, and N_2O emissions from livestock manure management require definitions of livestock species category and subcategories, annual population size, feed intake and feed characterization. The procedures employees to define livestock subcategories, develop population data, and feed characterization data. Feed digestibility coefficients for each livestock sub-categories is required to help estimation of feed intake for use in calculation of CH_4 and N_2O emissions from enteric fermentation and manure sources. Data on livestock population, management system, livestock production, feed type and feeding system can be collected at the farm level or from existing data records held by producers (e.g. from individual smallholder farmers, commercial private farms, or from research center farms). Primary data on livestock population, milk yield, live-weight, feeding situation, feed types, livestock management system, manure management system can be collected at farm level through questionnaire based survey. In contrast, reliable data on feed characteristic (Digestibility (DE%), crud protein (CP) content of feed) can be more difficult to obtain at farm level instead these data can often be obtained from research.

3.1.1. Livestock species categories and subcategories

The livestock population category and subcategories need to be defined to create relatively homogenous sub-groupings of animals. The criteria for grouping into subcategory will be based on difference in breed, age, sex, production objective (dairy, meat, multipurpose). By dividing the population into these subcategories, country-specific variations in animal performance within the overall livestock population can be reflected. The steps to characterize livestock sub-category is: 1) Identify livestock species applicable to each GHG emission sources: 2) determine GHG emission estimation methods applicable: 3) identify the most detail characterization required.

The livestock species that contribute to more than one emission source category in Ethiopia are typically: cattle, sheep, goats, horses, camels, mules/asses, and poultry according to their importance (Table 1). The cattle species in Ethiopia are the major contributor to GHG emission due to their number and level of emission compared to other livestock species. The majority of cattle populations in Ethiopia are indigenous type but small number of exotic dairy cattle breed and crossbred are found in urban and peri-urban areas. The indigenous cattle breeds are the major contributor to GHGs emission in Ethiopia because of their large population size compared to other livestock species. In terms of distribution, about 70% of cattle population in Ethiopia is found in the highland mixed crop livestock production system. The pastoral and agro-pastoral production system accounts for rest 30% of cattle population in Ethiopia. By dividing the cattle production system into these production system country specific variation can be reflected

Table 1. Livestock species that contribute to GHG emission and their emission sources category in Ethiopia

Livestock species	GHG emission sources category
Cattle	CH_4 from enteric fermentation and CH_4 and N_2O from manure management
Sheep	CH_4 from enteric fermentation and CH_4 and N_2O from manure management
Goat	CH_4 from enteric fermentation and CH_4 and N_2O from manure management
Camel	CH_4 from enteric fermentation and CH_4 and N_2O from manure management
Horse	CH_4 from enteric fermentation and CH_4 and N_2O from manure management
Mule	CH_4 from enteric fermentation and CH_4 and N_2O from manure management
Donkey	CH_4 from enteric fermentation and CH_4 and N_2O from manure management
Poultry	CH_4 and N_2O emission from manure management

3.2 GHG emission estimation approach in livestock population in Ethiopia

On the base of existing reviewed emission estimation method, level of emission and trend, and livestock and feed characterization data, IPCC, tier 2 (IPCC, 2006) emission estimation approach is identified suitable in Ethiopia for the source categories of methane emission from enteric fermentation in cattle (table 2). For methane emission from manure management there is no manure characteristic data (e.g. volatile solid content) available to use tier 2 emission estimation approaches and current level of emission is also small and does not warranty detail characterization data to use tier 2 approaches. Hence, tier 1 emission estimates approach can be used for methane emission from manure management. For nitrous oxide emission estimation from manure management (direct source), tier 2 approach can be applied, because of availability of country specific feed characterization data for estimation of nitrogen excretion rate in cattle species. However the indirect emission of nitrous oxide from manure management could not be accounted because of their relative importance (CRGE, 2011).

Table 2. GHG emission source category and calculation approaches

No	Major GHG emission source categories in Ethiopia	Calculation approach relevant to Ethiopia
1	Methane emission from enteric fermentation in cattle	IPCC, Tier 2
2	Methane emission from manure management	IPCC, Tier 1
3	Nitrous oxide emission from manure management (direct emission)	IPCC, Tiers 2

Level of characterization required for each GHG emission sources:

Once you determined the emission calculation approach under each source category, you need to identify the most detailed characterization required to support each emissions estimate for each livestock species category and sub-category (Table 3). For sources category of methane emission from manure management in Ethiopia, the 'basic' characterization data (livestock population) could be used for all livestock species category and sub-category, due to lack of country specific information on manure characteristics. However, for estimation of methane emission from enteric fermentation in cattle enhanced characterization (tier 2) is required to collect information on livestock and feed characterization. The same characterization data can be used to estimate nitrous oxide emission from manure management using tier 2 methods.

Table 3. Level of characterization (livestock and feed) required for estimation of GHG emission in Ethiopia

Livestock Species category	GHG emission calculation methods	Level of characterization required
Cattle	• Tier 2 approach for CH_4 emission from enteric fermentation and N_2O emission from manure management • Tier 1 approach for estimation of CH_4 emission from manure management	• Detailed enhanced characterization on livestock species and feed characterization • Basic characterization (livestock species category/sub-category) data for CH_4 emission from manure management
Sheep	Tier 1 approach for all GHG emission	Basic characterization
Goat	Tier 1 approach for all GHG emission	Basic characterization
Horse	Tier 1 approach for all GHGs emission	Basic characterization
Mule	Tier 1 approach for all GHG emission	Basic characterization
Donkey	Tier 1 approach for all GHG emission	Basic characterization
Camel	Tier 1 approach for all GHG emission	Basic characterization
Poultry	Tier 1 approach for all GHG emission	Basic characterization

3.3. Basic characterization for livestock population (tier 1 approach)

Basic characterization applies to livestock species category and subcategory that have default emission factor. The following input data are required to support the emissions estimates using IPCC default value.

Livestock species and categories: A complete list of all livestock populations that have default emission factor values must be developed. Based on IPCC classification for cattle the relevant categories in Ethiopia are: high producing dairy cows (pure exotic), low producing (crossbreed), other cattle (indigenous multipurpose cattle), other livestock species are: sheep, goats, camels, horses, mules and asses, and poultry. Feedlot cattle can be treated as one separate category.

Annual population: Seasonal births or slaughters may cause the population size to expand or contract at different times of the year, which will require the population numbers to be adjusted accordingly. It is important to fully document the method used to estimate the annual population, including any adjustments to the original form of the population data as it was received from farmers, central statistical agencies or from other sources.

Annual average populations are estimated in various ways, depending on the available data and the nature of the animal population. In the case of animal alive the whole year like dairy cattle, estimating the annual average population may be as simple as obtaining data related to one-time animal inventory. However, estimating annual average populations for a growing population (e.g., feedlot cattle and broiler) requires calculation/adjustment to the original data received. Most animals in these growing populations are alive for only part of a complete year (for example, in Ethiopia commercial feedlot fattening based on grain diet are practiced for duration of 3 or 6 months). Animals should be included in the populations regardless if they were slaughtered for human consumption or die of natural causes. Equation 1 estimates the annual average of livestock population.

AAP =Days _alive(NAPA/365)* *(Equation 1)*

Where:

AAP = annual average population

NAPA = number of animals produced annually

For example broiler chickens are typically grown approximately 60 days before slaughter. Estimating the average annual population as the number of birds grown and slaughtered over the course of a year would greatly overestimate the population, as it would assume each bird lived the equivalent of 365 days. Instead, one should estimate the average annual population as the number of animals grown divided by the number of growing cycles per year. For example, if broiler chickens are typically grown in flocks for 60 days, an operation could turn over approximately 6 flocks of chickens over the period of one year. Therefore, if the operation grew 60,000 chickens in a year, their average annual population would be 9,863 chickens. For this example the result from equation would be:

Annual average population = 60 days ● (60,000 / 365 days) = 9,863 chickens

Dairy cows: The majority of cattle population in Ethiopia is indigenous type found in smallholder and pastoral production system and small number of improved dairy cattle population also exist in peri-urban and urban milk shed areas.

Dairy cows in Ethiopian context are defined here as mature cows (pure exotic and crossbreed) that are producing milk in commercial quantities for human consumption (IPCC, 2006). In Ethiopia the dairy cow population is comprised of two well-defined segments: (i) high-producing exotic dairy cow population found in urban and peri-urban commercial operations; and (ii) low producing dairy cow population managed under medium input production system. These two segments could be evaluated separately by defining two dairy cow categories. However, the dairy cow category does not include indigenous cows kept for multipurpose production (meat, milk and draft power). Low producing multi-purpose cattle and cattle managed under pastoral production system should be considered as other cattle category (indigenous cattle).

3.4. Enhanced characterization for livestock population (tier 2 approach)

Enhanced characterization requires detailed information on:

- Definitions for livestock category and subcategories;
- Livestock population by subcategory, with consideration for estimation of annual population as per tier 1; and
- Feed intake estimates for the typical animal in each subcategory.

The livestock population subcategories are defined to create relatively homogenous sub-groupings of animals. By dividing the population into these subcategories, country-specific variations in age structure and animal performance within the overall livestock population can be reflected. Enhanced characterization seeks to define animals, animal productivity, and diet quality and management system used to support a more accurate estimate of feed intake for use in estimating methane production from enteric fermentation using tier 2 method. The same feed intake estimates should be used to provide harmonized nitrogen excretion rates to improve the accuracy and consistency of CH_4 and N_2O emissions.

Definitions for livestock subcategories

IPCC 2006 recommends classifying livestock populations into subcategories for each species according to age, production system, and sex. Representative cattle species sub-categories in Ethiopia are shown in Table 4.

In Ethiopia, cattle populations are classified into at least three categories: pure exotic, crossbred and indigenous cattle. These categories can be further divided into: mature dairy cow, growing and young cattle. Feedlot cattle can be considered as separate category and could be further subdivided into those cattle that are fed a high-grain diet (commercial feedlot) and those cattle that are grown and finished solely on pasture (small holders fattening).

Ethiopia is a country with distinct production system differences, due to difference in climate, breed, feed and feeding system, and manure management. These differences need to be considered in order to obtain accurate estimate. For this, first define production system then define categories and sub-categories within these production systems. For example, livestock production system in Ethiopia can be classified into urban and peri-urban production system, mixed crop-livestock system (mixed moisture sufficient and mixed moisture deficit system) found in the highland, and pastoral and agro-pastoral production system found in the low land areas. Both urban and peri-urban systems are located around Addis Ababa and regional towns and take the advantage of the urban markets, the production system is based on the use of pure exotic breed and crossbred dairy cows for commercial purpose, manures are managed in liquid based-system or pit form, feed and feeding system is based on concentrate supplementation. The mixed crop-livestock production system is part of the subsistence farming system found in mixed highland area. Feed resources are mainly natural grazing, crop residues and small amount of cultivated forages whereby a greater fluctuation in availability and quality are manifested almost throughout the year (Alemayehu, 2003). In this system most livestock manure is left on pasture/grazing land, used as fuel for energy sources or construction purpose. The pastoral and agro-pastoral production system is found in extensive range land area of lowland part of the country. The major feed resources are grass, shrubs, browse from rangeland. Livestock manure is managed as a solid left on rangeland/pasture.

Table 4. Definition of livestock (cattle) population category and sub-category in Ethiopia

Cattle species category	Sub-category	Age	Feeding system	Manure management system
1. Dairy cattle breeds (exotic)	Mature dairy cows	> 3 years	Stall feeding in urban and peri-urban dairy commercial production system	Liquid storage, Pit
	Growing heifers	2-3 years		
	Young female	1-2 years		
	Matured males (breeding bull)	> 3 years		
	Growing male	2-3 years		
	Young male	1-2 years		
2. Crossbred dairy cattle	Mature dairy cows	> 3 years	Communal grazing and cut and carry system found in mixed crop livestock	Spread on pasture, fuel, construction
	Growing heifers	2-3 years		
	Young females	1-2 years		
	Mature males (breeding bull)	> 3 years		
	Growing male	2-3 years		
	Young male	1-2 years		
3. Indigenous cattle	Mature cows	> 3 years	Free grazing in pastoral and agro-pastoral to limited grazing in mixed crop livestock, system, feedlot	Spread on pasture, fuel, construction
	Growing heifers	2- 3 years		
	Young females	1- 2 years		
	Oxen	> 3 years		
	Breeding bulls	2-3 years		
	Young male (steers)	1-2 years		
	Mature feedlot cattle fed on forage	2-3 years		
	Growing/fattening cattle fed a high-grain diet and housed in dry lot	1-2 years		

For each of the representative animal sub-categories defined, the following information is required:

- Annual average population (number of livestock similar to for Tier 1 basic characterization);
- Average daily feed intake (megajoules (MJ) per day and / or kg per day of dry matter); and
- Methane conversion factor (percentage of feed energy converted to methane), data on methane conversion factor is not available specific to Ethiopian feed, IPCC default value can be used.

Generally, data on average daily feed intake are not available in Ethiopia condition, and need to be estimated from available feed characteristic and animal productivity data.

The following general data should be collected for estimating the feed intake for each representative animal category/sub-category:

Live Weight (LW), kg: Live-weight data should be collected for each animal sub-category.

These live-weight data can be obtained from previous study or to estimate by collecting data from representative sample studies or from CSA if these already exist. Under field condition measuring the actual live weight of animal may be difficult as weighing scale may not be available, instead heart girth measurement tap can be used to obtain approximate weight of animal.

Average weight gain per day (AWG), kg per day: Data on average weight gain can be obtain or collected for feedlot animals and young growing animals. Mature animals are generally assumed to have no net weight gain or loss over an entire year. Mature animals frequently lose weight during the dry season or during temperature extremes and gain weight during the following season (IPCC, 2006). However, increased emissions associated with this weight change are likely to be small. Reduced intakes and emissions associated with weight loss are largely balanced by increased intakes and emissions during the periods of gain in body weight. In general it is difficult to collect data on average daily weight gain under field condition. Weight gain can be varies among breed and can be obtained from previous studies by research or from central statistical authority (CSA) or other sources. Table 5 presents average daily weight gain of some of the major cattle breed in Ethiopia. These data are collected from different published literature sources in Ethiopia

Mature weight (MW), kg: The mature weight of the adult animal of each sub-category is required to define a growth pattern, including the feed and energy required for growth. Mature weight of a breed or category of cattle is generally considered to be the body weight at which skeletal development is complete (IPCC, 2006). The mature weight will vary among breeds and should reflect the animal's weight when in moderate body condition. This is termed 'reference weight' (ACC, 1990) or 'final shrunk body weight' (NRC, 1996). Estimates of mature weight for some cattle breeds in Ethiopia are available from research work (Table 5).

Table 5. Example of body weight (in kg) of some cattle breed in Ethiopia at different age

Parameters	Weight by breed type					
Male	Boran	Horro	Barca	Arsi	Zebu	Fogera
Birth weights	24.5	18.3	22.1	21.5	0	21
6 months weight	115	84	99			
Yearling weight	156	112	116			
Adult/mature weight	318		380	257	300	
Female						
Birth weights	24.5	18.3	22.1	21.5		21
Six months weight	115	84	99			
Yearling weight	156	112	116			
Adult or mature weight	225		280	257	250	

Mekonnen, 1994; Habtamu Abera, 2012; Workneh et al (2002); [1] Mekonenen et al., 1996; Kiwuwa et al., 1983; IAR, 1976; Goshu and mekonnin 1997

Average number of hours worked per day: Data on average number of hours worked for oxen per day is required to estimate net energy for work. For drought animals, the average number of hours worked per day must be determined. In Ethiopian highland mixed crop livestock production system oxen are used only for a maximum of 3 months per year for cultivation of crop land. During this period they used for a maximum of 8 hours per day. In order to obtain accurate estimate of energy requirement for work adjustment to annual base is required.

Feeding situation: Data on feeding situation is required to estimate net energy requirement for activity (when animal move from place to place in search of feed they spent energy). Feeding situation in Ethiopia are represented (Table 6) by (i) extensive range grazing system found in pastoral areas and mixed crop livestock system where animal move from place to place (ii) stall feeding with no movement in search of feed (dairy and feedlot) mostly found in peri-urban and urban production system: (iii) pasture or cut and carry system with limited movement found in mixed crop livestock production system in the highland.

Table 6. Livestock feeding situation and activity coefficient required for calculation of net energy for activity.

Feeding situation	Definition	Activity coefficient (Ca) is dimensionless)
Extensive grazing	Animals graze in open range land or hilly terrain and expend significant energy to acquire feed (open grazing in pastoral area and communal grazing found in mixed crop livestock system).	0.36
Stall feeding (dairy and feedlot)	Animals are confined to a small area as a result they expend very little or no energy to acquire feed (Example; dairy cattle in urban and peri-urban commercial dairy production and feedlot animals).	0.00
Pasture based	Animals are confined in areas with sufficient forage requiring modest energy expense to acquire feed.	0.17

Sources: Adapted from IPCC, 2006

Milk production data: for lactating animals, data on daily milk production is required to calculate energy requirement for lactation. The data on milk production can be obtained from milk production record (private commercial dairy and small holder farmers, public owned livestock farm). In case of smallholders and pastoral production system it is difficult to obtain these records under Ethiopian condition, as there is no recording system implemented. These data need to be collected from farmers through questioner based survey or obtained from CSA, research centers or other reliable sources. Example of milk production data compiled from different sources for different cattle breeds in Ethiopia are presented in (Table 7).

Table 7. Data on average milk production and lactation length for different breeds in Ethiopia

Cattle breed	Milk yield (kg/lactation)			Lactation length (days)			Average milk yield (kg/day)	Sources
	N	Mean	S.e	N	Mean	S.e	Mean	
Indigenous cattle breed								
Arsi cattle breed	3	589.33	124.80	4	258.67	18.65	2.28	Million et al. 2004; 2001;2006
Barca cattle breed	3	713.24	39.90	3	247.67	31.80	2.88	Million et al 2001; Goshu Mekonnen et al. 1983
Boran cattle breed	4	592.25	136.00	3	202.00	19.00	2.93	Gebeyehu Goshu, 1999; Moges Dereje et al. 1998
Fogera cattle breed	2	592.50	279.5	2	231.00	56.00	2.56	Asheber Sewalem, 1992, Mekonne et al. 1987
Horro cattle breed	2	529.00	21.00	2	201.00	28.00	2.63	Beyene Kebede, 1996.
Dairy cattle breed (Exotic dairy cattle)								
Holstein Friesian dairy cattle	4	3746.4	216	2	342.5	195	10.93	Million et al. 2011;
Jersey dairy cattle	2	1640		2	277.1		6.0	Diriba et al. 2013
Crossbred dairy cattle breed								
½ Jersey* ½ Arsi	3	1869.67	250	3	351.67	13	5.32	Million et al. 2004; 2001;1997
½ HF* ½ Arsi	4	1726.7	229	4	382.39	9	4.52	Million et al. 2004; 2001;1997
½ HF* ½ Barca	3	2160.65	235	1	326		6.63	Million et al 2001; Goshu Mekonnen et al. 1983
½ HF* ½ Boran	4	2327.06	228	3	306.2	22	7.60	Gebeyehu Goshu, 1999; Moges Dereje et al. 1998
½ HF* ½ Fogera	2	2428.65	95	2	400.45	14	6.06	Asheber Sewalem, 1992, Mekonne et al. 1987
½ HF* ½ Zebu	5	1983.72	156	4	337.67		5.87	Kiwuwa et al. 1983

N= number of data set/experiment; HF= Holstein Friesian; S.e =standard error

Fat content (%): Average fat content of milk is required for lactating cows. It is estimated to be 4% for Holstein Friesian and their crosses with indigenous breed and 5.5% for indigenous breed.

Percent of females that give birth in a year: Data on percentage of females that give birth annually is required only for mature cows and can vary with breed and management system. These data can be collected through survey using representative samples, or obtained from previous research work or from CSA if any. Percent of females that give birth in a year required to calculate net energy requirement for pregnancy.

Feed characteristic data: feed characteristic data such as feed digestibility (DE%), protein (CP) content are required to calculate CH_4 emission from enteric fermentation and nitrogen excretion from manure.

Feed digestibility (DE%): Complete information on digestibility values for different livestock classes and diet types are not available in Ethiopian condition that can be used in estimating feed intake. However IPCC 2006 digestibility values for range of livestock class and diet type are available and can be used in estimating feed intake. These for cattle (Table 8), common ranges of feed digestibility are 45-55% for crop by-products and range lands; 55-75% for good pastures, good preserved forages, and grain supplemented forage-based diets; and 75-85% for grain-based diets fed in feedlots. Variations in diet digestibility results in major variations in the estimate of feed needed to meet animal requirements and consequently associated methane emissions and amounts of manure excreted. It is also important to note that digestibility, intake, and growth are co-dependent phenomena. For example, a low digestibility will lead to lower feed intake and consequently reduced growth. Conversely, feeds with high digestibility will often result in a higher feed intake and increased growth. A 10% error in estimating DE will be magnified to 12 to 20% when estimating methane emissions and even more (20 to 45%) for manure excretion (IPCC, 2006).

Table 8. Digestibility coefficient for different feed or diet type (Adopted from IPCC, 2006)

Feed or diet characteristic	Locality	Digestibility coefficient
Crop residue and communal grazing/green feed	Mixed crop-livestock	45-55%
Range grazing animal	Pastoral and ago-pastoral	45-55%
Cattle feed on green feed, good preserved grass hay and grain supplemented forage diet	Urban and peri-urban dairy Small holder fattening	55-75%
Concentrate based diet fed in feedlot	Peri-urban fattening	75-85%

Digestibility data should be based on measured values for the dominant feeds or forages being consumed by livestock with consideration for seasonal variation. In general, the digestibility of forages decreases with increasing maturity and is typically lowest during the dry season. Due to significant variation, digestibility coefficients should be obtained from local scientific data (research) wherever possible. Although a complete census of digestibility is considered unrealistic, at a minimum digestibility data from research studies should be consulted.

Some of feed characteristic such as measured values for Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Crude Protein (CP), % ash for major feed in Ethiopia are presented in Table 9. These feed characteristic data are measured in the laboratory to indicate the nutritive value of the feed for ruminant livestock. Determination of these values can enable DE to be predicted as defined in the recent dairy NRC (2001). The concentration of crude protein (CP) in the feed can be used in the process of estimating nitrogen excretion rate for determination of N_2O estimation.

Table 9. The mean chemical composition and nutritive value of Ethiopian feeds by class on percent DM basis (EIAR, 2007)

Composition	Dry forage and roughages	Green forages and roughages	Energy supplement	Protein supplement
DM	91.3	44	78.7	78.9
EE	2.1	3.2	3.6	6.9
Ash	8.1	10.6	4.3	10.2
CP	6.7	10.9	13.9	30.6
NDF	68.1	56.2	29.3	48.5
ADF	44.6	39.3	10.3	28.6
Hemicelluloses	18.0	16.9	18.8	28.3
Lignin	9.3	8.8	2.7	6.99
DOMD	47.1	50.3	82.2	65.3
ME	7.3	7.6	13.1	10.2

DM= Dry matter; EE=Ether extract; CP=crude protein; NDF= Neutral Detergent Fiber; ADF= Acid Detergent Fiber; DOMD=Digestible organic mater; ME=Metabolizable energy

IV. METHODS FOR ESTIMATION OF METHANE EMISSION FROM ENTERIC FERMENTATION AND MANURE MANAGEMENT IN CATTLE

4.1 Methane emission from enteric fermentation in cattle

Methane is produced in ruminant as a by-product of enteric fermentation, whereby carbohydrates are broken down by bacteria in the digestive tract. The amount of methane that is produced depends on: The type of digestive tract. Ruminant livestock have an expansive chamber, the rumen, which fosters extensive enteric fermentation and high CH_4 emissions. The main ruminant livestock are cattle, goats, sheep, and camel. Non-ruminant livestock (horses, mules, asses) and mono-gastric livestock (poultry) have relatively lower CH_4 emissions because much less CH_4-producing digestion takes place in their digestive systems. Among ruminant species methane emission from sheep and goat are considered to be small to quantify.

In general methane production by ruminant livestock is influenced by dietary characteristics as well as the fermentation conditions in the rumen. In addition to the above one methane production from enteric fermentation depends on production level, stage of lactation, pregnancy, age, size of livestock (feed intake is positively related to animal size, growth rate, and production e.g., milk production, or pregnancy) and management related interventions like grazing regime, feeding regime, housing and milking.

Among Ethiopian livestock species the major contributor to CH_4 emission are cattle which account for 83% of emission. Cattle also represent a large portion of Ethiopian livestock population. As a result IPCC tier 2 approaches for estimation of methane emissions from enteric fermentation in cattle is preferable as long as enhanced characterization data available. Detailed country-specific data (input data) required for determination of feed intake for cattle species are presented in chapter 2. The Tier 2 method also requires disaggregated livestock population sub-categories (See chapter 2) to be used to calculate emission factors. The key considerations for the tier 2 method are collection of detailed activity data (See chapter 2) and the development of emission factors.

The method for estimating methane emission from enteric fermentation using tier 2 methodology requires three basic steps:

Step 1: Divide the livestock population into subcategory and characterize each sub-category as described in Chapter 2.
Step 2. Estimate feed intake (gross energy) required for calculation of methane emission factor
Step 3: Calculate methane emission factors for each subcategory in terms of kilograms of methane per animal per year.

Step 4: Multiply the subcategory emission factors by the subcategory populations to estimate subcategory emission

Step 5. Sum-up the sub-category emission to get total emission from cattle

4.1.1 Calculation of feed intake or gross energy (GE) intake for cattle

Animal performance and diet data are required to estimate feed intake, which is the amount of energy (MJ/day) an animal needs for maintenance and for activities, growth, lactation, work, and pregnancy. The equations to estimate feed intake is as follows:

Net energy for maintenance: (NE_m) is the net energy required for maintenance, which is the amount of energy needed to keep the animal in equilibrium where body energy is neither gained nor lost (Jurgen, 1988).

$$\mathbf{NE_m} = \boldsymbol{Cfi} \bullet (\boldsymbol{Weight})^{0.75} \qquad \textbf{(Equation 2)}$$

Where:

NE_m = Net energy required by the animal for maintenance, MJ per day

Cf_i = Coefficients for calculating NE_m, MJ per day per kg which varies for each animal category (0.386 for matured cows; 0.370 for lactating, non lactating and bull and 0.322 for growing cattle)

Weight = live-weight of animal, kg

Example: Using input data on live-weight and coefficient for energy maintenance (Cf_i) from IPCC 2006, the value for net energy for maintenance can be calculated for each cattle species sub-category as follows (Table 10):

Table 10. Net energy for maintenance of indigenous cattle by sub-category

Sub-category	Live weight in kg	Cf_i (Mj/day)[1]	Net energy for maintenance (Mj/day/animal)
Matured cows	253.00	0.386	24.48656
Growing heifers	216.00	0.322	18.14246
Young female	113.67	0.322	11.2096
Oxen	313.75	0.370	27.58287
Breeding bull	313.75	0.370	27.58287
Growing male	113.70	0.370	12.88315

[1]Adapted from IPCC, 2006; Live weight from Table 6.

Net energy for activity: **(**NE_a) is the net energy needed for animals to obtain their food, water and shelter. It is based on its feeding situation rather than characteristics of the feed itself. The equation for estimating NE_a for cattle is:

$$NE_a = Ca \bullet NE_m \qquad \textbf{(Equation 3)}$$

Where:
NE_a = net energy for animal activity, MJ per day
Ca = coefficient corresponding to animal's feeding situation (activity coefficients for stall feed=0, pasture animal with limited movement=0.17; range grazing animal =0.36)
NE_m = net energy required by the animal for maintenance, MJ per day

Example: Calculating net energy for activity
Using the above equation and activity coefficient of 0.36 for grazing animal and 0 for young animals (IPCC, 2006) the net energy value for activity for each subcategory are presented in the following table (Table 11).

Table 11. Net energy requirement of indigenous cattle for activity

Sub-category	C_a (Activity coefficient)[1]	Net energy for activity
Matured cows	0.36	8.815
Growing heifers	0.36	6.531
Young female	0.36	4.035
Mature male (oxen)	0.36	9.930
Breeding bull	0.36	9.930
Growing male	0.36	4.638

[1]Adapted from IPCC, 2006

Calculation of Net Energy for growth**:** (NE_g) is the net energy needed for growth (i.e., weight gain; NRC 1996). Constants (C) for conversion from calories to joules and live to shrunk and empty body weight have been incorporated into the equation (IPCC, 2006).

The equation for calculating Net Energy for growth in cattle is:

$$NE_g = 22.02\ BW/(C^*\ MW)^{0.75} * WG^{1,097} \qquad \textbf{(Equation 4)}$$

Where:
NEg = net energy needed for growth, MJ per day
BW = the average live weight (BW) of the animal in the population, kg
C = a coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls (NRC, 1996)

MW = the mature live body weight of an adult animal in moderate body condition, kg
WG = the average daily weight gain of the animals in the population, kg per day

Example of calculating Net Energy for growth

Net energy for growth can be calculated using live-weight, matured weight and daily weight gain of individual animal in equation 4 for each sub-category. The result is presented in Table 12

Table 12. Estimate of Net Energy for growth requirement of indigenous cattle breed

Sub-category	Growth Coefficient (C)	Live weight[1]	Matured weight[1]	Weight gain[3]	Net energy for growth
Matured cows	0.8	253	253	0	0
Growing heifers	0.8	216	253	0.3	8.462
Young female	0.8	113.67	253	0.4	5.228
Oxen	1.2	313.75	313.75	0	0
Breeding bull	1.2	313.75	313.75	0.3	7.029
Growing male	1.2	113.7	313.75	0.4	3.283

[1]Matured weigh of indigenous cattle was estimated using average matured weight of different breeds (Table 6)

[3]Daily weight gain was obtained from Boran (Mekonnin et al., 1994 and Horro breed (IAR, 1976) in Ethiopia

***Net energy for lactation*: (**NE_l) is the net energy required for lactation. For cattle the net energy for lactation is expressed as a function of the amount of milk produced and its fat content expressed as a percentage (e.g., 4%; NRC, 1989). Both milk production and fat content varies with breed.

The equation for calculating Net Energy for lactation is:

$$\mathbf{NE_1 = Milk \bullet (1.47 + 0.40 \bullet Fat)} \qquad \textbf{(Equation 5)}$$

Where:
NE_l = Net energy for lactation, MJ per day
Milk = Amount of milk produced, kg of milk per day
Fat = Fat content of milk, % by weight.

Example: Calculating net energy for lactation

Using the above equation we can calculate net energy requirement for lactation. Average daily milk yield of indigenous cattle breed in Ethiopia is estimated to be 2.5 kg per day per cow (chapter 2 in table 7) with 4% fat contents.

Calculating Net energy for lactation (NE_l)= 2.5 (1.47+0.40*4%)= 3.715 Mj/day/cow

***Net energy for work*:** (NE_{work}) is the net energy required for work. It is used to estimate the energy required for draft power for cattle. The net energy requirement for work that is reported by Bamualim and Kartiarso show that about 10 percent of a day's net energy for maintenance requirements is required per hour for typical work for drought oxen (IPCC, 2006).

Net energy for work in cattle can be calculated using the following equation:

$$NE_{work} = 0.10 \bullet NE_m \bullet Hours \qquad \textbf{(Equation 6)}$$

Where:

NE_{work} = net energy for work, MJ per day

NE_m = net energy for maintenance, MJ per day

Hours = number of hours of work per day

Example of calculating net energy for work

Working hours for oxen in Ethiopia is estimated to be 6-8 hours per day for a maximum of 90 days. Based annual adjustment the net energy requirement for work for oxen sub-category is estimated to be 5.52 Mj/day.

***Net energy for pregnancy*:** (NEp) is the energy required for pregnancy. For cattle, the total energy requirements for pregnancy for a 281-day gestation period averaged over an entire year are calculated as 10% of NE_m. When using NE_p to calculate GE for cattle, the NE_p estimate must be weighted by the portion of the mature females that actually go through gestation in a year. For example, if 45% of the mature females in the animal category give birth in a year, then 45% of the NEp value would be used in the GE equation below. Under Ethiopian mixed crop livestock system on average 45% of mature females give birth in a year (ILRI, 2001).

The equation for calculating net energy for pregnancy

$$NEp = C_{pregnancy} \bullet NE_m \qquad \textbf{(Equation 7)}$$

Where:

NEp = net energy required for pregnancy, MJ per day

$C_{pregnancy}$ = pregnancy coefficient (0.10)
NE_m = net energy required by the animal for maintenance, MJ per day

Example of calculating Net energy for pregnancy: Using the above equation multiply the net energy for maintenance for matured cow sub-category (Table 10) by the pregnancy coefficient value of 0.1 (IPCC, 2006) and herd pregnancy rate (45%). The result in net energy requirement for pregnancy is then=1.10 Mj/day/cow.

Calculation of ratio of net energy available in diet for maintenance to digestible energy consumed (REM)

Ratio of net energy available in diet for maintenance to digestible energy consumed (REM) is required to estimate gross energy: For cattle, the ratio of net energy available in a diet for maintenance to digestible energy consumed (REM) is estimated using the following equation (Gibbs and Johnson, 1993):

$$\mathbf{REM = 1.123 - (4.092 * 10^{-3}) * DE\% + (1.126 * 10^{-5}) * DE\%^{2}} \qquad \textbf{(Equation 8)}$$

Where:
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

Example for calculation of REM: using DE% value of 50% from Table 8. (Crop residue and grazing based system)

$$\mathbf{REM = 1.123 - (4.092 * 10^{-3}) * 50\% + (1.126 * 10^{-5}) * 50\%^{2} = \qquad 1.1201}$$

Calculation of the ratio of net energy available in the diet for growth to digestible energy consumed (REG)

Ratio of net energy available in diet for growth to digestible energy consumed (REG) is required to estimate gross energy: For cattle, the ratio of net energy available in a diet for growth to digestible energy consumed (REG) is estimated using the following equation (Gibbs and Johnson, 1993):

$$\mathbf{REG = 1.164 - (5.160 * 10^{-3} * DE\%) + (1.308 * 10^{-5} * DE\%^{2})} \qquad \textbf{(Equation 9)}$$

Where
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

Example of calculating REG using DE% value of 50% from Table 8 (crop residue and grazing based system)

$REG = 1.164 - (5.160 * 10^{-3} * 50\%) + (1.308 * 10^{-5} * 50\%^2) \quad = 1.1614$

Calculating Gross Energy, *GE*: GE requirement is derived based on the summed net energy requirements and the energy availability characteristics of the feed(s) using the following equation.

The equation for calculating GE is

$$GE = \frac{\dfrac{(NE_m + NE_a + NE_{work} + NE_L + NE_p)}{REM} + \dfrac{(NEg)}{REG}}{DE\%/100} \quad \text{(Equation 10)}$$

Substituting the entire net energy intake obtained in the above steps (Equation 1-8) in this equation (equation 10) together with DE% value (Table 9), can result in GE estimated value in Table 13 bellow. Digestibility value of 55% upper limit for grazing and crop reside feed was taken (IPCC, 2006)

Table 13. Calculating gross energy (GE) for indigenous cattle species by sub-category

Sub-category	Gross energy (GE) Mj/animal/day
Matured cows	6806.895
Growing heifers	5864.946
Young female	3623.749
Mature male (oxen)	7683.801
Breeding bull	7910.588
Growing male	3694.803

Determination of methane conversion factor (Y_m)

The extent to which feed energy is converted to CH_4 depends on several interacting feed and animal factors. CH_4 conversion factors for livestock species and diet type specific to Ethiopia are not available; the values provided in Table 14 are adapted from IPCC, 2006 and can be used for cattle species sub-category. These general estimates are a rough guide based on the general feed characteristics and production practices found in different part of many developed and developing countries. When good feed is available (i.e., high digestibility and high energy value) the lower bounds should be used. When poorer feed is available, the higher bounds are more appropriate. A CH_4 conversion factor of zero is assumed for all juveniles consuming only milk (i.e., milk-fed calves).

Table 14. Methane conversion factors (Adapted from IPCC 2006)

Cattle category	Y_m
Feedlot feed cattle (feed 90% concentrate)	3.0%+_1.0%
Dairy cow (exotic and crossbred)	6.5%+_1.0%
Dairy heifers (exotic and crossbred)	5.5%+_1.0%
Local breed heifers	6.5%+_1.0%
Calves weaning (exotic and crossbred)	5.5%+_1.0%
Calves weaning (local breed)	5.5%+_1.0%
Indigenous cattle that feed low quality crop residue and by product	6.5%+_1.0%
Indigenous cattle on grazing (rangeland)	6.5%=-1.0%

4.1.2 Calculation of methane emission factor for enteric fermentation

Once the value for feed intake (GE) is calculated the next step is to calculate methane emission factor using equation 11 (IPCC, 2006) and methane conversion factor (Y_m) from table 14.

$$EF = \frac{GE*(Y_m/100)*365}{55.65} \qquad \textbf{(Equation 11)}$$

Where

EF= Methane emission factor from enteric fermentation, kg CH_4/animal/year

GE= Gross energy intake Mj/animal/day

Tm= Methane conversion factor, percent of gross energy in feed converted to methane

The factor 55.65 (Mj/kg methane) is the energy content of methane

Example of calculating methane emission factor: To calculate methane emission factor (EF) we need methane conversion factor (Y_m) from table 14 and GE value from (Table 13) for each livestock sub-categories. Substituting these values in equation 11 can give EF value for each livestock sub-category as presented in table 15.

Table 15.Ccalculating methane emission factor (EF) for enteric fermentation in cattle species by sub-category

Sub-category	CH_4 emission factor (Kg /animal/year)
Matured cows	29.01951
Growing heifers	25.00375
Young female	15.44896
Oxen	32.75798
Breeding bull	33.72483
Growing male	15.75188

Total methane emission from enteric fermentation can be calculated by multiplying sub-category emission factor with number of animal in each sub-category and sum-up the sub-categories to arrive at total emission from cattle (Table 16)

Table 16. Example of methane emission from enteric fermentation indigenous cattle in Ethiopia

Sub-category	Number of animal[1]	Total CH_4 emission(kg/ year)
Matured cows	20545625	596223970
Growing heifers	1972285	49314521
Young female	2958427	45704620
Oxen	12000000	393095760
Breeding bull	3846111	129709440
Growing male	4095873	64517700
Total	55067082	1356390204

[1] **CSA, 2013**

4.2 Methane emission from manure management in cattle

This section present on how to estimate CH_4 produced during the storage and treatment of manure and from manure deposited on pasture. The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock (IPCC, 2006).

Manure (and urine) management releases both CH_4 and N_2O, although the emissions of these GHGs are influenced by different factors. CH_4 is emitted during the storage and treatment of manure under anaerobic conditions.

CH_4 is most readily emitted when:

- Large numbers of animals are managed in a confined area (e.g., dairy farms, commercial feedlots, and poultry farms).
- When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits)
- When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited onto pastures and rangelands, it tends to decompose under more aerobic conditions, producing less CH_4.

Manure related emissions result from the anaerobic decay of organic material in livestock manure. Manure management systems that promote anaerobic conditions such as liquid/slurry storage facilities and anaerobic lagoons produce the most methane. A relatively small percentage of livestock manure is managed in this manner in Ethiopia and emission of methane from these systems is negligible. Manure spreading directly on soils and pastureland, and composing maintain aerobic conditions and have limited methane production potential. Manure spreading on soils, crops and pastureland is the most common practice in extensive systems in Ethiopia.

Because of lack of country specific data on VS rates, manure conversion factor (MCF) values, maximum methane producing capacity (B_o) values, specific to Ethiopia, tier 1 methodology using IPCC default emission factor were used to estimate CH_4 emission from manure management. The share of methane emission from manure management is not significant (less than 10% of total emission from livestock in Ethiopia which imply currently there is no need to collect data for higher tiers (IPCC, 2006). Tier 1 is a simplified method used to estimate methane emission it only requires basic characterization (livestock population data by animal species/category) and temperature data, in combination with IPCC default emission factors.

Calculation of methane emission from manure management (tier 1)

$$CH_{4manure} = \Sigma_{(T)} (EF_{(t)} * N_{(T)}) \qquad \textbf{(Equation 12)}$$

Where:

$CH_{4manure}$ = CH_4 emissions from manure management, for a defined cattle population category, kg CH_4 per year

EF(t) = emission factor for the defined livestock population, kg CH_4 per head per year

N(T) = the number of head of livestock species/category/sub-category *T*

T = species/category/sub-category of livestock

IPCC, default emission factors by average annual temperature are presented in (Table 17.) for cattle population. These emission factors are adapted from IPCC developed for Africa the region that most closely matches the animal operations in Ethiopia. Table 18 shows the default emission factors for different livestock and temperature classification. Emission factors are listed by the annual average temperature. The temperature data should be based on CSA or national meteorological statistics, where available. It may be good practice to estimate the percentage of animal populations in different temperature zones and compute a weighted average emission factor. Where this is not possible, the annual average temperature for the entire country could be utilized.

Table 17. Dairy cows default methane emission factor from manure management (Adapted IPCC, 2006)

Sub-category	**CH_4 emission factor by average annual temperature (°C)**		
	Cool	Temperate	Warm
Livestock species	Less than 15	15-25	Greater than 26
Mature cow	1	1	1
Growing and young cattle	1	1	1

For indigenous cattle based on 45% of manure usage is for pasture/rangeland/grazing land

Table 18. Example of calculation of methane emission from manure management

Sub-category	Indigenous cattle Population[1]	CH_4 emission factor (Kg Ch_4/animal/year for Temperature (15-25 ^{0}C)	CH_4 emission from cattle sub-category (Kg CH_4/year)
Matured cows	20545625	1	20545625
Growing heifers	1972285	1	1972285
Young female	2958427	1	2958427
Oxen	12000000	1	12000000
Breeding bull	3846111	1	3846111
Growing male	4095873	1	4095873
Total	55067082	1	55067082

[1]CSA, 2013; Assume temperature between 15-25 ^{0}C in highland

V. METHODS FOR ESTIMATION OF NITROUS OXIDE EMISSION FROM MANURE MANAGEMENT IN CATTLE

Nitrous oxide emissions from manure management vary significantly between the types of management system used and can also result in indirect emissions due to other forms of nitrogen loss from the system. The calculation of the nitrogen loss from manure management systems is an important step in determining the amount of nitrogen that will ultimately be available in manure applied to manage soils, or used for feed, fuel, or construction purposes.

N_2O emission from manure management in cattle species

The tier 1 method entails multiplying the total amount of N excretion (from all livestock species/categories) in each type of manure management system by an emission factor for that type of manure management system. Emissions are then summed over all manure management systems. The tier 1 method is applied using IPCC default N_2O emission factors, default nitrogen excretion data, and default manure management system data. A Tier 2 method follows the same calculation equation as tier 1 but would include the use of country-specific data for some or all of these variables. For example, the use of country-specific nitrogen excretion rates for livestock categories would constitute a tier 2 methodology.

The calculation of direct N_2O emissions from manure management in cattle is based on the following equation:

$$N_2O_{D(mm)}=\{ \Sigma_s\{ \Sigma_t (N_{(t)}* Nex_{(t)}* MS._{(t.s)})\}*EF_{3(s)}\}*44/28 \qquad \text{(Equation 13)}$$

Where:
$N_2O_{D(mm)}$ = direct N_2O emissions from manure management, kg N_2O per year
$N_{(T)}$ = number of head of livestock species/sub-category T
$Nex_{(t)}$ = annual average Nitrogen (N) excretion per head of cattle sub-category T, kg N per animal per year
$MS_{(t,s)}$ = fraction of total annual nitrogen excretion for each livestock /sub-category T that is managed in manure management system S, dimensionless
$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system S, kg N_2O-N/kg N in manure management system S
S = manure management system
T = Sub-category of livestock
44/28 = Conversion of (N_2O-N)(mm) emissions to N_2O(mm) emissions
0.02 default value of Kg N_2O-N/KG N excreted.

Estimation of nitrogen (N) excretion rate in cattle using tier 2 methodologies

The annual amount of N excreted by each livestock sub-category depends on the total annual N intake and total annual N retention of the animal. Therefore, N excretion rates can be derived from N intake and N retention data. Annual N intake (i.e., the amount of N consumed by the animal annually) depends on the annual amount of feed digested by the animal, and the protein (CP) content of that feed. Total feed intake depends on the production level of the animal (e.g., growth rate, milk production, draft power). Annual N retention (i.e., the fraction of N intake that is retained by the animal for the production of meat or milk) is a measure of the animal's efficiency of production of animal protein from feed protein.

Nitrogen intake can be calculated from data on feed and crude protein intake developed in chapter 2 and 3. Default N retention values are provided (0.02 for dairy cattle and 0.07 for other cattle; IPCC, 2006). Rates of annual N excretion for each livestock species/sub-category (Nex(T)) are derived as follows (Equation 14):

$$Nex(T) = N\,\mathrm{int}ake(T) \bullet (1 - N\,retention(T)) \qquad \text{(Equation 14)}$$

Where:
$Nex_{(T)}$ = annual N excretion rates, kg N per animal per year
$N_{intake(T)}$ = the annual N intake per head of animal of sub-category *T*, kg N per animal per year
$N_{retention(T)}$ = fraction of annual N intake that is retained by animal of sub-category *T*, dimensionless

Example of Tier 2 method for estimating nitrogen excretion for cattle

Nitrogen excretion may be calculated based on the same dietary assumptions used in estimating enteric fermentation emissions. The amount of nitrogen excreted by cattle can be estimated as the difference between the total nitrogen taken in by the animal and the total nitrogen retained for growth and milk production. Equations 15 and 16 can be used to calculate the variables for nitrogen intake and nitrogen retained for use in Equation 13. The total nitrogen intake is derived as follows:

$$N_{intake(T)} = GE/18.45*(CP\%/100/6.25) \qquad \text{(Equation 15)}$$

Where:
$N_{intake(T)}$ = daily N consumed per animal of sub-category *T*, kg N per animal per year
GE = gross energy intake of the animal, in enteric fermentation model, MJ per animal per day
18.45 = conversion factor for dietary GE per kg of dry matter of, MJ per kg. This value is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock.
CP% = percent crude protein in diet

6.25 = conversion from kg of dietary protein to kg of dietary N, kg feed protein per (kg N)

Nitrogen intake for indigenous cattle can be calculated using equation 14 and gross energy value from Table 13 and CP% value from Table 9. The result N intake is presented in Table 19.

Table 19. Example of calculation of N intake for indigenous cattle breed

Sub-category	GE (Mj/day/animal)	Daily N intake, in kg /animal	Annual N intake, in kg/animal
Matured cows	6806.895	0.05195	18.96043
Growing heifers	5864.946	0.04476	16.33666
Young female	3623.749	0.02765	10.09386
Oxen	7683.801	0.05864	21.40303
Breeding bull	7910.588	0.06037	22.03474
Growing male	3694.803	0.02820	10.29178

CP% content of feed =8.8%

Calculation of N retention for indigenous cattle

$\mathbf{N_{retention} = milk(milk\ PR\%//100/6.38)+(WG(268-(7.03*NE_g)/WG))/1000/6.25}$ **(Equation16)**

$N_{retention(T)}$ = daily N retained per animal of sub-category *T*, kg N per animal per day
Milk = milk production, kg per animal per day
Milk PR% = percent of protein in milk, calculated as {1.9 + 0.4 ● %Fat}, where %fat is an input, assumed to be 4% (applicable to dairy cows only)
6.38 = conversion from milk protein to milk N, kg protein per (kg N)
WG = weight gain, input for each livestock category, kg per day
268 and 7.03 = constants (NRC, 1996)
NE_g = net energy for growth, calculated in enteric fermentation, MJ per day
1000 = conversion from grams per kilogram, g per kg
6.25 = conversion from kg dietary protein to kg dietary N, kg Protein per (kg N)

Nitrogen retention by cattle species can be calculated using equation 16 and input data on daily milk yield of indigenous cattle (2.5 kg/day), the value for percentage of protein in the milk (Milk PR% =(1.9+0.4*4%=191.6%), daily weight gain and net energy for growth from Table 12. The result of N retention for indigenous cattle by sub-category are presented in Table 20

Table 20. Example of calculation of N retention for indigenous cattle breed

Sub-category	N retained, kg/animal/day	N retained, kg/animal/year
Matured cows	0.0075	2.740
Growing heifers	0.0076	2.786
Young female	0.0113	4.114
Oxen	0.0000	0.000
Breeding bull	0.0092	3.375
Growing male	0.0135	4.913

Nitrogen excretion can be calculated using equation 13 and input data on N intake from table 20 and N retention from Table 20. The result of N excretion is presented in Table 21

Table 21. Example of calculation of N excretion for indigenous cattle breed

Sub-category	N excretion, kg per animal/year
Matured cows	17.633
Growing heifers	15.193
Young female	9.387
Oxen	19.905
Breeding bull	20.492
Growing male	9.571

Once you estimated the N excretion for indigenous cattle by sub-category the next step is estimation of N_2O emission using input data on N excretion from table 21, IPCC default emission factor (for direct N_2O emissions from manure management system (EF_3= 0.02*44/28=0.031429)). The value for fraction of total annual nitrogen excretion (MS) of 45% (45% of manure left on pasture in Ethiopia; CRGE, 2011). Using the above values in equation 12, you will get the calculated N_2O emission for indigenous cattle in Table 22.

Table 22. Example of calculation of direct N_2O emission for indigenous cattle

Sub-category	**Emission factor, kg N_2O-N/kg N excretion)**	**N_2O emission (kg N_2O per animal/year)**
Matured cows	0.031429	0.2492
Growing heifers	0.031429	0.2147
Young female	0.031429	0.1326
Mature male (oxen)	0.031429	0.2813
Breeding bull	0.031429	0.2896
Growing male	0.031429	0.1352

The average N_2O emission calculated for each animal by sub-category can be multiplied by cattle population number to get the total sub-category emission in kg per year. (See Table 23)

Table 23. Example of calculation of total direct N_2O emission for indigenous cattle

Sub-category of indigenous cattle	Population number	Total N_2O emission (kg /year)
Matured cows	20545625	5119970
Growing heifers	1972285	423449.6
Young female	2958427	392287.4
Oxen	12000000	3375600
Breeding bull	3846111	1113834
Growing male	4095873	553762
Total	55067082	11646931

VI. GREEN HOUSE GAS EMISSION REPORTING

GHG emission can be reported at different level depending on the country requirement. The approach for Ethiopia condition is to sum-up the different livestock species category emission to get the total GHG emission from livestock species at farm level (house hold level) then the household level emission can be aggregated to village level. The village level report can be aggregated to woreda level, and woreda level reports to regional level. The regional GHG emission data will be summed-up to get the national level emission report. The various GHG estimate can be conversion to carbon dioxide equivalent (tCO_2e) to arrive at one GHG emission factor. A summary of CH_4 and N_2O emission factors estimated for indigenous cattle in Ethiopia, in unit of kg /animal/year and in tCO_2e/animal/year are indicated in Table 24 and Table 25 respectively.

The total GHG emission from indigenous cattle in 2013 in Ethiopia is estimated to be 36 million tCO_2 equivalents. The major contributor is CH_4 from enteric fermentation 86% of total emission. CH_4 and N_2O from manure management contributed only 3.5% and 9.6% of total GHG emission respectively (Table 26).

Table 24. CH_4 and N_2O emission factor (kg/animal/year) for indigenous cattle in Ethiopia tier 2 methodology

Sub-category	CH_4 emission from Enteric fermentation (kg/animal)	CH_4 emission from manure management (kg/animal)	Total CH_4 emission (kg/animal)	N_2O emission (direct) (kg/animal/year)
Matured cows	29.01951	1	30.01951	0.2492
Growing heifers	25.00375	1	26.00375	0.2147
Young female	15.44896	1	16.44896	0.1326
Mature male (oxen)	32.75798	1	33.75798	0.2813
Breeding bull	33.72483	1	34.72483	0.2896
Growing male	15.75188	1	16.75188	0.1352

Table 25. Green house gas (CH_4+N_2O) mission factors in tone of carbon dioxide equivalent for indigenous cattle in Ethiopia

Sub-category	CH_4 emission (tCO_2e/animal/year)	N_2O emission (tCO_2e/animal/year)	GHG emission factor (tCO_2e/animal/year)
Matured cows	0.690449	0.073763	0.764212
Growing heifers	0.598086	0.063551	0.661637
Young female	0.378326	0.03925	0.417576
Mature male (oxen)	0.776434	0.083265	0.859698
Breeding bull	0.798671	0.085722	0.884393
Growing male	0.385293	0.040019	0.425312

To converter to CO_2 equivalent; Kg CH_4/Kg CO_2 = 23; Kg N_2O/Kg CO_2=296

Table 26. Example of calculation of total GHG emission for indigenous cattle in Ethiopia for year 2013

		CH_4 emission		N_2O (direct) emission	Total GHG emission
Sub-category	**Unit**	**Enteric fermentation**	**Manure management**		
Matured cows	tCO_2 /year	13713151.3	472549.4	1515511.05	15701212
Growing heifers	tCO_2 /year	1134233.98	45362.56	125341.078	1304938
Young female	tCO_2 /year	1051206.26	68043.82	116117.076	1235367
Mature male (oxen)	tCO_2 /year	9041202.48	276000	999177.6	10316380
Breeding bull	tCO_2 /year	2983317.12	88460.55	329694.789	3401472
Growing male	tCO_2 /year	1483907.1	94205.08	163913.561	1742026
Total	tCO_2 /year	31196974.7	1266543	3447491.71	35,911,009

To converter to CO2 equivalent; Kg CH4/Kg CO_2 = 23; Kg N_2O/Kg CO_2=296

REFERENCE

AFRC, Technical Committee on Responses to Nutrients (1990). Nutritive Requirements of Ruminant Animals:Energy. Rep. 5, CAB International, Wallingford, U.K.

Alemayehu and Tegegn Fentahun, 2012. The effect of climate change on ruminant livestock population dynamics in Ethiopia. Livestock Research for Rural Development 24 (10) 2012

Alan, D. 2008. Strategies to Reduce Greenhouse Gas Emissions through feeding and Grazing management. Swift Current Research Centre EMBO Rep. 2008 June; 9(6): 508–511.

Asman, W.A.H., Sutton, M.A. and Schjoerring, J.K. 1998. Ammonia: emission, atmospheric transport and deposition. *New Phytol.*, 139, p. 27-48

CRGE (Ethiopia's Climate Resilience Green Economy) 2011.Green Economy Strategy, Federal Republic of Ethiopia.

EPA (Environmental Protection Agency). 2003. Global Warming-Emissions. U.S. Environmental Protection Agency.

Francis, G., Kerem, Z., Makkar, H.S.P. & K. Becker, 2002. The biological action of saponins in animal systems: a review. Br. J. Nutr., 88, 687-605.

Frank O'Mara, Michael Ryan, John Connolly, Pat O'Toole, Owen Carton, J.J. Lenehan, Dan Lovett, Bernard Hyde, Eddie Jordan and Michael Hawkins. 2000. Climate Change Emissions of Greenhouse Gases from Agriculture and Strategies for their Reduction (2000-LS-5.1.1) Synthesis Report. UCD School of Agriculture, Food Science and Veterinary Medicine Teagasc, Johnstown Castle Research Centre, Co. Wexford, Ireland. *(www.epa.ie/EnvironmentalResearch/ReportsOutput)*

Gibbs, M.J. and Johnson, D.E. (1993). "Livestock Emissions." In: International Methane Emissions, US Environmental Protection Agency, Climate Change Division, Washington, D.C., U.S.A.

Gibbs, M.J., Conneely, D., Johnson, D., Lassey, K.R. and Ulyatt, M.J. (2002). CH4 emissions

from enteric fermentation. In: Background Papers: IPCC Expert Meetings on Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, p 297–320. IPCC-NGGIP, Institute for Global Environmental Strategies (IGES), Hayama, Kanagawa, Japan.

Gebeyhu Goshu, 1999. Reproductive and productive performance of Friesian-Boran crossbred Cattle at Cheffa State farm, Wollo, Ethiopia. Msc. Thesis, School of Graduate studies, Alemaya University

Green House Gas Protocol, 2012. Agricultural Guidance draft document, a sector specific supplementation to corporate standard for agriculture, horticulture and fisheries. Agricultural Protocol, World Resource Institute (WRI). http://www.ghgprotocol.org/standards/agriculture-guidance.

IPCC, 2001. In: Houghton, J.T., et al. (Eds.), Climate Change 2001: The Scientific Background, vol. 94. Cambridge University Press, Cambridge, UK.

International Panel for Climate Change (PCC, 2006). Guideline for National Green House Gas Inventory, Agriculture, forestry and other land use, Chapter 10 emission from Livestock and manure management.

Jurgen, M.H. (1988). Animal Feeding and Nutrition, Sixth Edition, Kendall/Hunt Publishing Company, Dubuque, Iowa, U.S.A.

Keberu Belayneh, 2000. Milk production and Lactation persistency of crossbred (Friesian * Arsi) cattle at Agarfa Multipurpose training centre, Bale, Ethiopia. Msc. Thesis School of Graduate studies, Alemaya University

Kiwuwa, G.H., Trail J.C. Yousef, M., Worku, G., Anderson F.M. and Durkin. J., 1983. Crossbred dairy cattle productivity in Arsi region, Ethiopia. ILCA Research Report. No. 1. Addis Ababa, Ethiopia. p29.

Mekonne Haile-Mariam and Goshu Mekonnen. 1987. Reproductive performance of Fogera cattle and their Friesian crosses at Gonder, Ethiopia. Eth. J. Agri. Sci. 9:95-114

Million Tdesse, Tadelle Dessei Gifawesn Tesema, Tamirte Degefa and Yohanis Gojam 2006. Study on Age at first calving, calving interval and breeding efficiency of Bos tauruus, Bos indicus and their crosses in the highlands of Ethiopia, EJAP (6) 2. PP 1-16

Million T., Tadelle D. and Egbert K. 2004. Genetic and Non genetic Effects on productive and Reproductive Parameters of Arsi Cattle and their Holestien Friesian crosses in Ethiopia, Eth. J.Anim.Prod. 4(1). 71-79

Million Tadesse and Tadelle Dessie, 2003. Milk production performance of Zebu, Holstein Friesian and their crosses in Ethiopia. *Livest. Res. Rural Develop.,* 15:31-40.

National Research Council (NRC) (1996). Nutrient Requirements of Beef Cattle, 7th Edit., Nat. Acad. Press, Washington, DC.

Mills, J.A.N., Dijkstra, J., Bannink, A., Cammell, S.B., Kebreab, E. & J. France, 2001. A mechanistic model of whole-tract digestion and methanogenesis in the lactating dairy cow: Model development, evaluation, and application. J. Anim. Sci., 79, 1584-1597

Moss, A.R., Jouany, J.-P. & J. Newbold, 2000. Methane production by ruminants: its contribution to global warming. Ann. Zootech., 49, 2004, 231-253.

Monteny, G.J. and Erisman, J.W. 1998. Ammonia emissions from dairy cow buildings: A review of measurement techniques, influencing factors and possibilities for reduction. Neth. J. Agric. Sci., 46, Pp. 225-247.

National Research Council (NRC) (1996). Nutrient Requirements of Beef Cattle, 7th Revised Ed., Nat. Acad. Press, Washington., DC

National Research Council (NRC) (1989). Nutrient Requirements of Dairy Cattle, 6th Ed., Nat. Acad. Press, Washington, DC.

Nicks, B., Laitat, M., Vandenheede, M., Desiron, A., Verhaege, C. and Canart, B. (2003). Emissions of Ammonia, Nitrous Oxide, Methane, Carbon Dioxide, and Water Vapor in the Raising of Weaned Pigs on Straw-Based and Sawdust-Based Deep Litters. *Animal Research Journal*, **52**: pp. 299-308.

Seyoum Bediye, Zinash Sileshi and Dereje Fekadu. 2007. Chemical Composition and Nutritive Values of Ethiopian Feeds. EIAR, Addis Ababa, Ethiopia.