Assessment of Biomass Fuel Resource Potential And Utilization in Ethiopia: Sourcing Strategies for Renewable Energies

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Abstract- In recent years, there has been renewed interest on renewable biomass based energies. This is due to growing environmental benign, energy security concern and spiraling price of fossil fuel. In the case of poor economies like Ethiopia quality of life and energy consumption are tidily conjoined. This article assessed biomass fuel resource potential of Ethiopia and also investigated strategies for its modern utilization, with particular emphasis on sourcing options for cleaner energies. With proper sourcing strategies, biomass supplies green and cleaner renewable energy for wider human, industrial and transportation services. There is, however, no systematic study on strategies for efficient use of biomass fuel resource in Ethiopia. Abundant and untapped availability, user as well as environmental friendliness, applicability for wider fuel need purposes, competitiveness in terms of cost of production, its rural poverty linkages and multitude of other factors make biomass based fuels prior energy source of Ethiopia. Hence, innovative investment on renewable biomass based fuels (e.g. biogas, bioethanol and biodiesel) and broad distribution of improved fuel stove technologies to rural and urban households, as well as energy conservation technologies for industries and service sector should be promising areas for policies targeting green growth. Hence, developing appropriate institutions and technologies for renewable energies sourcing from biomass is invaluable.

Keywords- renewable energy, sourcing strategies, biomass fuel, resource potential, efficient utilization.

1. Introduction

Ethiopia with landmass of 1.1million square kilometers is third giant and second populous nation in the Sub-Saharan Africa with estimated population of about 85.5million. United Nation Development program [UNDP, 2010] ranked Ethiopia 157th in the human development index, with per capita average annual income of 120$ and about 40% of the population below poverty line. The energy poverty of the country is manifested in its indigenous biomass resource resilience. National energy balance of Ethiopia has been so far predominated by two sort energy resources (Hydro and biomass). The latter sourcing over 80% of its energy needs. As a result, the country has been suffering from massive depletion of indigenous biomass resources. Moreover, domestic petroleum consumption is completely imported resilient posing its evolving economy to recent fossil fuel prices soaring.

At global scale more than 3billion (nearly half of world human) deprived of access to modern energy alternatives. All of these people live in poor countries and depend on traditional biomass resources to meet their basic energy need. This has caused worsening health and environmental consequences. Central premise of world energy strategy, thus, has aimed at shifting from use of high-cost and environmental damaging fossil fuels to cost-effective renewable energies that can be sourced from renewable resources (biomass, wind, hydro and solar). Major challenge in Ethiopia's energy sector is aligning national energy supply with socio-cultural and economic developmental needs. However, energy crisis in the country is reflected in its overreliance on indigenously sourced biomass fuel. As compared to other energies sources, biomass can be used for production of fuel with diverse and wider uses. Given broad resource base, technological innovation on biomass for generation of renewable fuels marked turning point in world energy system.

This article was motivated by lack of well elaborated study on strategies for biomass based energies in Ethiopia. Despite insisting the need to ameliorate the negative consequences of biomass fuel consumption on the livelihood of the poor in Ethiopia, energy proponents have seldom developed comprehensive strategies for its efficient utilization. This article was inspired by threefold objective: (1) assessed biomass fuel potential and utilization pattern (2) reviewed comprehensively the existing state of knowledge on biomass fuel utilization and related issues (3) proposed strategies and policies for efficient biomass fuel utilization.

2. Theoretical framework

This article developed theoretical framework dealing with biomass resource optimization in generating renewable biomass fuel. Biomass resource supply can be formulated as:

$$Z_t = \sum_{i=1}^{n} X_{it} \qquad (1)$$

Were Z_t stands for total biomass resource produced in time period t, X_{it} is biomass supply from specific source i which are diverse. These may include: aquatic, forest, livestock sector, energy crops, agricultural residues, industrial and urban wastes, etc. But X_{it} denotes total biomass resource supply form corresponding source. Suppose, only X'_i represents a useful biomass resource that can be potentially convertible to fuel $Z_i{}'$. Then, it is this component of biomass that is essential for renewable biomass fuel production. So, the formula in eqation1 can be rewritten as:

$$Z_{it}{}' = \sum_{i=1}^{n} X'_{it} \qquad (2)$$

Were Z'_{it} shows aggregate volume of raw biomass resource possessed by the country at a point in time that can be potentially converted into renewable fuel. Deviation might perhaps arise from:

- Competitive uses of biomass for non-fuel purposes (fiber, food, fodder etc.)
- Co-products like biochemical, biomaterial etc. that can be obtained in conversion process and,
- interrelated factors

This potentially useful energy may be used in traditional way (firewood, charcoal, agricultural residue), converted into renewable biomass fuel (biogas, biodiesel or bioethanol etc.), and partly wasted. Wastage of biomass energy arises from:

- Loss of resources at consumption stage due to inefficient ways of utilization (like lack of improved cook stove and energy saving technologies in industrial and service sectors)
- Resource loss during conversion/processing or resource mining due to poor conversion technology

Hence, optimization involves:

- reducing/minimizing loss in useful biomass fuel resources
- maximizing renewable biomass production
- improving efficiency of traditional biomass fuel consumption

Therefore, economic optimization involves maximizing the net energy value of useful biomass resources. Thus, economic maximization involves specification of production function. Hence, production function for specific biomass sources can be specified as:

$$X'_i = T_i F(L, K, A, Y_i) \qquad (3)$$

Where *L* represents labour resource, *K* is capital, T_i is technological factor for specific biomass source, *A* denotes land resources and *Y* stands for other factors that are pertinent to producing biomass fuel from source *i*.

Main stream economic optimization requires maximizing biomass resource production subject to constraints. Cost of production may be specified as:

$$\mathrm{C_i} = w\mathrm{L_i} + \mathrm{rK_i} + \varphi \mathrm{T_i} + \psi \mathrm{A_i} \qquad (4)$$

Where, C_i total cost involved in production of biomass fuel from source i, w is wage rate, r retal rate for capital, φ per unit cost of technology, ψ rental rate of land used for production of biomass fuel under source *i*.

Formulation of Lagrange

$$\mathcal{L}_i = \sum_{\mathrm{i}}^{\mathrm{N}} \mathrm{T_i F(L, K, A, Y_i)} - \lambda_i \sum_{\mathrm{i}}^{\mathrm{N}} [\mathrm{C_i} - \{w\mathrm{L_i} + r\mathrm{K_i} + \varphi \pi_\mathrm{i} + \psi \mathrm{A_i}\}] \qquad (5)$$

Following the simple mathematical optimization system, one can determine the optimal values of the resources (inputs). Identifying the optimal input mix helps to determine the optimal amount of biomass production required. What we outlined so far is the main stream economic problem, nevertheless in renewable energy production; there are multifaceted constraints, and objectives (reducing greenhouse effect fossil fuels and ensuring food security etc.). The complex inter-linkages among critical factors revolving around renewable biomass fuel production and utilization are outlined below.

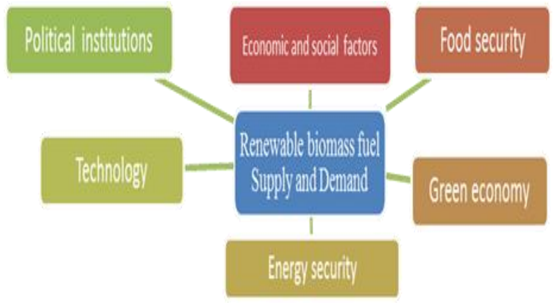


Fig. 1. Key issues revolving renewable biomass fuel production and utilization

Source: devised by author

3. Review of literature

In the theoretical and empirical literature there are contrasting views on biomass resource use for basic human energy needs. The early proponents poised pessimistic view towards biomass fuel consumption. This band of theorists viewed that reliance on biomass resources for basic energy need deprives health and other wellbeing of users and also degrade the environment. Optimistic insisted that sustainable harnessing of biomass with the aid of modern technologies; offer renewable energy. Existing knowledge on biomass energy utilization was reviewed below.

Biomass resources comprise of residues from agriculture, harvests from forest (in the form of firewood, charcoal, residues), crop residue, energy crops, animal manure, residues from agro-industrial and food processes, municipal solid wastes, and other biological resources [1; 2; 23; 13]. These resources could be directly utilized for basic energy needs (e.g. firewood, charcoal, dung cake etc.) or transformed into invaluable renewable energies (e.g. biogas, biofuel, bioelectricity, hydrogen energy etc.) for household as well as industrial and transportation sectors.

Biomass was the oldest form of fuel used in history of humankind and is also the fuel which was the mainstay of the global fuel economy till the middle of the 18th century [20, 13]. It accounts for 35% of primary energy consumption in developing countries, constituting about 14% of the world's total primary energy consumption and is only organic petroleum substitute that is renewable [14]. It is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles and providing process heat for industrial facilities [23]. It is the first-ever fuel used by humankind and is also a fuel which was the mainstay of the global fuel economy till the middle of the 18th century [20].

Biomass-based energies are basically derived from three sources: agricultural residues, forestry residues and energy crop. High fossil fuel prices and national security concerns have sparked interest on bio-based fuel development in continental Africa [6]. Hence, studies identify that biomass based energy can help reduce emission [16; 18]. However, biomass energy production may cause worsening food security due to competition for scarce resources. Energy security concern, however, sparked interest on renewable energy technologies. Resurgence of interest on production of renewable energy from biomass resources is thus geared varieties of social, economic, political, environmental and technical factors [4].

Biomass is the general term which includes phyto-mass or plant biomass and zoo-mass or animal biomass/ cattle excreta [20]. Studies indicate that biomass resources offer renewable energies that can play a pivotal role in the current global strategies for reducing greenhouse gas emissions by partially replacing fossil fuels [7]. For instance, in Thailand with modernization, instead of reducing biomass energy consumption; there has been continuously increased tendency of its utilization for both households and production of modern energy [20].

Studies identified six categories of biomass resource for energy production: energy crops on surplus cropland, energy crops on degraded land, agricultural residues, forest residues, animal manure and organic wastes [15]. Growing biomass energy yielding plants have been viewed to offer multiple benefits for energy security and livelihood of rural households. A recent study identified biomass energy as a major contributor to not only energy consumption in Sub-Saharan Africa but also to employment and poverty alleviation [12]. The author concluded that promoting the production and use of all types of biomass energy should be a priority, rather than discouraging as the so called "traditional fuel". A case study was conducted on agro-village of Shandong in China indicated that biomass from agricultural residues offer livelihood energy and increases the villagers' incomes as well as reduce green gas emission [23]. In case of India, decentralized power generation using biomass gasification was investigated and found that biomass based energy has several distinct advantages such as wide availability and uniform distribution that puts it ahead among the renewable energy[3].

From industrialized countries viewpoint, an empirical study using French data analyzed household energy choice and fuel wood consumption, and concluded that in this era of soaring price of oil and growing need to combat global warming, wood appears to become increasingly competitive and desirable for the environment[17]. The authors identify wood as a perfect substitute for polluting fossil fuels provided local production potential and sustainable availability for European Union. Hence, biomass is considered as the renewable energy source with the highest potential to contribute to the energy needs of modern society for both the industrialized and developing countries worldwide [14]. Furthermore, utilization of forest biomass has emerged as a key strategy for addressing a variety of environmental and energy related needs in the United States [5]. Despite remarkable contribution of biomass to world energy balance its use is in a primitive and inefficient manner in developing countries lead to a host of adverse effect on human health, environment, and social wellbeing [3]. Biomass based electricity schemes already provide over 9GigaWatt of worldwide generation capacity [21].

4. Biomass energy supply potential and utilization

4.1. Biofuel resources potential (Supply)

To shade light on this reality, the macro energy potential and exploitation level was presented below. In table1, biomass resource production potential of the country was presented. There is dearth of well documented and update data on biomass resources of Ethiopia. Various secondary sources were reviewed. As shown in table1, Ethiopia has ample and diverse biomass resources presenting opportunities to harness for renewable biomass fuels.

Table 1. Summary of Ethiopian biomass resource potential

1. *Agricultural biomass residue* 1.1. Coffee Residues • 214,299tonnes/year • Production of briquettes charcoal	1.2. *Bamboo* • Largest bamboo growing area in Africa 469,664ha • Charcoal briquettes & multiple goods
1.3. *Enset* • Indigenous drought resistant staple food • multifold purposes residue(fuel, fed for cattle,)	1.4. *Banana* • biomass residue for fuel
1.5. *Cotton Stalk residue* • Potential 400,301.5tonnes • Yield 89,000 tonnes per year	1.6. *Sawmill residue* • 25,000tonnes per year • Production of substitutable fuel industries
1.7. *Chat (cash crop)* • Yield 6,608 tonnes year(826 charcoal tonnes/year • One of the exportable good • Charcoal production or directly used	1.8. *Energy plants (Jatropha, Castor bean, palm tree etc.)* • suited to agro ecology • cheap cost of factors • land for Jatropha investment 23.3million ha
1.9. *Crop residues* • Multiple uses (fertilizer, fodder, building material, etc.) • Potential supply presented in table2.	1.10.*Animal residue* • Multi-uses (fertilizer/compost, fuel, house decoration, utensil production etc.) Potential supply presented in table2
2. *Woody biomass resources* 2.1. *Forest (*Natural and planted) • Forest coverage 12.2 million ha (11% of total land mass) [9] • Timber & non-timber products	2.2. *Other woody biomass resources* • Coverage 44.65milion ha (41%) [9] 2.3. *Grasses* • production of biofuels • Used as fodder & other purposes
3. *Waste industries* 3.1. municipal solid wastes • clean urban environment • data unavailable on potentialities	3.2. *Agro-industrial by products* • for bagasse and ethanol production • 700,000ha suitable land for sugarcane(MWE) • 1billion ethanol potential(MWE)

Sources: various secondary sources cited in the table

Table 2. Potential supply of biofuel in Millions of tons

Region	Woody biomass stocks	Woody biomass annual yield	Crop residue	Animal dung	Total	Share
Tigray	30.99	0.08	0.86	2.09	33.95	0.03
Amhara	138.89	5.84	6.24	7.43	152.55	0.15
Oromiya	373.34	19.90	10.96	10.62	394.92	0.40
SNNP	227.95	10.10	5.67	4.01	237.63	0.24
Afar	21.64	1.44	0.12	2.64	24.41	0.02
Benshan gul	76.61	3.53	0.21	0.18	77.00	0.08
Gambela	69.16	3.32	0.08	0.12	69.36	0.07
Dire Dawa	0.06	0.03	0.04	0.04	0.13	10^{-4}
Harari	0.09	0.01	0.05	0.02	0.15	$2(10^{-4})$
Total	938.73	44.26	24.23	27.15	990.10	1.00
share	0.95		0.02	0.03	1	

Source: Ministry of water and Energy (MWE)

Table 2 indicates that total biomass fuel supply of Ethiopia is about 990billion tons excluding Addis Ababa and Somalia. Woody biomass constitutes 95% of total potential supply. Animal dung and crop residues account mainly for 3% and 2% respectively. Regional distribution reveals that Oromia supplies about 40% of biomass resources followed by SNNP (24%) and Amhara (15%) in that order. Remaining regions own insignificant share of national biomass fuel resources.

4.2. Biomass fuel utilization pattern (Demand)

Heavy skewedness of Ethiopia's energy consumption towards biomass resources is attributed to deprivation of access, deep rooted poverty, technological backwardness, and numerous other factors. International Energy Agency report evidenced the unhealthy reliance of Ethiopian economy on biomass fuel resources for national energy requirement which has caused multifarious puzzles. According to the report, in the year 2008 alone 92% of Ethiopia's energy demand was met from biomass source. Hydro power and oil products claimed mainly 1% and 7% respectively. These shows the extent to which national energy balance of the county is resilient on biomass resources.

Trend and share of different biomass fuel sorts in total biomass consumption for the last decade was presented below. Firewood was the major biomass type consumed in Ethiopia. The country is the number one producer in its share to world's charcoal and woody fuel wood as compared to other African countries. Evidences indicate that 99% of households, 70% of industries and 94% of service enterprises use biomass as energy source. Trend in total biomass consumption different sectors implies that households consumed almost all biomass fuels in the last decade. Computed average share of household biomass fuel consumption out of total biomass consumption as fuel over the 11 years stood at about 99.6%.

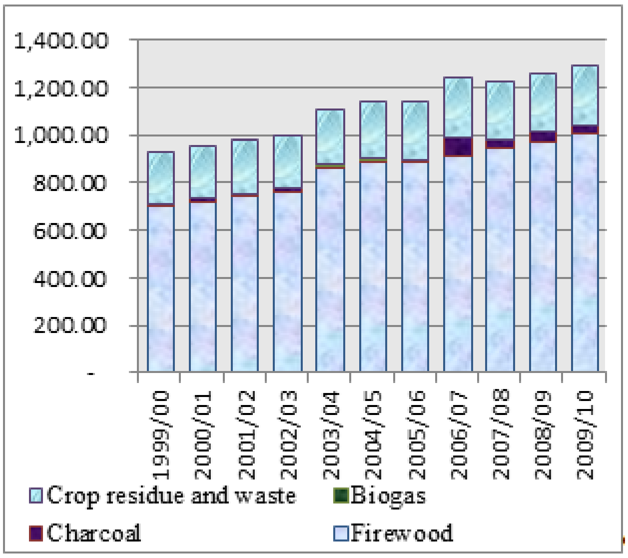
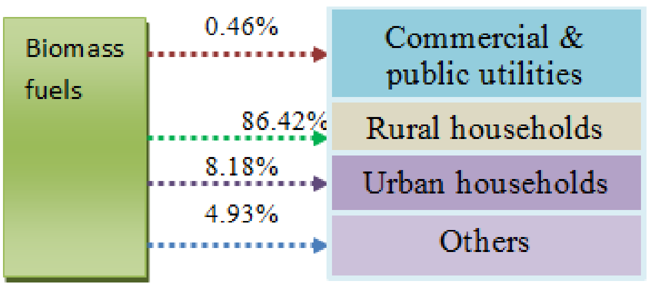


Fig. 2. Trends and patterns of biomass consumption in Tera Joules (TJ) (Source: MWE)

The Food and Agriculture Organization (FAO) has estimated that for the world as a whole total charcoal production in 2009 was 47million tones and increased by 9% since 2004 [8]. Africa accounted for an overwhelming share of world's charcoal production (about 63% of global production) in the 2004. Ethiopia is among the leading producer (8%) in the world production of charcoal following Brazil (11%). FAO report also put Ethiopia among the five top world's wood fuel producing country in the period 2004-2009 only next to India(16%), China (11%) and Brazil (7%) in that order. Ethiopia according to the report had 4th rank in its share to global wood fuel production contributing about 5% in the covered period. Fuel wood is preferable energy source for industrial heating in small and medium scale industries (e.g. soap industry). Charcoal is also utilized by small cottage and craft industries.

Table 3. Average share of biomass fuels consumption by sectors for the last decade (1999/00-2009/10)



Source: MWE

As presented in fig.3 above, distribution of biomass fuel by end use sectors implies that on average over the last decade rural households consumed over 86% of biomass fuel followed by urban household (8.2%) and other sectors (about 5%). These include agricultural and industrial sectors.

Table 4. Annual biomass energy consumption in Tcal

Region	Fuel wood	Char coal	Res-idues	Dung	total	Share
Tigray	6,865	249	435	2,260	9,809	**0.044**
Amhara	49,033	220	10,530	15,917	75,699	**0.339**
Oromiya	58,281	577	3,150	9,762	71,771	**0.322**
SNNP	44,138	75	4,971	677	49,862	**0.223**
Afar	1,813	18	0	2	1,833	**0.008**
Bene Shangul	2,472	27	328	10	2,837	**0.013**
Gambela	771	1	3	0	775	**0.003**
Somali	3,293	118	118	132	3,662	**0.016**
Dire-Dawa	196	22	24	0	242	**0.001**
Harari	128	6	30	0	164	**0.001**
Addis Ababa	5,617	429	78	392	6,517	**0.029**
total	172,608	1,742	19,667	29,152	**223,169**	**1**
share	**77%**	**1%**	**9%**	**13%**	**100%**	

Source: MWE

In table 2 above, it is discerned that about 77% of annual biomass consumption in Ethiopia is met from fuelwood followed by animal dung (13%) and crop residue (9%) respectively. Regional distribution of biomass consumption was also presented in the table. Annually about 88% of total biomass fuel is consumed mainly in three regions Amhara (34%), Oromia (32%) and SNNP region (22%). The annual biomass fuel consumption inculcates all sorts of energy utilization (industrial, rural and urban households, commercial and other sectors).

4.3. Sourcing strategies for renewable energy from biomass

Key biomass based energy strategy may largely involve innovative technological investment, which use biomass more efficiently to produce modern renewable fuels to meet energy needs in various sectors. Such technological investment requires biomass conversion to non-solid form (biogas, bioelectricity, hydrogen fuel production, bioethanol, and biodiesel etc.) and more efficient use of solid biomass fuel using modern cooking stove technologies. These potential advantages include: reduction in indoor air pollution, decreased per capita energy consumption and various other societal welfare benefits. There are multitude of factors that determine pace and pathways of renewable energy generation from biomass sources. Here we identified technologies and institutions as major underlying factors that determine the pace of developing renewable energies from biomass resources. Institutions are key determinants of investment on modern renewable energy technologies with no exception for biomass. It also involves various stakeholders along the whole supply and demand value chain. Hence, institutional factors play critical role in success of renewable biomass energy for energy security.

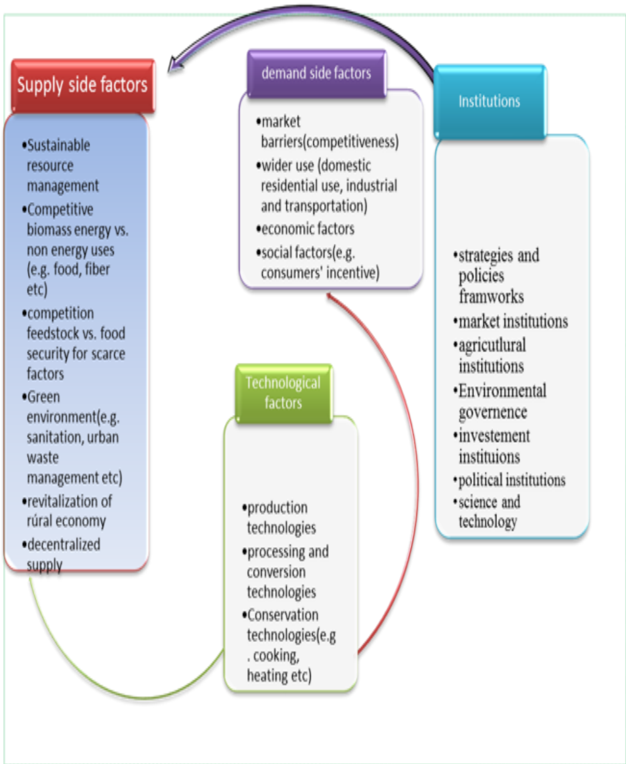


Fig. 3. Conceptual linkage between critical factors in renewable biomass fuel (Source: devised by author)

Institutions, thus, affect both demand and supply side of biomass energy based economy in addition to influencing technological factors. Technologies in turn influence the demand and supply sides as discussed below. In the following section the article presented some strategies for biomass fuel technologies. Biomass as discussed above can sustainably source the energy need for green growth when it is harnessed to generate renewable energies.

State of the art of pathways of biomass sourcing for renewable energies has been presented below. Integration of modern scientific innovation into indigenous knowledge greatly helps in enhancing modern energies from ample resources owned in Ethiopia. Intuitions and policies outlined above play critical role in smoothening the chain of renewable biomass fuel generation.

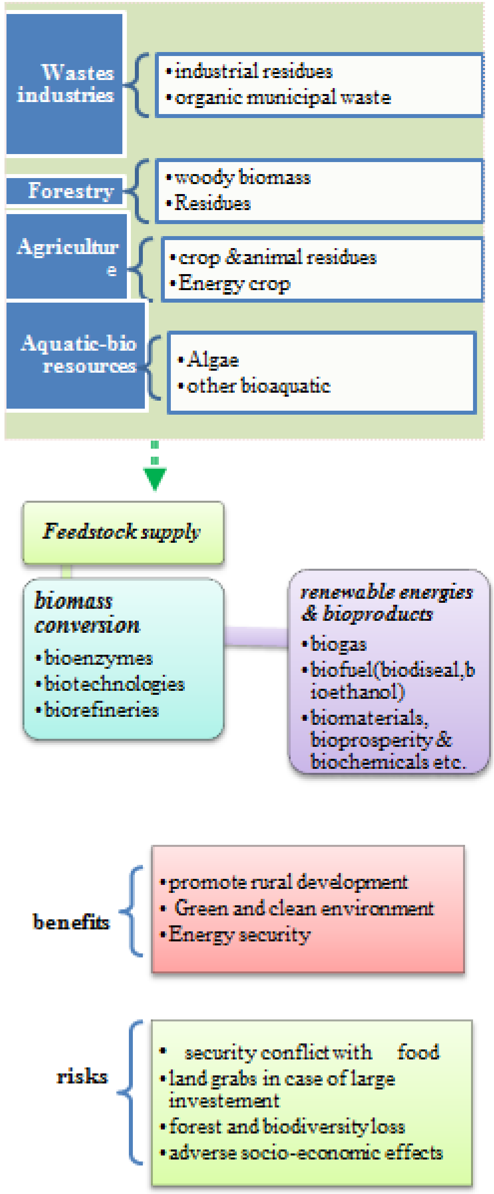


Fig.4. Pathways of generating renewable fuel from biomass (Source: devised by author)

4.3.1. Biomass gasification/Biogas

Given resource potential, biogas is one of the promising clean energy for Ethiopian households. It involves gasification of biomass resources. The sole technology for biogas production in Ethiopia so far is anaerobic digestion/fermentation that based on animal residue. The major advantage of biogas based on manure is that it is renewable. In this view, Ethiopia endowed with huge potential. It is the first in Africa and tenth in the world in terms of livestock ownership. Biogas technology has been implemented at small scale rural and off-grid areas.

Report of International Energy Association identifies two sorts technology for conversion of biomass into biogas. These are: thermo-chemical processes which is fast and can produce biogas and other fuels, with only 2%-4% of ash, and anaerobic fermentation which is slow and converts only a fraction (50%- 60%) of feedstock but produces soil conditioners as a byproduct.

By easing pressure on the natural forest, biogas can help to reduce environmental puzzles as well as ameliorates health risks. Use of biogas augments household productivity as it frees labour involved in searching of collectible fuels. Biogas also enhances human capital as it eases burden on children time for schooling and delivers clean fuel for reading. Women and girls are customarily liable for biomass fuel collection. The unbalanced share of burden of collecting and managing traditional fuels has resulted to women's disproportionate lack of access to education and income, and inability to escape from poverty [9].

Dung input has competitive use as fertilizer. Cost of fertilizer has been escalating. Compost obtained from biogas provides alternative fertilizer for farmers. Hence biogas has an aptitude to reduce burden of rising price of fertilizer. But its utilization is hindered by various factors. The prime challenge is cost of financing which poor rural households are unable to afford. Hence, collective actions and institutions for decentralized biomass fuel/biogas are crucial for channeling finance and technology to remote rural areas.

4.3.2. Liquid biofuel (biodiesel and bioethanol)

Massive dependence on fossil import increasingly exposed Ethiopia to international price volatility. That exacerbated its balance of payment. Hence, an overriding emphasis has been given to biofuel. Its wide use for energy needs in household, transportation and industrial applications makes biofuel promising candidate of energy diversification option in Ethiopia. Local production and utilization of ethanol has been already started as a blending to gasoline (B5) which has been upgraded into (B10). Data obtained from MWE indicates that the country has produced and consumed about 5.55Tera Joule (TJ) and 4.8TJ in the year 2008/09 and 2009/10 respectively. The government of Ethiopia has also set clear plan of increasing biofuel production. Figure6 presents the target plan to be achieved in the next five year regarding ethanol production. The plan is to increase Ethanol production from its level of 7.1Million litter in the year 2010 to 181.6million liters by the end of the period (2015).

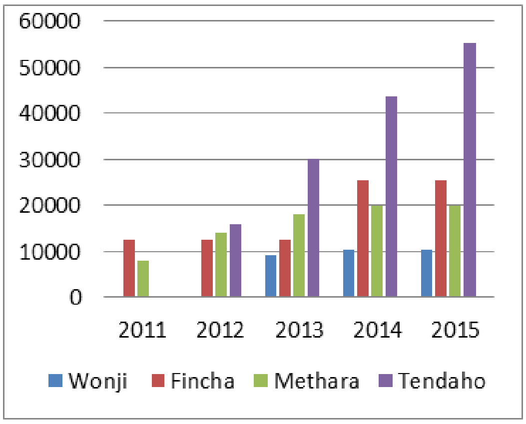


Fig. 5. Ethanol production plan in state sugar factories (Source: Ethiopian Sugar Agency (ESA))

Ethiopia also possesses ample potential for production of biodiesel. The country has promoted production mainly of three feedstock, Castor bean, Jatropha curcas, and palm tree. In this light, at national level, the country has allocated attendant land (23.3million ha) to feedstock production. But whether biofuel can competes with other sorts of energies depends on multitude of factors (e.g. price of feedstock, price of other fuels, availability of sufficient land, etc.).

Concern over competition between food security and feedstock production has reigned in agenda of many countries. The tradeoff may arise from two perspectives. Firstly, competition of biofuel for food crops (sugar cane, maize etc.) directly affects food security in case of 1^{st} generation biofuel. Secondly, competition for scarce resources (land, labour, capital etc.) with food products in the case of 2^{nd} generation, but in the case of 3^{rd} generation (on degraded land) yield is poor.

4.3.3. Hydrogen energy (bio electrification)

Hydrogen energy is electrical power that can be produced from resources such as fossil fuel, water and biomass. Hydrogen fuel from renewable biomass resources provides environmentally benign energy alternative for substituting polluting fossil fuel. However, sophisticated technologies in the biomass conversion process, infrastructural requirement as well as huge capital investments limited its application mainly in industrialized countries. Production of hydrogen from renewable biomass has several advantages compared to fossil fuels [11]. Despite aforementioned constraints biomass based hydrogen power provides techno-economically and environmentally convenient fuel option.

4.3.4. Cooking stove technologies

Existing biomass fuel utilization in Ethiopia is due to inefficient obsolete technologies at mining, conversion and consumption stages. This also triggers health risks to disproportionately susceptible women and children. In standard efficiency measurement, diverse biomass fuel sources have varied degree of efficiency. For instance, heating value and consumption factors can be used to compare efficiency level of different sorts of biomass fuel categories. In energy economics fuel efficiency is measured in terms of Mega Joules (MJ) per unit Kilogram of the specific energy consumed. Thus efficiency of different fuel categories can be measured and compared using standard unit (MJ/KG). This kind of efficiency measurement is based on input-output approach. It implies how much Joules energy is produced as output from a given amount of biomass resource. It also represents heat values and conversion factor of biomass fuels. Based on this approach energy studies discovered that facto that charcoal is the efficient than other biomass as presented in the table2 followed by sawdust. But charcoal is an output from wood. But charcoal mining not efficient.

Table 4. Efficiency measures for biomass fuels

Fuel	Kcal/kg	MJ/kg
Fuel wood	3,700	15.5
Biome leave and litters[1]	3,700	15.5
Roots [1]	3,700	14.3
Charcoal (5.25% mc dry basis, 5% wet basis, 4%ash)	6,900	29
Saw dust (11% mc dry basis,10% wet basis, 1%ash)	4,040	18.6
Agri-residue	3,585	15
Maize stalk [2]	3,585	15
Dung (15% mc dry basis,13% wet basis, 22.5%ash)	3,300	13.8

Source: MWE

There are numerous indicators of fuel efficiency. These may include the indoor air pollution, green house effects (e.g. deforestation, CO_2 emission during production, conversion and consumption), etc.

Improved cook stove technologies have two essential benefits. Firstly, it helps to reduce indoor air pollution. Secondly, it reduces amount of fuel consumption. In doing these it ameliorates health risks as well as reduces growing pressure on the natural environment. Nevertheless, widespread use of improved cook stove has been deterred by various factors. The formidable problems may include meager income of the poor to afford, lack of infrastructure, sluggish market penetration in to remote villages, lack of know-how of utilization and information gap. Lack of technologies, capital and incentives to develop renewable energies from biomass resource remain the major constraint.

5. Conclusion and policy recommendations

Driven by massive population growth and rural poverty, biomass is expected to source significant share Ethiopia's energy requirement. With the aid of appropriate strategies biomass resources can provide renewable energy. This article has identified major strategies for renewable biomass fuel for future energy diversification in Ethiopia that may assist to reduce susceptibility to price of fossil fuel, reduce dependence on import, help reduce poverty and promote sustainable development. There are several attractive prospects for harnessing renewable biomass resources for modern energy generation in Ethiopia. In light of this, the country has already shown its fortitude. However, it has been severely constrained by economical, institutional and technical factors. It may involve various risk and tradeoffs like food security which need critical policy attention.

Various policy options might assist to promote modern biomass fuel utilization. For instance, sustainable resource management (SRM) during biomass resource extraction, processing/conversion and utilization is vital. Strategies should encompass holistic socio-cultural, economic and technological renovation. Hence, assuring sustainability of biomass fuel utilization and concurrently increasing supply of biomass resources through measures like afforestation are animated intervention fields. Institutional and technological factors as well as supply and demand side factors play key role in renewable biomass energy production and utilization.

Linking rural villages with decentralized modern biomass and other renewable energy investments (like solar, wind and mini-hydropower) are essential to reach the remote rural sector. For this purpose, incapacitating collective actions, rural institutions and other stakeholders for decentralized renewable energies (including biomass) and awareness rising is critical. Enhancing private-government cooperation on modern renewable energies and promoting dissemination of energy saving technologies are important policy measures. Furthermore, developing energy infrastructure for modern biomass fuel generation is invaluable. Creating conducive investment opportunities and businesses for private investors engaged on biomass fuel as well as identifying proper means of facilitating financial resources for decentralized biomass based energy investments (e. g. linking with carbon financing) are also indispensible. Smoothening market for renewable fuels and assuring sustainability of supply and adoption of appropriate renewable energy technologies is crucial. Policy measures should thus target technological innovation both from demand perspective and supply side to ensure sustainable production and utilization of biomass resources that can cater energy security.

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