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Impending sources of energy to replace fire wood in semi arid climatic zones: A case study in Ethiopia

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Abstract

The present study paper shows an alternative source of energy that can decrease the extensive use of fire wood in Ethiopia. The country's entire rural area and significant part of urban population is completely dependent on fire wood as a source of energy. This practice takes its own toll, the forest is on the verge of being wiped out and as a result a clear change of climate and loss of natural biodiversity resources is visible. Fire wood is not the only source of energy available in the country. In this paper, based on their low cost, construction material availability and the required unskilled labor it is shown that biogas and solar energy are potentially feasible source of energy to replace firewood for cooking.

Keywords: Biodiversity, Biogas, Climate, Solar energy

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1. Introduction

Ethiopia is a country with diverse geographical features varied from high plateaus and mountains to deep valleys. The 2007 population and housing census of Ethiopia statistical report estimated 73.75 million populations, 80% lives in the high plateaus. This is almost half of the total land area that accounts more than 90% of the country's economic activities. 85% of the population is living in the country side practicing a mixed type of agriculture.

The main source of energy for the entire rural area is wood. Fuel-wood is virtually used for cooking, lighting etc. It is not only the rural population which completely dependent on fire wood as energy source, but also quite a substantial part of the urban dwellers rely on the indigenous wood-fuel in the form of charcoal for cooking and space heating purposes.

The traditional three stones open type of firing system (Figure 1) used by the entire rural population and significant parts of the urban dwellers have very low energy conversion efficiency.

Figure 1. The traditional three stones open type of firing in Hawassa town

As a result more wood is required to cover a specific energy requirement of a household daily. The annual deforestation rate of about 0.2 million hectare (Alemayehu, 2003) mainly supplies the fire wood demand of the entire rural and urban community (Figure 2). Fast growing population accompanied by increasing need of energy has already wiped out almost all the countries available forest and brings a tremendous high pressure on the remaining (which is assumed to cover 3.6% of the land) (Alemayehu,2003).

Figure 2. *Cordia africana* ready for fire wood in Hawassa College of Agriculture

The involvement of men in fuel wood collection, a job that traditionally was left to women, is a sign of increasing fuel supply shortage. If the today deforestation rate sustains, at the end of this decade 1.4 million hectare of forest land will be wiped-off.

Today, fire wood is commonly used for cooking. As a consequence a considerable amount of forest is felled and hence loss of biodiversity is widely observed. The desired situation is to replace the existing fire wood demand by an alternative possible energy source for cooking.

Based on the above facts the major objective of this case study is to make a brief investigation on the availability of alternative energy sources that can replace fire wood.

2. Methodology

The general system approach is employed to investigate the availability of alternative energy sources. The fire wood based system requires a certain input (wood) and gives certain output (heat). This system can be replaced by an "alternative system" (Figure 3) which has got a different input and same or better output. The alternatives could be the different energy sources with their respective inputs to produce the heat required for cooking.

The alternatives could be one of the following: biogas, solar, wind, geothermal, hydropower, etc, differing in either their system complexity or costs. All these sources of energy as a system have a number of things in common as either from input or output point of view. The important potential sources of energy which promise to conserve the environment and cost effective are discussed in more detail in the following sections.

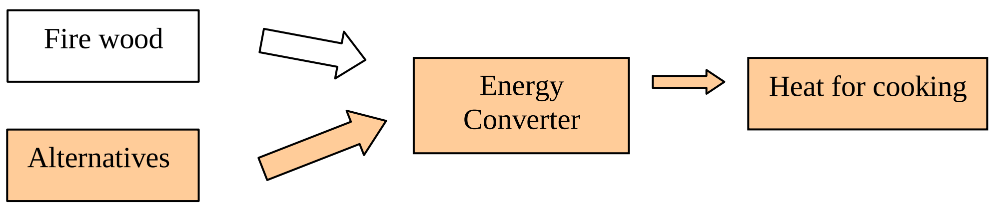

Figure 3. Simple illustration of fire wood system replaced by alternatives

2.1. Biogas

2.1.1. Biogas production

Anaerobic treatment of complex organic materials can be considered in its simplest form as a four stage process (Figure 4).

In most family-size digesters, animal waste is the most widely used raw material. This has been due to the fact that it is readily available, close to the digesters and fairly wet so that it reduces the amount of water needed. There are plenty of other types of raw materials that can be used in biogas digesters and show different yield per liter or kg dry matter. Manure's from animals like cows, sheep and goats are examples of raw materials that are available in abundance on farms of Ethiopia. Especially considering the huge amount of cattle population (more than 72million) (CDE, 2003) which is considered to be number one in size through out Africa indicates the abundance of raw materials for biogas digesters.

In China human excreta is widely used to produce gas for the domestic use at household level (Paul, 2001) but in Ethiopia like many other African countries cultural beliefs, traditions and taboos can be strong inhibitions against its use.

Crop residues and other waste materials can form very important raw materials for gas production at house hold level. Actually vegetable materials yield higher amounts of gas than animal manure (FAO, 1997). Some crop residues available abundantly in the country side of Ethiopia includes: maize stock, coffee husks, fresh weeds, banana residues including peels, leaves, barley and wheat straw etc.

For every ton of food produced there will be ten tons of residues available. The use of farm residues will reduce the dependence on cow dung, so that even poor farmers with a small number of animals or even none can still operate a biogas plant. Experiments show that there is a higher gas yield if the raw materials are mixed instead of using a single one like cow dung. Water is another crucial element for fermentation and must be abundantly available. In some parts of Ethiopia (Figure 5) water is scarce and the value of its use for biogas must be weighed against alternative uses.

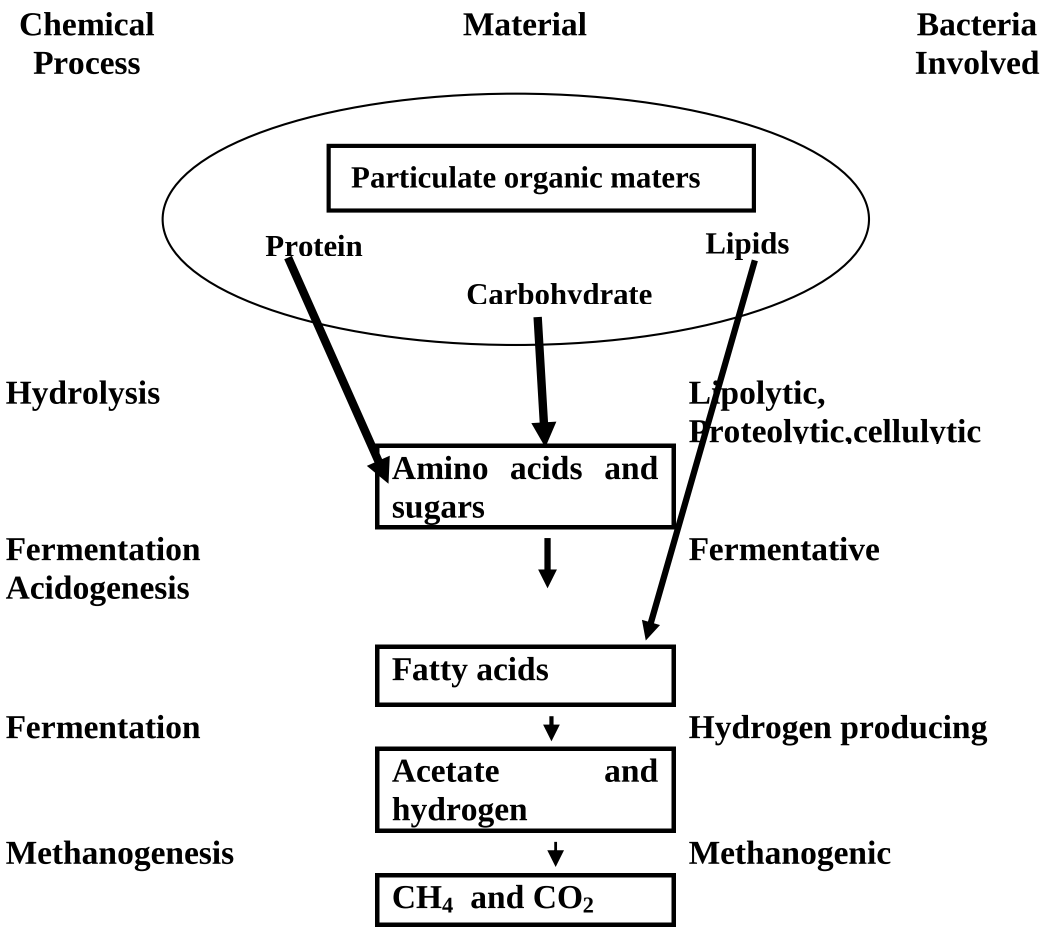

Figure 4. Four stage Processes and the responsible bacteria's in the digester (Source: Drummond Hislop. Energy Options: An introduction to small-scale renewable energy technologies. London: Intermediate Technology Publications, 1992)

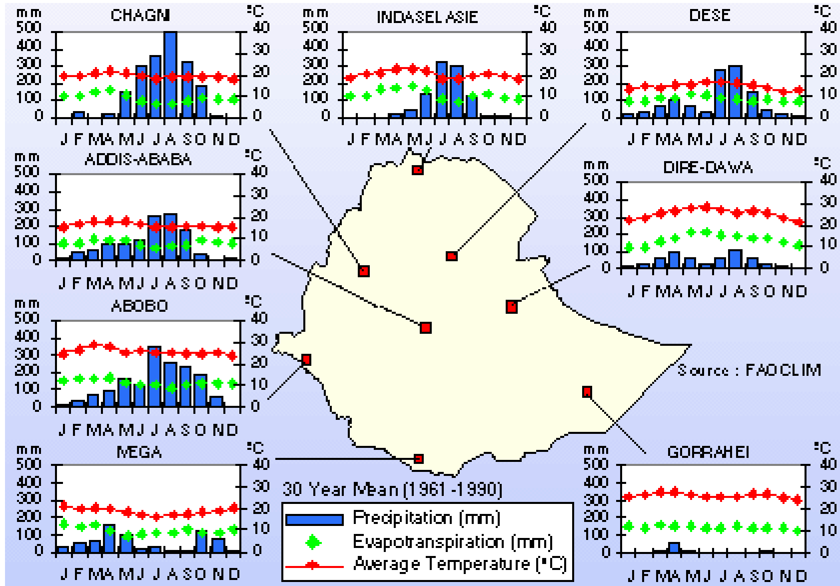

Figure 5. Meteorological Profile of Ethiopia (Source: FAOSTAT, 2012)

The problem could be partly solved during the rainy periods by collecting rain water but the best approach could be to integrate the development of biogas and pumped water development in other sectors of rural life.

2.1.2. Types of digesters

Digesters vary widely with regard to design. No single design can be considered as ideal, since arrangement and construction affects their efficiency. The design of a digester depends upon the type and volume of waste it requires to process. Other factors such as geographical, environmental and social conditions have their own influence. During the past 30 years or so, India and China developed highly successful biogas digesters (Drummond, 1992).

Typical Indian made design (Figure 6) can be easily adapted to the Ethiopian conditions.

Materials required to construct this type of digester are cement, clay bricks, gravel, iron bar and PVC hollow pipe (for the gas network).This materials are available in Ethiopia with reliable cost. Assuming the material availability, it is estimated that 3 masons and 5 casual workers or daily laborers could be able to complete the construction of one 8 m^3 digester within 15 days (personal communication).

2.1.3. Implications of biogas system

Organic wastes from agriculture, agro- industries, municipalities and other human activities can easily be converted into energy and manure through anaerobic digestion. The benefits of anaerobic digestion are not only extraction of energy but also better environment, health, and other socio-economic profits (Figure 7).

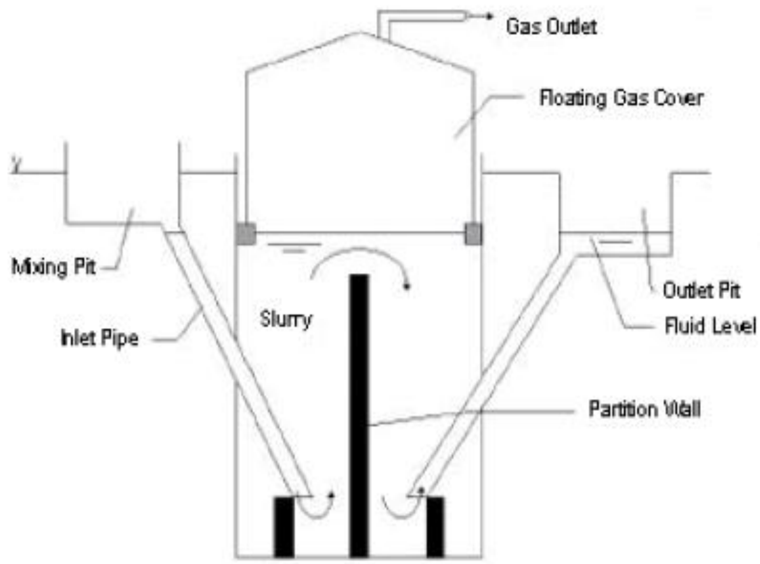

Figure 6. Floating drum (Indian type) biogas Digester (Source, Engineers without Boarders, 2004)

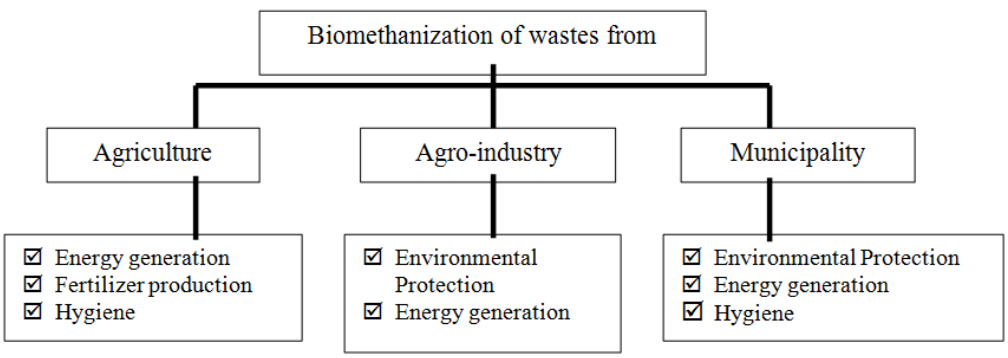

Figure 7. Biomethanization and its benefits adapted from FAO (Source FAO, A System Approach to biogas technology, June 1997)

2.2. Solar energy

With solar collectors, high enough temperature can be reached for cooking. A solar cooker with parabolic mirror was developed and marketed in India as early as 1950. Although it was sold for low price, it didn't attract much interest due to

- The fact that cooking had to be done in the open air and problems when clouds appeared and
- Difficulties connected with the people working away from home the whole day like to have a warm meal in the evening and in the morning.

To overcome such problems, both transport of heat inside the house and storage of heat for cooking is desirable. This is technically achievable, but of course it makes the system more expensive. One can think of a system which functions only for transporting heat. This may be possible by combining the system with an inside storage. Storage has the advantage that the total sunshine over the day can be used for a few hours cooking and, even more important cooking can be done when the sun is not shining. Storage reduces the collector area required by accumulating the energy during the off-time, but adds to the total price as compared with the one without storage.

It is also possible to make a special system with a parabolic mirror where storage units are heated over the whole day and then cooking takes place on these 'hot plates'(Figure 8 and 9).

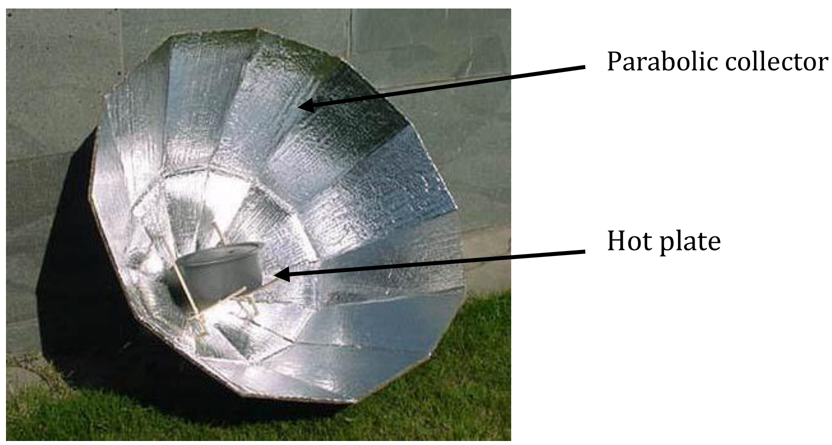

Figure 8. Solar cooking with parabolic Collector and 'hot plate' (Source: Teong, 2002)

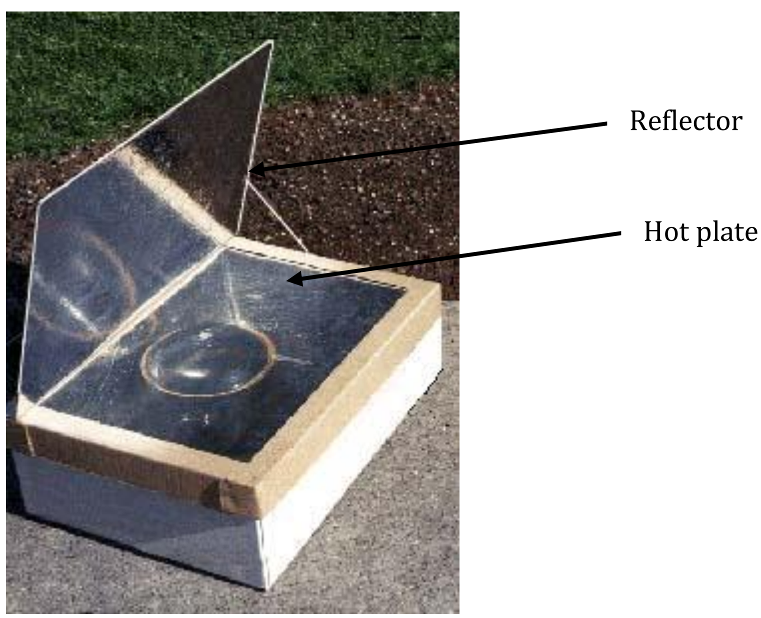

Figure 9. Box type solar oven (Source: Teong, 2002)

Average solar insolation per day can reach up to 5.3 KWH[1] (441.7 W[2]) per m^2 in most part of Ethiopia (Wolde-Georgis, 2004). For cooking we may estimate a requirement of 2 KWH per family per day, probably used in about an hour. This implies a power of 2 KW for cooking without storage collectors with an area of about 5 m^2 would be necessary. For cooking with storage, the solar radiation of the whole day is used. The daily average net heat received by a collector is:

$$441.7 \cdot 12 = 5.3 KWH/m^2$$

Assuming about 50 percent losses due to storage, we find out that the collector area of about A= (2kwh * 1/0.5*5.3kwh) m^2 = 1m^2 is required.

Summarizing the possibilities of using solar energy for cooking:

Open air cookers

1. Parabolic mirror with direct heating of cooking pots (Figure 8).
2. Oven type closed system with glass cover and extra mirror surface radiating in to the oven.

In- house cookers

3. High quality flat plate or focusing collectors with continuous heat transport to inside
4. As 2, but in house storage added, combined with the oven itself
5. Parabolic collector heating several hot plates over the whole day; the plates are transported inside by hand and used for cooking

Cooking with heat transport and storage systems is considerably more expensive than the simple open air cookers but they are also more acceptable. It is very difficult to estimate the prices of cooking systems without complete design and development. The open air cooking systems (open parabolic mirror and box type) are simple and cheap. From price estimate given by Arbaminch Solar Initiative (AMSI, 2002) it can be concluded that a single aluminum foil made parabolic concentrator capable of producing a usable energy of about 600W and maximum temperature of 198°C costs $100 US. The system with mirror and hot plates is probably not very cheap because of the number of hot plates and the special fitting pans required.

2.3. Wind energy

Betz (Magdi and Adam, 2011) proofed that the power density sometimes called “power flux” or power extracted per unit cross sectional area in a stream of moving air is proportional to the cube of its velocity. In their article, they also shown that the maximum fraction of that power extracted by a windmill is 59.3 % (Magdi and Adam, 2011). This actually meant that all of the power in a wind stream cannot be extracted by a windmill.

With the present economic context of rural Ethiopia; the design, construction, performance test and installation of locally made windmills demands and depends on time (to pass through all regional and national routine protocols), cost (for fabrication and manufacturing), skill and knowledge. However, to revert

[1] Kilo-Watt-Hours
[2] Watt

the persisting trends on biomass dependency, it is paramount important to devise user friendly and cost efficient mechanism to harness the wind potential for cooking. In the past a lot of efforts have been made to harness wind energy worldwide, but most of them are focused on water pumping and hydroelectric generation at a meso- level. Further research effort may require designing a proto type cost effective system that can fit the household requirement at least for cooking.

2.4. Geothermal energy

Studies have shown that in certain parts of Ethiopia, geothermal resources offer great promise for providing economically feasible electric power generation. Though there are no comprehensive data on the potential of the available geothermal energy in the country, the jet of steam coming out of the ground and shot into the air, as well as, the numerous amounts of springs at boiling point are clear indicators of the available underground thermal energy inside the Rift valley of Ethiopia.

Geothermal energy has proven to be capable of supplying impressive amounts of readily usable power. Interest is growing in many quarters over the possibilities of geothermal energy generating electricity by tapping natural sources of underground steam as an answer to the energy crisis. Geothermal energy plants could be placed any place where that hot rock is available with in 5-6km of the surface of the earth (Taffa, 2002). However to harness this tremendous potential, it needs a huge capital investment and well skilled labor at a macro level.

2.5. Hydropower

Among most renewable sources of energy development, small hydro power has been found most attractive; but one of the main bottlenecks in taking up of small hydro is their larger investment cost. Even by using labor and locally available materials, the design and construction of small hydro schemes are expensive. The main part of the cost is taken by the turbine and the generator set which should be imported from abroad by a hard currency.

All of the private investment offers in hydropower development have been in medium and large hydropower schemes (Mengistu, 2004). Therefore, currently the use of small hydro as a source of power for rural population is not attractive and feasible for private investors.

3. Results and discussion

Due to the lack of available quantitative data, a qualitative relative comparison among different energy sources is made (Solar, Geothermal, Biogas, Wind and Hydro). The comparison is done with respect to initial investment costs, operation costs, local construction material availability and skill required (Table 1).

The barriers impeding wider use of solar energy and biogas for cooking in Ethiopia have in general been:

- Unfamiliarity of the technology to the public, its reliability, ease of installation and subsequent maintenance

- Lack of awareness on the economics of solar and biogas energy against conventional electrical energy and
- Lack of policy initiatives to promote use of these renewable energy resources.

These barriers have to be removed to enhance and radically alter the level of use of solar and biogas energy in Ethiopia.

Table 1. Qualitative comparison of alternative energy resources. (Adopted from HBF, 2001)

Alternative	Initial investment costs	Operational costs	Local cons. material availability	possibility to be owned by single family	Skilled labor requirement
Solar, Biogas	low	low	available	Yes	low
Geothermal, Wind, Hydropower	very high	high *	not available	No	high

** The power station requires highly paid qualified personnel*

4. Conclusions

Increments in agricultural production are possible through modern methods. But this advancement in science will be useless unless there is enough forest to keep the biodiversity stable and to protect the soil as well as the environment. If the forest is removed, the soil on which life and agriculture depends is wasted, then the struggle to live a better life will remain a nightmare. What are the means to maintain the forest and hence the soil? One of the possible answers is reducing the high pressure on the forest gradually by changing the culture of using fuel wood and wood products as a source of energy. This case study revealed that biogas and solar energy are the potential sources of energy to replace firewood in rural Ethiopia. Therefore the problem should be recognized by the authorities, who have overall control of the policy. A new strategic policy that promotes the use of biogas and solar energy should be devised and implemented through the appropriate government infrastructures. Finally, in all such efforts, the government should ensure that the different renewable energy resources are used economically, efficiently and in an environment-friendly way, the energy technologies are well popularized and the technologies are affordable to the majority of the households.

Above all, to accelerate resource mobilization for the household energy sub-sector development and also to decrease the burden imposed on the existing small forest coverage, the government needs to create the necessary condition to make private sector participation an attractive area of investment together with human resource development in the energy as well as forestry sectors.

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