Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.6, No.1, 2016

Bio-Gas Technology Adoption in Rural Ethiopia: It's Effect on the Crisis of Deforestation

Lemlem Tajebe
Wolaita Sodo University, College of Agriculture, P.O.BOX 138, Wolaita Sodo, 'Ethiopia

Abstract
In developing countries, like Ethiopia, high population growth is the root cause of deforestation. The population has been increasing considerably since the turn of the 20th century with an annual growth rate of 2.58%. Either searching for new agricultural land or to promise the firewood demand people vastly encroached into forest land, this creates severe stress on the environment. As various figures explained, about 1.24 million ha of natural high forests cleared between 1990 and 2014. Since, nearly all of the households in rural areas and over 20 percent in urban centers depend on fire-woods, the situation leads to high rate of deforestation. To lessen the crisis of deforestation and to play down the high reliance on it the Ethiopia Alternative Energy Development and Promotion Center (EAEDPC) has launched the Biogas Plants to be reach at least 10,678 households between 2008 and 2014 in the selected Woreda's of four regions of the country, namely, Oromia, Amhara, Tigray, and SNNPR. However, despite the provision of the technology, a study that strongly concerned and assesses about the contribution of biogas plant for the problem of deforestation in particular and its advantage for sustainable development in general was lacking. To clearly observe the effect of biogas plant for various development activities the conversion factor was employed. The results confirmed that the scattered 10,678 bio-digester plants started to bring tangible benefits. Commencing this movement about 8732 tons of charcoal 27,162 tons of fuel wood and 5336 hectare of forest was saved. Moreover, about 66,463 [t] of biomass and 485 [t] of fossil fuel was substituted with the total implemented plants. This leads to the reduction of 64,684 [t CO_2eq] per year. Besides, 43,662kt of organic matter is made available as organic fertilizers. This makes farmers to be more productive within a small parcel of land. Hence, Biogas plant is environmental friendly, beneficial to a society and can augment the income of people; this lead to a sustainable way of development.
Keywords: Deforestation; Biogas technology adoption; Sustainable development

1. Introduction

The global energy demand is growing and is expected to continue to grow in the coming decades with the projected growth of the population and with the expansion of energy-dissipative economic activities. The industrialized countries depend primarily on modern energy while the developing countries heavily rely on traditional fuel (Mulugeta, 2002). In the industrialized world modern energy sector contributes more than 97 percent of the total primary energy demand and the remaining 3 percent was from biomass. In developing countries, the pattern is completely different and the contribution of modern energy is less than 49 percent (Miller, 1996).

Globally, 55% of the wood extracted from forests is for fuel, and is responsible for 5% of global deforestation (UNFCC, 2010). FAO (2000) statistics suggest that some 1.86 billion m^3 of wood is extracted from forests for fuel wood and conversion to charcoal. Of this total, roughly one-half comes from Asia, 28% from Africa, 10% from South America, 8% from North and Central America and 4% from Europe. More than 80% of the population in Sub-Sahara Africa relies mainly on solid biomass, that is to say firewood, charcoal, agricultural byproducts and animal waste in order to meet basic needs for cooking and lighting (Davidson *et al*., 2007).

In Ethiopia, nearly all of the households in rural areas and over 20 percent in urban centers depend on firewood for their cooking requirements, the situation leads to high rate of deforestation. Besides, these biomass fuels are burnt using smoky and inefficient traditional stoves with very poor combustion in unventilated kitchens producing a high concentration of dangerous pollutants: primarily carbon monoxide and particulate matter, and also nitrogen oxides and polyaromatic hydrocarbons (WHO, 2007). Moreover, the Organization estimates that exposure to indoor air pollution increases the risk of Acute Lower Respiratory Infections (ALRI) in children and Chronic Obstructive Pulmonary Disease (COPD) in adults. It is linked to poverty, with poor people more likely than richer people to use fuels that result in poor household air quality. The challenges are overwhelming a joint effort by all stakeholders is required to achieve considerable progress (World Energy Outlook, 2009).

Biogas technology is an integrated waste management system that is a clean, renewable, naturally produced and under-utilized source of energy. It is produced in an air tight tank from a variety of substrates, such as animal manure, food waste, energy crops and industrial wastes. This is a multi-biological process where the organic waste is mainly converted to a gaseous product composed of 50-70% methane and 25-40% carbon dioxide and trace of hydrogen sulfide, water vapor and ammonia (Igoni, 2007). The energy release allows biogas to be used as a fuel. The benefits to the household include diversification of energy supply, indoor air quality and health improvement, provision of an organic fertilizer with rich crop nutrients, enhanced regional and

rural development opportunities, and creation of a domestic industry and employment opportunities (Rio and Burguillo, 2008). Thus, the study attempted to assess the role of biogas technology adoption and its effect on the crises of deforestation in the rural parts of Ethiopia.

2. Methodology

The essay offers a great weight on critical analysis of secondary data and literatures. The specific methods employed here include review and analysis of the existing facts and figures on each of the questions of concern; causes and rate of deforestation, the trend of biogas plant adoption, and development implications of biogas technology. The essay heavily relies on NBPE (2014) report. To illustrate the role of biogas technology for various developmental activities the conversion factor was employed by coordinators of NBPE, the ministry of Water, Irrigation and Energy and SNV/ Netherlands Development Organizations i.e;

1 biogas plant ⇨
- Prevents 0.3 ha forest/yr from deforestation
- Mitigate 4 tons CO_2 eq/year
- Enhance the soil nitrification by 2.7 t (DM) bio-slurry/yr
- Reduces workload 0.08333 [per-year/yr]
- Reduces exposure to indoor air pollution by [5per/hh]

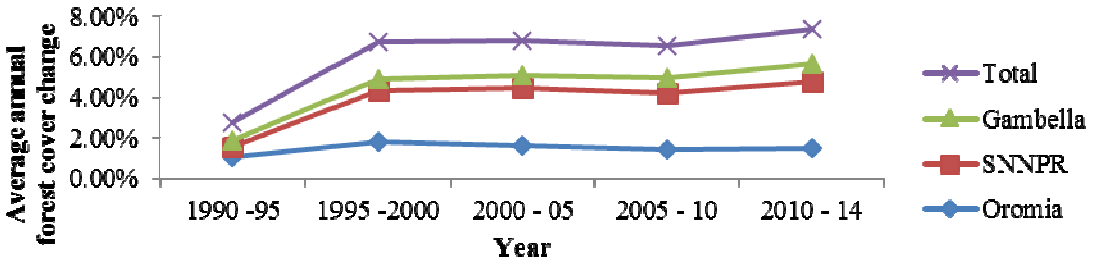
The size of the disseminated Biogas digesters (M^3) was different, 4, 6, 8, and 10, principally with adopter's cattle size. Thus, results obtained from the above conversion factor are varying according to its size. Therefore, there is a direct relation between the size of the digester and the assorted benefits attained. Data was obtained from SNV/ Netherlands Development Organizations, REDD+/ Reducing Emissions from Deforestation and forest Degradation and Ministry of Water, Irrigation and Energy. Then the collected data was analyzed and correlated using MS-excel, 2007 and presented in the form of tables and figures.

3. Results and Discussion

3.1. Causes and Rate of Deforestation in Ethiopia

One of the underline causes of deforestation and forest degradation through increasing demand for farmland, fuel wood, grazing land, settlement areas/expansion of urbanization. In Ethiopia estimates of deforestation, which is mainly for expansion of rain-fed agriculture, vary from 80,000 to 200,000 hectares per annum (EPA, 1997). Platt (2004) argued that forest fragmentation, conversion and modification have significant economic, social and environmental implications such as disruption in continuity of the natural landscape. This results in deterioration of vital habitats that sustain valuable biodiversity as well as broader issues such as air pollution. Though, Ethiopia has a population policy and strategy that aimed to control the high population growth and the pressure on natural resources, including forest (Getachew, 2008) but the effort to bargain the two thus far needs more work.

Figure 1 Forest cover changes in percentage for different periods as forecasted by WBISPP

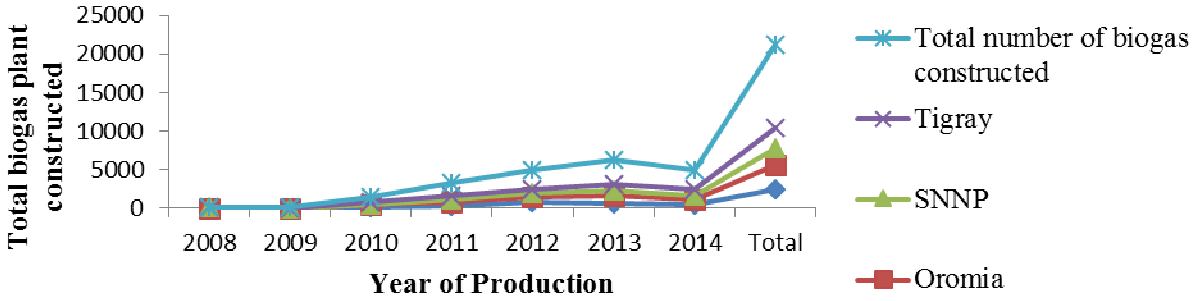


The above graph shows forest cover change in various parts of the country, Oromia, SNNPR and Gambella. The forest cover change from 2000-05 in Oromia, SNNPR and Gabella with the respective rate of 1.41%, 2.77% and 0.75%. Again, the deforestation rate increased from 2010-2014 and approached to 1.47%, 3.30% and 0.73%, respectively. Several case studies claim that agriculture and fuel wood as the major causes of deforestation. In Ethiopia, nearly all of the households in rural areas and over 20 percent in urban centers depend on firewood for their cooking requirements, the situation leads to high rate of deforestation. For instance, agricultural land expansion accounts for 82% of the high forest lost in parts of the South-central Rift Valley (Gessesse and Christiansson, 2008). In another study in the central and southern Rift Valley of Ethiopia, agricultural activity was determined to be the major cause accounting for 80% of the observed change in land cover and degradation in the period 1973 – 2000 (Bedru, 2006). Environmental destruction on this level will complicate the livelihood of the people living in rural areas since a majority of these people depend on agriculture and livestock keeping, and therefore rely on productive soils (Kupaza 2010).

3.2. Biogas Plant Adoption in Ethiopia

Biogas energy is in demand and their number is increasing gradually. As the NBPE, (2014) report showed that through the money obtained from SNV dissemination of the plant is increasing. In the present day, the programme equipped 10,678 households with bio-digester plants. The most important domestic uses of biogas are cooking and lighting. The plant harvest direct benefits from domestic biogas through the reduced use of traditional fuel sources, access to clean energy, reduced workload and health improvement all resulting in improved living conditions, from which particularly women and children will benefit more.

Figure 2 NBPE Biogas Plant Installation Report from 2008 - 2014 in Ethiopia



The benefits of biogas are not limited to the rural households only. Biogas contributes to job creation and skills enhancement (masons, managers, technicians, extension staff), private sector development, saving of foreign exchange as a result of a reduced use of kerosene, economic return for the public (economic internal rate of return of 78% for Ethiopia), slowing down of the rate of deforestation, and greenhouse gas reduction (NBPE, 2007). This process of modern-sector self-sustaining growth and employment expansion is assumed to continue until all surplus rural labor is absorbed in the new industrial sector. Thereafter, additional workers can be withdrawn from the agricultural sector only at a higher cost of lost food production because the declining labor to land ratio means that the marginal product of rural labor is no longer zero. Thus the labor supply curve becomes positively sloped as modern-sector wages and employment continue to grow. The structural transformation of the economy will have taken place, with the balance of economic activity shifting from traditional rural agriculture to modern urban industry.

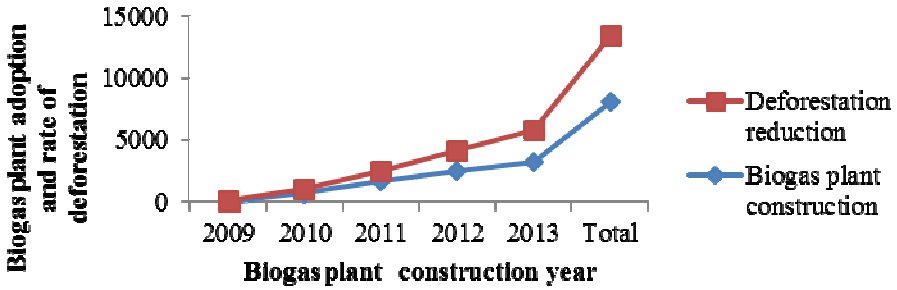
3.3. Developmental Implications with Biogas Technology

3.3.1. Environmental Benefit of Biogas plant

In Ethiopia, majorly rural people either searching for new agricultural land or to realize their fuel-wood demand vastly encroached into forest areas, resulting in a high rate of deforestation and forest degradation. According to Andrews (1999), no sector of human activity impacts the environment more pervasively than the production and use of energy. As various figures explained in Ethiopia about 1.24 million ha of natural high forests cleared between 1990 and 2014 (WBISPP, 2004). Energy conservation, use of alternative energy, and improved energy efficiency fill a significant role by enhancing the potential for sustainable development (Roosa, 2010). Inefficient and environmentally insensitive energy use causes a decline in the sustainability. This is due to the extensive environmental impacts resulting from energy use.

The EPE (1997) stated that the policy of energy resources integrates energy development with energy conservation, environmental protection and sustainable utilization of renewable resources. Moreover, promote the development of renewable energy sources and reduce the use of fossil energy resources for ensuring sustainability and for protecting the environment, as well as for their continuation into the future. Alike the intent of the planned policy, Biogas, a clean and renewable form of energy, could augment conventional energy sources because of its environment friendliness allowing for efficient waste utilization and nutrient recycling (Bhat *et al*., 2001). It is a versatile source of energy which meets several end uses, including cooking, lighting and motive power generation (Rubab and Kandpal, 1995). When used as a cooking fuel, it provides for better combustion than the less efficient cooking fuels like fire-wood. It is comparatively clean and hygienic because bacteria and other pathogens are destroyed through anaerobic treatment (Jingura and Matengaifa, 2008).

Figure 3 the link between biogas plant and the rate of deforestation



The introduction of biogas technology saved 8732 tons of charcoal 27,162 tons of fuel wood and 5336 hectare of forest. Moreover, about 66,463 [t] of biomass and 485 [t] of fossil fuel was substituted with the total implemented plants. This leads to the reduction of 64,684 [t CO_2eq] per year (NBPE, 2014). The current finding was in line with Bajgain and Shakya (2005). They declare that Biogas technology is helpful in reducing deforestation in several ways. Akinbami *et al*. (2001) adds that generally the new and renewable energy resource systems also offer attractive prospects because they preserve ecosystems and retard degradation of the environment. In fact, a proper functioning of biogas system in particular can provide multiple benefits to the users and the community resulting in resource conservation and environmental protection (Yadvika, 2004). Generally, biogas digesters have come to symbolize access to modern energy services in rural areas, and offer significant environmental benefits (Srinivasan, 2008).

All these benefits clearly show the MDG relevance of this biogas intervention by mainly contributing goal seven, ensuring environmental sustainability through integrating the principle of sustainable development into counties policies and pogrammes and by reversing the loss of environmental resources. This can be monitored through energy related indicators, such as the propagations of land area covered by forests, GDP per unit of energy use (as proxy of energy efficiency); carbon dioxide emissions (per capita); the programme of population using solid fuels and the % of renewable energy used versus the total energy consumption (UNDP, 2004).

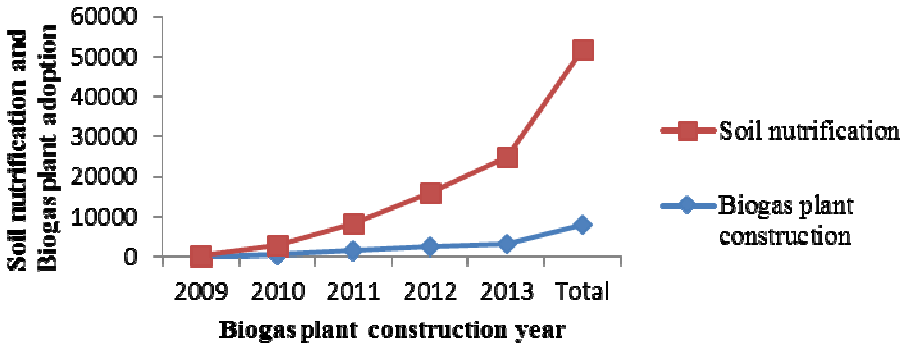
3.3.2. Economic Benefit of Biogas plant

Ethiopia has made clear that renewable energy will be a key economic driver, emphasizing green growth and clean energy as integral to its Growth and Transformation Plan, a five-year strategy to reduce poverty and spur national development. Recognizing electricity as a vital enabler of economic growth and human development, the plan aims to minimize the gap between demand and supply, increase per capita consumption, and generate power for export. Specifically, it sets goals to increase hydropower capacity from 2000 MW to 8,000-10,000 MW, double the number of electricity customers, from two million to four million by expanding access for new areas, and raise the national electrification rate from 41% to 75% (GTP, 2010). Therefore, National Biogas Program is also part of the growth and transformation plan and the program has contribution to the electrification and energy generation. The rate of production of biogas digester shows that it is constantly increasing from year to year. The energy production and power installation were also increasing accordingly. As a result the gross energy production of the first phase exercise was equivalent to 74,387MWh and net power installation of 20,717KW (NBPE, 2014).

The application of bio-slurry[1] in a farmland sustains cropping systems through better nutrient recycling and plays a direct role in plant growth as a source of all necessary macro and micronutrients. Since bio-slurry improves the water holding capacity of the soil, the soil structures, the soil aeration, the supply of carbon to the soil, and crumb structure. As a result it enhances yields much more than the inorganic nutrients. The NBPE (2014) report shows, as a result of biogas digester constructed so far by the programme 43,662kt of organic matter is made available as organic fertilizers. Hence it recovers the physical, chemical, and the biological properties of the soil.

[1] Bio-slurry, a by-product of biogas, is a high quality organic fertilizer and conditioner for soil that surpass farmyard fertilizer.

Figure 1 the link between biogas plan and soil nitrification



This leads to reduce the expenses and application of chemical fertilizer. Lantz *et al*. (2007) find out the same result with the current study. They discovered the advantage of biogas technology for the improvement of crop production. In Ethiopia where the technology is so far introduced and effectively slurry application is done bio-slurry is a good organic fertilizer that can replace or and increase the productivity of the farmers. Moreover, Biogas technology creates job opportunity for 564 people (NBPE, 2014).

The advantage obtained from the technology potentially enhances the economic welfare of adopter farmers' (NBPE, 2014). Moreover this certainty condenses the distinctly reliance of rural people on the natural resources, upshot in lessen the problem of environmental deterioration. One of the basic premises of sustainable development is that poverty is largely responsible for environmental degradation. Therefore, removal of poverty (i.e., development) is necessary for environmental sustainability. This, it is argued, implies that economic growth is absolutely necessary for sustainable development. The only thing that needs to be done is to change the quality of this growth (WCED, 1987) to ensure that it does not lead to environmental destruction. In drawing such an inference, however, there is the implicit belief that economic growth is necessary (if not sufficient) for the removal of poverty.

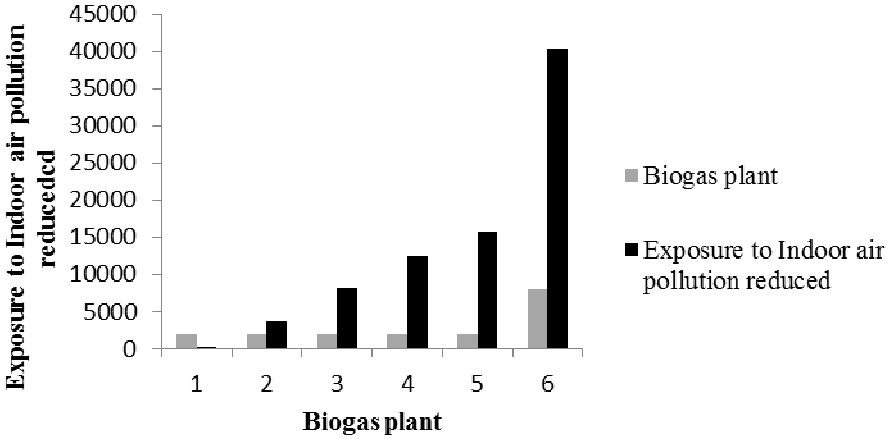
3.3.3. Social Benefit of Biogas Plant

Replacing biomass energy with biogas could help to solve a lot of problems that are typically associated with using biomass fuels. The indoor air quality of homes is dramatically improved as a result of employing biogas instead of burning firewood, crop residues and dung cakes. The substitution of highly polluting traditional fuels with biogas virtually eliminates indoor air pollution that causes respiratory disease, particularly among women and children who spend a lot of time in smoke-filled kitchens. Biogas is widely accepted in Ethiopia as a cooking and lighting fuel and mainly benefits women and children.

In Ethiopia the utilization of biomass fuel causes to be the death of 72, 400 people/year due to indoor air pollution (WHO, 2009). Besides in India, studies suggest that 130,000–150,000 women may die prematurely as a result of indoor air pollution (Smith, 2000). A study of rural households in central Kenya found that exposure to high emissions from cooking and other domestic activities for adults' results in women being twice as likely as men to be diagnosed with acute respiratory infection or acute lower respiratory infections (Ezzati and Kammen, 2001). This has been confirmed by similar studies in Gambia (Campbell, 1997) and Guatemala (Bruce *et al*., 1998). In addition, the increased time and energy involved in the collection of biomass fuels contributes to the physical burden and ill health of women and children.

The rural women work more hours a day and this workload are aggravated by the scarcity of firewood. Children's are often taken out of school to assist their mothers in collecting firewood. In reverse Biogas technology reduces the overall workload of women by providing the daily energy demand. As a result of the introduced technology the workloads on the women and children reduce and 40,315 peoples (women's and children) are protected from indoor air pollution (NBPE, 2014).

Figure 2 Biogas plant and indoor air pollution reduction



Introduction to Biogas technology has both direct and indirect influence on development. With Biogas energy, women and children are less exposed to hard work concerned with harnessing fuel wood together with toxic fuel from the indoor pollution when burning firewood. This leads to more time for education and income generating activities together with possibilities of lighting beyond daylight, which may create the opportunity for improved education, evening classes and improved informational work for women and children, increase the family´s income, and improve living standards.

Utilization of renewable energy may also contribute to increased quality on the local schools by providing electricity and get access to educational media, which may improve the student's attendance. The local clinics may also improve due to the possibility of refrigerating medicines, sterilizing of equipment, easier access to freshwater and more advanced sewage systems to reduce diseases (Martinot, 2005). Besides, with the output of biogas technology, one pillars of sustainable development, social sustainability, achieved. A socially sustainable system must accomplish fairness in distribution and opportunity, adequate provision of social services including health and education, gender equity, political accountability and education (UN, 2012). In other words, Biogas plant can change lifestyles by interacting with social issues, empower women and reduce poverty, urban migration, and population growth.

4. Conclusions and Recommendations

4.1. Conclusions

Future growth and overall quality of life are critically dependent on the quality of the environment. The natural resource base of a country and the quality of its air, water, and land represent a common heritage for all generations. To destroy that endowment indiscriminately in the pursuit of short-term economic goals penalizes both present and, especially, future generations. In many of the poorest regions of the globe, it is clear that increasing population density has contributed to severe and accelerating degradation of the very resources that these growing populations depend on for survival. In Ethiopia deforestation essentially occurs to meet the two major demands, agricultural land and fire-wood.

To meet expanding needs environmental devastation must be halted and the productivity of existing resources stretched further so as to benefit more people. The best solution for this is the adoption of biogas technology. Biogas technology is best suited to convert the organic waste from agriculture, livestock, industries, municipalities and other human activities into energy and manure. The use of energy and manure can lead to better environment, health, and other socio-economic gains. Along with, biogas is in most contexts a sustainable energy source resulting in reduced consumption of firewood, kerosene and charcoal. This makes life easier for rural people, especially for women and children, who are more vulnerable from indoor air pollution and firewood collection. As well, the output from the bio-slurry consists of essential macro nutrients for crop growth, in so doing reduced the need for exploitation of new agricultural land. Therefore with renewable energy obtained from the biogas plant, extreme poverty and hunger will be eradicated.

In Ethiopia 10,678 bio-digester plants were constructed during 2008-2014. From the distributed and adopted least amount of biogas plants, visible development attained. The amount of forest deforestation and degradation reduced. Since biogas technology minimizes the dependence of rural people on fire-wood, for cooking and lighting. The by-product of the bio-slurry reduced the major problem of land degradation through the increment of land fertility. Therefore, farmers without the need to encroach to forests, for expanding their land, can be productive with the presented parcel of land. Hence environmental problems alleviated through biogas technology this causes the environmental sustainability to be assured. Furthermore, capital allotted for the

purchasing of inorganic fertilizer can be shifted for other activities; this basis secured economic sustainability. Moreover, problems particularly for female, children and elderly related to indoor air pollution mitigated. Children get time for schooling and women can take part in diverse developmental activities. Therefore, with the adoption of biogas technology sustainable development can be achieved.

4.2. Recommendations

Based on the findings of the study, the following points are recommended.

- Biogas technology, relative to fossil fuel, with less cost has multidimensional benefits. Most of the rural people demand can be answered with it. Likewise, the country with large scale adoption and implementation of this uncomplicated and promising technology the amount of money invested to import fossil-fuel and inorganic fertilizer can be reduced. Hence to realize the entire pro it is suggested to intensify biogas plant in various parts of the country.
- As the report of NBPE shows some of the key implementation challenges for the dissemination of the technology are; high investment cost, inadequate promotion of the program and lack of credit service. Thus the government has to solve these confront to benefit the people in the short run and to bring a sustainable development in the long run.
- During data collection the researcher examined that organizations with more similar objectives do not know each other. Thus to come up with concrete, problem solving and innovative result it is good if those organizations bring in cooperation.
- This paper relies on the secondary data, thus further study is recommended to integrate primary data to genuinely investigate the advantage obtained from the technology. Moreover, policy makers that deals mainly about environment and energy needs to deal in depth about the technology to advocate the tools performance in the study area and beyond.

5. References

Akinbami, J., Ilori, M., Oyebisi, T., Oyebisi, I., Adeoti, O. 2001. Biogas energy use in Nigeria: current status, future prospects and policy implications. *Renewable and Sustainable Energy Reviews;* 5: 97–112.

Andrews, R.1999. Managing the environment managing ourselves. New Haven, Connecticut: Yale University Press.

Bajgain, S. and Shakya, I. 2005. The Nepal Biogas Support Program: A successful model of public private partnership for rural household energy supply; Ministry of Foreign Affairs.

Bedru Sherefa, 2006. Remote Sensing and GIS for Land Cover/ Land Use Change Detection and Analysis in the Semi-Natural Ecosystems and Agriculture Landscapes of the Central Ethiopian Rift Valley. PhD Thesis. Technische Universität Dresden, Fakultät Forst- Geo-und Hydrowis senschaften, Institut für Photogrammetrie und Fernerkundung, Dresden.

Bhat, P., Chanakya, H., Ravindranath, H. 2001. Biogas Plant dissemination: success story of Sirsi, India. *Energy for Sustainable Development* 1: 39-46.

Bruce, N., Neufeld, L., Boy, E. and West, C. 1998. Indoor Biofuel Air Pollution and Respiratory Health: The Role of Confounding Factors among Women in Highland Guatemala. *International Journal of Epidemiology* 27:454–58.

Campbell, H. 1997. Indoor Air Pollution and Acute Lower Respiratory Infections in YoungGambian Children. *Health Bulletin;* 55:20–31.

Davidson, O., Chenene, M., Kituyi, E., Nkomo, J., Turner, C. and Sebitosi, B. 2007. Sustainable Energy in Sub-Saharan Africa. International Council for Science Regional Office for Africa.

Ezzati, M. and Kammen, D. 2001. Indoor Air Pollution from Biomass Combustion and Acute Respiratory Infections in Kenya: An Exposure-Response Study. *The Lancet;* 358:619-624.

FAO. 2000. Global Forest Resources Assessment. Forestry paper 140, (2000). ISSN 0258-6150

Gessesse ,D. and Christianson, C. 2008. Forest decline and its causes in the south-central Rift Valley of Ethiopia: Human impact over a one hundred year perspective. *Ambio*; 37(4): 263-271.

Getachew, M. 2008. "A review of the National population policy of Ethiopia. Digest of Ethiopia's National Policies and Strategies and programs." In: Forum for Social Studies (FSS) Taye Assefa (ed.) Addis Ababa, Ethiopia.

GTP. 2010. Growth and Transformation Plan (GTP) - 2010/11-2014/15. The Federal Democratic Republic of Ethiopia, Ministry of Finance and Economic Development (MoFED), Addis Ababa.

Igoni, A., Ayotamuno, M., Eze C, Ogaji S., Probert, S. 2007. Designs of Anaerobic Digesters for Producing Biogas from Municipal Solid-Waste. *Applied Energy*; 85: 430-438.

Jingura, R. and Matengaifa, R. 2008. The potential for energy production from crop residues in Zimbabwe. *Biomass and Bioenergy* 32: 1287–1292.

Kupaza, R. 2010. Access to energy in rural areas. The Arusha Times. Tanzania.

Lantz, M., Mattias, S. and Björnsson, L. 2007. The prospects for an expansion of biogas systems in Sweden - Incentives, barriers and potentials. *Energy Policy;* 35: 1830-1843.

Martinot, E. 2005. Renewable Global Status Report. Available at: http://www.worldwatch.org/system/files/ren21-2.pdf

NBPE. 2014. Results-based approaches to support the National Biogas Programme of Ethiopia. Report for SNV. Vivid Economics.

Platt, R. 2004. Global and local analysis of fragmentation in a mountain region of Colorado. *Agriculture, Ecosystems and Environment*; 101(2-3): 207-218.

Rio, P. and Burguillo, M. 2008. Assessing the impact of renewable energy deployment on local sustainability: Towards a theoretical framework. *Renewable and Sustainable Energy Reviews*; 12; 1325–1344.

Roosa, S. 2010. Sustainable Development Handbook. The Fairmont Press, Inc. 700 Indian Trail Lilburn, GA 30047.

Srinivasan, S. 2008. Positive externalities of domestic biogas initiatives: Implications for financing. *Renewable and Sustainable Energy Reviews*; 12:1476-1484.

UN General Assembly, 2012. Secretary-General's Input to the Open Working Group on Sustainable Development Goals, 12th December 2012.

UNDP.2004. Guidelines for annual reporting of MDG 7 for Uganda.

UNFCCC, 2010. United Nations Framework Convention on Climate Chang.

WBISPP (Woody Biomass Inventory and Strategic Planning Project) (2004): A national strategic plan for the biomass energy sector. Addis Ababa.

WHO. 2007. Indoor Air Pollution: National Burden of Disease Estimates [for Ethiopia]. World Health Organisation.

World Commission on Environment and Development, 1987. Our Common Future. Oxford University Press, New York.

World Energy Outlook. 2009. ISBN: 978 92 64 06130 9.

World Health Organization, 2009. Guidelines for indoor air quality: Dampness and mould. WHO Regional Office for Europe, Copenhagen, Denmark.

Yadvika, A. 2004. Enhancement of biogas production from solid substrates using different techniques a review.