Investigation of Energy Distribution System for Sustainability and Low Carbon Development in the Case of Amhara Regional State, Ethiopia

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Research Article

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Abstract

The quality and reliability of electric power supply systems determine the quality of life and the growth of a nation. Electricity is present in every aspect of our daily lives. Renewable energy is, without a doubt, one of the most critical drivers of a country's socio-economic growth, and its importance in this regard cannot be overstated. Electricity access plays a significant role in other sources of energy. Electricity has made life much more straightforward in various sectors and facets of human endeavors, such as education, health, agriculture, and all households. Efficient power consumption and energy savings have become a major issue these days as the need for power demand increases day to day in Ethiopia. Ethiopia’s electricity coverage and per capita consumption are among the lowest in sub-Saharan Africa. Only 44 percent of over 110 million Ethiopians have access to electricity. Around 83% of the population lives in areas with less than 2% of the population having access to electricity. Electricity is a necessary component of any modern economy. A country's economic growth and development are dependent on the availability of a sufficient power supply at a fair cost. However, to meet the demand and minimize greenhouse gas emissions, cost-effectiveness and efficiency in electricity generation and distribution must be improved further.

Introduction

About 1.3 billion people do not have access to electricity today [21], mostly in developing countries rural areas [23]. A rapid growth in energy demand has increased the available options of energy-producing methods in the electric industry. As an electric utility company, maintaining supply and demand balance needs to exploit available energy resources efficiently. Energy is essential for any country's society and economic development. As a result, humans began searching for energy sources a long time ago to meet their mobility, food, and other needs. The early 18th century saw a significant increase in humanity's ability to extract more energy from readily available natural resources such as oil, coal, and gas, which are both inexpensive and easy to harvest [13].

Renewable energies are one of the energy sources that are gaining popularity these days. Renewable energy supplies are still available and continually regenerate over time [9]. Ethiopia has abundant renewable energy resources (solar, wind, biomass, tidal, wave, and geothermal power) that can be used to electrify remote areas of the world as stand-alone electric energy supply systems. Traditional biomass energy is the most common source of energy in Ethiopia's rural areas, accounting for about 83 percent of the country's total population [1].

Ethiopia has a wealth of renewable energy resources, with the capacity to produce over 60,000 megawatts (MW) of electricity from hydroelectric, wind, solar, and geothermal sources. Electricity demand has been steadily growing in Ethiopia due to the country's rapid GDP growth over the last decade. Despite Ethiopia's energy capacity, the government is experiencing energy shortages and load shedding. It tries to serve over 110 million people and meet rising electricity demand, which is expected to increase by around 30% per year.

To limit wood usage while improving air quality and reducing CO2 emissions, the government aims to distribute 9 million more powerful stoves by 2015. Access to modern and sustainable energy resources in rural areas, where most of the population lives in poverty, is a pressing issue that has only recently been recognized as critical in the global development agenda [24]. Rural societies are heavily influenced by energy. It is essential for all aspects of human well-being, including access to safe drinking water, health care, education, and agricultural productivity. However, energy access can increase carbon emissions in (least developed countries) LDCs, mainly if fossil fuels are used.

The vast majority of Ethiopia's population lives in rural areas, where modern energy resources are scarce. As a result, in 2011, only 4.8 percent of the rural population had access to electricity, despite the fact that 85.2 percent of the urban population did [15]. Also, in cities, half of the households cook with conventional biomass (wood, dung, and agricultural residues). In rural areas, almost everyone does (except for 0.2 percent who use kerosene and 1.2 percent who use charcoal).

It cannot only satisfy the requirement but also generate enough electricity from clean or renewable sources. The energy sector is highlighted prominently in the strategy; total power demand is expected to rise from 4 TWh in 2010 to more than 75 TWh in 2030. The plan expresses optimism that the energy sector can satisfy the need and generate enough electricity to export. As shown in Table 1, energy production and distribution in Ethiopia include various state and non-state actors. Ethiopia is fortunate to have abundant hydropower resources. The total hydropower capacity is projected to be 650 TWh per year [33].

For the reduction of poverty and the promotion of economic development, access to modern energy is critical. Communication technology, education, industrialization, agricultural improvement, and water supply systems all necessitate plentiful, efficient, and cost-effective resources. With growing energy demand, rising imported fossil fuel costs, and environmental concerns, renewable energy is a financially intelligent investment. Ethiopia is endowed with several types of renewable energies. Energy access and consumption level is an indicator for the wellbeing and development level of a Household [16]. In this regard, it is possible to forecast the willing of each household to participate/share both in cash and in kind to the project that will be constructed in nearby feature.

Today life is tough without electric energy because it is one of the driving forces in a growing economy, for instance, lights, appliances, and cooling and heating for homes and businesses. However, it is common knowledge that a large proportion of the population in many developing countries lacks access to electricity [10]. According to recent estimates, nearly 33% of the world's population lacks access to electricity [34]. Equal access to modern energy helps raise wages and benefits to advance the development agenda by improving education, reducing indoor air pollution, and improving environmental sustainability.

On the other hand, rural energy access is still underdeveloped in most African countries south of the Sahara [11]. Ethiopia is one of these countries, with restricted access to modern energy and a strong dependence on traditional biomass energy sources. Although the country has experienced rapid

economic growth in recent years, maintaining this growth in the future would necessitate a significant increase in energy supplies [26, 27]. Sustainable development is described as hydropower projects built and operated in an economically viable, environmentally friendly, and socially responsible manner. As the most powerful energy, hydropower can currently turn 90% of available energy into electricity, which is higher efficiency than any other type of generation (Jha, 2010). Moreover, even these few households consume tiny amounts of electricity, usually lighting in the evenings (Tsegazeab, 2014). Ethiopia is a significant hydropower potential, and where there is also a tremendous unsatisfied demand [30].

The Ethiopian government, according to the National Growth and Transformation Plan, aims to achieve universal electrification and is developing large-scale hydroelectric projects to help achieve this objective [26, 27]. To meet the projected rise in domestic electricity demand and export electricity to neighboring countries, the Ethiopian Electric Power Corporation aims to incorporate alternative power plants such as solar, wind, geothermal, fuel oil, and gas-based plants [7]. However, policy advice based on comprehensive energy analysis to improve electricity access and diversification of the energy supply mix to develop a sustainable power sector is lacking in Ethiopia.

Ethiopia has a hydropower capacity of 45,000 MW, a geothermal potential of 7,000 MW, a solar energy potential of 5.5 kWh/sq. m/day annual average daily irradiation, average wind speed of 7 meters per second at 50 meters above ground level 1,350 GW, natural gas 4 TCF (113 billion m^3), coal > 300 million tons, and oil shale – 253 million tons [3]. This paper aims to look into the energy distribution system in the Amhara Regional State of Ethiopia to obtain free and environmentally sustainable electricity using green gas.

Materials And Methods

Location of the study area

The research was carried out in Ethiopia's Federal Government includes the Amhara Regional State. It is located in between 8.72°N -13.25°N latitude and 38.33°E-40.29°E longitudes. The region's topography is mainly characterized by a chain of mountains, hills, and valleys ranging from 1379m-3809 m above sea level [2]. Together, these two geographical conditions provided the most specific sites for the source of energy development within the study area and are located in Fig. 1.

Description of the data

Site identifications, data collection, and survey and data interpretation are also part of the study's methodology. The information in this article is based on both primary and secondary sources. Field surveys were used to collect and observe the first results. At the same time, secondary data for the study were acquired from the web, reports, books, newspapers, review of the latest scientific literature presented in journals, books related to renewable energy, Internet sources, energy office of the Amhara region, and country data obtained from various ministries of the governments of Ethiopia to collect qualitative and quantitative information. Based on data collected, a comprehensive literature review is carried out on

Ethiopia's renewable energy potentials and current state. The questionnaire design was detailed enough to generate the required data at household, community, and district levels. Data analysis and interpretation are made in keeping with MATLAB and excel [20].

Table 1
Potential and exploited source of energy in Ethiopia [17]

Energy Resource	Exploitable Potential [MW]	Average Capacity Factor [%]	Estimated Energy [GWh/year]	Gross Potential
Hydro	45,000	50.55	199,268	650,000 GWh/year
Wind	10,000	30.91	27,077	1035 GW
Solar	NA	20	526	5.2 KWh/m2
Geothermal	7,000	90	55,188	NA
Biomass	530	89.38	4,150	50 million tons/year
NG	6004	84.85	4,459	112 billion m3
Coal	00	68	596	320 million tons
Total	**63,530**		**291,264**	

As indicated in Table 1, the potential and exploited source of energy in Ethiopia. To achieve growth, remote rural areas, particularly in developing countries, need affordable and reliable electricity. Similarly, a review of the most relevant rural electrification literature demonstrates that RESs are one of the most suitable and environmentally sustainable ways to provide electricity in rural areas.

Results And Discussion

Because of the rapid rise in energy demand in recent decades, energy consumption has become a significant concern. Furthermore, environmental problems associated with traditional energy supplies, such as climate change and global warming, are pushing us to seek out renewable energy sources. According to World Health Organization [35] estimates, direct and indirect effects of climate change cause the deaths of 160,000 people per year, with the rate expected to double by 2020. Natural disasters such as floods, droughts, and significant increases in atmospheric temperature are caused by climate change [36].

There are several benefits of using alternative sources, including the following [4]:

- At any moment, there is a high level of accessibility to secure electricity.
- Reduce your reliance on fossil fuels and protect yourself from oil price volatility.
- Boost economic productivity and build new jobs in your community.
- Defend the environment.

- Allow for more efficient use of natural resources in the region.

Environmental Sustainability: The role of electricity services in achieving these targets at the local level were measured by meeting the following data needs: (a) increases in agricultural productivity due to pumped irrigation, storage, and cooling facilities contributing to reducing overuse of land and reducing pressure on the ecosystem; (b) reduced deforestation and contribution towards reducing greenhouse gases through the use of electricity services; (c) increased availability of cleaner water through electric pumping and (d) decrease in rural-urban migration due to rural electrification.

Table 2
Regional estimation of small hydropower potentials

Region	Approximate small hydropower potential
Oromia	35 MW
Amhara	33 MW
Benishangul-Gumuz	12 MW
Gambella	2 MW
SNNP	18 MW

Table 3
Status and Coverage of Rural Electrification in Ethiopia Rural Towns Connected Over Three Years [8, 18]

Region	Connected in 2005/6	Connected in 2006/7	Connected in 2007/8	Under Connection in 2007/8	Total Connected (b)	Total
Afar	3	15	6	5	24	29
Amhara	47	224	92	257	363	620
Benshngul	3	19	22	9	44	53
DireDawa	1	2	4	1	7	8
Gmbella	3	11	7	0	21	21
Harari	1	1	2	1	4	5
Oromia	68	264	161	297	493	790
SNNP	34	171	102	116	307	423
Somalia	6	16	26	10	48	58
Tigray	13	61	33	55	107	162
Total	179	784	455	751	1418	2169

From Table 2 and Fig. 2 shows the regional estimation of the small hydropower potential of Amhara 33MW. Since hydropower is a dependable source of electricity, it can help to improve the energy situation in many rural areas.

When compared to other sources of energy, the advantages of electricity are its flexibility and comfort. One of the factors that facilitate and enhances social and economic growth is the availability of modern energy or electricity. Electricity offers social advantages such as better illumination and connectivity (radio, television, and telephone) and significantly improving the efficiency of electrical appliances and machines in some cases. Refrigeration, hospitals, schools, workshops, and shops are examples of popular rural electricity applications, as indicated from Fig. 3, the potential and exploited source of energy in Ethiopia. Electricity has the potential to accelerate economic growth that is already underway. Communities that are extremely poor and have little economic activity are unlikely to benefit economically from an energy supply, but they may benefit significantly socially from improved lighting and communication.

Since Ethiopia has a great deal of hydro and wind power potential, the interconnectors will create opportunities for the foreign electricity market, mainly to sell electricity to east African countries. Apart from this, the interconnectors will have mutual benefits for the reliability and security of the interconnected grid system itself and the social-economical & political stability of the region.

From Table 3, Figs. 4 and 5 depicts that rural towns connected three years of electrification in Amhara regional state. Access to electricity has proven to be a critical component of a country's socio-economic growth, both for its citizens and infrastructure. In today's world, it serves as a foundation for urbanization and industrialization. Since power lines are limited to large cities and towns, developing countries lag far behind developed countries in many areas. Despite being one of the most populous countries in Eastern Africa, Ethiopia has a low electricity penetration rate. Electricity is accessible to 41% of the population, but only 17% of households are linked to the central grid [31]. Per capita, energy consumption is 100kWh, which is the lowest in the sub-Saharan average of 510kWh. The majority of non-electrified areas are located in rural areas of countries.

Figure 6 shows that biomass appears to be the sole energy source for more than half of the population, accounting for 57.7%. In contrast, other energy sources such as kerosene electricity and solar energy account for 11.3 percent, 4.2 percent, and 3.5 percent, respectively. An in-depth examination reveals that the food preparation process (injera baking and stew cooking) absorbs 99.5 percent of the biomass. In comparison, the remaining 0.5 percent is used for lighting [14].

Energy security concerns struggle to alleviate the environmental impact of fossil fuels, and progresses in a dominant role in encouraging renewable options has led to the radical increment in the utilization of renewable energy [25]. It promotes economic and social growth by rising efficiency, wages, and employment, reducing workloads and freeing up time for other activities, and promoting the availability of higher-quality or lower-cost goods through local manufacturing [6]. In addition to the economic benefits, access to electricity would have various social services, especially in rural areas. Improved lighting with

better access to electricity replaces kerosene, candles, and other conventional lighting sources in rural areas and provides brighter and more efficient lighting [29]. Figure 5 presents a brief description of the electrified and non-electrified UEAP of Ethiopia.

The fact that anthropogenic activities emit greenhouse gases due to the consumption of energy resources is also worth noting (GHGs). GHGs emitted after energy consumption includes carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sculpture hexafluoride. Even though data on the rate of fuel switching from conventional fuels to electricity after the connection is missing, using electricity for cooking reduces indoor air pollution, which is the leading cause of respiratory diseases in women and children due to carbon monoxide and particulate matter emissions [35]. On the other hand, developing countries will increase their electricity services as their economies grow, having significant consequences on global energy supply and the global environment [19]. Despite its widespread importance, electricity is not readily available, and many people continue to rely on alternative energy sources such as wood, charcoal, and kerosene [28]. Villagers use candles, kerosene lamps, and batteries in non-electrified areas to meet part of their energy needs. Regardless, the inconvenience and environmental and health risks, rural households usually expend a large portion of their income on these energy sources.

Ethiopia's energy balance is dominated by biomass energy. Biomass fuels account for 88 percent of the total energy supply in the world (wood, charcoal, and agricultural residues). In Ethiopia, biomass energy is primarily used for cooking in both residential and commercial settings. Biomass fuel demand is increasing at the same rate as food production (i.e., 6 percent annually) ([5].

Conclusion

Energy is one of the essential elements required to alleviate poverty and promote socio-economic development. Access to electricity has proven to be a critical component of a country's socio-economic growth, both for its citizens and its infrastructure. In today's world, it serves as a foundation for urbanization and industrialization. Although international agreements such as the Paris Agreement and Agenda 2030 demonstrate political will for change, they are insufficient. The critical gaps are inadequate commitment to national energy and climate goals, a lack of well-informed strategies and initiatives to scale up clean energy and energy savings, and a lack of financial capital to fund them. There is a lack of political intervention to enforce a just change that leaves no one behind. As a result, our overarching aim is to assist local, national policymakers in closing the gap between internationally negotiated goals and national implementation.

This paper has been used to investigate the Energy Distribution System and the combination of renewable energy technology of socio-economic optimization. While expanding access to electricity for the poor can reduce energy poverty and improve quality of life, it is not clear how effective and sustainable development comprises economic, social, and environmental gains.

Declarations

Authors' contributions

All research activities, such as data collection, review, assessment, and results, were completed by the author. The final manuscript was read and accepted by the author.

Conflict of interest: The authors stated that there was no competitive interest within the authors and publication of a given research paper.

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Figures

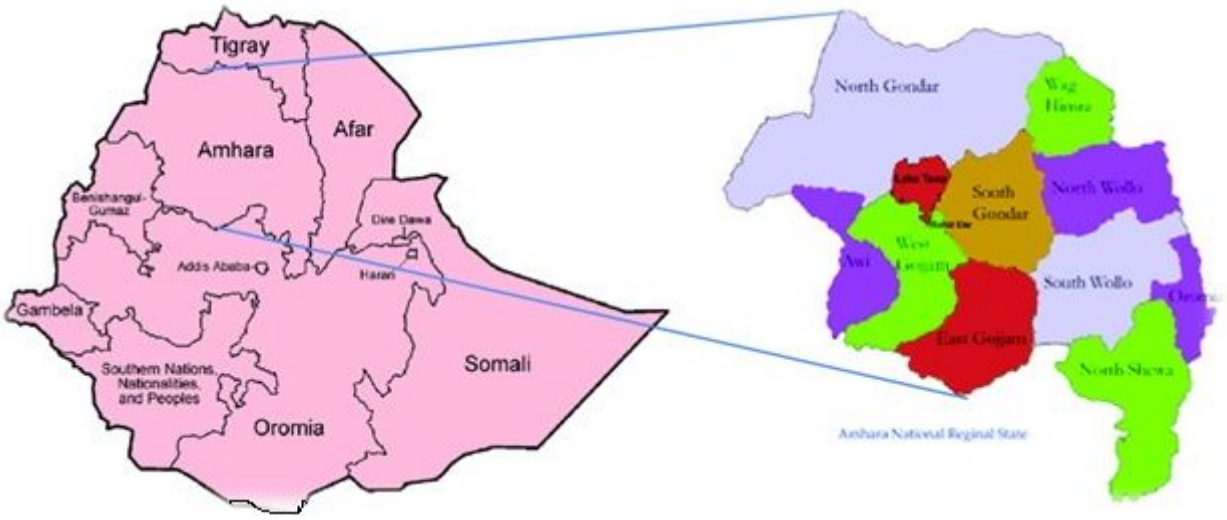

Figure 1

Location map of the study

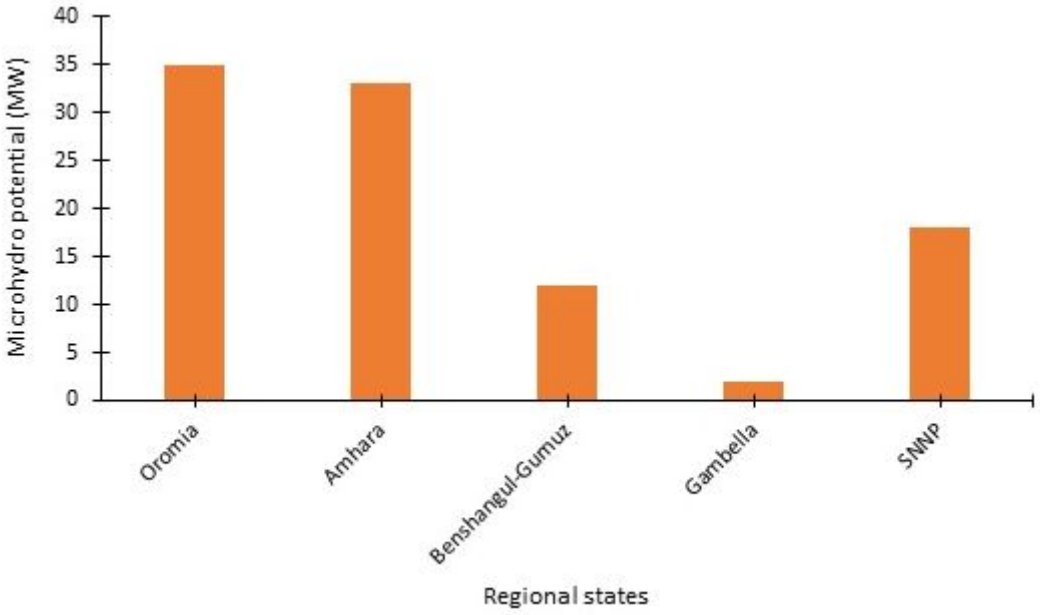

Figure 2

hydropower potential in Ethiopia per region [12]

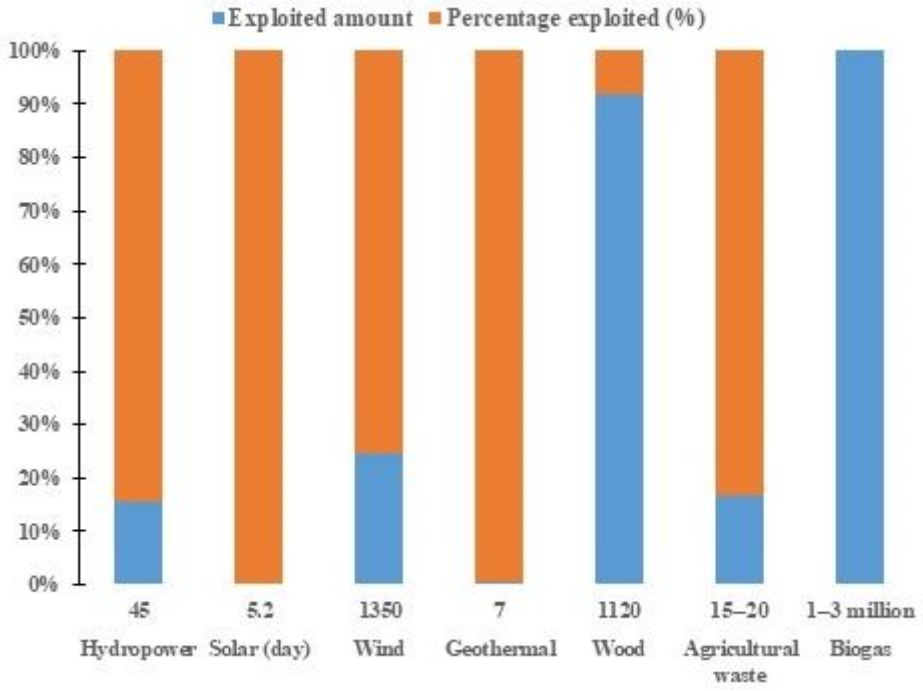

Figure 3

Different potentials in Ethiopia per region

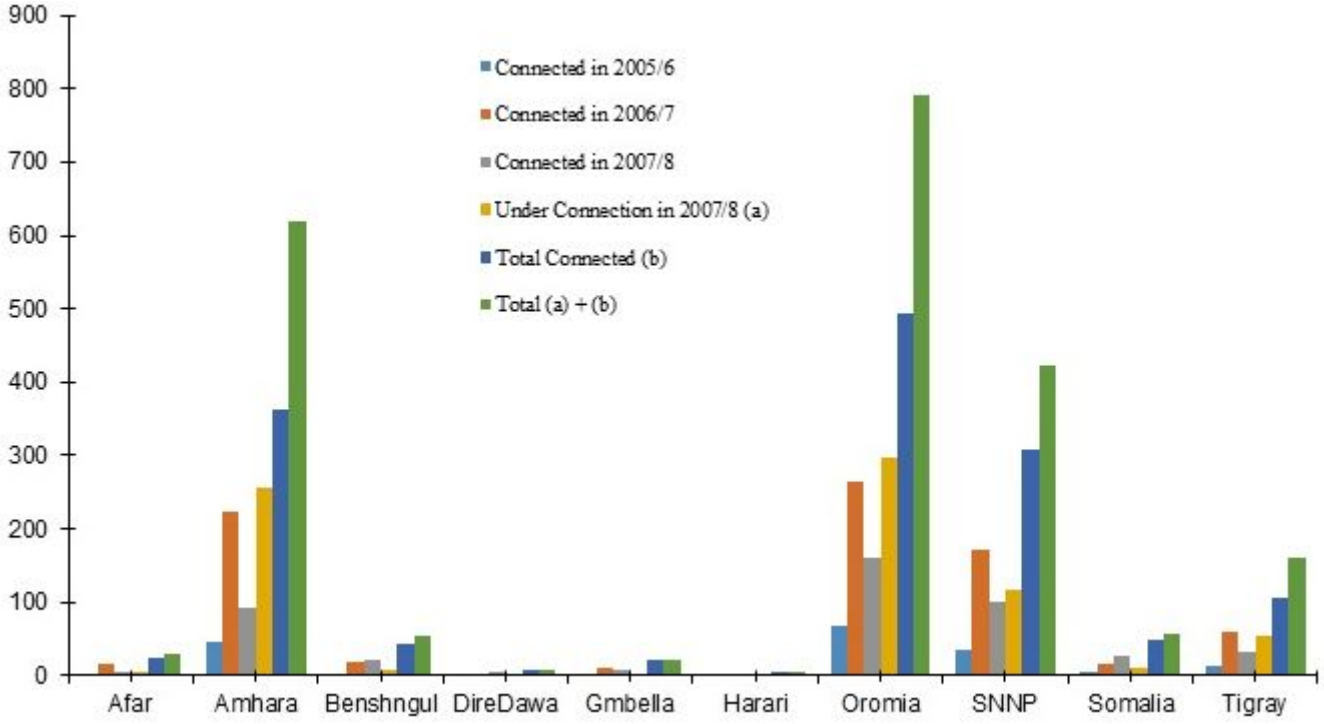

Figure 4

Ethiopian regional state Rural towns connected over three years electrification in Amhara.

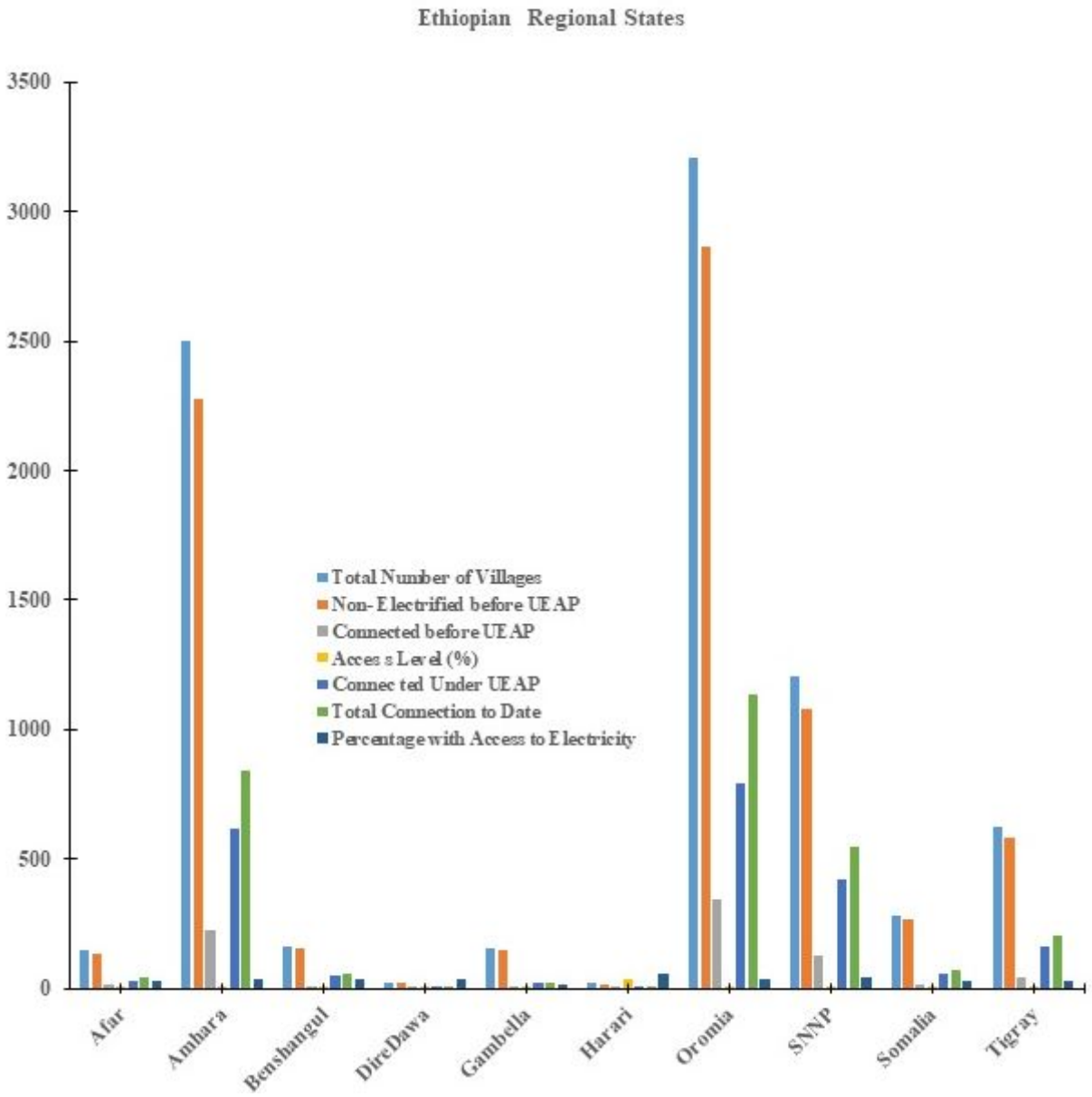

Figure 5

Ethiopian regional state total number of villages

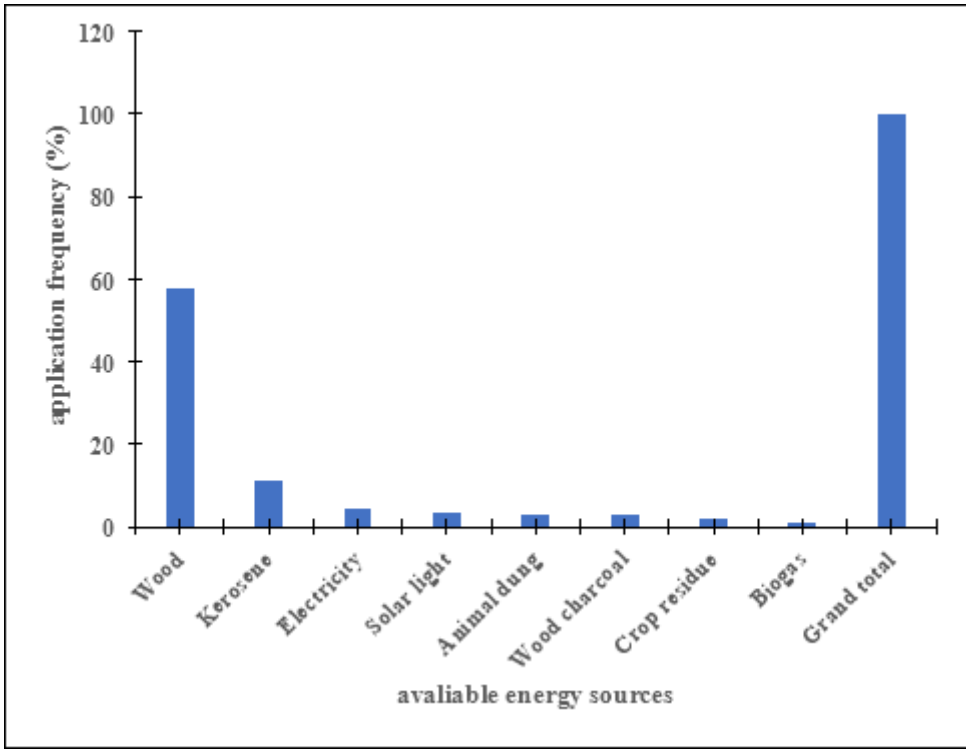

Figure 6

The complete proportion of different forms of rural energy in use