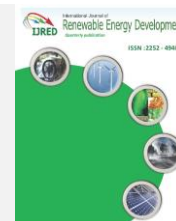




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# Status and Benefits of Renewable Energy Technologies in the Rural Areas of Ethiopia: A Case Study on Improved Cooking Stoves and Biogas Technologies

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**Abstract:** The majority of Ethiopia's people (85%) reside in rural areas, deriving their livelihood from agriculture. Ethiopia's energy system is characterized mainly by biomass fuel supply, with households being the greatest energy consumers. The household sector takes up nearly 94 % of the total energy supplies. Access to energy resources and technologies in rural Ethiopia is highly constrained which makes the energy supply and consumption pattern of the country to show many elements of un-sustainability. The concern on cooking practices, household economics, health, forest and agricultural resource management, and global greenhouse gas emissions has emerged as a transformative opportunity to improve individual lives, livelihoods, and the global environment. More decentralized renewable energy projects could play an important role in mitigating traditional biomass fuel use. Improved cooking stove (ICS) dissemination projects have been launched involving the private sector in the production and commercialization of the stoves. In doing so, about 3.7 million ICSs have been disseminated in the country so far which benefited stove users, producers and the total environment as about 30 million hectare of forest per year can be conserved. Conversion of animal waste to biogas energy to replace traditional fuel and use of the slurry as a fertilizer is the other current focus of the government of Ethiopia and installed more than 860 biogas digesters. The benefits obtained from these technologies are considerable and promising. However, the programs are not that much benefited the rural households where it had been intended to address. So, due attention should be given for those of the rural households in order to address the fuel wood crisis, environmental degradation and their health condition.

**Key words:** Renewable energy; improved cooking stoves, biogas, rural households

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## 1. Introduction

Energy is the core factor that can affect other important developmental factors such as education, health, gender, environment, economic growth, food security and water. There should be sustainable access to modern energy services in order to improve the productivity and wellbeing of rural community. Approximately one-half of the world's population relies on biomass: wood, crop residues, dung and charcoal - as the primary source of domestic energy, burning 2

billion kg of biomass every day in developing countries (Ezzati *et al.* 2000). It account for more than one-half of all energy use in many developing countries and for as much as 95 % of all energy use in some of the poorest nations (Manuel 2003). Other studies indicate that about 1.2 billion people lack access to electricity and 2.8 billion still rely on unsustainable solid biomass. Among these, around 85% are without electricity and

78% depend on solid biomass live in rural areas (Abebe *et al.* 2012; Memoire 2013).

In Ethiopia, 50% of the population has an income that is below the poverty line. The wide spread poverty is mentioned as a critical factor in continued dependency on biomass energy sources and persistent traditional and inefficient means of utilizing them (Abebe *et al.* 2012). The people in the country rely on injera as their primary source of food which is most often heated by means of open fire. Baking injera accounts for over 50% of all primary energy consumption and over 75% of all household energy consumption. Due to the shortage of firewood in growing Ethiopian communities, baking injera on open fire is becoming increasingly expensive. Women and young children have to walk many miles a day to collect firewood to The per capita energy consumption of Ethiopia (0.3 toe) is among the lowest in the world (GTZ 2000). However, the energy requirements of a large and fast growing population and the fact that the major proportion is supplied by traditional energy sources have serious implications on the natural resource base.

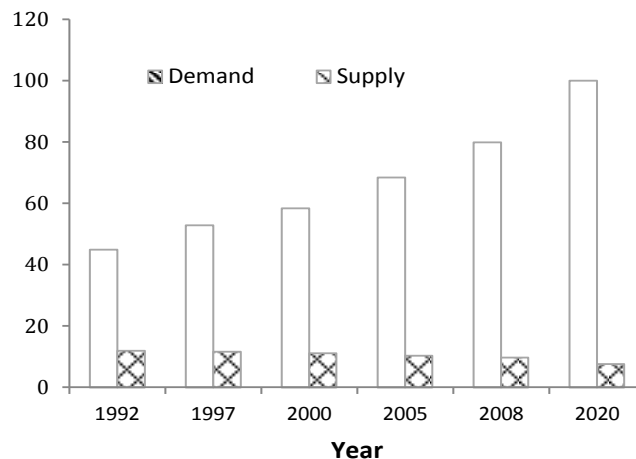
**Energy Demand and supply in Ethiopia**

The consumption of wood fuel has far exceeded its supply. Excessive dependence on biomass energy involves a trade-off in agricultural productivity, the crop residues and animal wastes being diverted from farms, where they supplement soil nutrition, to provide energy needs (Environmental science division (ESD), 2000). Similarly, as wood fuel scarcity has become increasingly serious, rural households who depend on

feed their families (Wolde-Giorgis 2002). Consequently, the rural people are being affected by indoor air pollution and environmental degradation and deforestation. According to a report by FAO (2010), Ethiopia loses about 141,000 ha of forest each year which in turn results in fuel wood scarcity.

From the total biomass consumption, fuel wood contributes about 77 %, dung 8.5 %, agricultural residue 7.5 %, charcoal 1 % and 6 % is from modern energy forms (EREDPC 2007). Such heavy reliance on biomass fuels, particularly, wood and dung, contribute to deforestation, and land degradation. This is partly because use of these fuels in urban areas is an important source of cash income for people in both urban and rural areas (Forum for environment 2010) collecting fire wood have to travel further distances (takes eight hours) (Cunningham *et al.* 2003) to obtain wood fuel, thus causing loss of human availability for productive work. Furthermore, wood fuel depletion will advance further deforestation and lead to a general environmental degradation (ESD 2000).

The energy consumption trends in Ethiopia indicate that the overall energy consumption is increasing from time to time and this is attributable to the high population growth and the associated increase in energy demand. Due to the unsustainable utilization of natural resources, there has been an imbalance between the demand for fuel wood and the sustainable supply. The fuel wood demand and supply projection (Fig 1) shows that the demand is growing at a faster rate than the supply (EFAP 1994).



**Figure 1.** Fuel wood demand and supply (million m<sup>3</sup>)

Such considerable existence of imbalance on demand and sustainable supply results in deforestation which is a significant issue in Ethiopia, with a large population dependent on wood fuel. Ethiopian forests are being destroyed at a rate of 200,000 hectares a year, with

demand exceeding renewable supply by more than a factor of five. Studies have indicated that the total forest coverage in Ethiopia has been reduced from 40% to 3 % in the 20<sup>th</sup> century (Forum for environment 2010).

In general, the pattern of energy supply and consumption shows many elements of unsustainability. The energy problem in the country arises not from excessive reliance on non-renewable energy sources, but rather that one form of energy-wood fuel-is being consumed at an unsustainable rate, while the vast potential of other forms of renewable energy (solar, wind, hydropower, etc) remains undeveloped. This could be due to the lowest income of households who are still below the poverty line and the household energy activity is loaded on women which together limit the development of sophisticated technologies in the household level.

In most cases, the traditional energy consumption is related to low technology energy conversion systems. Low technology energy conversion usually implies low efficiency (average 10 %) and high pollution (Chipman and Dzioubinski 1999). Thus, technology is a critical link between the supply of energy services and access, affordability and environmental compatibility. Renewable energy technologies: Solar energy, wind energy, biofuels and improved cooking stoves (ICS) are those of the technologies.

The intention here is just to assess the status and benefits of production and dissemination of improved cooking stoves (ICS) and biogas technologies as these are the technologies being distributed in the rural areas of Ethiopia. In this regard, the government of Ethiopia has designed related energy policy so as to address the problem of the fuel wood demand and supply and the associated problems.

## 2. Methodology

To obtain the necessary data both primary and secondary were used. Secondary data was gathered from literatures published by GIZ, SNV Ethiopia and other sources from internet more for ICS. To collect primary data both the federal and regional rural energy institutions officials, stove producers, masons' and energy technology owners were communicated and interviewed.

Concerning the biogas data, structured interview questionnaires for the two respondent groups; biogas user households and masons was formulated to conduct field survey. Gender aspects were considered in order to collect the views of women as they could be mainly affected by energy issues. Before the fieldtrip it was assumed to visit 2-3 HH per district per day, in order to be able to have enough time for a deeper look of each plant and for travelling from one to another plant. Since the plan was to spend 4 weeks for the trip, the result was 16 survey days plus two travel days per week. That makes 16days\*2HH=32HH (biogas plant owners).

32 HH (3.7%) of all biogas plants (859 plants) were randomly selected but 28 were visited due to transport problem. The selection of plants in each of the four regions and in each district was based on the total number of biogas plants installed. Only those districts having more than 25 biogas plants were considered in the sampling process. For those districts having between 25 and 100 biogas plants, 2 HH were interviewed. For those having more than 100 biogas plants, 3 or 5 HH were chosen to be surveyed.

## 3. Results and Discussion

### Status and Benefits of improved cooking stove (ICS) dissemination

The benefits associated with ICS fall in two categories: those that are internal to the household and those that are external. Reduced concentrations of smoke and consequently indoor air pollution; money and time saved in searching fuel; and reduced biomass use as reported by Dereje (2005), i.e decreasing fuel wood consumption will also decrease pollution and the proportion of income share that is spent for energy.

Not all the benefits are experienced or perceived immediately by the end users. Since the users feel the impacts of internal benefits directly, these may have a greater influence on the decision to invest in ICS. Less pressure on forest and energy resources (deforestation); reduced greenhouse gases; and skill development and job creation in the community producing and installing the stoves are considered to be the external benefits.

### Economic advantage for ICS producers

Up to 2013, more than 500 small-scale producers (416 (83 %) are active) have been established in 280 districts in 11 regions (Figure 2) of the country for 'mirt' stove and are being benefited from the programs (GIZ 2010). According to this study, and responses from interviewed producers in Amhara and Oromia, the minimum number of stoves sold per month was 45. The current cost to produce one 'Mirt' stove is about 61 Ethiopian Birr (ETB) (including 6 ETB for his own labor cost), and the producer sells the stove with an average price of 90 ETB, then he/she has a profit margin of around 48 %.

$$\begin{aligned} \text{The profit margin} &= \frac{\text{Selling price} - \text{cost of production}}{\text{Cost of production}} \times 100 \% \\ &= \frac{90 \text{ ETB} - 61 \text{ ETB}}{61 \text{ ETB}} \times 100 \% \sim 48 \% \end{aligned}$$

Therefore, the producers can get a minimum net profit of **1305 ETB** per month from 45 'mirt' stoves.

For 'gonziye' stove, the cost for production is 21 ETB (including 15 ETB for labour cost) and sells it with a current price of 50-60 ETB. Thus the producers have a minimum profit margin of 138 %. The minimum numbers of stoves sold per month is 10. Therefore, the producers receive a net profit of 290 ETB from 10 stoves only.

According to the interview made with Ethiopian alternative energy production and promotion corporate (EAEPCC), a total of 5506 producers have been trained from nine regions and two administrative cities of Ethiopia up to 2012/13 (Figure 2) and become advantageous from the profit.

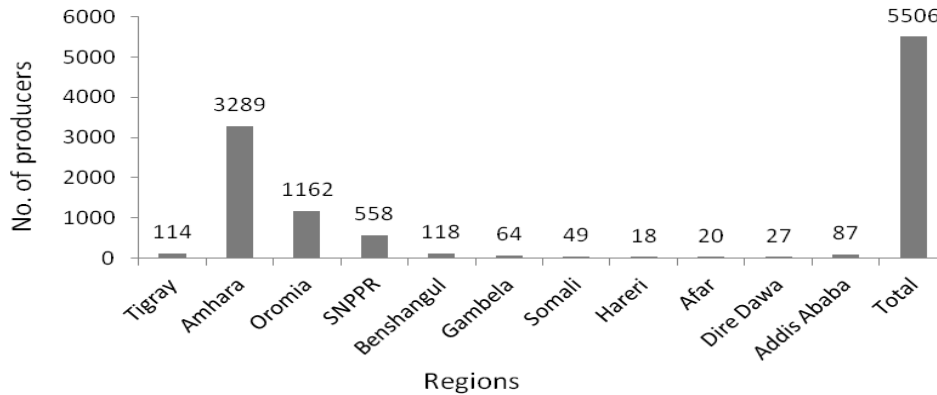


Figure 2. Number of ICS producers trained per regions

**Advantage of using ICS for Biomass conservation**

Studies (Table 1) show that 14 ha/year and 15-18 ha/year of forest is preserved from a single 'mirt' and 'gonziye' stoves, respectively. That means 1282161\*14~18 million and 3-3.5 million ha land per year is preserved by the use of 'mirt' and 'gonziye' stoves, respectively from 2006-2013 (Table 2). This indicates that use of 'mirt' and 'gonziye' stoves significantly reduce the demand and maximize the supply for fuel wood.

The CO<sub>2</sub> sequestered by the preserved forest per year can also be calculated. From Table 1, it is evident that use of a single 'mirt' stove help to preserve 14 ha of land and thereby 980 ton of CO<sub>2</sub> per year. Accordingly,

1282161\*980= 1257 million ton of the green house gas is sequestered per year. From the 'gonziye' stove we have 195867\*1058 (or 1269) = 207 to 249 million ton of CO<sub>2</sub> can be stored per year. This again can be converted to monetary values for carbon credit projects as indicated in Table 2.

It is also evident that production and dissemination of gonziye injera stove (especially the new version) is highly important as its fuel saving is larger (64 %) as compared to the open fire and 14 % more than that of 'mirt' stove. Besides, 'gonziye' is a stove made from clay which is easy to be adapted by artisans (potters) (after a short training) and the rural household users so that they can easily buy and use it relative to 'mirt'.

**Table 1.**  
Benefits of ICS

Stove type	Benefits per stove per year		
	Fuel saving (%)	Forest preserved (ha/yr)	CO <sub>2</sub> Preserved (ton/yr)*
Mirt	50	14	980
Mud closed	18	5	353
Gonzie old	54	15	1058
Gonzie new	64	18	1269
Lakech	25	7.3	503

\*Calculated based on secondary data , Source: GIZ, 2007; EEA, 2011.

**Table 2.**  
Benefits obtained per ICS type and number disseminated

Stove type	Number	Wood saved (Kg)	Money saved(ETB/yr)	Forest preserved(ha/yr)	CO <sub>2</sub> stored (mill ton/yr)
Mirt	1,282,161	64,108	80,135	17,950,254	1256
Gonzie	195,867	105,768	132,210	2,938,005	207
Lakech	51,622	12,905.5	16,131	376,840	26
Mud closed	1,748,057	314,650	393,312	8,740,285	617
Total	3.3 million	497,432	621,790	30 million	2107

Source: GIZ, 2005; EEA, 2011; Survey data

**Benefits of ICS for women and Children**

Another important point is that most of the internal benefits work to improve the condition of women, who are predominantly responsible for cooking and collecting fuel wood particularly in the rural areas of Ethiopia. Additionally, in many rural settings, women cook with their children strapped on their backs or the children are always around in the kitchen. Any reduction in pollutants emitted from cook stoves will be beneficial for children’s as well as for women’s health. Women are also participating in stove production. Gender segregated data monitoring by GIZ and EAEDPC revealed that women producers are more effective than men. Hence the recruitment of new stove producers is made to be more females (Figure 3).

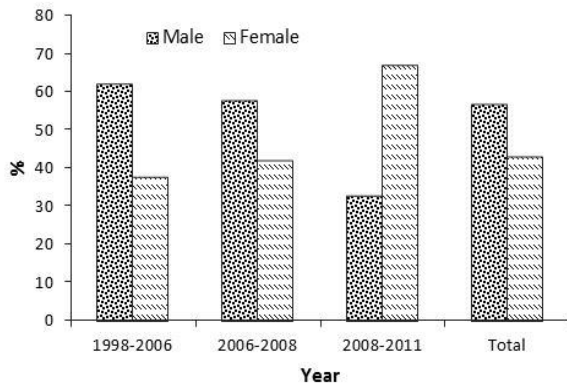


Figure 3. Gender segregated ICS producers  
Source: survey data and GIZ, 2007

**Biogas plant dissemination and benefits**

The Ethiopian government under the national biogas program of Ethiopia (NBPE) in collaboration with the Netherland Development Organization (SNV Ethiopia), an international NGO, had embarked on an ambitious biogas program to construct 14,000 plants till end of 2013 to address the rural energy crisis and indoor air pollution caused by the burning of traditional biomass and implemented in Amhara, SNNPRS, Oromia and Tigray regions (Anonymous 2011). Results of biogas user survey conducted in Ethiopia reveals that about 859 biogas plants were installed in the household level in the four regions up to 2011. The benefits obtained are put in quantitative way by taking the figure 859 in subsequent discussions.

**Size of biogas plants installed**

According to the feasible study of the biogas program of Ethiopia, those rural people who have at least four heads of cattle can have a biogas plant (Eshete et al. 2006). The survey result showed that the corresponding minimum size of biogas digesters for daily cooking and lighting is 6m<sup>3</sup>. The regional wise distribution is shown in Table 3. Among the observed biogas plants 6m<sup>3</sup> is common in Tigray and SNNPR. However, 8 and 10m<sup>3</sup> are common in Amhara and Oromia regions, respectively. Generally, it can be said that 6m<sup>3</sup> biogas plants are common in the country level which is an indication that the biogas owners possess more than two heads of cattle.

**Table 3**  
Percentage of plants per size and region

Region	Plant Size (m <sup>3</sup> )			
	4	6	8	10
Tigray	-	100	-	-
Amhara	-	20	80	-
Oromia	-	33	22	44
SNNPR	3	83	-	17
<b>Total</b>	<b>2</b>	<b>61</b>	<b>21</b>	<b>18</b>

Source: survey data

**Economic benefit of installed biogas plants**

It was found that once a biogas plant is installed, it can generate money for farmers at least in two ways: substituting expenses of fuel and chemical fertilizer. It is estimated that the average saved money per owner per year is 4493, 2150, 3898 and 3400 ETB in Tigray, Amhara, Oromia and SNNPR respectively. The overall saved money is shown in Figure 4.

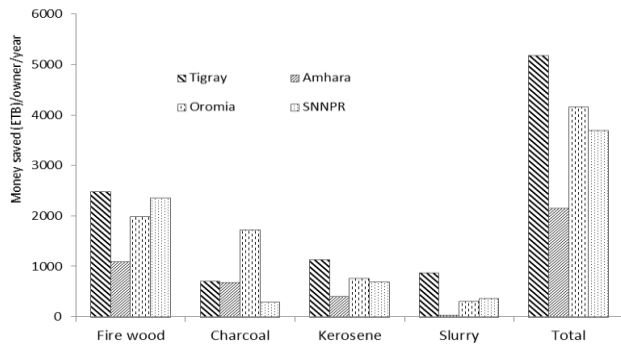


Figure 4. Expenses saved per region/year, Source: Survey data

The second income generation, replacement of the chemical fertilizer by the slurry, is not that much practiced, but many farmers intend to use it in the future. So far, 682 ETB in Tigray, 270 ETB in Oromia and 300 ETB in SNNPR have been saved per owner and year. Thus, more than 5175 ETB/owner can be saved per year if a farmer installs a biogas plant to use the gas as energy source and the slurry as fertilizer. Tigray is the region where highest replacement of fuel and chemical fertilizer is observed, while the lowest replacement occurs in Amhara region. Two farmers in Oromia have already started selling the slurry after making compost. One sells it for 15ETB/25kg of compost which supplements his cattle fodder, and the other sells 100ETB/container (the container is about equal to 70Kg). The latter has developed a surplus

**Table 4**  
 Masons' income before and after installing biogas plants

Mason code	No. of digesters installed/year	Income (ETB)/month		
		Before biogas	After biogas	Improvement
M1	30	300.00	6000.00	5700.00
M2	20	300.00	4000.00	3700.00
M3	12	300.00	2400.00	2100.00
M4	7	300.00	1300.00	1000.00
M5	5	500.00	1335.00	835.00
M6	7	400.00-500.00	2273.00	1773.00-1873.00
M7	7	400.00-500.00	2273.00	1773.00-1873.00
M8	15	2500.00	4376.00	1826

Source: Survey data

income of 3300ETB by selling in average 33 containers/month.

**Mason's income**

One of the benefits of biogas plant dissemination is maximizing the masons' income. The masons' income before starting biogas installation was 300-500ETB/month. However, the monthly income is maximized and it is 1300-6000 ETB as shown in Table 4.

The amount of payment for masons to install a specified biogas plant differs from region to region. In Oromia and SNNPR, the biogas owners pay 1114-1739 for masons depending on the volume of the plant. In Tigray and Amhara however masons are only paid from the subsidy by the government (Table 5).

Based on Table 5 it can be said that there is significant difference in the payment for masons of the northern and southern regions. Such a difference may not be encouraged as they may move from the north to the south which may hinder the plan of biogas plant distribution in the northern part of the country.

In general, results from interviews of masons indicate that they are highly benefited (income increases more than 100%) from the program and even they kept aside their previous work (worked up to 22 years) and totally depend on the income of installing biogas plants. They have started installing plants by organizing themselves and making a union to increase their economic benefit.

For the advantages, it can be positively noticed, that expectations and experiences are very similar: cooking, lighting, fertilizer and time safe, the factors leading to biogas are satisfied by the biogas system. Concerning the gender ratio, both men and women vote these 4 factors as their majors, though for women the cooking improvement is most important, while men aim at producing fertilizer.

**Table 5**  
Source and amount of masons' payment per region

Region	Digester Size(m3)	Source of payment		
		Government	Owner of digester	Total
Tigray	4	2000.00	-	2000.00
	6	2400.00	-	2400.00
	8	2600.00	-	2600.00
	10	2800.00	-	2800.00
Amhara	4	-	-	-
	6	2300.00	-	2300.00
	8	2500.00	-	2500.00
	10	-	-	-
Oromya	4	-	-	-
	6	2360.00	1114.00	3474.00
	8	2360.00	1419.00	3779.00
	10	2360.00	1739.00	4099.00
SNNPR	4	-	-	-
	6	2200.00	1114.00	3314.00
	8	2200.00	1200.00	3400.00
	10	2200.00	1400.00	3600.00

Source: Survey data

### Environmental analysis

Benefits can be tangible (we can put value on it) and intangible (we cannot put value on it). The emission saved (other than carbon) from wood, charcoal and kerosene, controlling pollution by the proper use of slurry, minimization of indoor pollution due to the use of traditional fuels and the decrease of women's load are considered to be intangible for this study, but highly rewarding. The tangible benefits are presented below.

### Decrease in deforestation

Deforestation has negative implications for the local environment (increased erosion) and the global environment (acceleration of climate change, threatened biodiversity). The reduction of forest cover also reduces the existing capacity to sequester carbon, and releases the already fixed carbon. According to the global non-timber forest product (NTFP) (2006) report, many African nations have had over three quarters of their forest cover depleted.

This study reveals that because of the dissemination of biogas in Ethiopia deforestation is decreasing and will be reduced more. The amount of fire wood saved due to the introduction of biogas was surveyed and the equivalent number of trees was calculated using literature value i.e. 712kg of dry wood is equivalent to 6 large trees (USDA forest service 2010), and to produce 1kg of charcoal 5.45kg of wood are required (Rensselear, 2010). Thus using 6trees/712kg of wood and 1kgcharcoal/5.45kg of wood as conversion factors,

and taking the total biogas users into consideration, the yearly decline in deforestation is estimated and showed in Figure 5.

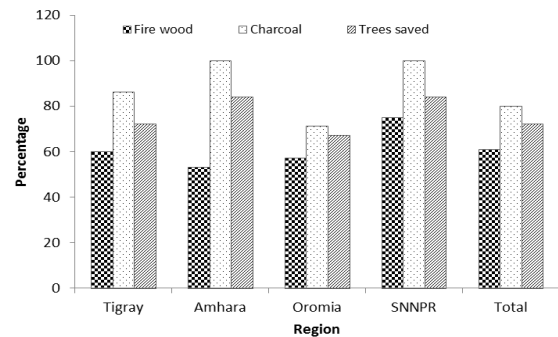


Figure 5. Annual deforestation decline rate, Source: Survey data

### Emission saving

Emissions during charcoal production are more significant than those from charcoal burning. The global warming potential of current largely inefficient methods of charcoal production (pyrolysis) is considered to be higher than that of emissions during combustion (Global NTFP 2006).

A healthy tree stores about 13 pounds (6kg) of carbon annually (USDA forest service 2010). Figure 5 indicates that yearly 72% (44196) trees are saved due to biogas dissemination so far in the four regions of Ethiopia by replacing some part of the fire wood and charcoal by biogas. Besides the carbon saved, which otherwise



would be released when cutting trees, about 265176kg of carbon is stored per year. The carbon emission savings for each of the four regions from wood, charcoal and kerosene is shown in Figure 6.

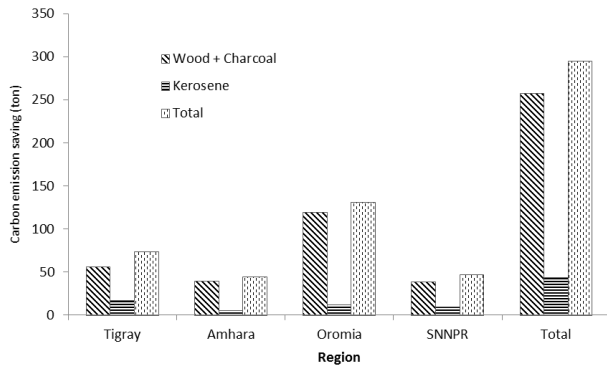


Figure 6. Carbon emission savings  
Source: Survey data and Jindal, 2006

According to Kituyi (2002) and Jindal (2006), carbon sequestration projects' economic and environmental benefits are particularly relevant for Africa which needs increased investment to support poverty alleviation and infrastructure development. Accordingly, the numbers of trees saved due to biogas introduction sequester carbon which leads to the clean development mechanism (CDM) mentioned in article 12 of the Kyoto protocol. The international prevailing price for carbon credits range from \$3.50 to \$15.80 per ton of CO<sub>2</sub> sequestered (Jindal, 2006). Thus, the economic benefit obtained can be calculated by taking the average value \$9.65 and the amount of carbon sequestered. About \$10538 could be gained only from 859 biogas users. Imagine the income if at least 50% of the country's population would be biogas user.

## Conclusion

Although there is a significant experience in the production, performance tests, promotion and dissemination of ICS and biogas in Ethiopia using strategies like: focused on commercial stove dissemination (rather than direct subsidy); encouraging private sector participation in production and marketing; promoting decentralized production; enhancing the capacity of public institutions and organizations to promote energy efficiency; and promoting public awareness on energy and environment issues, the disseminated ICS to the rural households is very low (less than 2% of the total ICS disseminated), and only 6% of the intended biogas has been installed. However, growth in the annual dissemination rate and the degree of dissemination to low-income rural households is more relevant criteria for the growth and scale-up phase that the Ethiopian

program is currently in as almost all households use traditional biomass (wood, dung and crop residue). Moreover, the study revealed that almost all of the disseminated ICS are without a chimney implies that harmful substances caused by indoor air pollution are not fully protected i.e. one advantage of ICS has been missed. From the results obtained it can be deduced that biogas dissemination in the household level brings social, economical and environmental benefits to each user, district population and the country as a whole. Nevertheless, rate and coverage of rural households is negligible relative to the number of people live in the rural areas of Ethiopia.

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