ENERGY USE AND EMISSION REDUCTION IN DAIRY FARM

by

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(2011 - 20 - 113)

THESIS

Submitted in partial fulfillment of the

requirements for the degree of

B.Sc. – M.Sc. (Integrated) Climate Change Adaptation

Faculty of Agriculture

Kerala Agricultural University

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

VELLANIKKARA, THRISSUR – 680 656

KERALA, INDIA

2016

DECLARATION

I, hereby declare that this thesis entitled **"ENERGY USE AND EMISSION REDUCTION IN DAIRY FARM"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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ACKNOWLEDGEMENT

I bow my head to God Almighty, whose blessings filled me with power to complete this work

With due respect, I record my gratitude and utmost indebtedness to Dr. Shaji James P., Professor (Farm Power Machinery and Energy), Kelappaji College of Agricultural Engineering and Technology,Tavanur, Malappuram, and chairman of the advisory committee for his avuncular advice, guidance encouragement and creative criticisms during the course of this work and in the preparation of the thesis.

I express my profound gratitude to Dr. E. K. Kurien, Special officer, Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara for his scrupulous guidance, advices, valuable and timely suggestions given during my work.

It is my duty to acknowledge the help rendered to me by Dr. K. M. Sunil, Assistant Professor (Agricultural Meteorology), Krishi Vigyan Kendra Palakkad, Pattambi, Palakkad and member of the advisory committee.

I respectfully thank Dr. C. T. Sathian, Professor and Head, Department of Dairy Science, Kerala Veterinary and Animal Sciences University, Mannuthy, Thrissur and member of the advisory committee for his sincere advice and valuable help.

I would also like to extend huge, warm thanks to Dr. P. Indira Devi, Professor (Ag. Economics), Kerala Agricultural University for her valuable suggestions and encouragement.

I gratefully acknowledge the support and encouragement extended by Dr. Deepa Anand, Assistant Professor (Directorate of Entrepreneurship), Kerala Veterinary and Animal Sciences University, Mannuthy, Thrissur.

It is my great privilege to acknowledge the sincere advice and valuable help rendered to me by Dr. Abhitha, Krishi Vigyan Kendra Palakkad, Pattambi, Palakkad.

I thank Dr. Veerasamy Sejian, Senior Scientist, ICAR-National Institute of Animal Nutrition and Physiology, Bangalore for his guidance and encouragement provided over the research period.

I am short of words to acknowledge the selfless services offered by Mr. Maqbul. M, Project Engineer, Athul energy consultants Pvt. Ltd, Thrissur.

I would also like to extend my sincere thanks to Mr. Parameshwaran and Mr. Krishnan, owners of the dairy farm, Peramangallurmana, Ongallur, Pattambi, Palakkad and his beloved family, for their valuable support and help.

I am also indebted to Mr. Sanjo Jose V., Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur, for helping me and supporting me.

My heartfelt thanks are to all my classmates of Spartans-2011 for their support given to me during the whole college days.

I express my sincere gratitude to my parents, for their warm blessings and unfailing support enabled me to have everything at reach.

Athira P. Ratnakaran

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SYMBOLS AND ABBREVIATIONS

^0C	Degree Celsius
%	Percentage
AD	Anaerobic digesters
APHA	American Public Health Association
CFCs	Chlorofluorocarbons
CGIAR	Consultative Group on International Agricultural Research
DM	Dry matter
DMI	Dry Matter Intake
EECA	Energy Efficiency and Conservation Authority
E_{in}	Energy Input of the system
E_{out}	Output energy
EP	Energy Productivity
ER	Energy ratio
E_q	Equivalent energy coefficient
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	Greenhouse gases
GLEAM –*i*	The Global Livestock Environmental Assessment Model-interactive tool
GOI	Government of India

GWP	Global Warming Potential
h	hour
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HF	Holstein- Friesian
IFPRI	International Food Policy Research Institute
IFSM	Integrated farm system model
IPCC	Intergovernmental Panel on Climate Change
kg CO_{2eq}	Carbon dioxide equivalent in kilogram
LCA	Life Cycle Assessment
NEG	Net Surplus Energy
SE	Specific Energy
SIK	The Swedish Institute for Food and Biotechnology
TFI	Total Feed Intake
TS	Total Solids
VS	Volatile solids
WBCSD	World Business Council for Sustainable Development
Y	Yield

INTRODUCTION

CHAPTER 1

INTRODUCTION

Global warming is the most alarming environmental issue currently faced by the mankind as a warming planet will lead to catastrophic changes in climate. Climate change is real and the major indicators such as rise in global temperature, sea level rise, melting of the polar ice caps, warming of the oceans, rise in ocean heat content, rise in sea surface temperatures as well as change in extreme weather events affect agriculture, livestock, fishing, industry and various other sectors. Natural events and human activities are the major forces behind the rise in global temperature. Among these, human contribution is very significant, mainly due to anthropogenic emission of greenhouse gases (GHG) especially CO_2, CH_4 and N_2O. The 2013 report of Intergovernmental Panel on Climate Change (IPCC) summarized that human influence has been the dominant cause of the observed warming since mid-20th century.

It is well documented that the major anthropogenic factor in rise of GHG is the burning of fossil fuels resulting in the release of CO_2 and changes in land use whereas CH_4 and N_2O release is mainly from agricultural sectors. Even though we focus more on the rise in CO_2 level, it is now estimated that the level of rising CH_4 concentration is also playing a significant role in the global climate. The global warming potential of CH_4 is much higher than other gases and even a slight variation in the concentration level of CH_4 can cause great variations over the earth's surface temperature. Methane is the most abundant organic gas in the atmosphere. The percent contributions of methane and carbon dioxide among GHGs were around 50 percent and 20 percent respectively (Lapp, 1975). Human activities such as livestock rearing, paddy cultivation, biomass burning and coal mining will contribute to the building up of methane concentration level. The anoxic methanogenic environment in the rumen of cattle also results in methane emission. Hence there is a need to understand the GHG emissions especially methane and nitrous oxide emissions from the livestock because they are the major contributors to the GHG budget, with emissions coming from enteric fermentation and also by improper management of manure.

The basic necessity for economic and social development of a country is energy, as proper and accurate analysis of energy consumption is required for policies of energy use (Liang *et al.*, 2007). By providing proper energy services and renewable energy technologies, we can reduce the GHG emission from the energy system (IPCC, 2011). Among different sectors, agriculture is considered as the major consumer of energy in order to supply the rising population with adequate amount of food (Samavatean *et al.*, 2011). Renewable energy plays a great role in providing the sustainable energy sources as well as in mitigating climate change (IPCC, 2011). Conservation of energy is necessary for economic growth and helps to fill the gap between the supply and demand. Energy conservation generally means using energy more efficiently. This involves avoidance of energy wastage without affecting productivity and economic growth rate. Conserving the usable energy which is wasted not only improve the economy but also reduce the impact on environment and there by result in long term availability of non-renewable sources of energy (Kaur *et al.,* 2012).

Livestock is considered as a poor convertor of energy. This is because the solar energy and the soil nutrients are transferred to the green plants which are fed to the livestock and most part of this energy intake is supplied to maintain the body metabolism whereas small part produce meat and milk (Frorip *et al.,* 2012). Energy use can be reduced by proper dairy management techniques. Milk chilling, milking, feed processing and hot water production are the major areas which consume more energy in the dairy farms. It is estimated that around 44 percent of the electricity consumption in a dairy farm is attributed to milking (Anon, 2014). Reducing the energy use by use of more energy efficient methods would help to curb the energy use in the farms.

Dairy farmers are under immense pressure because of the rising energy cost and an increased focus on GHG emissions. Apart from other sectors, livestock contribute largely to the emission pool by the release of methane resulting from improper manure management and enteric fermentation. India is often pictured as a big emitter due to its large cattle population. The percentage increase in enteric methane emission by Indian livestock was greater than the world livestock (70.6% *vs* 54.3%) between the years 1961 to 2010 (Patra, 2014). The methane emission from enteric fermentation and improper manure management in India is often the focus of criticism. India being figured fourth in the list of largest emitters, it is imperative that the Indian dairy sector need to be monitored in order to evolve mitigation strategies.

India being a developing country is having huge potential for harnessing renewable energy sources. In the last few decades, the use of biogas is considered as an environment benign alternative to conventional energy sources across the world. Biogas has attracted wide attention because of its high energy efficiency and simplicity of the technology. Conventional biogas plants are generally low cost and the operation does not require sophisticated technology. This is highly relevant for a country like India as this can be adopted in rural areas. It has been estimated that around 980 million tons of cattle dung is produced in India each year, which could produce over 41000 million cubic meters of biogas per annum (Khoiyangbam *et al.,* 2011).

The rising energy costs, the global concern over enteric methane emission and the emission from poor manure management in Indian dairy farms need to be investigated in a systematic way for evolving strategies for betterment of the dairy sector in terms of energy efficiency and emission reduction. This in turn is likely to have a positive impact on productivity and profitability of dairy farms.

More comprehensive study and data are required to estimate the GHG emissions from Indian cattle. Most of the quantifying methods used to estimate GHG emissions from ruminants are highly complex. The measurement techniques and equipment are in general expensive making the investigations difficult to cope up with our present conditions. Hence more intensive research should be promoted in this area. Better modelling techniques have to be generated to estimate typical

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emission ranges for Indian dairy farms, so as to control the factors affecting emission for regulating climate change.

Considering the above factors, the present study was undertaken to assess the greenhouse gas emission from a dairy farm as well as to study the energy use pattern with a view to aid evolution of strategies to contain emissions and improve the overall energy efficiency. The following specific objectives were focused in the present study:

i. To study the energy utilization pattern in a medium dairy farm with a view to suggest energy conservation measures and renewable energy use.
ii. To assess the greenhouse gas emission in the farm with a view to propose mitigation strategies.

REVIEW OF LITEREATURE

CHAPTER 2

REVIEW OF LITERATURE

The global efforts to contain greenhouse gas (GHG) emissions has received more attention and acceptance during the recent years as the people of both developed and developing countries are facing the catastrophic effects of climate change. Farming sector is badly affected by these hazards and at the same time this sector is also contributing to GHG emissions. A comprehensive review of the research conducted in the recent past on GHG emissions and its contribution from the dairy sector, its mitigation through renewable energy use and related issues are presented in this chapter.

2.1 CLIMATE CHANGE AND GREENHOUSE GASES

There was strong evidence that most of the global warming observed over the last 50 years had mainly occurred due to anthropogenic forcing of GHGs, aerosols, and land surface changes (IPCC, 2007). Since 1900, the global surface temperature of the Earth had risen by 0.8°C and since the seventies by about 0.5°C. This rise was mainly due to the increase in GHGs concentrations especially CO_2 and CH_4 (Scafetta, 2010). Global warming is generally referred to as the ongoing rise in the global average temperature and as the earth is getting warmer, disasters like hurricanes, drought and flood were also climbing up, leading to climate change (Venkataramanan, 2011).

The synthesis report of the IPCC (IPCC, 2014) confirms that human influence on the climate system was clear and growing, with impacts observed across all continents and oceans. The report further confirmed that many of these changes in the past six to seven decades are unprecedented and they were almost certain that human activities are the major cause for current global warming. In addition, they found that, "the more human activities disrupt the climate, the greater the risks of severe, pervasive and irreversible impacts for people and ecosystems, and long-lasting changes in all components of the climate system".

2.1.1 Greenhouse gases

Over the last three centuries since industrial revolution, the atmospheric concentrations of major long lived greenhouse gases (GHGs) like CO_2, CH_4, N_2O and Chlorofluorocarbons (CFCs) are increasing due to the human activities. Even though focus was more on CO_2 as the major greenhouse gas, other gases are also responsible for accelerated warming across the globe. Among these, CH_4 was one of the major GHGs having a global warming potential much greater than CO_2 and its rising level was mainly due to hike in population as about 70 percent of the emission was contributed by anthropogenic activities (IPCC, 2007). Some GHGs are having lifetime more than 100 years like CFCs and hydrochlorofluorocarbons (HCFCs). These gases have contributed to the depletion of ozone layer and hence consequent to the Montreal protocol a major part of these gases were replaced by hydro fluorocarbons (HFCs). HFCs do not react with ozone but they are considered as very strong GHGs due to their higher lifetime of more than 242 years (Thomas *et al.*, 2016)

2.1.2 Sources of GHGs

There was growing concern across the world in controlling the emission of GHGs. Production of GHGs from burning of fossil fuels, motor vehicle exhausts and deforestation became the targets to be controlled in order to prevent further warming (Watson *et al.*, 1992). Steinfeld *et al.* (2006) stated that the GHG emission from agricultural sector was around 25.5 percent of total anthropogenic emissions and livestock has contributed around 18 percent. Inefficient energy use caused several environmental impacts and the emission of GHGs by combustion of fossil fuels was the major cause for climate change (Meul *et al.*, 2007).

The contribution of CH_4 from the livestock sector was mainly through enteric fermentation in the ruminants. N_2O emission was mainly through improper manure management and CO_2 emission by land use changes (Herrero *et al.*, 2011). It was observed that global warming may affect the regions or populations distant from the sources of GHGs. India is ranked 4th in the list of GHG emitting countries

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and we need to adapt and mitigate to cope up with this changing climatic scenario (Robbin, 2016).

2.1.3 Energy and GHGs

Dalgaard *et al.* (2001) reported that development of energy efficient agricultural systems would help to reduce the GHG emission from agricultural sector. Energy use was one of the key indicators for developing more sustainable agricultural practices. Reduction of GHGs emission could be achieved by relying more on green energy or by improving the energy use efficiency, by which more output was produced per unit of energy (Corre *et al.,* 2003). James and Regina, (2011) reported that by using energy efficient pump sets and by improving the water use efficiency using modern irrigation techniques, we could conserve huge amount of energy and water. Soil and water engineering techniques would resist the reduction in the ground water level during summer and helps in the conservation of energy. The household energy needs are currently depending on fuels having huge environmental impacts. So farmers were advised to shift their energy use and depend more on renewable sources of energy like biogas, solar and wind energy which are not only efficient and profitable, but also reduce GHG emissions (James and Regina, 2011).

2.2 LIVESTOCK FARMING IN INDIA

According to Kityali *et al.* (2005) the livestock wealth is more fairly distributed when compared to land and most of the poorer section of the society depends on livestock farming. Livestock ensures security of production systems through various ways, besides contributing food and inputs for crop production. Livestock farming also provides savings and funds to the poorer section of the society. It was observed that about 26 percent of the world's land areas are utilized for livestock grazing and they produce 13 million tons of waste in a year which causes gaseous emissions posing serious impact on the environment (Steinfeld *et al.*, 2006). India is having a large number of cattle population (around 185 million) comprising of 98 million buffaloes, 124 million goats, 61 million sheep, 14 million pigs and 489 million poultry birds, and thereby contributing 5 percent of the total Gross Domestic Product (GDP) and one fourth of the agricultural GDP (Kumar and Singh, 2008).

2.2.1 Dairy sector in India

Livestock sector provides employment to about 8.8 percent of the total population in India and also provides livelihood to more than two-third of rural community. This sector contributes 4.11 percent GDP and 25.6 percent of the total agricultural GDP, where India stood first in the total buffalo and second in cattle population in the world (GOI, 2014). The contribution of dairy sector was the highest to the total value of agriculture and allied sectors and around 20 million people were employed in the livestock sector (GOI, 2003). India has developed as the world's largest producer of milk and milk production in India increased from 17 million tonnes in 1950-51 to 84.6 million tonnes in 2001-02 (GOI, 2003). Pingali and Khwaja (2004) found that consumption of milk and milk products are showing an increasing trend. The milk yield per cow of Brazilian dairy farms were twice as high as Thai dairy farms, but when compared to Thai and Brazilian dairy Indian dairy farms had the least yield per cow.

2.3 ENERGY USE IN AGRICULTURAL AND DAIRY FARMS

EECA (1996) reported that energy delivered to agriculture was primarily 30 percent petrol, 50 percent diesel and 12 percent electricity. The dairy sector and meat processing industries dominated the energy use, accounting for about 41 percent and 20 percent of direct energy consumed by the sector (Wells, 2001). On-farm energy, both renewable and fossil fuels were consumed directly and indirectly (Hulsbergen *et al.*, 2001; Pervanchon *et al.*, 2002; Corre *et al.*, 2003). Schafer (2003) reported that agriculture is the major economic sector which consumed more energy and emitted considerable amount of GHG. Analysis of energy consumption in agriculture sector is imperative because agriculture is considered as one of the major sectors which utilizes more energy in order to supply the rising populations with adequate amount of food (Samavatean *et al.*, 2011).

2.3.1 Energy consumption

Mousavvi- Avval *et al.* (2011) reported that for producing soybean in Golestan province of Iran, highest share was consumed by electrical energy out of the total energy inputs. Energy conservation in dairy sector can be attained by optimizing energy consumption, thereby improving the energy efficiency. In order to understand the bottlenecks and to improve the production processes for achieving an energy efficient system, it is important to study the energy flow and energy efficiency (Maysami, 2013).

The total consumption of fossil fuels and electricity in a dairy farm were estimated as 7824 and 1699 MJ per cow (Sefeedpari *et al.*, 2014). Moghimi *et al.* (2014) reported that 2190.77 kWh of electrical energy, 98.47 h of human labour and 72.95 L of diesel fuel per hectare were used for the production of wheat in Gorve city in Iran. In dairy farms, fossil fuels and electricity were used for feed processing, milking, chilling, transportation, water pumping and for heating. Fossil fuels and electricity had a consumption rate of 6.37 percent and 1.39 percent which was around 9405 and 2056 MJ per cow. In order to reduce the use of fossil fuels and emission of resulting GHGs in dairy farms, replacement of fossil derived fuels by renewable sources of energy like biogas and solar energy is required (Hosseinzadeh-Bandbafha *et al.,* 2016).

2.3.2 Energy use efficiency

Energy use efficiency is generally expressed in energy productivity (EP) (Refsgaard *et al.*, 1998; Corre *et al.*, 2003) which is the amount of energy (MJ) needed for the production of one unit of a product. Efficiency improvement is generally considered as the ability to produce the outputs through minimum input and improved energy efficiency techniques help to curb emissions and thereby climate change (Varone and Aebischer, 2001). Inefficient energy use can lead to environmental impacts. Eco-efficiency is mainly focusing on minimum environmental impact by maximum production through minimal use of resources (WBCSD, 2000; Jollands *et al.*, 2004).

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Few studies were carried out on the energy efficiency in livestock farming. Pimentel (2009) concluded that the energy efficiency of the livestock sector is lower when compared to crop production. In his study, the energy inputs such as working hours, mass of materials, fuel and machinery were compared with the energy output from the products. By estimating energy indices we could assess the energy efficiency of the dairy farm production as outlined by Zangeneh *et al,* 2010). Maysami (2013) introduced indicators for comparing the energy inputs and outputs and also to assess the energy efficiency of the system. Hosseinzadeh-Bandbafha *et al.* (2016) reported that direct energy mainly included electricity, diesel fuel and natural gas which are directly measurable whereas indirect energy are those that are used to produce farm inputs like pesticides, fertilizers, machines and concentrates.

2.4 PRODUCTION OF GREENHOUSE GAS FROM LIVESTOCK

FAO (2003) reported that livestock is a major contributor to the global greenhouse gas emission through the emission of methane from ruminants. According to FAO, livestock sector is contributing 18 percent to the anthropogenic GHG emissions (FAO 2006). Olesen *et al.* (2006) found that the farm N efficiency is closely linked with the GHG emission per product and so N efficiency can be used as a proxy for comparing the efficiencies of farms. According to IPCC (2007) cattle farms were the major contributors of methane gas. Methane emissions mainly occur in the ruminants through their natural digestive process (enteric fermentation) and improper manure management. Methane emission from manure was less compared to the methane emissions from enteric fermentation per head of cattle (Herrero *et al.*, 2008).

More recently, FAO reported that dairy sector is releasing 4 percent to the global GHG emissions (FAO, 2010). Hagemann *et al.* (2011) concluded that the GHG emission from livestock sector in developed countries are lower because of the lack of substantial land use changes, dilution by emissions from other sectors and also due to the higher productivity. Cattle produces 7-8 times more methane than sheep and goats, enteric methane is mostly produced in the rumen (87- 90%) and to a small amount (13-10%) in the large intestine (Dini *et al.*, 2012). Steinfeld

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et al. (2013) is of the opinion that livestock sector contributes both directly and indirectly to climate change through the emission of GHGs like methane and nitrous oxide which is having 25 times to 300 times global warming potential (GWP) of CO_2 respectively. He is also of the opinion that livestock sector contributes around 18 percent of global GHG emissions. The major areas which contribute to the emission in the dairy farms included transportation, use of machinery, storage and process cooling in which combustion of fossil fuel was involved. According to them, enteric methane emission and improper manure management were the other factors responsible for release of GHGs to the atmosphere.

The the slurry storage facilities had a significant contribution to GHGs emitted from livestock and these were highly variable and depended on several factors such as manure type, composition, storage and bedding content, (Masse *et al.*, 2003; Umetsu *et al.*, 2005; Dinuccio *et al.*, 2008) and storage temperature (Masse *et al.*, 2003; Umetsu *et al.*, 2005; Park *et al.*, 2006; Amon *et al.*, 2001, 2006).

Knapp *et al.* (2014) reported that feeding and nutrition have modest (2.5 to 15%) potential to mitigate methane emission through enteric fermentation in cattle. Sudars *et al.* (2015) found that dairy farming is responsible for 30.4 percent of agricultural emission in 2013 and livestock is considered as the most important contributor of GHG emission in the agricultural sector. Global CH_4 emission from livestock sector is expected to rise to 60 percent by 2030, if the CH_4 emission grows in direct proportion to the projected increase in livestock population. Dairy farm is considered as one of the major consumers of energy and they contribute largely to the GHG mainly through the emission of CH_4 and N_2O by enteric methane emission and improper manure management (Hosseinzadeh- Bandbafha *et al.*, 2016). They further reported that about 80 percent of the agricultural CH_4 and 35 percent of the total anthropogenic methane emission are mainly related to cattle. According to them, N_2O emission from accumulated manure is around 1.13 kg which is equivalent to 338.62 kg of CO_2 and manure caused the release of 5.23 kg of methane equivalent to 130.8 kg of CO_2 per cow per annum.

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2.4.1 Enteric fermentation

Methane is emitted from the livestock by both direct and indirect means. They release CH_4 and N_2O from enteric fermentation, nitrification and denitrification process in manure and from urine (Kaspar, 1981). Among all other species cattle population contribute mostly to the enteric CH_4 production (Johnson and Johnson 1995). Methane emitted by enteric fermentation can be accounted to the anaerobic decomposition of the organic compounds in the feed (Moss *et al.*, 2000). It is known that the dairy and the cattle are the major contributor to methane emission and their increase in population has also lead to more emanation (FAO, 2006). In ruminants like cattle, sheep, buffaloes and goat, fermentation take place in the rumen and releases large amount of CH_4 per unit feed of energy consumed (Sejian *et al.*, 2010). Methane is the predominant GHG emitted from the ruminant livestock sector and additionally, manure management can also add a significant share to the livestock emissions (Sudars *et al.*, 2015).

2.4.2 Manure management

According to the report of IPCC (2006) the amount GHG emissions from the manure mainly depend on several factors such as the nitrogen content in the manure, type of storage and handling, amount of manure produced, temperature and duration of storage. Apart from the enteric methane, animal excreta also release methane especially when stored in anaerobic condition (Klevenhusen *et al.*, 2011). Merino *et al.* (2011) found that methane emission from manure management was 33.2, 2.0 and 0.3 kg $head^{-1} \cdot year^{-1}$ for dairy cattle, beef cattle and dairy ewes. Stored liquid manure is the major source of methane globally (VanderZaag *et al.*, 2011). Manure methane emission is higher in intensively managed dairy operations with manure storage systems and very less in extensive or grazing systems (Knapp *et al.*, 2014). Nitrous oxide emissions mainly occur due to nitrification of ammonium to nitrate or denitrification of nitrate under low oxygen conditions. It is the direct emission from manure storage and dung or urine deposited in the pasture by grazing animals or animal manure applied to the soil (Sudars *et al.*, 2015).

2.5 ESTIMATION OF GHG IN DAIRY FARM

Kebreab *et al.* (2006) contented that methane emission is generally estimated based on the dry matter intake (DMI) of carbohydrates, digestibility, size of animal, milk components and digestibility of the compounds. Ellis *et al.* (2007) evolved an equation to predict the methane emission from a minimum set of inputs which is one of the best but a complex method. They concluded that the measurement of GHG such as methane in livestock requires expensive equipment and is a complex procedure, so prediction equations were mostly used. Several highly expensive and complex techniques have also been developed to estimate methane emission like whole animal chambers (Grainger *et al.,* 2007), and sulfur hexafluoride (SF_6) tracer technique (Pinares-Patino *et al.,* 2008; McGinn *et al.,* 2009). Lassey (2008) reported that accurate and specific methane measurements are necessary to develop mitigation strategies which can distinguish among treatments and are applicable to on-farm conditions. Rotz *et al.* (2012) reported that NH_3 and N_2O emissions are estimated based on the aerobic and volatization conditions of the manure.

2.5.1 Estimation of GHG using models

Dijkstra *et al.* (1992) and Baldwin (1995) reported that several models have been modified and adapted to estimate the methane emission from rumen fermentation. Mills *et al.* (2003) and Kebreab *et al.* (2008) reported that the non-linear mechanistic model of methane production helps to enhance the scientific estimation of methane production from cattle. IPCC (2006) has developed guidelines to estimate the emission where as its accuracy is widely challenged. Bryant and Snow (2008) stated that these models would serve as an excellent alternative for the expensive, time consuming and difficult experimentation techniques which were used in the farm and field for GHG estimation.

2.5.2 Different type of models

There are several tools and models developed to estimate the GHG emission from livestock sector. The models used for the estimation of CH_4 were classified mainly in to two groups; they are the empirical models and dynamic mechanistic models (Kebreab *et al*., 2006). IPCC (2006) Tier II model and Moe and Tyrrell (1979) model are examples of empirical models but these models could not accurately predict the CH_4 emission under all conditions because they considered only feed characteristics and other factors were not accounted. Mechanistic models like MOLLY (Baldwin, 1995) and COWPOLL (Dijkstra *et al.,* 1992) which included climate and management factors also had limitations due to lack of detailed and accurate data (Sejian *et al*., 2010). Integrated farm system model (IFSM) is a whole farm model which was used to simulate the whole farm emissions of CH_4 and the management strategies to reduce the emission (Rotz *et al*., 2009). The low prediction accuracy of the current whole farm models were widely challenged because they lead to incorrect mitigation recommendations (Sejian *et al*., 2010). Another important model which was developed for the estimation of GHG emission in livestock sector was GLEAM –*i* (Gerber *et al*., 2013) of FAO.

2.5.2.1 GLEAM – i (The Global Livestock Environmental Assessment Model)

Global Livestock Environmental Assessment Model (GLEAM) of FAO uses spatially explicit information from different sources and depends on IPCC (2006) guidelines for computation of emissions. Gerber *et al.* (2013) stated that the GLEAM model investigates the environmental implications of on farm production practices. Data sources are gridded livestock of the world (FAO, 2007), National Inventory Reports of Annex I countries (FAO, 2009), International Food Policy Research Institute (IFPRI), Life Cycle Inventory data from the Swedish Institute for Food and Biotechnology (SIK), Consultative Group on International Agricultural Research (CGIAR) and statistics from FAO (FAOSTAT, 2009).

GLEAM was developed with the objective of determining various mitigation techniques and packages that are suitable for adoption in different production systems. Incorporation of various economic parameters in the Gleam or coupling the economic models in to it could make it useful for bio- economic modeling (Britz and Witzke, 2008; Havlik *et al*., 2011; Rosegrant *et al*., 2008).

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2.6 EMISSION REDUCTION TECHNIQUES

Use of renewable energy sources has gained global popularity because of their benefits in reducing environmental impacts of energy use, especially the reduction of GHG emission. Renewable energy was accepted as a sustainable source available on reasonable cost with no negative effects (Dincer, 1999; Charters, 2001). Bull (2001) suggested that GHG reduction from the electrical power sources could be achieved through the use of more renewable source of energy. The best logical measure is the biogas production along with on farm power generation (Burton and Turner, 2003). GHG emission reduction by using various technological methods could be adopted, such as improved energy management systems, physical and biological carbon sequestration and a shift to low or zero carbon emission technologies based on renewable and sustainable sources of energy (Sims *et al.*, 2004).

Sovacool (2008) stated that renewable energy technologies offer the cheapest form of power generation. GHG emission is mostly reduced by the use of renewable sources of energy through effective management of manure and also eliminating the use of chemical fertilizers in crop production (Masse *et al.*, 2011). Agriculture and livestock sector contributes to the emission scenario and the reduction of emission can be achieved in agriculture through beneficial management practices and making use of biomass energy such as animal waste or plant biomass energy (Feroze *et al.*, 2014).

2.6.1 Emission reduction using renewable energy sources

The report of the IPCC (2014) highlighted that there are methods to limit climate change as well as the adverse effects associated with it. Conservation of energy and use of renewable energy are important among the many solutions that allow for sustainable development. They further advocated that, "stabilizing temperature increase to below 2°C relative to pre-industrial levels will require an urgent and fundamental departure from business as usual. Moreover, the longer we wait to take action, the more it will cost and the greater the technological, economic, social and institutional challenges we will face".

2.6.1.1 Anaerobic digestion of manure for emission reduction

Anaerobic digesters (AD) produced renewable energy as biogas having methane content of 60-80 percent (Steffen *et al.*, 2000). It was found that the anaerobic digestion process produced biogas at a rate of 0.30, 0.25 and 0.48 L/g volatile solids and recovered methane from animal waste at a rate of 0.2–0.4, 0.2–0.3 and 0.35–0.6 L CH_4/g volatile solids (VS) from swine, bovine and poultry slurries (Kramer and Kuzel, 2003).

Amon *et al.* (2006) reported that GHG emission from dairy manure slurries could be reduced effectively by anaerobic digestion process and N_2O emission was reduced by 28 percent in anaerobic digestion process when compared to field application of raw manure. Chantigny *et al.* (2007) conducted a comparative study by applying mineral fertilizer, raw liquid swine manure and anaerobically treated swine manure in the crop field and found that anaerobically treated one resulted in more forage yield and high N uptake when compared to the raw liquid swine manure. Masse *et al.* (2007) contented that anaerobic digestion process improved the mineralized fraction of P and N and also conserved the crop nutrients. Vanotti *et al.* (2009) reported that the anaerobic digester manure as a fertilizer can reduce the odour and would also improve the mineralized nitrogen content and N: P ratio, resulting in the improved nutrient uptake simultaneously and minimising the nutrient loss. Anaerobic digestion will eliminate the zoonotic pathogens and parasites which are present in animal manures with the added benefit of reduction in odour emissions by 70-95 percent thereby enhancing human/farm cohabitation in rural areas (Masse *et al.*, 2011)

2.6.1.2 Emission Reduction of Carbon dioxide

Anaerobic digestion is the best alternative to reduce the carbon and environmental footprint of the household livestock operations. Effective management of livestock waste and the effluent from the digester can be used as an excellent nutrient rich biofertilzer in croplands that can reduce the use of synthetic fertilizer and thereby the CO_2 emissions (Wilkie, 2008). The effluent from anaerobic digester is better to meet the crop needs than the raw manure because this reduces the use of chemical fertilizers and hence the carbon footprint of livestock products (Masse *et al.*, 2011).

2.6.1.3 Reduction of N_2O emission

Peterson (1999) reported a lower N_2O emission in anaerobically treated slurry when compared to raw slurry. Avrahami *et al.* (2002) and Amon *et al.* (2006) stated that there was a huge variation in N_2O emission from a dairy farm. This was because the emission rate depended on the soil temperature, moisture, organic content and composition, crop type, land management and manure application method. Management of the bedding material and solid manure reduced the N_2O emission from housing and storage (Monteny *et al.*, 2006).

2.6.1.4 Emission Reduction of CH_4

Long term storage and liquid handling of manure will increase the CH_4 emission where as dry handling, solid storage and short term storage will reduce the emission. AD of manure with biogas capture will lead to low CH_4 emission (Wilkie, 2008). AD has the potential to eliminate and reduce the emission of CH_4 from the stored livestock manure and this process can be adopted by the livestock farmers for sustainable livestock waste management because it has the potential to reduce the GHG emission (Masse *et al.*, 2011).

2.6.2 Other emission reduction strategies

2.6.2.1 Alternate management practices

GHG emissions can be reduced by proper bedding material (Groenestein and Van Faassen, 1996) and good management of the manure heaps, because considerable amount of methane and nitrous oxide are emitted under sub-optimal conditions (Huther *et al.*, 1997). Nitrous oxide emissions can be reduced by choice of fertilizer form, by use of nitrification inhibitors, by suitable land drainage

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MATERIALS AND METHODS

management, storage of solid manure and by providing good housing systems and management (Harrison *et al.*, 2003). Masse *et al.* (2011) reported that the present animal waste and manure management practices are causing health hazards to human, animal and wild life.

2.6.2.2 Diet Modification

Oil derived from plants and animals could reduce the ruminant methane production by 25 percent (Waghorn *et al.,* 2002). Use of condensed tannins in forage has the potential to reduce the CH_4 emission in ruminants (Puchala *et al.*, 2005). Beauchemin and McGinn (2006) stated that diet modification is one of the best methods to reduce GHG emission in livestock sector. Faster growth, higher milk yield and shorter dry periods in dairy cows will have low methane emissions (Monteny *et al.,* 2006). In order to enhance the productivity, manipulation of dietary composition of feed is the best nutritional management strategy which has the potential to reduce CH_4 emission (Yan *et al.*, 2006). Shibata and Terada (2009) reported that highly concentrated feed and starchy crop wastesp roduced less methane emission from cattle when compared to high roughage feed.

CHAPTER 3

MATERIALS AND METHODS

The methodology and procedures used for estimation of energy inputs from various sources for assessment and analysis of energy utilization pattern in the dairy with a view to suggest possible renewable energy use is described in this chapter. The experimental organization for the estimation of greenhouse gas emissions from the dairy using the Global Livestock Environment Assessment Model so as to assess possibilities for emission reduction and climate change mitigation is also explained here.

3.1 LOCATION OF THE STUDY

The study was conducted at a medium scale dairy unit viz. Peramangallur dairy near Pattambi in Palakkad district of Kerala. The geographical coordinates of the location is 10°80" N Latitude and 76°19" E Longitude. The annual precipitation in the study area was 2749 mm. The study was undertaken during the period from February to July 2016.

3.2 CHARACTERISTICS OF THE DAIRY AND DATA COLLECTION

Total herd, type of breed, number of lactations and the details of the farm were obtained by personal interview with the dairy farm owner.

The total area of dairy farm was around 1.5 ha and the different production processes in the dairy farm were observed and classified in to 4 different units mainly the cow shed, milk processing unit, fodder unit and the biogas unit. The pictorial representation of the dairy farm is shown in Figure 1.

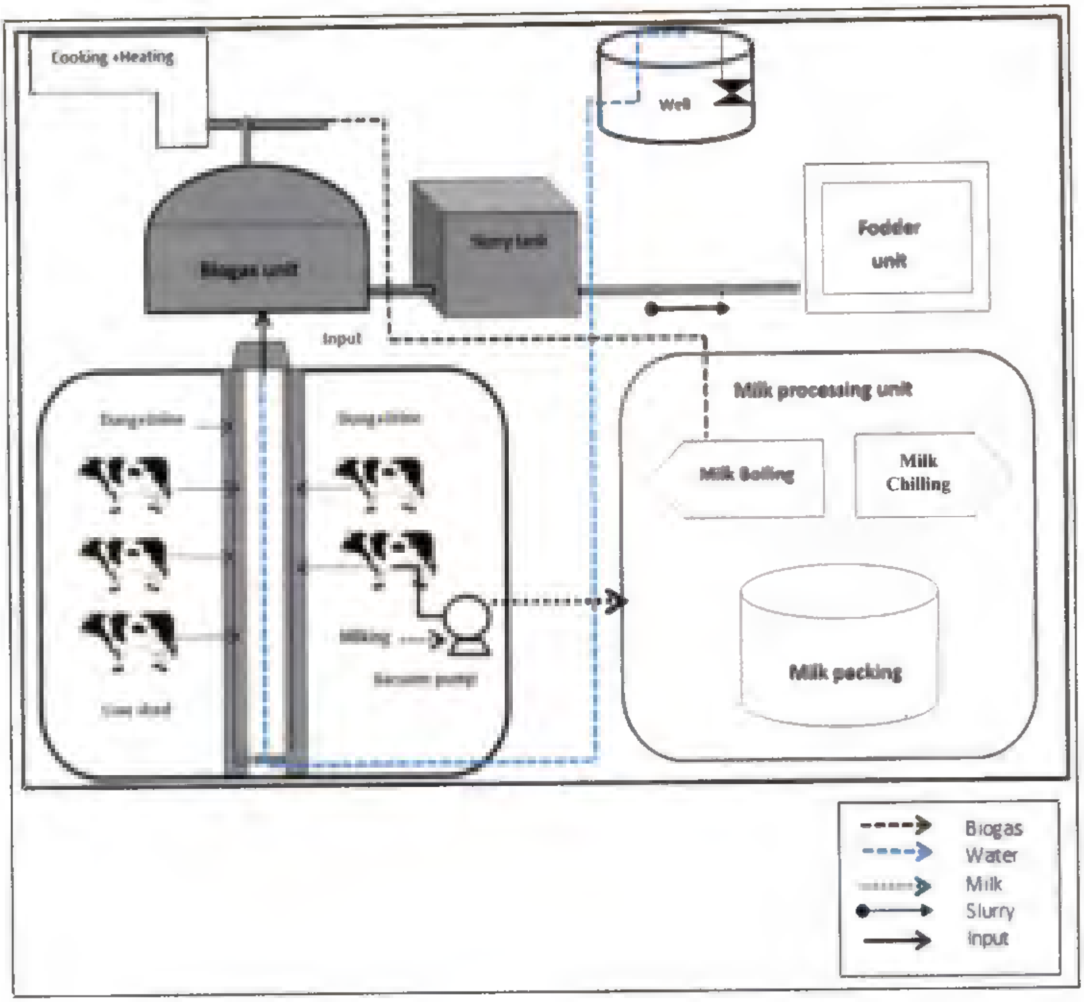

Figure 1. Pictorial representation of the dairy farm

3.3 ENERGY ACCOUNTING

Unit operations in the dairy farm were identified, flow diagrams prepared and energy accounting was done.

Flow diagrams were prepared for the following units of the dairy:

i. Cow shed
ii. Milk processing unit
iii. Biogas plant
iv. Fodder production unit

Figure 2 shows the milk packing machine in the milk processing unit. Required information on various inputs such as fuel, electricity, feeds, total working hours of labourers, total working hours of machinery and equipment were observed. The energy usage of various electrical gadgets and equipment were estimated by using a power quality analyzer and a single- phase power meter. Figure 3 shows the power quality analyzer (Fluke 1730) which is also a three-phase energy logger ideal for conducting energy analysis. Figure 4 shows the single-phase power meter (Model- PG09, Meco Powerguard) for measuring the electrical energy consumption of household and dairy appliances. This collects and records the current, voltage and power consumption of the equipment.

Figure 2. Milk packing machine in the milk processing unit

Total working hours of electrical equipment were observed. The number of labourers and their working hours were also observed and recorded. Biogas consumption data was collected using a biogas flow meter to observe the use of biogas and also the time taken was recorded. The source wise energy use in different units was calculated. The unit wise energy flow diagrams were prepared and the source wise energy inputs in different units were calculated. Other required data was gathered by personal interviews with the dairy farmer in the farm.

Figure 3. Power quality analyzer

Figure 4. Single phase power meter

3.4 ENERGY USE PATTERN

Data on external inputs such as human labour, machinery, diesel, electricity and feed were used to calculate the energy input. The outputs were milk and biogas.

3.4.1 Equivalent energy coefficient of inputs and outputs

Equivalent energy coefficient of inputs is defined as the energy used from primary production to the end user (Mousavi- Avval *et al.*, 2012). Energy of fuels and electricity is the heating value (enthalpy) and the energy needed to make their energy available by mining, refining and transportation (Sefeedpari, 2012).

The muscle power used in farm operations which comes from metabolic energy of food consumed was considered as the equivalent energy of the human labour (Kitani, 1999; Mousavi- Avval *et al.*, 2012). The energy coefficient of the feed is not the calorific or heating value of the feed but the energy required for the production processes of the feed such as transportation, packing, processing and manufacturing (Tabar *et al.*, 2010).

The energy utilized for tractors and agricultural machinery was denigrated during their economic life time and the total energy of agricultural machinery was calculated. The machinery energy was calculated by using the equation proposed by (Gezer *et al.*, 2003). The energy equivalent coefficients of different inputs and outputs obtained from various research publications is exemplified in Table1. Energy use for water consumed in the dairy for washing, cleaning and drinking purposes could be calculated by considering the amount of electricity used by the pumping system. Heating value of 1 m^3 biogas (70% methane) was taken as 5339 kcal having a thermal efficiency of 60 percent (Mathur and Rathore, 1992).

3.4.2 Energy inputs and outputs in the dairy farm.

Different energy inputs and outputs for each unit operation in the production processes were assessed and quantified in terms of per 1000 L of milk produced. The data on inputs and outputs were converted to energy inputs and outputs using equivalent energy coefficients as outlined by (James and Kamaraj, 2003; James and Regina, 2011 and Mousavi- Avval *et al.*, 2012).

Table 1. The energy contents of the inputs and outputs of dairy farm

Items (unit)	Energy content (MJ unit^{-1})	References
A. Inputs		
1. Machinery (h)		
(a) Electric motor (kg)	64.80	Singh and Mittal (1992)
(b)Prime movers other than electric motors (self-propelled machines) (kg)	68.40	Singh and Mittal (1992)
(c)Farm machinery excluding self – propelled machines (kg)	62.70	Singh and Mittal (1992)
(d) Other machinery	62.70	Singh and Mittal (1992)
2. Diesel fuel (L)	47.80	Kitani,(1999)
3. Electricity (kWh)	11.93	Ozkan *et al*. (2004)
4. Human labour (h)	1.96	Nabavi-Pelesaraei *et al*.(2013)
5. Feed[a]		
(a)Concentrate (kg)	13.60	Frorip *et al*. (2012)
(b) Straw (kg)	9.25	Tabatabaeefar *et al*. (2009)
(c) Grass silage (kg dry matter)	1.50	Wells (2001)
B. Outputs		
1. Milk (kg)	2.70	NRC (2001)
2. Farmyard manure (kg dry matter)	0.30	Singh and Mittal (1992)

a. Metabolizable energy

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3.4.2.1 Energy input

Total energy input was determined by the sum of the input factors multiplied by the appropriate energy conversion coefficients for each factor (James and Kamaraj, 2003, Kazemi *et al.*, 2015). For lighting the dairy premises as well as for operations such as pumping water, milking, chilling milk and milk packing, energy consumption was calculated by using equation (1). Energy calculation for human labour (transportation, cleaning and washing, feeding, dung removal, transportation, slurry pumping, feeding, feed mixing) was calculated by using equation (2). Diesel use in the farm was calculated based on the total diesel consumption to the equivalent energy coefficient. Energy input was calculated for the machinery and equipment by using equation (3) (Gezer *et al.*, 2003). The average lifetime of a tractor was reported to be 10 years with most frequent period being 10-15 years and 5-9 years (Singh, 2010). Apart from a normal tractor, 12 (horse power) HP power tiller (Figure 5) was made use of for transportation of fodder to the dairy and hence the life time was taken as 15 years. Assuming the motor is being operated under normal conditions, the life was taken as 15 years (Barnes, 2003). Figure 6 shows the power tiller used for transportation in the farm.

$$E = P \times T \times E_q \qquad (1)$$

Where 'P' is the power (kW), 'T' is the time (h), 'Eq' is the equivalent energy coefficient (MJ) from Table 1 and 'E' is the energy (MJ).

$$E = N \times T \times E_q \qquad (2)$$

Where 'N' is the total number of labours, 'T' is the time (h), 'Eq' is the equivalent energy coefficient (MJ) from Table 1 and 'E' is the energy (MJ).

$$ME=\sum G \times M \times t/T \qquad (3)$$

'ME' is the machinery energy for the dairy (MJ), 'G' is the material mass used for manufacturing (kg), 'M' is the production energy of material (MJ kg^{-1}),'t' is the time for which the machine is used (h) and 'T' is the economic life time of machine (h).

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The energy inputs for the feed was obtained by classifying the feed into roughage and concentrate and observing the total feed given from which the total amount is converted to its equivalent energy coefficient. Individual components of the feed were weighed using a digital platform weighing scale (Figure 6).

Figure 5. Power tiller for transporting fodder

Figure 6. Weighing the feed

3.4.2.2 Energy output

Energy output for milk was obtained by observing the total amount of milk produced in the farm. The daily milk production was observed by using a digital platform weighing scale (platform dimension of 400 x 400 mm, 50 kg capacity) during morning and evening hours. Total biogas production was measured using a biogas gas flow meter (Figure 7) with mechanical totalizer, manufactured by Siya instruments (Model : SI -2.5) and its energy content was taken as the heating value itself as no other energy input was involved in processing and transportation of biogas.

Figure 7. Biogas flow meter

3.4.3 Different types of energy and energy indices

Energy use was classified in to direct as well as indirect energy and renewable as well as non- renewable forms (Singh *et al.,* 2003). In this study the items included in indirect energy were feed and machinery while the components of direct energy were human labour, biogas, diesel fuel and electricity. Non-renewable energy included diesel fuel, electricity and machinery whereas human labour and feed were classified as renewable energy.

The calculated equivalents were used to assess the energy indices viz. energy ratio, energy productivity, net energy and specific energy using the following equations proposed by Nabavi-Pelesaraei *et al.* (2013) and Mandal *et al.* (2002):

$$E.R= E_{out}/E_{in} \qquad (4)$$

$$NEG= E_{out}-E_{in} \qquad (5)$$

$$EP= Y/E_{in} \qquad (6)$$

$$SE=E_{in}/Y \qquad (7)$$

Where 'E.R' energy ratio; 'NEG' is net surplus energy (MJ per head of cow) 'EP' is energy productivity (kg MJ^{-1}), 'SE' is specific energy (MJ kg^{-1}), 'E_{in}' is energy input of the system and 'E_{out}' is the output energy (MJ/cow) and 'Y' is the yield (milk production per cow). The energy use efficiency is one of the indices which show the energy efficiency of the dairy farm.

3.5 ASSESSMENT OF POTENTIAL OF THE BIOGAS UNIT IN RENEWABLE ENERGY PRODUCTION AND EMISSION REDUCTION

The assessment of the present usage pattern of biogas and its production potential was done as described below:

3.5.1. Biogas plant

The details of the existing biogas plant (Figure 8) were studied and observations were made on: type of plant, material of construction, daily feed input, daily gas production capacity and size of output slurry tank. Size of the output slurry tank was estimated by measuring its dimensions and other details about the biogas plant were obtained from the farmer. The daily biogas production was determined by measuring the biogas with the help of a flow meter.

3.5.2. Biogas production potential

The biogas production potential was estimated by measuring the total quantity of dung available per day (kg) to the average biogas productivity of cow dung (Singh and Mital, 1992). The dung collection was done by classifying the cows in to different categories based on their body weight and the data was estimated by collecting and weighing dung produced by the cows.

Figure 8. Biogas plant in the dairy farm

The average body weight (kg) of the adult cows were determined by measuring the length (inches) and girth (inches) of each cow and the average weight was calculated using equation (8) suggested by Khan *et al*. (2003).

$$BW = LxG^2/300 \qquad (8)$$

Where 'BW' is the body weight (pounds), 'L' is the body length of the cow (inches) and 'G' is the heart girth (inches). Subsequently it was converted to kg using the conversion factor (1 pounds = 0.454 kilogram).

The existing biogas plant was studied and the daily slurry input (kg) was worked out from daily dung and the total water used for cleaning the shed and cows (liters). The dry matter content of the cow manure was obtained by estimating its moisture content by placing a sample of dung in the oven at 100°C for 24 hours. The actual weight and the dry weight were noted and dry matter content of the manure was estimated.

The slurry output (L) was estimated by observing the level difference in the slurry tank before and after pumping.

3.5.2.1. Methane content in the biogas

The percentage of methane content in the biogas was determined using a saccharometer (Figure 9). A measured quantity of biogas was passed through the saturated KOH solution in the saccharometer (Bovas, 2009). CO_2 was absorbed by KOH and the volume of gas which was collected at the top of the saccharometer was regarded as methane. The methane content was estimated using equation (9).

$$\text{Methane content} = 100 \times \frac{\text{Volume of gas collected at the top}}{\text{Total volume of gas injected}} \qquad (9)$$

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Figure 9. Saccharometer for measuring the methane content of biogas

3.5.2.2 Total solids (TS)

The total solids (TS) contents were determined by the procedure followed by American Public Health Association (APHA, 1989). A measured volume of well mixed sample was transferred to a pre-weighed dish (A) and evaporated to dryness in an oven. The sample was dried for one hour in the oven at 103- 105°C. The dish was then cooled and weighed. This was repeated until concordant weights were obtained. TS were determined using equation (10).

$$TS = \left[\frac{W1 - W2}{\text{Sample volume (ml)}} \text{ X } 1000 \right] \text{ mg/l} \qquad (10)$$

W1= Weight of the dried residue with dish, mg

W2= Weight of the dish, mg

3.5.3 Conventional energy use and biogas equivalent

Daily gas production (L/day) from the existing biogas plant was measured using a biogas flow meter by connecting it at the outlet of the biogas plant. Daily biogas use (L/day) for cooking and other household activities as well as the consumption for dairy were recorded. The total biogas production, total consumption and available balance were noticed. The total consumption of electricity in the farm for milk production process per day was observed and recorded. The biogas equivalent for electricity was also estimated using the following conversion factor suggested by Mital (1996) as 0.75 m^3 = 1 kWh.

3.6 GHG EMISSIONS

3.6.1 GHG emission due to inputs

Dairy farm productions, storage, transportation, use of machinery and chilling milk results in the combustion of fossil fuels directly and indirectly which emit GHG to the atmosphere. The amount of GHG emissions from inputs per 1000L of milk produced was calculated by using the GHG coefficient of the inputs given in Table 2. The respective emission values were calculated by multiplying the input rate (diesel fuel, electricity and machinery) by its corresponding emission coefficient.

Table 2. GHG emission coefficients of various inputs

Inputs	GHG coefficients (kg CO_2 eq Unit -1)	Reference
Diesel fuel (L)	2.76	Taki *et al.* (2012)
Electricity (kWh)	0.608	Nabavi-Pelesaraei *et al.* (2014)
Machinery (MJ)	0.071	Taki *et al.* (2012)

3.6.2 Estimation of GHG emission using model

Apart from the GHG emission by combustion, cows are the major contributor of GHG emission through enteric fermentation and by manure management. The model "Global Environmental Assessment Model-interactive tool (GLEAM-*i*)" proposed by FAO for the assessment of greenhouse gases and mitigation potential in livestock was used in the present study.

3.6.2.1 GLEAM–i Model Overview

"GLEAM-*i", is a model of the food and agricultural organization (FAO) of the United Nations and was developed with the objective of giving support to different stake holders such as policy makers, scientists and non-governmental organizations as well as different sectors of the civil society for determination of GHG emission from the livestock sector. Gerber *et al*. (2013) described the model as given below:

"GLEAM–*i* is a spatially explicit modelling framework that simulates the environmental impacts of the livestock sector using a LCA (Life cycle assessment) approach. In LCA approach, all the inputs and output related to a specific product within a specific boundary system is determined."

3.6.2.2 Characteristic features of the model

This model covers the emission of three major greenhouse gases CO_2, CH_4 and N_2O which are likely to be emitted from agricultural operations. Global warming potential (GWP) is the ability of a gas to trap heat in the atmosphere equivalent to CO_2, in a given time period. As suggested by Gerber *et al.* (2013), "the GWP of CH_4 and N_2O is 25 and 300 implicating that the heat trapping ability of CH_4 and N_2O is 25 and 300 times that of CO_2 respectively, for a period of 100 years. Here the model uses the 100 years GWP values as per the fifth assessment report (AR5) report of IPCC, 2014".

The model characterizes the animal population, feed, transport, manure management and herd dynamics which could improve its accuracy and specificity in the estimation of GHG emission through enteric fermentation and manure management. Even though the model had wide applicability for six different livestock species (cattle, buffalo, sheep, goat, pig and chicken) and their edible products the present study was concerned only on cows for the estimation of CO_2, CH_4 and N_2O at different stages of production. The model uses IPCC (2006) Tier 2 methodologies for the calculation.

GLEAM-*i* consisted of three modules for data input which included the herd module, manure module and feed module. Herd module was concerned with the animal populations and its characteristics. Feed module was for determining the feed characteristics and the ration. Manure module determined the emission from manure by calculating the nitrogen which was deposited and applied in the field.

The detailed numeric results obtained from the model could give the summary graphs. From the greenhouse gas emission graphs, total GHG emissions from different sources, expressed in CO_2 equivalent could be determined. The shares of each gas (CO_2, CH_4 and N_2O) in the total emissions and also the share of emission from different sources such as enteric fermentation and manure management were also obtained.

3.6.2.3 Data collection for the model (Minimum data set)

The observations required for the input data in the model was taken based on the specified parameters.

Module 1 (Herd) evaluates the number of animals per GIS grid cell where they have been managed with different farming system. Here the total animal numbers (heads), total adult female and animal (heads) was determined from our observations and herd parameters were determined for age at first calving (weeks), adult female replacement (percentage), mortality of young males and females (percentage), mortality of adult animals (percentage) and fertility of adult females (percentage). The data was procured through personal interviews with the dairy farmer and accessing his records. Average birth weights (kg) of the calves were obtained by weighing the calves and from the data provided by the farmer. The average body weights (kg) of the adult cows were determined as explained in section 3.5.2 and milk yield as in section 3.4.2.1. The sample of milk was collected and the protein and fat percentages were estimated.

The feed module calculated the various feed components, nutrient content and the emission per feed given. The input data was acquired by observing and weighing the total amount of feed (percentage over dry matter intake) and classifying them as roughages (grass, hay and silage), grains (wheat, barley, maize etc.) and agro- industrial by-products (bran and oil cakes). The detailed ration of the feed (percentage of dry matter intake) was observed, weighed and calculated.

The dry matter of individual feed was obtained by finding the dry weight of the sample using an oven. The samples were placed in an oven at 60^0C for 48 hours until they were thoroughly dry.

The total dry matter intake of the feed was calculated as shown below:

Calculations

Container weight = W_o g

Weight of the container and sample weight before drying = W_1 g

Wet sample weight = W_2 g (W_1 g- W_o g)

Container and sample weight after drying = W_3 g

Dry sample weight = W_4 g (W_3 g - W_o g)

Dry matter = (W_4 g / W_2 g) x 100

Dry matter intake (DMI) of the feed was found from the total feed intake and the dry matter (DM) of the feed, using equation 11.

$$DMI = \frac{TFI \times DM}{100} \qquad (11)$$

'DMI' is the dry matter intake of the feed, 'DM' is the dry matter of the feed and 'TFI' is the total feed intake by the cow in a day (kg).

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In manure module, the manure production from each animal type was estimated. The total quantity of dung was obtained by classifying the cows into different categories based on the body weight and collecting the dung from each category. Information on how the manure was managed in the farm such as, usage of anaerobic digester, dry lot, liquid /slurry, daily spread, solid storage, deposited in uncovered anaerobic lagoon and paddock was collected.

3.6.3 Total GHG emission

The GHG emission from enteric fermentation and manure management was determined from the model. The emission due to usage of various inputs was estimated using the procedure explained in section 3.6.1. The total emission from the dairy farm was then estimated and the possible emission reduction by different strategies were analysed based on the available information.

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The results of the study conducted for identifying the energy utilization pattern and to assess the greenhouse gas emission in a medium dairy farm with a view to propose mitigation strategies involving energy conservation and renewable energy use are described in this chapter.

4.1 PRODUCTION PROCESS IN THE DAIRY FARM

The dairy farm consisted of 43 cows of Holstein- Friesian (HF) breed in which 9 were calves and 34 cows. Specific information about the dairy farm and the cows are given in Table 3. The dairy operations in a day commenced with washing of the cows manually by pressurized water from a water pump. The waste wash water was directed through a gutter running through the middle of the cow shed in to the biogas plant. Dung was also removed manually by flushing the water. The dung and urine of the cows mixed with wash water forms a slurry which flow by gravity in to the biogas plant digester.

Table 3. Herd characteristics

Breed of cows	Holstein – Friesian
Total no. of cows in the farm (herd)	43
Lactation period (days)	305
Dry period (days)	60
No. of lactations (times/day)	2

Figure 10 depicts the complete process in the dairy farm. Feed for the cows were prepared by mixing the different components manually. The fodder was manually cut and transported to the dairy farm by using a power tiller and fed to the cows manually by labourers. Milking of the cows was done using a milking machine operated by the labourers for about 4 hours. The milk was then collected in a can and taken for packing after filtering it manually. Prior to introducing milk to the packing machine, the system was flushed with hot water at 80°C. A portion of the milk obtained was boiled for the production of other milk products viz., (curd and butter). Biogas was utilized for heating water for hot water flushing as well as for boiling milk using biogas stoves. The packed milk and milk products were further stored and preserved in the freezer.

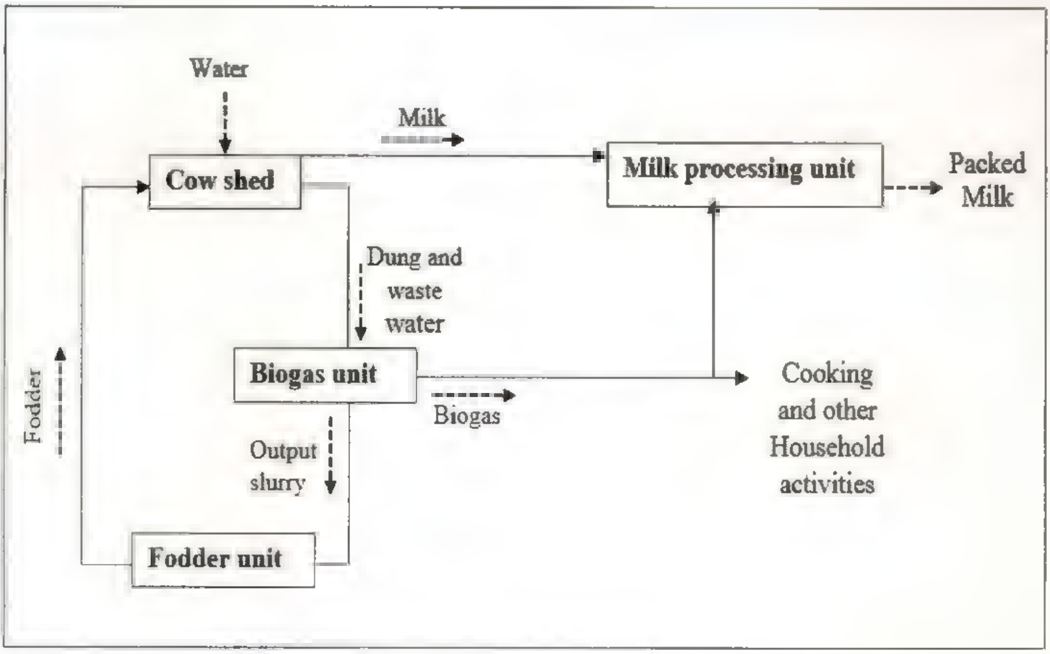

Figure 10. Process flow chart of the dairy farm

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The biogas produced was utilized for domestic cooking, hot water production and boiling milk. The slurry collected in the slurry tank adjacent to the outlet tank of the biogas plant was further pumped in to the fodder unit by an electric pump. It was observed that the process and equipment used in milk processing are more or less traditional and involved transportation of milk manually.

4.2 ENERGY ACCOUNTING IN MILK PRODUCTION

Milk production and processing operations could be broadly grouped in to four sections for the purpose of energy accounting *viz;* (i) cow shed (ii) milk processing unit (iii) biogas plant and (iv) fodder unit.

4.2.1 Energy flow in cow shed

Figure 11 illustrates the energy flow from different sources in various operations in the cow shed. About 69 percent of electricity used in this section was utilized for pumping water. Out of 26.27 kWh used per 1000 L of milk, it was noted that 7.7 kWh was consumed by milking machine and only a small quantity of electricity was consumed for lighting (2%). It was observed that washing and cleaning were done immediately before milking. The electrical energy was utilized for pumping water, washing and cleaning the floor as well as for operating the milking machines. Human energy of the labourers was also utilized for this operation.

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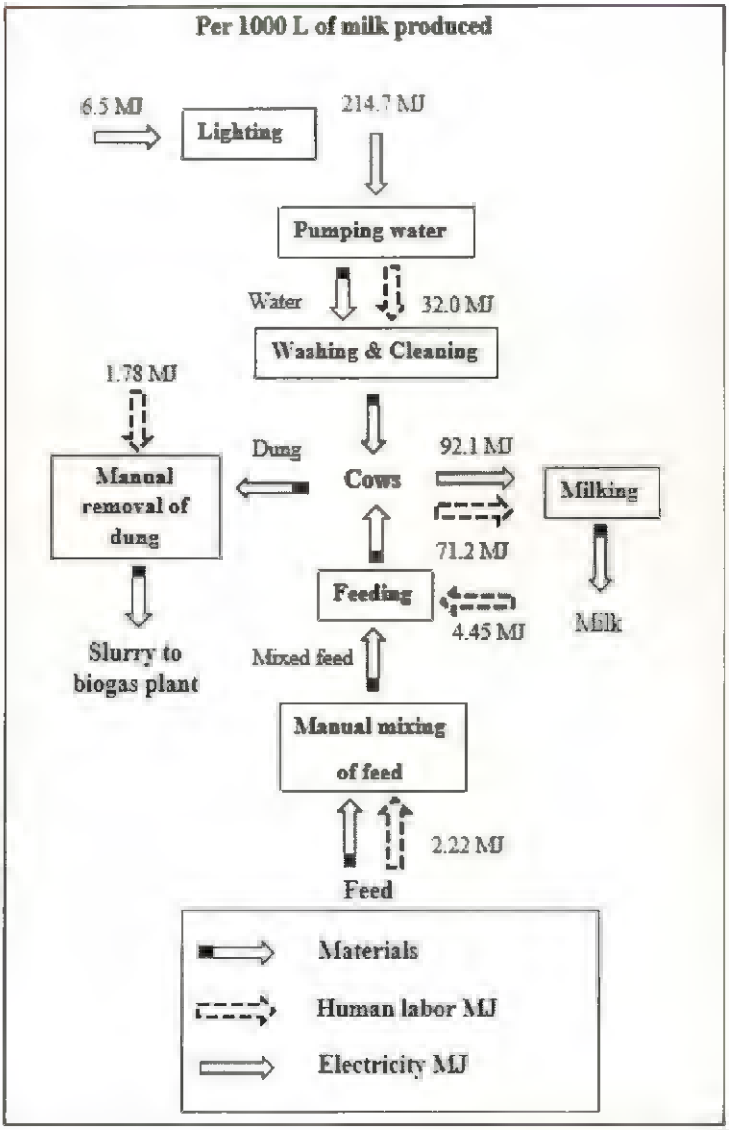

Figure 11. Energy and material flow in the cow shed

Major portion of the human energy consumption in this section 71.2 MJ per 1000 L of milk produced was for milking the cows. A considerable quantity (32 MJ) of the human energy was used for washing and cleaning and only a small quantity was used for mixing the feeds and removing the dung. There was no energy input other than human labour for the cleaning operations in which the dung was washed down to the gutters using pressurized water direct from the pumping line. The waste water along with dung and urine mixed together and eventually flowed into the biogas plant though the inlet pipes. Only electrical and human energy were consumed in this section.

Table 4 represents the source wise energy input in the cowshed. Here the electricity was mostly used for pumping water followed by milking. Only a minor quantity was used for lighting. Out of the total human energy consumed in the cowshed, 64 percent was utilized for milking and 29 percent for washing and cleaning. Other operations like feed mixing consumed only a lesser fraction of human energy.

Table 4. Source wise energy input in the cow shed

Energy input (MJ) per 1000L of milk produced					
Process	Electricity	%	Process	Human labour	%
Lighting	6.5	2	Washing and cleaning	32	29
Pumping Water	214.7	69	Milking	71.2	64
Milking	92.1	29	Mixing of feed	2.2	2
			Dung removal	1.7	1
			Feeding	4.4	4
Total	313.3	100	Total	111.5	100

4.2.2 Energy flow in milk processing unit

The energy flow in the milk processing unit is depicted in Figure 12. A total of 36.1 kWh of electricity per 1000 L of milk produced was consumed for chilling and storing of milk and milk products in the freezer. 8.1 kWh of electricity per 1000 L of milk produced is consumed by another freezer which was used for the preservation of other milk products.

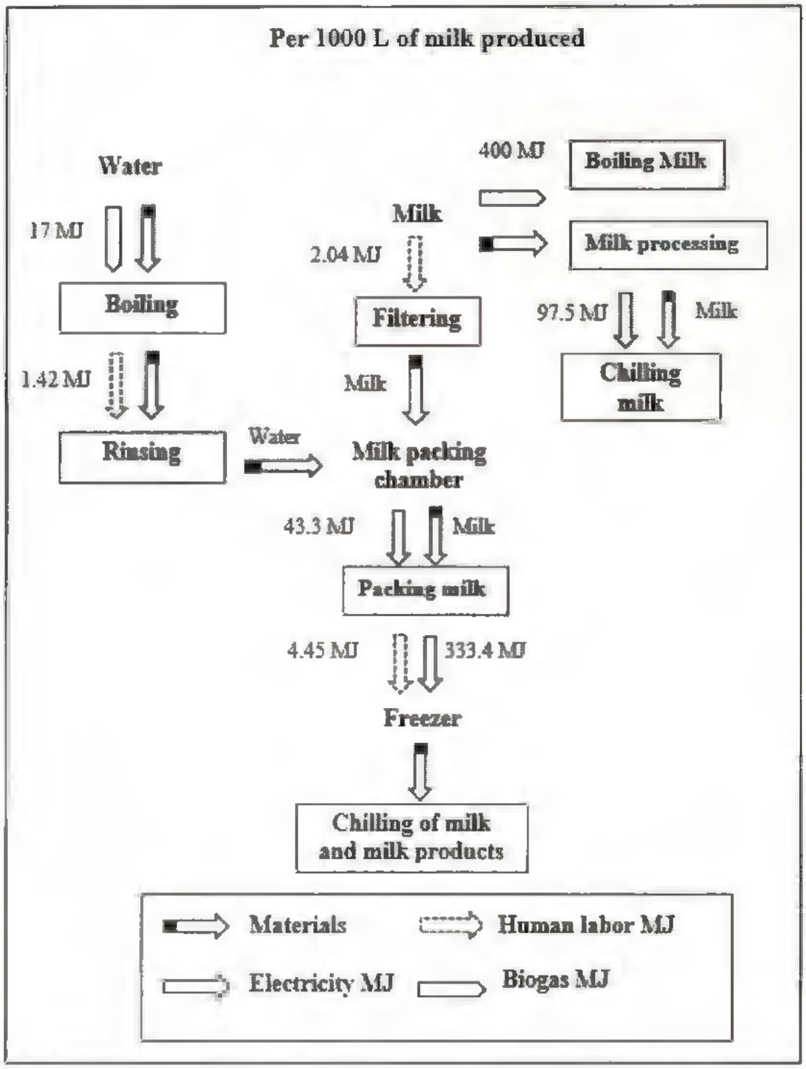

Figure 12. Energy and material flow in the milk processing and packing unit

The freezer usage varied depending on the rate of sale of the products as well as the season. On an average the duration of daily milk chilling time (including the cut–off time) was 15 hours for the first freezer and 5 hours for the second

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freezer. Only a small quantity of electricity was consumed by the milk packing machine which was about 9 percent. In this section 91 percent of electricity was used for the chilling of milk and milk products. Human energy was utilized mostly for flushing system with hot water, filtering milk and for transferring milk to the tank of the packing machine.

On an average, 18 and 26 percent of human energy was utilized for flushing the system with hot water and filtering process. Human energy was mostly utilized for milk packing which was about 2.27 man hours per 1000L of milk produced which was nearly 56 percent of the total consumption. Apart from electrical and human energy inputs, biogas was also used as a major source of energy. Biogas was utilized for heating water used for rinsing of equipment and boiling milk for preparation of other milk products (curd and butter).

Table 5. Source wise energy input in the milk processing unit

Energy input (MJ) per 1000L of milk produced								
Process	Electricity	%	Process	Human labour	%	Process	Biogas	%
Chilling milk	333.4	70	Hot water flushing	1.42	18	Heating water	17	4
Milk packing	43.3	9	Filtering	2.04	26	Boiling milk	400	96
Products preservation	97.6	21	Milk packing	4.45	56			
Total	474.3	100		7.91	100		417	100

The source wise energy input in the milk processing unit is shown in Table 5. Seventy percent of the total electrical energy was consumed for chilling milk and 21 percent for preserving other milk products in the dairy. Apart from human and electrical energy usage, biogas was used for boiling milk (96%) and heating water (4%).

4.2.3 Energy flow in biogas unit

Figure 13 illustrates the energy use pattern in the biogas plant. Here the electrical energy of 10.9 kWh per 1000L of milk produced was utilized only for the pumping of slurry from the slurry tank to the fodder unit. The slurry was pumped nearly two times in a week to the fodder unit. Human labour was also utilized for this operation. Dung, urine and waste water was automatically mixed to form slurry in the washing and cleaning process and was diverted through a gutter in to the biogas plant. Hence this section consumed only very little energy compared to other sections.

Table 6. Source wise energy input in the biogas unit

Energy input (MJ) per 1000 L of milk produced					
Process	Electricity	%	Process	Human labour	%
Slurry pump	131.23	100	Slurry pump	8.9	100
Total	131.23			8.9	

Table 6 shows the source wise energy input in the biogas unit. Electricity was consumed only for slurry pumping and human energy of 8.9 MJ was also used for slurry pumping.

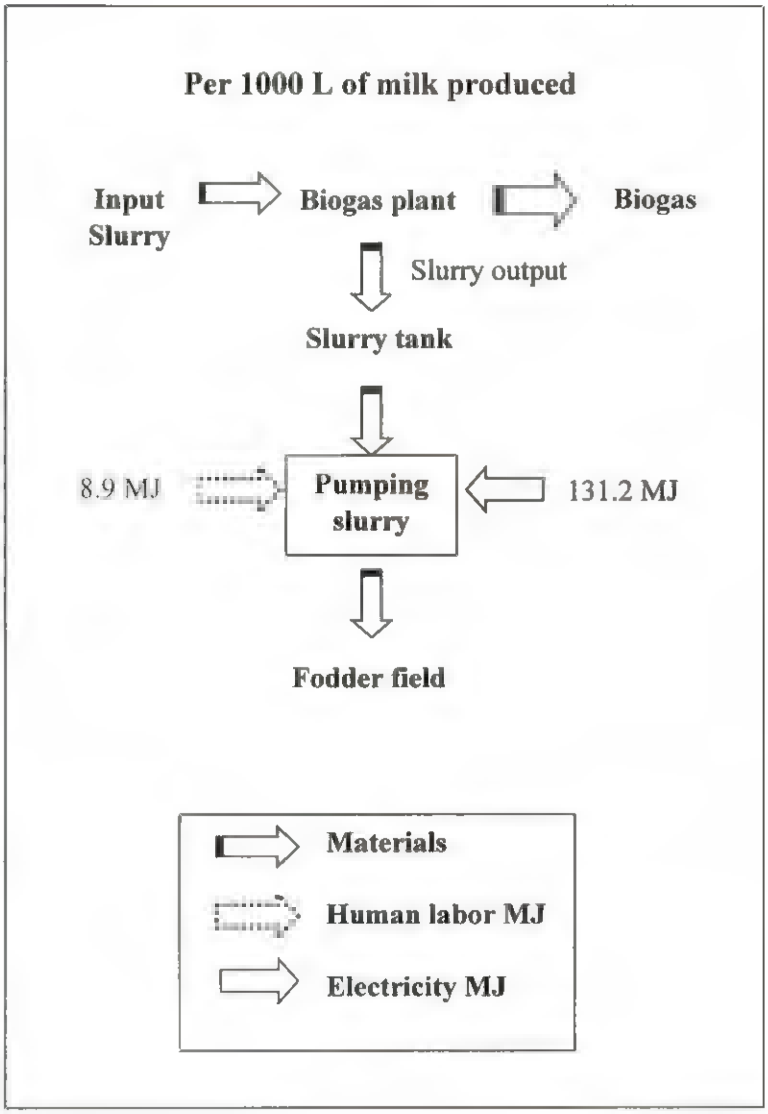

Figure 13. Energy and material flow in the biogas unit

4.2.4 Energy flow in fodder unit

The energy flow in the fodder unit is shown in Figure 14. Human energy was mostly utilized for various processes in the fodder unit. A major portion of human energy was expended for fodder cutting (84%). Fodder cutting was done manually by two labourers and there after only a small quantity of human energy was utilized for transporting the fodder (16%). The fodder after cutting was transported to the cow shed by utilizing a diesel power tiller. Electrical energy use was negligible in the fodder unit. When we consider all the other sections most of the energy use was in the form of electrical and human energy and diesel consumption was only noted in the fodder unit which could be quantified as only 0.68 liters per 1000 L of milk produced.

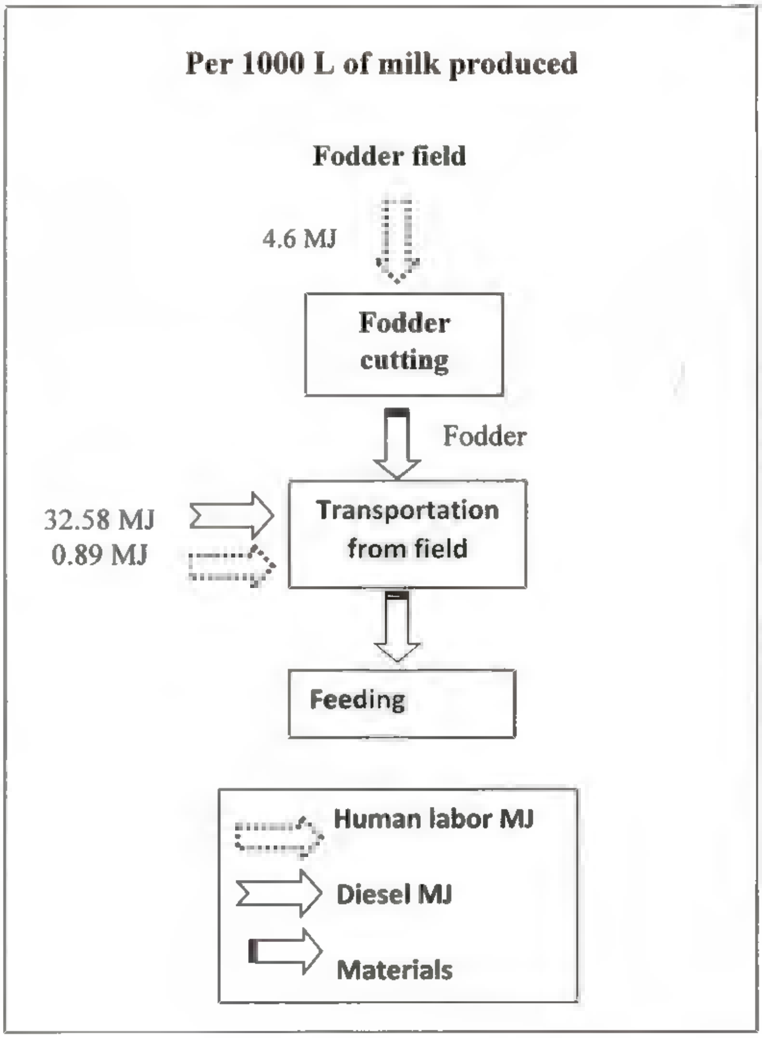

Figure 14. Energy and material flow in the fodder unit

Table 7 represents the source wise energy input in the fodder unit. Of the total human energy use, 84 percent of the energy was utilized for fodder cutting and 16 percent for transportation. Diesel was used only for transportation which amounted to 32.4 MJ of energy.

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Table 7. Source wise energy input in the fodder unit

Energy input per (MJ) 1000 L of milk produced					
Process	Human labour	%	Process	Diesel	%
Fodder cutting	4.6	84	Transportation	32.5	100
Transportation	0.89	16			
Total	5.49	100		32.5	100

4.3 ENERGY USE PATTERN

The pattern of energy use from different sources in the four different units of the dairy is described in this section.

4.3.1 Electrical energy use

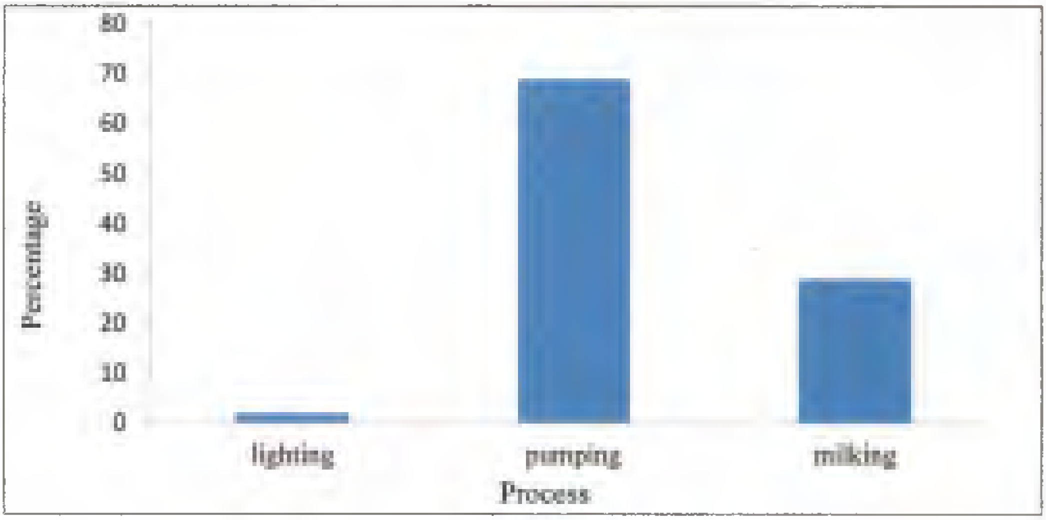

Figure 15. Electrical energy usage in cow shed

Figure 15 shows that major part of the electrical energy used (69%) was used for pumping water for different purposes in the cow shed especially for washing and cleaning. Only a minor fraction (29%) was used for milking and lighting (2%). This shows that water conservation is important in reducing the electrical energy use in cow shed.

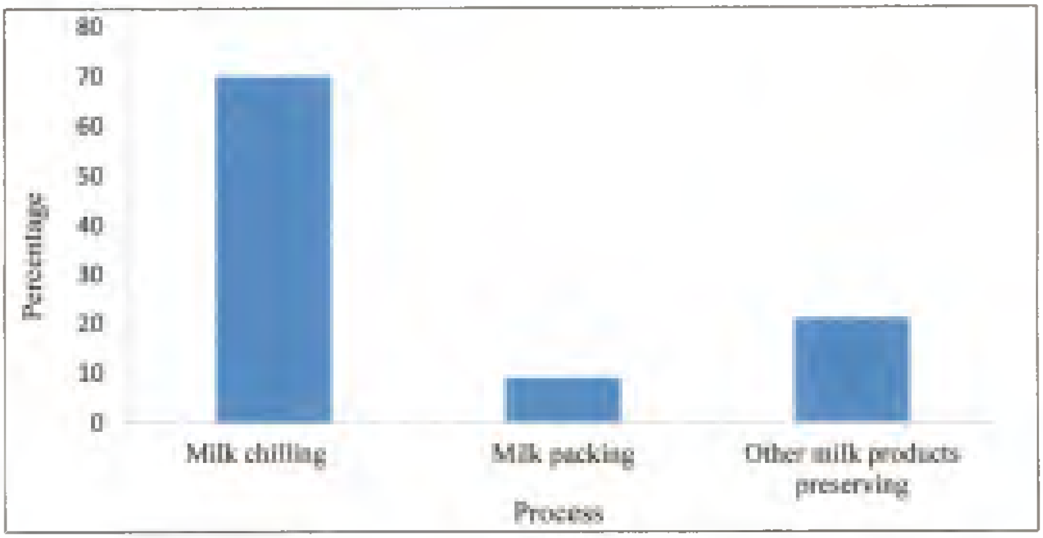

Figure 16. Electrical energy usage in the milk processing unit

Figure 16 depicts the electrical energy usage in the milk processing unit. 70 percent and 21 percent of the total electrical energy in the milk processing unit was utilized for chilling milk and preservation of other milk products. Only 9% of electrical energy was consumed for milk packing.

4.3.2 Human energy use

Figure 17 depicts the human energy consumption and it is evident that 64 percent of the human energy was used for milking and 29 percent for washing and cleaning purposes. The energy use for other purposes like mixing of feed, dung removal and feeding was comparatively very less.

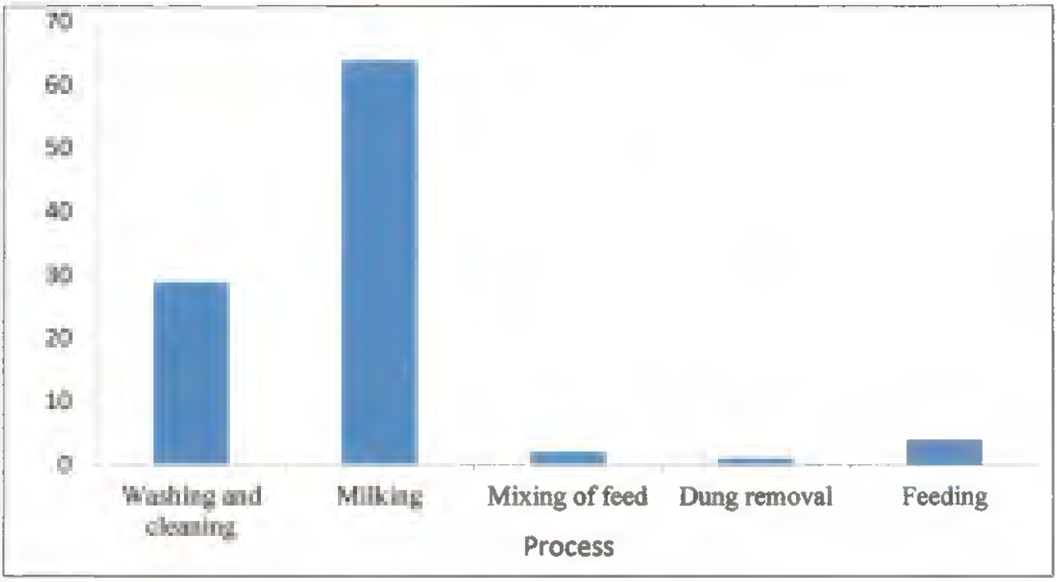

Figure 17. Human energy usage in the cow shed

Figure 18 illustrates the human energy use in milk processing unit. 56 percent and 26 percent of the human energy respectively were consumed for milk packing and filtering process and only very little energy was used for flushing the milk packing chamber with hot water.

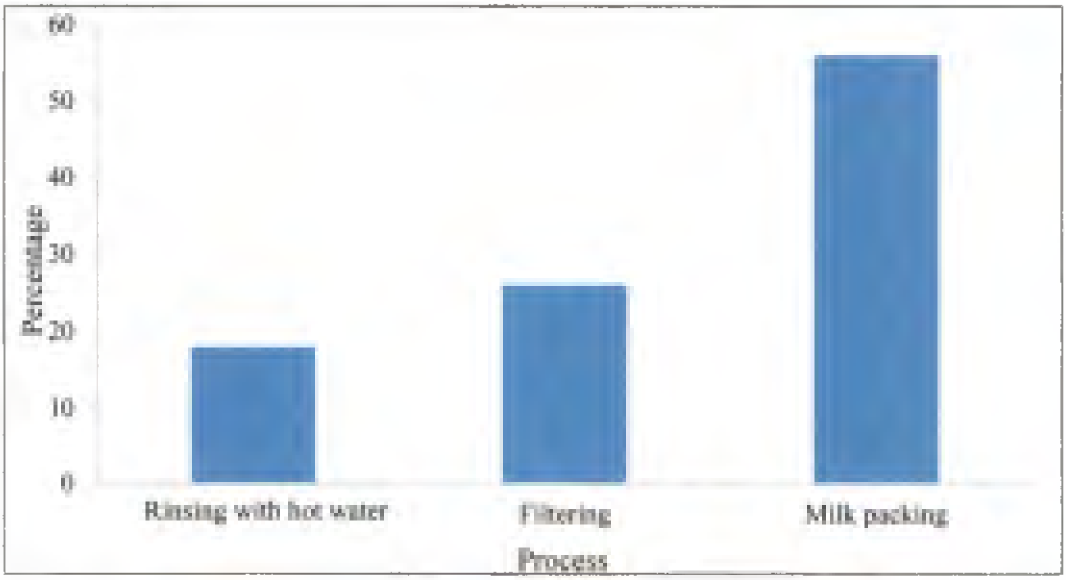

Figure 18. Human energy usage in the milk processing unit

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Human energy usage in the fodder unit is shown in Figure 19. Highest amount of human energy (84%) was used for fodder cutting and only 16 percent of the energy was utilized for transportation of the fodder.

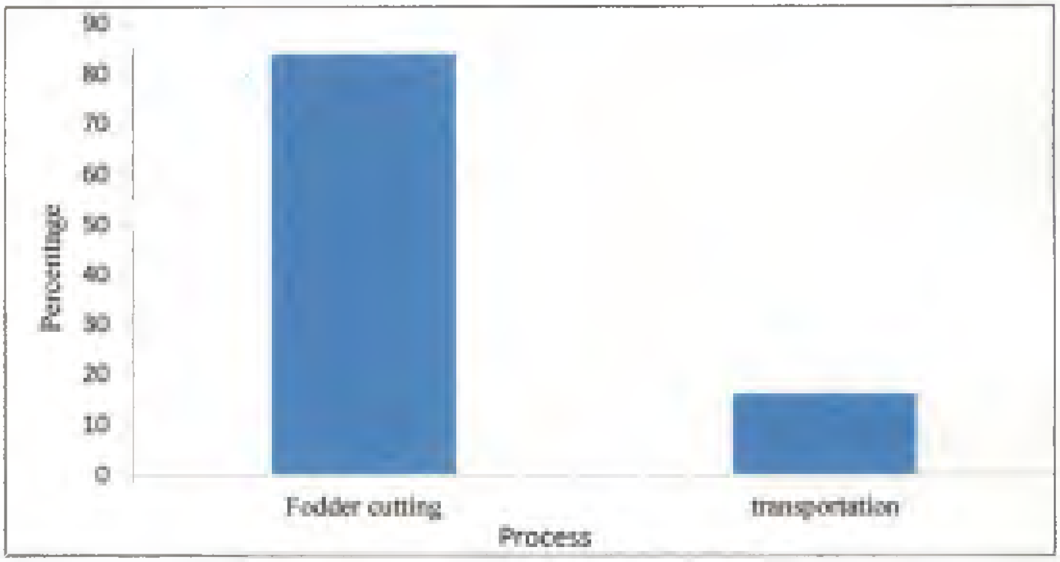

Figure 19. Human energy usage in the fodder unit

4.3.3 Energy input

The material inputs and the corresponding energy inputs in the dairy farm are depicted in Table 8. The highest energy input was accountable to feed which was 36301 MJ per 1000 L of milk produced followed by electrical energy input which amounted to 918.8 MJ per 1000 L of milk produced. Total machinery energy was obtained as 6.2 MJ per 1000 L of milk produced and was very small compared to other energy inputs.

Hosseinzadeh-Bandbafha *et al.* (2016) reported that feed constituted the highest average energy input of 135,079 MJ cow^{-1} which was about 91.48 percent of the total energy inputs. In the present study 97 percent of the energy was accountable to feed. The average energy contribution of fossil fuels and electricity were 9405 and 2056 MJ cow $^{-1}$ respectively in their study. In the present study 4.6 MJ/ cow/ day of electricity was used whereas usage of other fossil fuels were negligible. The total fossil fuel and electricity consumption of 7824 and 1699 MJ cow^{-1} was estimated in a similar study conducted by Sefeedpari *et al.* (2014) and the results varied due to the differences in the production situation. However, the acquired results from different farms could vary based on the total energy consumptions in the dairy and farm operations.

Table 8. Input of material and energy

Inputs	Quantity per 1000 L of milk produced	Total energy per 1000 L of milk produced (MJ)	Percentage of total
1. Diesel (L)	0.68	32.5	0.08
2.Electricity (kWh)	77	918.8	2
3.Human labour (h)	68.2	133.8	0.35
4.Total Feed		36301	97
(a)Concentrate (kg)	2318.1	31527.1	
(b) Straw (kg)	340.9	3153.3	
(c) Grass silage (kg dry matter)	1080.4	1620.6	
5. Total Machinery		6.2	0.016
(a) Electric motor	2.51 x 10^{-3}	0.16	
(b) Prime movers other than electric motors (including self-propelled machines) (kg)	2.7 x 10^{-3}	0.14	
(c) other machinery	0.0946	5.9	
The total energy input (MJ)		37392.3	100

4.3.4 Energy output

Table 9 represents the outputs of material and energy. The amount of total output energy was calculated as 5062 MJ per 1000 L milk produced. Biogas and milk contributed 2362 MJ and 2700 MJ per 1000 L of milk produced. Hosseinzadeh-Bandbafha *et al.* (2016) found that out of the total output energy, 91.36 percent was related to milk and only 5.62 percent and 3.02 percent was related to meat and manure, respectively. Whereas in our study, out of the total energy output, 53 percent was accountable to milk and the remaining 47 percent was to biogas.

Table 9. Output of material and energy

Outputs	Quantity per 1000 L of milk produced	Total energy per 1000 L of milk produced	Percentage of total
Milk (kg)	1000	2700	53
Biogas (m^3)	107.4	2362	47
Total energy output (MJ)		5062	100

4.3.5 Unit wise energy inputs

Unit wise energy inputs in milk production are presented in Table 10. The energy input quantities represent the equivalent energies. When compared to other sources, electrical energy was the predominant energy source in all sections, except the fodder unit. Of the total energy input in cow shed 74 percent was supplied as electrical energy, followed by human energy (26 %). Electrical energy consumption of 53 percent was observed in the milk processing unit because milk chilling and milk packing are the predominant processes which utilized it. Biogas unit consumed 46 percent of energy in the milk processing unit. Electrical energy usage was zero in the fodder unit whereas, out of the total 38 MJ (per 1000 L of milk produced) of energy, 32.5 MJ was derived from the diesel consumed for transportation of fodder.

Unit wise energy consumption in milk production is depicted in Figure 20. The result indicated that the maximum consumption of electrical energy could be observed in the milk processing unit and there is zero consumption in the fodder unit. Human energy was mostly used in the cow shed and biogas consumption was highest in the milk processing unit.

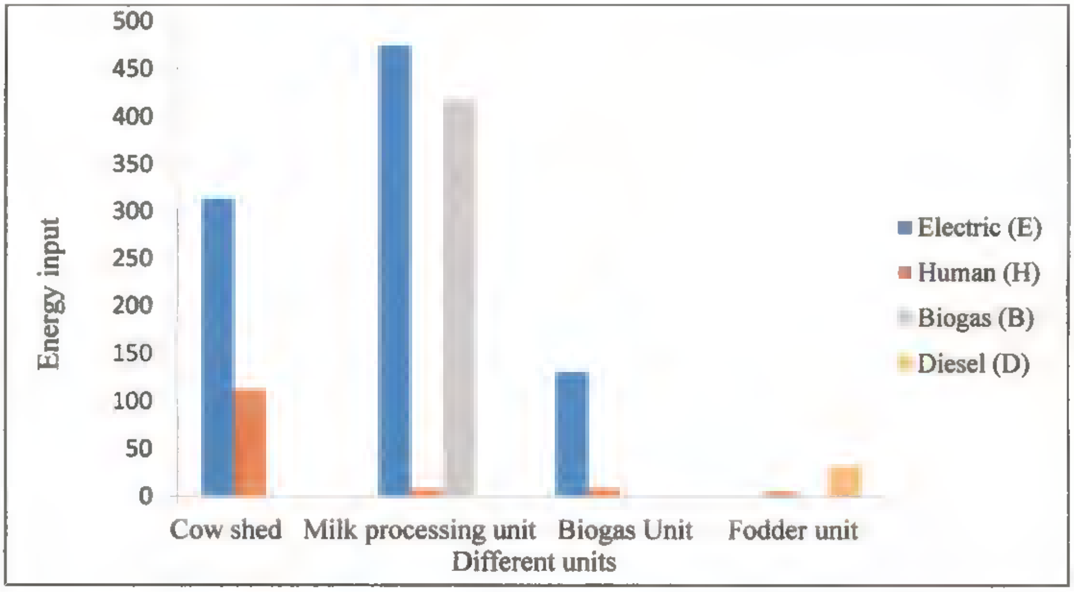

Figure 20. Unit wise energy consumption for milk production.

4.3.6 Different types of energy

Consumption of different types of energy in the milk production process was estimated and illustrated in Table 11. Renewable energy use in the dairy under investigation was calculated as 97 percent and the non-renewable energy use was only 3 %. The study conducted by Sefeedpari (2012) showed that renewable energy contributed around 52.86 percent in dairy farms. Hosseinzadeh-Bandbafha *et al.* (2016) estimated the share of direct energy as 8.1 percent. The direct energy fraction in the present study was only 4 percent. In consideration of the results of both the studies referred above, it was observed that the contribution of renewable energy in medium or small dairy farms in Kerala was generally fair where as a very small percentage was obtained as direct energy.

In the dairy farm under present investigation, electricity was used as the major power source for running various equipment and machines such as for water pump, milking machine, milk packing machine, freezer for milk chilling and lights. Diesel fuel usage was for transportation and was not significant in comparison to other sources. Thus for sustainable production of the farm and for reducing the use of fossil fuel and GHG emissions it is necessary to adopt to renewable sources of energy such as biogas and solar energy in the farm. Depending on renewable sources of energy than fossil fuels can improve the overall energy efficiency and aid emission reduction which is also an eco-friendly way to combat climate change.

Table 10. Unit wise energy in milk production (per 1000 L of milk processed)

Process	Energy input, per 1000 L of milk produced, MJ								
	Electric (E)	Human (H)	Biogas (B)	Diesel (D)	Total (T)	% E	% H	%B	% D
Cow shed	313.3	111.5	-	-	424.8	74	26	-	-
Milk processing unit	474.3	7.9	417	-	899.2	53	0.7	46.3	-
Biogas unit	131.2	8.9	-	-	140.1	94	6	-	-
Fodder unit	-	5.5	-	32.5	38	-	14	-	86
Total units	918.8	133.8	417	32.5					

Table 11. Different types of energy

Items	MJ (Quantity per 1000 L of milk produced)	% of total energy
Direct / Indirect energy		
Direct energy	1502.1	4
Indirect energy	36307.2	96
Total	37809.3	100
Renewable / Non-renewable energy		
Renewable energy	36434.8	97
Non- renewable energy	957.5	3
Total	37392.3	100

4.3.7 Energy indices

The different energy indices such as energy ratio, energy productivity, net surplus energy, specific energy and energy intensity were calculated and the results are shown in the Table 12. Where the net surplus energy was calculated as -164.9 MJcow^{-1}, energy ratio was 0.13, energy productivity was 0.026 kgMJ^{-1} and specific energy was 37.2 MJkg^{-1}. Energy ratio indicated the inefficient use of energy in the farm. Better production could be attained in the farm by maximizing the output with minimum input.

Table 12. Energy indices in milk production process

Item	Unit	Average
ER	-	0.13
NEG	MJ cow^{-1}	-164.9
EP	kg MJ^{-1}	0.026
SE	MJ kg^{-1}	37.2

4.4 POTENTIAL OF BIOGAS UNIT IN RENEWABLE ENERGY PRODUCTION AND EMISSION REDUCTION

The salient results on the investigations done to assess the potential of biogas unit attached to the dairy in renewable energy production and emission reduction are discussed in this section.

4.4.1 Biogas plant

The biogas plant available in the dairy was a fixed dome type plant, which consisted of a digester with a dome shaped gas holder. The digester and the dome were constructed with brick masonry and reinforced cement concrete. The plant was constructed underground so as to protect it from physical damage and also to save space. The plant had a capacity to produce 60 m^3 of biogas per day. The digester capacity was 150 m^3 so as to enable feeding of 3 m^3 slurry per day. The slurry was formed by mixing of wash water with dung and urine in the cow shed which drained automatically by gravity flow to a trough at the center of the cow shed and directed to the digester of the biogas plant through the inlet pipes. This gas was supplied for household cooking and the milk processing unit through the gas piping. The spent slurry was collected in a slurry tank of 51.2 m^3 capacity and pumped occasionally to the fodder crop.

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4.4.2 Biogas production potential

The important parameter for assessing the biogas production potential was the availability of cow dung in a day. The body weights of cows along with their dung production are given in Table 13. Forty six percent of the cows had a body weight in the range 400-500 kg and the calves had a body weight ranging from 300-400 kg. The average dung production of 43 cows in a day was found to be 697.4 kg.

Other relevant parameters considered are shown in Table 14. The water used in the dairy for cleaning the floor of the cow shed as well as washing the cows was found to be 12,840 L per day, which was diverted to the biogas plant along with the dung and urine. The TS of cow dung was estimated to be 19.8 percent. The total slurry input to the biogas plant was estimated by considering the total dung production and water used in the dairy which was 13.6 m^3. The daily slurry output was observed to be 14.3 m^3. The difference between the output and input slurry volumes could be accounted to the urine produced by the cows and slight variations in the actual water use. The average methane content of the biogas produced was found to be 70 percent.

An important aspect observed with the operation of the biogas plant is that the hydraulic loading rate of the system is very high due to the addition of wash water. The water use in the dairy was observed to be very high (0.29 m^3/cow /day). This results in reduction of the Hydraulic Retention Time of the biogas plant to significantly short duration so that the anaerobic digestion is likely to be incomplete. This also resulted in lower gas volumes.

Table 13. Dung productions based on body weight classification

Body weight	Number of cows	Total Dung production
200- 300	5	61.5
300-400	4	58.3
400-500	20	303.9
500-600	14	273.3
600 above	Nil	-
Total	43	697.4

Table 14. Parameters of the dairy relevant to biogas production

Average body weight of cow, kg	495.9
Total dung production per day, kg	697.4
Average methane content of biogas, %	70
Total solids of outgoing slurry, mg/ L	60,000
Average biogas productivity of cow dung, L/ kg	40
Slurry output, m^3	14.3
Dry matter content of cow dung, %	19.8
Input, m^3	13.6
Total water used per day, L	12,840
Estimated daily gas production, m^3	27.8
Volume of slurry tank, m^3	51.2

The average biogas usage of the farm was found to be 8605.25 L/day. The estimated daily gas production was 27896L and only 8605.25 L of biogas was utilized in the farm. The total electricity usage in the farm was 16.93 kWh/day. Estimated utilization potential is given in Table 15.

Table 15. Biogas production potential in the dairy farm

Type of feed stock	Gas yield (L/kg)	Manure availability per day in the farm (kg)	Gas yield per day (L)	Gas utilized (L/Day)	Biogas balance (L/Day)
Cattle dung	40	697. 4	27896	8605.25	19290.7

4.4.3 Conventional energy usage and Biogas equivalent

The consumption of electricity use per day for the milk production processes is shown in the Table 16. The energy consumption was more for milk chilling which was 73.3 MJ per day followed by pumping water 47.2 MJ. Very little energy consumption was observed for lighting which was only 1.4 MJ per day. When the process is advanced more energy sources like electricity will be consumed. The biogas equivalent for each process is shown in the Table 16. Replacement of electrical energy use by biogas can save the conventional energy usage as well reduce the environmental impacts.

Figure 21 is the graphical representation of the electricity usage per day and their biogas equivalent. It is clear from the figure that 7.5 m^3 of biogas will be required to meet this higher consumption of 6.15 kWh/ day for milk chilling and 3.96 kWh/ day for pumping water.

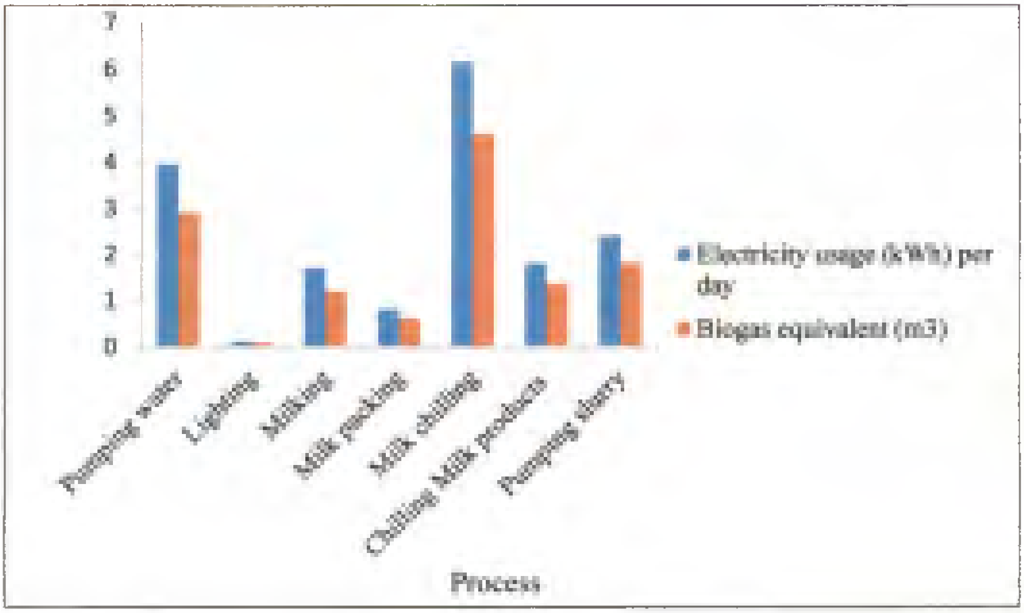

Figure 21.Consumption of electricity in milk production process and their biogas equivalent (per day)

Table 17 depicts the biogas balance and the daily biogas production in the farm. The daily biogas production was estimated as 27.8 m^3/ day. The farmer at present utilized only 8.6 m^3/ day. The total electricity usage in the farm was estimated as 16.93 kWh / day for which the equivalent quantity of biogas 12.6 m^3/ day. The balance biogas of 19.2 m^3 is more than the requirement and hence apart from the electricity demand of the dairy, domestic demand of the farmer and his family can also be met from biogas.

Table 16. Consumption of electricity in milk production process and their biogas equivalent (per day).

Process	Electricity usage (kWh) per day	Energy usage (MJ) per day	Biogas equivalent, m^3
Pumping water	3.96	47.2	2.9
Lighting	0.12	1.4	0.09
Milking	1.7	20.2	1.2
Milk packing	0.8	9.54	0.6
Milk chilling	6.15	73.3	4.6
Chilling Milk products	1.8	21.4	1.35
Pumping slurry	2.4	28.6	1.8
Total	16.9	201.6	12.6

Table 17. Biogas balance in dairy farm

Total Electricity usage, kWh / day	16.93
Biogas equivalent, m^3	12.6
Biogas yield, m^3 /day	27.8
Estimated biogas usage m^3/ day	8.6
Present biogas balance m^3/ day	19.2

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4.5 GHG EMISSION IN THE FARM

The results of the studies conducted to estimate the GHG emissions from the dairy farm are presented in this section.

4.5.1 GHG emissions due to inputs

The GHG emissions in milk production due to use of different inputs are shown in Table 18. The total emission from the use of diesel fuel was 1.88 kg CO_{2eq} per 1000L of milk produced and the emission from the electricity usage was nearly 46.8 kg CO_{2eq} per 1000L of milk produced.

Table 18. GHG emissions due to inputs in milk production (Per 1000L of milk produced)

Input	GHG coefficient, kg CO_{2eq} per 1000 L of milk produced	Emission, kg CO_{2eq} per 1000 L of milk produced
Machinery (MJ)	0.071	0.44
Electricity (kWh)	0.608	46.8
Diesel fuel (L)	2.76	1.88
Total	-	49.12

4.5.2 Estimation of GHG emissions using model

The GHG emission from the dairy farm was estimated by running the simulation model GLEAM- *i* and Table 19 shows the different input parameters used for the herd module. The farm consisted of 43 cows in which 9 were calves and 34 were matured female cows. There were no adult reproductive males in the farm. The average age of first calving was around two years. Only one cow was replaced in the farm. The average weight at birth and the weight of the adult cows were 25 kg and 495 kg, respectively.

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Table 19. Different parameters for the herd module

Parameters	Quantity
Total animals	43
Adult reproductive females (heads)	34
Adult reproductive males (heads)	0
Age at first calving (weeks)	104
Fertility of adult females (%)	73.9
Mortality of young females (%)	23.1
Mortality of young males (%)	7.6
Mortality of adult animals (%)	0
Adult female replacement (%)	2.9
Average weight at birth (kg)	25
Average weight of adult females (%)	496
Milk yield (kg)/day	220.16
Milk fat content (%)	3.49
Milk protein content (%)	2.79

Table 20 shows the total milk production of cows during a week and the relevant parameters of milk viz. milk fat and protein content. The total milk yield during a week was 1541.1 L and this data was extrapolated for determining the annual average milk yield of the cow.

Table 20. Daily data of milk production, milk fat and protein content

Day	Milk production (L)	Milk fat content	Milk protein content
1	196.52	3.9	2.80
2	203.12	4.1	2.92
3	222.15	3.7	2.79
4	226.09	2.6	3.04
5	217.5	3.5	2.74
6	235.17	3.1	2.12
7	240.5	3.5	3.1
Average	220.16	3.49	2.79

The feed module included the feed components. The percentage over dry matter intake (DMI) of feed components is given in Table 21. A total of 943 kg of feed was given to cows on daily basis (roughage and concentrate) which included hay, napier grass, maize powder, pellets, urad bran, bran and ground nut cake. The total dry matter intake was 719.41 kg and the DMI/cow/day was estimated to be 16.73 kg.

Manure module is based on the manure management systems and in the present study 90 percent of the total manure in the farm was subjected to anaerobic digestion in the biogas plant and remaining 10 percent was removed and applied to the nearby fields within 24 hours of excretion.

Table 21. Dry matter intake of different feeds

Feed type	Feed intake (kg)	Dry matter (%)	Dry matter intake (DMI)
Rice Bran	300	87.1	261.3
Maize powder	50	90.2	45.1
Urad bran	100	58.3	58.3
Ground nut cake	10	62.5	6.25
Pellets	50	91.5	45.75
Hay	75	86.6	64.95
Napier grass	363	65.5	237.77
Total (kg)	948	541.7	719.41
Average DMI/cow/day=719.41/43 = 16.73 kg			

4.5.3 Results from the model

The results obtained from the model gave a satisfactory estimate of the GHG emission from the dairy farm. Table 22 shows the estimated total emission by gas as 168,035 kg CO_2-eq /year. The contribution of the major GHGs such as CO_2, CH_4 and N_2O was 20157, 126697, 21180 kg CO_2-eq /year, respectively. Out of the total GHG emissions, major share was contributed by CH_4 (75%) followed by CO_2 (12%) and N_2O (13%). Total CH_4 emissions were found as 322 g CH_4 /cow/day in the farm. The CH_4 emission is mostly affected by the cow feeding systems and the N_2O emission is related to the nitrogen excretion from the animal. There is always a slight effect of the manure management technologies in the GHG emission of the dairy cow (FAO, 2010). These results are comparable with the recent study of

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Broucek (2014) where he estimated the values CH_4 emission in dairy cows in the range of 151 to 497 g/day whereas lactating cows produced more CH_4 (354 g/day) than dry cows (269 g/day). The estimated emission was from HF cows and is in conformity with the observation of Bell *et al*. (2012). They observed that Holstein produces more CH_4 (299 g/day) than the crossbred (264 g/day).

From the model, total CH_4 emission from manure management was 41.36 g / head/ day in the farm. However it is not valid to compare the result from other studies, because of different methodologies and due to the absence of a single standard methodology for the estimation. So the emission values can vary based on the farming systems, type of feeding, body weight, milk production, manure management techniques and several other factors (Bell *et al*., 2012).

Table 22. Total emission by gas

Variable	Unit	Value
Total GHG emissions	kg CO_2-eq/year	168,035
Total CO_2 emissions	kg CO_2-eq/year	20,157
Total CH_4 emissions	kg CO_2-eq/year	126,697
Total N_2O emissions	kg CO_2-eq/year	21,180

Figure 22 illustrates the total GHG emissions in the farm. Of the total GHG emission in the farm, 75 percent of emission is in the form of CH_4, 11 percent of it is in the form of CO_2 and 12 percent by N_2O. Table 23 depicts the emission from enteric fermentation and manure management. Of the total CH_4 emission most of it is contributed by enteric fermentation. Manure management results in CH_4 and N_2O emission.

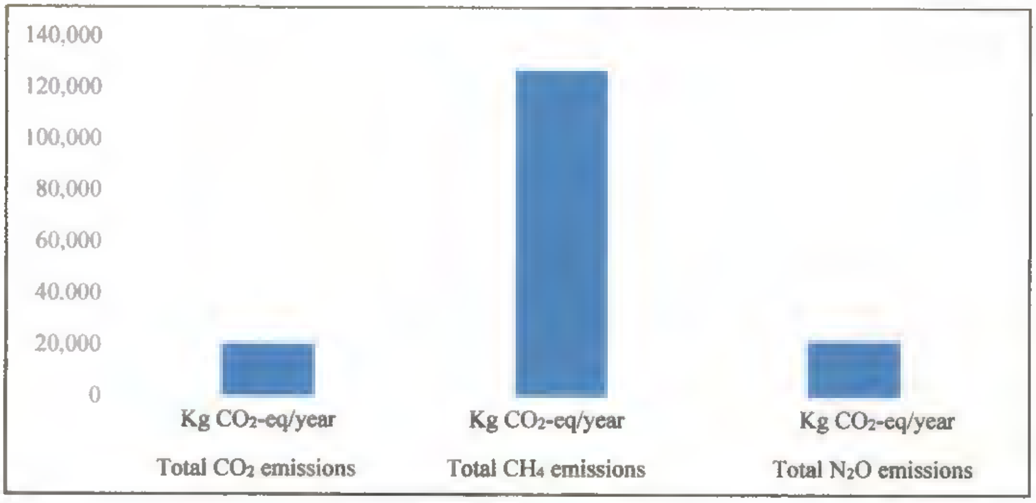

Figure 22. GHG emission

Table 23. Emission from enteric fermentation and manure management

Variable	Unit	Value
Enteric fermentation	kg CO_2-eq/year	110,397
Manure (methane)	kg CO_2-eq/year	16,300
Manure (nitrous oxide)	kg CO_2-eq/year	69

Figure 23 shows the graphical representation of the emission from enteric fermentation and manure management. Mitigation methods which can be adopted in this sector to reduce emissions are possible by identifying the major emission sources and by determining the factors which can contribute to the emission scenario. The amount of emission mainly depend on several factors such as livestock numbers, amount of manure produced, nitrogen content, type of manure storage, temperature and percent of manure decomposed anaerobically (IPCC, 2006).

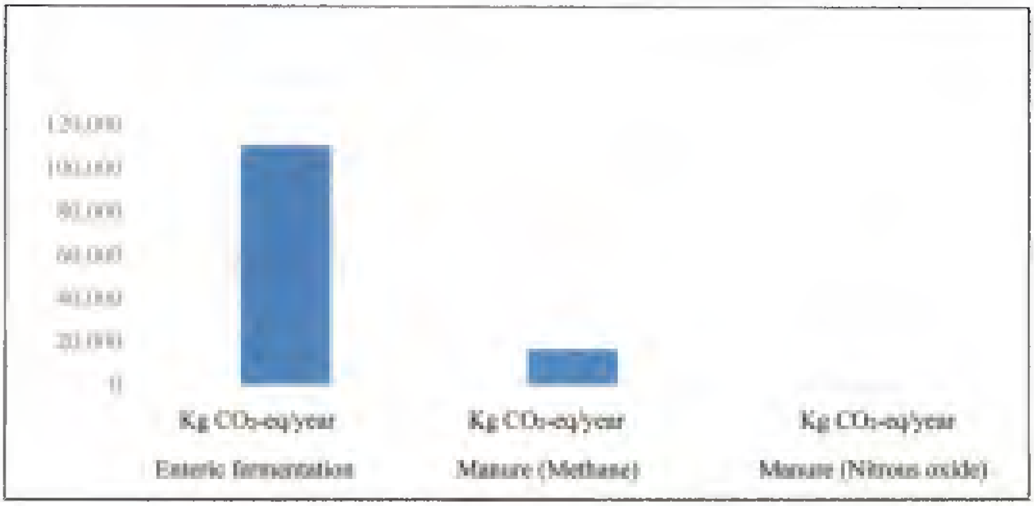

Figure 23. Emissions from enteric fermentation and manure management

4.5.4 Total GHG emission from various inputs in the farm

Table 24 illustrates the total GHG emission in the farm. The total GHG emission estimated was 1626.6 kg CO_2 eq per 1000 L of milk produced. The maximum share was from enteric fermentation and manure management techniques.

With effective manure management techniques in the farm, emission was reduced than expected and also by the production of electricity by biogas we could control the emission from electricity which is accounted as 46.8 kg CO_2 eq per 1000 L of milk produced and thereby we can restrict the total.emission to 1579.8 kg CO_2 eq per 1000 L of milk produced. When we estimate the values for a year, out of the total GHG emission of 3039.7 kg CO_2 eq /cow/ year it was found that GHG emission can be reduced to 2952.2 kg CO_2 eq / cow/ year by producing electricity from biogas.

GHG is mainly emitted during combustion of fossil fuels such as coal, oil and natural gas to produce electricity. Electricity usage can result in emission as well as many environmental impacts. If effective manure management techniques by using a biogas plant were not implemented in the farm, then the GHG emission in the farm would have been higher than estimated. Especially N_2O emission will be more which is released during improper manure handling and storage techniques. Effective manure management techniques in the farm also helped to reduce the odour emission. Biogas is clean and renewable fuel and by producing electricity using biogas could reduce the environmental impacts as well as GHG emissions in the farm.

Table 24.GHG emissions in the farm (per 1000 L milk produced)

Inputs	GHG emissions (kg CO_2 eq)
Diesel	1.8
Machinery	0.44
Electricity	46.8
Manure	203.6
Enteric fermentation	1374
Total GHG emissions	1626.6

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

The climate change mitigation strategies have a major focus on conservation of energy and use of renewable energy. With the rising population and with the limited sources of energy availability, we need to utilize energy more effectively. Moreover India has a commitment in emission reduction as per the Paris agreement. Dairy farms use more energy than any other agricultural sectors and the dairy farmers are now facing great challenges due to the increasing energy costs and the rising concerns about environmental impacts of GHG emissions. Use of renewable energy and adoption of energy efficient and environment friendly management methods will not only reduce the environmental impacts but will also help to improve the productivity and profitability of dairy farms. There are several ways by which we can reduce the consumption of electrical energy usage in dairy farm by using more energy efficient equipment's and by altering the management practices and by relying more on renewable sources of energy. Biogas plants can be seen as an integral part of a strategy aimed at production of renewable energy in dairy farms.

Animal sector is an important contributor of GHG emissions. Globally the livestock sector adds greenhouse gases, especially methane to the emission pool. The methane emission from enteric fermentation and improper manure management is often the focus of criticism and India is often pictured as a big emitter due to its large cattle population. India being figured fourth in the list of largest emitters, it is imperative that the Indian dairy sector need to be monitored in order to evolve mitigation strategies.

Hence the study was taken up to investigate the energy use pattern in a dairy farm of *Peramangallur mana*, Pattambi as well as the extent of methane emission with a view to analyze the economic and environmental advantage of producing renewable energy from anaerobic digestion of cattle dung. Based on this study the following conclusions were drawn:

- In the present study the total average input and output energy were calculated as 37392.3 MJ and 5062 MJ respectively, per 1000 L of milk produced.
- Feed and electricity had the largest share with 97 and 2 percent respectively in energy use.
- The lowest fraction of energy consumption was noted for diesel and machinery.
- Renewable energy use in the dairy under investigation was calculated as 97 percent and indirect energy 96 per cent.
- The different energy indices in the farm were obtained and the energy ratio was calculated as 0.13. The low energy ratio indicated the inefficient use of energy in the farm. Better production can be attained in the farm by maximizing the output with minimum use of input. The net surplus energy of the farm was calculated as -164.9 $MJcow^{1}$, energy productivity was 0.026 $kgMJ^{-1}$ and the specific energy was 37.2 $MJkg^{-1}$.
- Even though the efficiency of the farm was considered to be low, 97 percent of the energy consumption as renewable energy could be considered as a welcome aspect for sustainable dairy production.
- Unit wise energy consumption was also obtained and when compared to other sources, electrical energy was the predominant energy source in all sections, except the fodder unit. Electrical energy use was zero in the fodder unit.
- The total CH_4 emissions were obtained as 322 CH_4 g/cow/day in the farm.
- The total CH_4 emission from manure management was found to be 41.36 g/ head/ day.
- The total GHG emission from electricity usage in the farm was 87.46 kg CO_2 eq /cow/ year.
- The potential biogas production was 27.8 m^3 per day and only 8.6 m^3 was used presently. It was inferred that production of electricity with the available balance biogas of 19.2 m^3 per day could save electrical energy use.
- Out of the total GHG emission of 3039.7 kg CO_2 eq /cow/ year it was found that GHG emission can be reduced to 2952.2 kg CO_2 eq / cow/ year by producing electricity from biogas.

- The most efficient way to reduce GHG emission from manure management system is through anaerobic digestion and this can reduce the GHG emission from dairy cattle slurries and manure. Renewable energy use in dairy farms can be an effective strategy to combat emission reduction.

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ABSTRACT

ENERGY USE AND EMISSION REDUCTION IN DAIRY FARM

by

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(2011 - 20 - 113)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the

requirements for the degree of

B.Sc. – M.Sc. (Integrated) Climate Change Adaptation

Faculty of Agriculture

Kerala Agricultural University

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

VELLANIKKARA, THRISSUR – 680 656

KERALA, INDIA

2016

ABSTRACT

Dairy farms use more energy than other agricultural sectors and hence climate change mitigation strategies have a major focus on use of renewable energy along with adoption of energy efficient and environment friendly management methods to improve the profitability of dairy farms. It is widely believed that livestock is contributing largely to the emission pool. The methane emission from enteric fermentation and improper manure management is often the focus of criticism. India being figured fourth in the list of largest emitters, it is imperative that the Indian dairy sector need to be monitored in order to evolve mitigation strategies. Hence this study was intended to investigate the energy use pattern in a medium dairy farm as well as the extent of GHG emission with a view to analyze the economic and environmental advantage of producing renewable energy from anaerobic digestion of cattle dung. The study was conducted at the Permangallur Dairy Farm at Pattambi, Palakkad district. The energy use pattern in different sections of the dairy farm was observed using standard techniques and an energy analysis was done. The total GHG emissions from cattle (enteric fermentation and manure management) were analyzed by using the GLEAM-*i* model of FAO. In the present study the total average input and output energy were calculated as 37392.3 MJ and 5062 MJ per 1000 L of milk produced. Feed intake had the highest share (97%) from total input energy, followed by electricity (2%). The CH_4 emission per cow was found as 322 g/day in the farm. The total CH_4 emission from manure management was found to be 41.36 g / head/ day. The total GHG emission from electricity usage in the farm was 87.45 kg CO_2 eq /cow/ year. The potential biogas production was 27.8 m^3 per day and only 8.6 m^3 was used presently. It was inferred that production of electricity with the available balance biogas of 19.2 m^3 per day could save electrical energy. Out of the total GHG emission of 3039.7kg CO_2 eq /cow/ year it was found that GHG emission can be reduced to 2952.2kg CO_2 eq / cow/ year by producing electricity from biogas.

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APPENDICES

APPENDIX I

Data of body weight of cow

Cow No.	Length (inches)	Girth (inches)	Pounds	kg
1	66.980	76.042	1291.0	586.1
2	61.070	66.98	913.3	414.6
3	65.010	75.254	1227.2	557.2
4	63.040	70.920	1056.9	479.8
5	65.010	72.890	1151.3	522.7
6	66.980	75.254	1264.4	574.0
7	66.192	74.466	1223.5	555.5
8	62.252	67.768	953.0	432.7
9	70.132	72.496	1228.6	557.8
10	63.040	68.556	987.6	448.4
11	66.980	78.800	1386.4	629.4
12	57.130	73.284	1022.7	464.3
13	64.616	68.556	1012.3	459.6
14	66.980	76.830	1317.9	598.3
15	61.858	76.830	1217.1	552.6
16	61.070	70.920	1023.9	464.8
17	66.192	76.436	1289.1	585.2
18	62.252	67.768	953.0	432.7
19	62.252	69.738	1009.2	458.2
20	63.040	70.526	1045.2	474.5

21	57.130	73.284	1022.7	464.3
22	61.070	70.920	1023.9	464.8
23	63.040	70.920	1056.9	479.8
24	61.858	66.586	914.2	415.0
25	59.100	72.102	1024.1	465.0
26	61.070	67.768	934.9	424.4
27	63.040	74.860	1177.6	534.6
28	61.070	70.920	1023.9	464.8
29	60.676	70.920	1017.3	461.8
30	65.010	76.042	1253.0	568.9
31	59.100	76.436	1151.0	522.5
32	68.556	80.770	1490.8	676.8
33	55.948	67.768	856.5	388.8
34	62.252	70.132	1020.6	463.4
35	59.100	64.222	812.5	368.9
36	55.160	72.496	966.3	438.7

APPENDIX II

Data of milk production

Day 1			
Cow No.	Morning(kg)	Evening(kg)	Total(kg)
1	0.41	2.46	2.87
2	5.17	3.165	8.335
3	7.22	2.68	9.9
4	6.07	3.68	9.75
5	1.51	0.43	1.94
6	3.77	2.49	6.26
7	4.24	2.21	6.45
8	4.01	1.8	5.81
9	7.86	7	14.86
10	5.285	3.37	8.655
11	6.845	2.24	9.085
12	5.87	3.45	9.32
13	5.91	2.49	8.4
14	3.46	2.15	5.61
15	3.29	2.14	5.43
16	2.09	1.2	3.29
17	3.74	2.45	6.19
18	6.38	3.16	9.54
19	2.92	1.74	4.66

20	6.08	3.7	9.78
21	7.06	4.53	11.59
22	2.61	0.95	3.56
23	4.55	2.715	7.265
24	4.75	3.39	8.14
25	7.95	4.33	12.28
Day 2			
Cow No.	Morning(kg)	Evening(kg)	Total(kg)
1	3.83	1.59	5.42
2	5.11	3.14	8.25
3	3.18	1.9	5.08
4	6.02	3.61	9.63
5	1.225	0.75	1.975
6	4.63	2.57	7.2
7	4.3	2.13	6.43
8	4	2.65	6.65
9	6.78	3.93	10.71
10	4.32	3.23	7.55
11	5.67	3.3	8.97
12	6.24	3.65	9.89
13	5.88	3.51	9.39
14	6.24	4.48	10.72
15	1.32	3.18	4.5

16	4.37	2.35	6.72
17	5.31	3.5	8.81
18	2.78	1.79	4.57
19	3.13	1.72	4.85
20	1.83	1.08	2.91
21	4.24	3.04	7.28
22	6.28	2.86	9.14
23	2.95	2.005	4.955
24	5.32	2.87	8.19
25	7.25	4.22	11.47
26	5.44	2.98	8.42
27	8.07	5.37	13.44
28	3.45	3.00	6.45
Day 3			
Cow No.	Morning (kg)	Evening(kg)	Total(kg)
1	3.13	2.24	5.37
2	5.11	2.51	7.62
3	2.15	1.65	3.8
4	5.78	2.49	8.27
5	1.45	0.59	2.04
6	4.21	2.71	6.92
7	3.89	2.02	5.91
8	3.46	1.98	5.44

9	6.89	4.13	11.02
10	3.85	2.485	6.335
12	4.78	3.77	8.55
13	7.22	3.825	11.045
14	5.88	4.81	10.69
15	6.56	4.02	10.58
16	2.34	0.535	2.875
17	4.56	2.74	7.3
18	5.67	3.31	8.98
19	3.21	1.92	5.13
20	1.65	1.45	3.1
21	2.55	1.025	3.575
22	5.4	1.94	7.34
23	6.06	5.26	11.32
24	3.77	3.8	7.57
25	2.32	2.68	5
26	6.54	3.76	10.3
27	3.23	3.14	6.37
28	5.89	4.94	10.83
29	3.12	4.17	7.29
30	6.78	4.34	11.12
31	6.7	3.825	10.525
Day 4			

Cow No.	Morning (kg)	Evening(kg)	Total(kg)
1	4.43	2.625	7.055
2	4.85	2.775	7.625
3	4.033	1.755	5.788
4	5.96	3.65	9.61
5	0.675	0.56	1.235
6	4.16	2.305	6.465
7	4.2	2.28	6.48
8	3.28	2.55	5.83
9	7.73	4.65	12.38
10	4.64	3.19	7.83
11	8.16	6.02	14.18
12	2.1	3.3	5.4
13	5.915	1.53	7.445
14	7.7	3.55	11.25
15	2.6	1.28	3.88
16	3.72	2.195	5.915
17	1.005	3.14	4.145
18	3.23	1.87	5.1
19	3.285	1.765	5.05
20	1.905	1.035	2.94
21	4.265	2.53	6.795
22	6.78	4.015	10.795

23	6.512	1.775	8.287
24	5.91	4.188	10.098
25	6.53	4.21	10.74
26	5.96	2.865	8.825
27	8.9	4.28	13.18
28	2.87	1.34	4.21
29	6.5	3.69	10.19
30	7.4	5.37	12.77
Day 5			
Cow No.	Morning (kg)	Evening(kg)	Total(kg)
1	4.97	2.25	7.22
2	5.12	3.22	8.34
3	3.12	1.69	4.81
4	5.68	3.5	9.18
5	0.97	0.34	1.31
6	2.34	1.97	4.31
7	2.15	1.91	4.06
8	3.4	2.3	5.7
9	6.34	4.94	11.28
10	5.71	3.88	9.59
11	4.11	3.8	7.91
12	2.1	3.6	5.7
13	6.12	3.37	9.49

14	7.67	5.33	13
15	2.86	1.83	4.69
16	5.32	3.405	8.725
17	2.9	2.82	5.72
18	4.23	1.905	6.135
19	4.54	1.86	6.4
20	4.5	3.1	7.6
21	3.78	1.465	5.245
22	5.12	3.15	8.27
23	2.13	1.49	3.62
24	3.54	2.775	6.315
25	5.56	3.78	9.34
26	3.43	3.13	6.56
27	8.15	5.92	14.07
28	5.38	6.11	11.49
29	7.32	4.97	12.29
30	6.78	5.7	12.48
Day 6			
Cow No.	Morning (kg)	Evening(kg)	Total(kg)
1	4.155	2.81	6.965
2	5.35	3.17	8.52
3	3.28	1.95	5.23
4	5.69	3.605	9.295

5	0.44	0.325	0.765
6	4.3	2.315	6.615
7	3.215	1.48	4.695
8	4.19	2.08	6.27
9	7.19	4.525	11.715
10	5.13	3.48	8.61
11	6.61	3.655	10.265
12	1.232	1.54	2.772
13	6.06	3.73	9.79
14	6.76	3.12	9.88
15	1.23	4.395	5.625
16	3.2	2.69	5.89
17	4.74	2.943	7.683
18	3.35	1.35	4.7
19	2.465	3.905	6.37
20	1.77	1.12	2.89
21	2.76	1.83	4.59
22	5.38	2.085	7.465
23	3.25	1.415	4.665
24	5.6	2.925	8.525
25	6.9	4.27	11.17
26	5.39	2.92	8.31
27	7.01	4.53	11.54

28	10.34	6	16.34
29	7.02	4.375	11.395
30	10.045	6.58	16.625
Day 7			
Cow No.	Morning (kg)	Evening(kg)	Total(kg)
1	5.3	2	7.4
2	6.1	3.8	9.9
3	2.4	1	3.4
4	3.2	3.6	6.8
5	0.44	0.3	0.74
6	5	1.6	6.6
7	3	2.1	5.1
8	3.7	2.3	6
9	8	4.1	12.1
10	4.8	3.48	8.28
11	5.3	2.4	7.7
12	1.1	1.5	2.6
13	7.1	4.1	11.2
14	6.5	3.1	9.6
15	1.23	4.395	5.625
16	1.4	2	3.4
17	3.2	4.17	7.37
18	3.1	2.1	5.2

19	23	5.1	7.4
20	1.5	1.1	2.6
21	1.4	1.6	3
22	5	2	7
23	2.3	1.4	3.7
24	5.6	2.925	8.525
25	6.9	4.27	11.17
26	4.2	2.3	6.5
27	6.1	42.3	8.4
28	9.2	4.5	13.7
29	6.3	4.3	10.6
30	10	6.4	16.4