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Biomass Briquetting: Opportunities for the Transformation of Traditional Biomass Energy in Ethiopia

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Abstract
Traditional biomass is the major source of energy in many developing countries. In Ethiopia traditional biomass burning supplies more than 92% of national energy consumption. This has been causing different environmental and socioeconomic impacts. With traditional biomass being used as the primary source of energy in all sectors, there is huge demand for the development of alternative biomass energy technologies in Ethiopia. Similar situations in many developing countries led to the popularization of the briquetting technology. The briquetting process is the physical transformation of loose raw organic materials into high density fuel briquettes through a compacting process which increases the calorific value and combustion efficiency of the product. In Ethiopia, the available biomass resource such as wood, agro-industrial residues and municipal waste which is expected to meet the country's growing energy demand can provide huge opportunity for the adoption of the briquetting technology. The manufacture, repair and maintenance of briquette equipments can be addressed using local capacity. Thus there is a need for strengthening cooperation among all stakeholders concerned with energy and environment to promote the briquetting technology thereby contribute towards efficient and environmentally sustainable energy supply.
Keywords: Briquette, Biomass potential, Conversion technology, Market opportunity.

1. Introduction

Global energy demand is increasing rapidly due to increasing world population and economic growth. This increased energy use has led to various problems such as overexploitation of non renewable energy resources and other environmental problems such as deforestation, environmental degradation and climate change (Klimenko and Tereshin, 2010; UNEP, 2013; EEA, 2008). In recent years, due to growing concerns of environment protection, energy security, over exploitation and rising price of fossil fuels, there is growing interest in renewable energy development such as hydro, wind, solar, geothermal and bio-energy (EEA, 2008; WEC, 2008; WEC, 2013)

Ethiopia has huge renewable energy resource potential which includes biomass, hydropower, wind, solar, and geothermal energy. However, except the woody biomass (50%), agricultural residue (30%), hydropower (5%), wind (3%) and geothermal (1%) which are exploited, the available potential is not developed (MWE, 2012; MWIE, 2013; Geissler *et al.,* 2013). The country's energy sector is among one of the least developed in the world. The total national energy consumption of the country in 2010 was 1,300PJ which is the lowest from Sub-Saharan Africa (MWE, 2012; MWIE, 2013).

Ethiopia's energy consumption is predominantly based on Traditional biomass such as firewood, agri-residues, dung and charcoal. Traditional biomass supplies more than 92% of the total energy demand in the country while the remainder is supplied by oil products, hydro and geothermal (IEA, 2016; Edwards, 2010; Ethiopian panel on Climate Change, 2015). Biomass is used as the primary source of energy at households, commercial services and industries. The energy sector in Ethiopia is characterized by the predominance of the household sector, accounting for 93% of gross energy consumption (MWIE, 2013; Ethiopian panel on Climate Change, 2015). Majority of the total biomass consumption is used for domestic purpose which accounts 99% and the remainder 1% is used for industries commercial and public services. Domestic cooking in both rural and urban areas is dominated by the use of traditional fuel with 96% of the population depend on firewood, agricultural residue, dung and traditional charcoal to meet their energy needs (Bizzarri, 2010). The use of modern source of cooking fuel such as butane gas, electricity and kerosene for cooking covers only 0.4 % for rural and about 16% for urban areas (MWE, 2012). Biomasses are burned in a traditional way using energy inefficient stoves with a conversion efficiency of less than 10% (MWIE, 2013). Moreover, due to lack of other alternative energies the demand for biomass is high and increasing by 6% annually (Edwards, 2010; Lakew *et al*, 2011).

The heavy dependence on traditional biomass in Ethiopia is leading to different environmental and socio-economic problems including deforestation, soils erosion, water pollution, and indoor air pollution, deforestation and most importantly deforestation which affecting the limited forest resources of the country (Lakew *et al*., 2011; Bekele *et al*., 2013; Bizzarri, 2010). In addition 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. Furthermore, the growing demand for traditional use of biomass energy and lack of access to modern energy services is expected to impose pressure on the limited

biomass and forest stock of the country. Hence there is a need for the adoption and promotion of alternative modern biomass conversion technologies that can result in more efficient and eco-friendly energy supply.

Among the promising alternative biomass energy technologies, densification of biomass wastes in to fuel briquettes presents an opportunity to tackle the impacts traditional biomass. Briquettes produced from biomass and biomass wastes has shown the potential to alleviate cooking energy poverty and yielded environmental and socio-economic benefits in many developing countries (Grover and Mishra, 1996). The purpose of this paper is to examine the potential opportunities for biomass briquetting in Ethiopia. It highlights the possibilities for the wide adoption of the briquetting technology in Ethiopia in relation to some basic requirements for the briquetting technology. The paper begins with a short description of the briquetting technology and then presents short overview of the briquetting experience and current promotion efforts in Ethiopia and finally describes the potential opportunities for the wide adoption of biomass briquetting in Ethiopia.

Methods

This paper is prepared based on desk study and review literatures such as books, research papers, journals, conference and workshop reports, thesis and dissertations, and documents. Moreover, a personal visit to private and government institutions working on the promotion of the briquetting technology in Addis Ababa was made. Extensive interactions and discussion were undertaken with staffs of the institutions and visual observation to demonstration site, workshops and briquette plants were also used to verify some of the statements.

2. Biomass briquetting and its implication for sustainable energy

Briquettes are compact materials produced in the process of densification of loose biomass material such as wood charcoal dust, sawdust, crop residues and other solid biomass waste. The densification/briquetting process is the physical transformation of loose raw organic materials into high density fuel briquettes through a compacting process which increases the calorific value and combustion efficiency of the product (Grover and Mishra, 1996; Sharma *et al*., 2015; Njenga *et al*., 2013; Young and Khennas, 2003; FAO, 2013). The wider applications and use in a wider variety from households to industrial processes also made the technology attractive in many developing countries. Briquettes can be used for domestic cooking, in institutions for large scale cooking and in industries for productive use. In addition briquettes can be produced in different shape and sizes depending on the availability of burning stoves. Studies indicated that, biomass briquette has been used in many developing countries and has shown a potential to alleviate energy related problems as demonstrated in Philippines, Malaysia, Sri Lanka and Indonesia (Grover and Mishra, 1996), Kenya, Tanzania and Uganda (EEP, 2013), India (Raju *et al*., 2014), Rwanda (Nahayo *et al*., 2013), Brazil (Maia *et al*., 2014), Kenya (Njenga *et al*, 2013) and Peru (Sánchez *et al*., 2014). In general the adoption and promotion of briquetting can yield the following environmental, social and economic benefits:

- Can be produced in uniform size and quality and desired size and shape to fit stove and burners
- It is smokeless and Minimizes Indoor air pollution (avoids health impacts)
- The process increases the net calorific value per unit volume of biomass
- Briquette product is easy to handle, transport and store
- The process helps to solve the problem of residue disposal
- The fuel produced is uniform in size and quality
- Has long burning time/to save the consumption and dependency on fuel wood thereby Reduces fuel wood and deforestation.
- The process helps to solve the residual disposal problem (sanitation)
- The process can help to creates source of income and employment opportunity from production and marketing of briquettes
- Lower overall fuel costs for users as they are made from biomass waste, etc.

Moreover, briquettes can be produced from any type of biomass residues which is readily available. This has also contributed towards the popularization of briquettes in many developing countries where biomass is primary source of energy. Therefore Briquettes can be considered as one of the most important modern biomass technologies for its wider and diversified environmental, social and economic benefits. Ultimately, wide adoption of biomass upgrading technologies in Ethiopia can contribute efficient utilization of the currently wasted biomass resources, thereby contributing toward improving domestic energy supply, enhancing environmental protection and sanitation and reducing GHG emissions.

3. Briquetting Experience in Ethiopia

The briquetting technology has been introduced in 1980s.The first briquetting plant installed in Ethiopia was low pressure piston machine installed by private individuals. The raw-material is primarily saw dust (60%) and the rest 40% were coffee husk and cotton-seed husk. The briquettes are sold mainly to middle-class hotels in Addis Ababa which have installed wood-burning stoves of some sophistication (FAO, 2013; EEP, 2013).

The other significant effort on the briquetting technology in Ethiopia was the cooperation agreement signed by the Ethiopian government with the World Bank to implement the ENERGY I Project in 1985 in Dilla. However, the plant was not installed and remained idle for more than 20 years. The plant was installed and begun operation on September, 2012, with a capacity of producing 120 quintals of briquette (12 tones) in one work shift. The project has a capacity manufacturing of 1.5 tons of material per hour, and the yearly capacity ranges from 1,800 to 5,400 tonnes. The direct project beneficiaries of the plant are the members of the Gedeo Development Association. The briquettes are distributed in Dilla and its surroundings, as well as in deforestation prone zones and fuel scarce areas like Arsi-Negelle in the Central Rift Valley (Horn of Africa Regional Environment Centre and Network and Addis Ababa University available at: www.aau.edu.et/hoarecn/major-projects/dilla-briquette-factory/)

Current promotion efforts in Ethiopia

Currently there are encouraging efforts are being made to promote biomass briquetting in Ethiopia by different government institutions and private sector. Based on the visit institutions working on briquetting and discussion with staffs of institutions, the efforts on briquetting in Addis Ababa are presented as under. The principal government institutions working to promote the technology are Addis Ababa city Environmental Protection Authority (EPA) and Alternative Energy Development and Promotion Directorate (AEDPD) (within the Ministry of Irrigation, water and energy).

Addis Ababa city Environmental Protection Authority (EPA) is given the authority for environmental protection and management in and around the city. It is working in waste management of Addis Ababa city, environmental rehabilitation and other activities related to environmental protection and sanitation. With regard to biomass briquetting, Addis Ababa EPA is working to promote biomass briquetting from solid biomass wastes through awareness creation on the uses and benefits of technology, waste handling and turning waste to energy (briquettes), organizing jobless groups and women and providing training and demonstrations on briquetting process. In addition the institution undertakes research activities on briquette quality from different types of wastes. The raw materials used by the institution are mainly municipal solid wastes. The equipments used in the briquetting process are manufactured locally which includes Kiln, Hammer Mill and Hand Press Molder (Figure 1). Biomass wastes are first carbonized using a kiln then the charcoal is powdered in electric hammer mill and finally briquettes are produced using manual hand press mould which produces one beehive briquette at a time. A fine clay soil is used as a binder to facilitate the compacting process of the charcoal dust. The briquette produced is beehive.

A: Kiln

B: Hand press briquette molder

C: Hammer Mill:

Figure 1: Briquette equipments

Another institution visited was the FDRE Ministry of Water, Irrigation and Energy (MWIE). The MWIE has a section dedicated to the promotion and development of alternative energy which is "*Alternative Energy Development and Promotion Directorate*" (AEDPD). AEDPD has established a workshop that is used for research and development on different alternative energy resource. In the workshop experts were working on

designing and manufacture of different briquetting equipments. Among the equipments designed and fabricated in this workshop includes kiln, hammer mill and briquette molder described above (Figure 1). In addition a manufactured Agglomerator and a mechanical briquette molder which produces two beehive briquettes at a time were observed in the workshop (Figure 2).

A: Briquette molder

B: Aggromelator

Figure 2: Briquette molder and Aggromelator

In addition to the design and fabrication of the equipments, AEDPD is also undertaking training, demonstration, assistance and follow-ups to different groups and business entrepreneurs as weel as research and laboratory activities on briquetting equipments, briquette qualities and other alternative energy technologies.

Another briquetting experience was observed at Gogle Clean Cook Stove Factory. The company was established in 2009 primarily focusing on manufacturing improved cooking stoves. According to the owner, currently they are engaged in the manufactures a range of stoves and charcoal briquettes. The company produces briquettes using Electric powered press machine manufactured in china with a capacity to produce about 10,000 briquettes per day. The charcoal powder used is made from solid wastes carbonized and supplied by women groups in Addis Ababa and from *Prosopis* charcoal dust supplied from afar region.

The products are sold to a range of users including households, hotels, restaurants and other commercial services. The owner of the factory mentioned that, currently there is huge demand for briquettes from different consumers in Addis Ababa. He added that, there is a huge opportunity for densification of the available biomass wastes in and around Addis Ababa.

4. The potential opportunities for Biomass briquetting in Ethiopia

High dependence on traditional biomass energy necessitates the transformation of the biomass energy system through the adoption and promotion of modern biomass conversion technologies. Briquetting is considered as alternative source of clean energy supply in areas where traditional biomass is the primary source of energy. In Ethiopia where traditional use biomass dominates the energy sector, briquetting can be one the alternative conversion technologies. Besides, there are basic requirements for the briquetting technology to be developed and promoted as feasible and sustainable option for alternative energy. Some of the basic requirements such as availability of raw material, market opportunity, technological capacity and applicable policy and strategies in the Ethiopian context are discussed as follows.

4.1. Biomass availability

Ethiopia has ample and diverse biomass resources if developed and transformed to modern biomass utilization technology could contribute towards efficient and sustainable energy supply. According to the Woody Biomass Inventory and Strategic Planning Project (WBISPP), Ethiopia has a total biomass fuel supply of about 1.2 billion tons per year which includes 1.14 billion tons per year of woody biomass, 22.8 billion tons per year agricultural residues and dung 33 billion tons per year (Geissler *et al*., 2013).

Woody biomass

Woody biomass from natural forests supplies the highest proportion of biomass energy in Ethiopia. Total national consumption of wood (including charcoal equivalent of wood) is estimated to be 105.2 million tons per year with 5.7 million tons of charcoal which covers more than 95% of biomass consumption in the country (Geissler *et al*., 2013). This biomass is used for traditional burning with very low energy efficiency and majority

of the energy is lost during conversion. Hence introducing the briquetting technology can result in the efficient use of the currently wasted biomass resources. The available woody biomass stock of the country is also expected to supply majority of the growing energy demand of the country which necessitates the transformation of the biomass energy sector of the country. The total woody biomass stock of the country is estimated to be more than 1,140,810,456 tones with annual yield of about 50 million tons (WBISPP, cited in Geissler *et al*., 2013). This can provide a substantial opportunity for the adoption and promotion biomass briquetting.

In addition to the available stock, the prevalence of various evasive species which are causing different environmental and socio-economic problems in Ethiopia and the intention to mitigate impacts of these species could provide additional opportunities for the promotion of briquetting. For instance according to UNDP (2009), Ethiopia has a total area of 700,000 and 1,000,000 ha covered with *Prosopis* and *bamboo* respectively. In addition to the supply of clean energy, the use of these species as inputs for briquette production can contribute towards alleviating the problems associated with these species.

Residues from agriculture and agro-industry

The Ethiopian economy is primarily dominated by rain fed agriculture which includes livestock and crop production. The agriculture sector generates substantial quantities of crop residues such as crop residues from Teff, Wheat, Sorghum, Maize and Barley. Crop residues from agriculture are either left in the field to enhance nutrient recycling or used as animal feed. However, a considerable amount of crop residues in Ethiopia is used by rural household as a cooking energy using inefficient cooking stoves and much of it is wasted with no end use (Tucho and Nonhebel, 2015; Mengistu, 2013; GTZ, 2009; Global Methane Initiative, 2011). Agricultural and agro-industrial residues constitute averagely 15-20% of the total biomass energy consumed in Ethiopia (Aregaw, 2016; UNDP, 2009). According to the WBISPP farming systems survey the total potential supply of crop residues has been estimated to be 22.4 million tons per year of which 10.3 million are used as fuel (Geissler *et al*, 2013). The available crop residues can provide opportunity for the production of fuel briquettes for clean energy. It is stated that using residues from agriculture can provide a huge opportunity for the clean energy supply through the densification process (Aregaw, 2016; UNDP, 2009; Guta, 2012).

In addition to the residues from cereal crops, various agro-industries and commercial farms also generate considerable amount of biomass wastes such as Coffee husk, Cotton residue, Saw dust and *Jatropha* residues. According to Aregaw (2016), the total volume of Cotton residue from cotton plantations of state farms in 2000 was estimated to be about 89,000 tons per year.

Table 1: An estimate of residues from agro-industry and commercial farms

Residue type	**Residues (tones/year)**
Coffee residue (2001 estimate)	214,299
Cotton stalk state farms(2009 estimate)	126,370
Cotton stalk small holders (2006 estimate)	400,301.5
Saw dust	25,000
Total	**765,970.5**

Source: Various sources cited in UNDP, 2009

As indicated in the table above various agro-industries and commercial farms in Ethiopia generates significant amount of residues which can be used as inputs for briquette production. These agro-industrial residues are currently left unused or burned in the field contributing to environmental and socio-economic problems such as pollution and solid waste management problems (Aragaw, 2016; UNDP, 2009; GTZ, 2009; Mengistu, 2013). According to Global Methane Initiative (2011), biomass residues from agriculture and agro-industries in Ethiopia contribute to significant methane emission. It is also stated that introducing a suitable conversion technology for these agricultural and agro-industrial wastes could contribute towards clean energy supply, waste management and reducing deforestation (Aregaw, 2016; UNDP, 2009; Tucho and Nonhebel, 2015). Therefore, densification of agricultural residues in Ethiopia can provide opportunities for efficient utilization of biomass energy and clean energy supply.

Municipal solid biomass wastes

Solid waste management is one of the major challenges in many developing countries like Ethiopia. Solid wastes from household, agro-industries and food industries dumped in open lands or accumulated in open-dumping sites is one of the major problem in Ethiopian cities. Majority of the wastes generated are not appropriately collected and dumped (Table 2). Studies made in Ethiopian cities (such as Addis Ababa, Jimma, Bahir Dar, Awassa, Mekelle, Adama and Diredawa) indicated that, inadequate solid waste management has resulted in the accumulation of solid waste on open lands, in water ways and drains (Edwards, 2010; Beyene and Banerjee 2011; Cheever, 2011; Regassa *et al*., 2011; Kneeland and Knutson, 2012; Hailemariam and Ajeme, 2014).

Table 2: Amount of solid waste generated from 2003-2007 in Addis Ababa

Amount in m^3	2003	2004	2005	2006	2007
Amount of solid waste generated	760,244	789,134	819,121	850,247	882,557
Total amount of solid waste collected and disposed	544,689	517,356	538,387	615,336	432,570
Amount of solid Waste unattended	215,555	271,778	280,734	171,969	449,986
Percentage of unattended Waste	28%	34%	34%	20%	50%

Source: AASBPDA, 2003-2008 as cited in Edwards, (2010)

The above table shows that much of the solid wastes generated have not been appropriately managed. In addition Edwards (2010) indicated that, 70-75% of the solid wastes are organic wastes which can provide different benefits if appropriately managed and converted in to fuel briquettes. For instance in 2005 and 2006, the estimate of annual *chat* residue in Addis Ababa was 8,526 and 6, 608 tons per year with a gross charcoal production potential of 1,066 and 826 tons per year respectively (kebede and seboka, 2006; in UNDP, 2009). Thus, using the available solid wastes potential for briquette production can contribute towards meeting the goals of environmental/municipal sanitation and improved energy supply.

4.2. Technological capacity for manufacturing briquette equipments

Another basic component of the briquetting system is the equipments for carbonization, powdering the charcoal and densification. Hence the technological capacity to manufacture these equipments at local level is an important prerequisite for the wide adoption of the briquetting technology. Experiences from many developing countries shows the briquetting equipments can be produced using locally available materials with local technological capacity (Owen, 2012; Osarenmwinda and Ihenyen, 2012; Nartey, 2014). In addition Lohri *et al*., (2015) stated that, densification equipments such as Hand Presses, Agglomerators and Screw Extruders can be manufactured locally in Sub-Saharan African countries at a price competitive with imported equipment.

In Ethiopia, technological capacities to manufacture equipments such as Kiln, Hammer Mill, Hand Press, Agglomerators and Screw Extruders at a reasonable cost have been demonstrated by different government and private institutions. For instance during the visit to a workshop of the AEDPD, equipments like Kiln, Hammer Mill and densification equipments such as Hand Presses, Mechanical Press and Agglomerator were observed (see Figure 1 and 2). The experts mentioned that, the workshop is currently operating on the designing and manufacturing different types of briquette equipments and supplying to private enterprises and institutions working on biomass briquetting. The manufacturing cost of the equipments is also an alternative against imported machines and is affordable at household, community or small business level.

In similar ways a capacity to manufacture fully functional briquetting equipments has been observed in Wolaita Sodo Poly Technique Colleges under the order of WSU office of community services. The equipments were manufactured based on the designs from AEDPD and includes Kiln, Hand Press Molder and Hammer Mill. Moreover, another example on the local capacity to manufacture manually operating equipments using locally available materials has been demonstrated at Jimma University which includes extruder and kiln (Bogale, 2009). Bogale, (2009) also stated that, these equipments can be produced at a cost of 10,000 ETB that is affordable by households communities and small business enterprises. Therefore, the manufacture, repair, maintenance and technical aspects of briquette equipments can be well addressed locally in Ethiopia.

4.3. Market opportunity

Ethiopia is among the top traditional biomass energy consuming countries in the world (IEA, 2014; EEP, 2013; Bizzarri, 2010; Lakew *et al*., 2011). With the existing high dependence on and fast growing demand for biomass as a primary source of energy, the market opportunity for upgraded biomass briquettes in Ethiopia could be enormous. Trends on the share of biomass energy utilization indicate that, traditional biomass is consumed as a primary source of energy in household; commercial services sectors, public institutions and industries sectors.

Domestic cooking energy demand is met almost entirely by biomass fuels using energy inefficient traditional stoves. More than 99% of the total biomass energy of the country is consumed by residential/household sector (IEA, 2016; Guta, 2012). According to IEA (2014), all rural households and about 88% of urban households in Ethiopia depends on biomass energy. The existing huge demand for biomass energy for domestic applications with very low level of conversion efficiency could provide huge market opportunity for improved and efficient briquette fuels for domestic cooking.

In addition to the households sector, commercial services, industries and institutions such as universities, hospitals, schools, militarily camps that rely on biomass energy can provide a substantial opportunity for upgraded biomass briquette fuels. Guta, (2012), stated that, 70% of industries and 94% of service enterprises uses biomass as their source of energy. Studies also indicated that the total commercial services biomass consumption in 2013 was estimated to be 1.5 million tons per year with 0.16 million tons of charcoal (Geissler et al, 2013). The fact this very high reliance on biomass fuels at household, commercial, industrial and institutional level with wide spread use of traditional inefficient stoves can provide enormous market for improved biomass

briquette fuels. Moreover, it is indicated that there could be a huge market opportunity for upgraded biomass as a source of clean energy in Ethiopia at commercial and industrial level (Aregaw, 2016; UNDP, 2009; GTZ, 2009).

4.4. Applicable policies and strategies

The policies of the Ethiopian government encourage the development and transformation of biomass energy resource aiming at the development of indigenous energy resources. The Ethiopian National Energy Policy states that the development and utilization of indigenous energy resources with the aim of attaining efficiency and energy self sufficiency as the priority government objective in the energy sector development (objectives 5, 6&7). The policy proposes diversification and enhancement of modern biomass technologies for the purpose of increasing the national energy supply mix and also as a means to reduce the burden on the unsustainable use of the natural woody biomass resource base (aim 2). The policy also identifies biomass energy technologies such as biogas, biomass briquettes and ethanol production.

1.1.1 The environmental policy of the country also proposes "promotion and development of renewable energy sources and reduce the use of fossil energy resources, both for ensuring sustainability and for protecting the environment, as well as for their continuation into the future. Improving the living standards of poor people's through job creation in different bio-energy production processes through the adoption of energy sources and technologies to replace traditional biomass fuels is also clearly entrenched in the environmental policy of the country. Moreover, other policies and strategies such as Forest, Woodland and Tree Resources and the Conservation Strategy of Ethiopia in general support the development and transformation of indigenous biomass energy.

5. Conclusion

Biomass briquetting is a technology that can provide various socio-economic and environmental benefits particularly in developing countries where traditional biomass is the primary source of energy. Besides to the clean affordable cooking energy supply, it can contribute towards reduced deforestation, low indoor pollution, improved waste management and employment creation. In Ethiopia where the energy sector is primarily dominated by the use of traditional biomasses, biomass briquettes can be considered as appropriate technology for clean and eco-friendly energy supply. The available biomass resource, which is expected to meet the growing energy demand of the country, can provide a huge opportunity for the wide adoption of the briquetting technology in Ethiopia. In addition, the current high and growing demand for traditional biomass fuels in households, public institutions, commercial and service sectors makes the demand for improved briquette fuels enormous. The technological capacity to manufacture small to medium scale briquetting equipments using local capacity can also be achieved in Ethiopia. Moreover, environment and energy related policies that support the development and transformation of indigenous renewable energy resources of the country can facilitate the adoption and promotion of the technology.

In general, there is a huge opportunity for the wide adoption of biomass briquetting in Ethiopia. This can result in the efficient and sustainable use of the currently wasted biomass resources of the country and solve household energy poverty and the socio-economic impacts of traditional burning of biomass and contribute towards reducing the pressure on forest resources of the country. Hence, strengthening cooperation among stakeholders, provision of strategies and programs that supports the adoption of the technology and dissemination of information through training and awareness creation can contribute to the wide adoption of the technology.

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