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Challenges of Achieving Sustainable Development Goal 7 From the Perspectives of Access to Modern Cooking Energy in Developing Countries

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Sustainable development goal 7 (SDG 7) focuses on ensuring access to affordable, reliable, sustainable, and modern energy for all by 2030. This goal has a lot of synergies and associations with the rest of SDGs and in particular to goals 1, 3, 4, 5, and 15. Nevertheless, achieving this goal with the provisions of access to affordable and sustainable modern cooking energy will be very challenging when past failed programs are considered. The challenges could be paramount in Sub-Saharan Africa, where still the majority of the population does not have access to improved cooking energy services. The low achievement attributes to the interrelated deep-rooted socio-economic, cultural, and technical factors. Without breaking these barriers and having an integrated economic and social policy, achieving this goal remains ambitious without success. Hence, continuing with business as usual with the existing policy may not work. Besides, there can be unforeseen circumstances like the COVID-19 pandemic with a lot of health, economic, and social crizes that also needs to take into account. In addition to having a better policy to ease the socio-cultural issues, there should be the availability of sufficient economic incentives to invest in energy projects and support the households. Otherwise, achieving this goal may remain ambitious by leaving over 70% of the people in Sub-Saharan Africa dependent on traditional use of biomass energy by 2030. This study recommends further study on specific policy direction and system integration.

Keywords: sustainable development goal 7, cooking energy access, renewable energy, socio-technical issues, socioeconomic factors

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INTRODUCTION

Having access to improved energy technology is essential for social security, livelihood improvement, and economic growth. An improved energy system for households in warm climatic conditions mainly includes access to a suitable source of energy for cooking, lighting, and powering of appliances. Suitable energy sources refer to efficient and clean energy sources and technologies matching local demands and conditions. The modernity of the cooking energy services also follows the adoption of suitable technologies matching local expectations. Energy for home heating is not a big issue for them compared to countries in the temperate climate. Nevertheless, many people in developing countries will remain dependent on biomass energy and have no access to electricity by the year 2030 due to the increasing population and lack of electricity infrastructure (IEA, 2011). Most people deprived of access to improved energy technologies in developing countries are subsistent rural farmers relying on subsistent farming and poor urban households depending on daily income.

Lack of access to modern energy severely affects the quality of life, delivery of social services, and economic development. The declared Sustainable Development Goal 7 (SDG7) aims to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030. This goal has a lot of synergies and associations with the rest of SDGs, in particular with (goal 1) aiming to end poverty in all its forms (goal 3) aiming to ensure healthy lives and promote well-being for all at all ages (goal 4) to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (goal 5) aims to achieve gender equality and empower all women and girls and (goal 15) aiming to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (Nerini et al., 2018). Accessibility to improved and sustainable energy service is crucial to achieving better health, poverty reduction, socio-economic development, and improvement in livelihood in particular for women and girls who are traditionally shouldering household activities by being deprived of access to social and economic activities. Besides, providing access to modern cooking energy technology improves environmental consequences related to deforestation and soil nutrient loss.

Households deprived of access to modern energy technologies frequently use fuelwood collected from commonly owned forests available in their vicinity. Commonly owned forests are perceived to be common resource pools that everybody has access to and obtains without restriction. These resources also serve as sources of income for poor rural and urban households depending on biomass energy selling (Arnold et al., 2006). Heavy reliance for both energy and income increases firewood scarcity and deforestation (Allen and Barnes, 1985; Arnold et al., 2006). Thus, achieving goal seven provides a lot of benefits by reducing environmental degradation related to deforestation (goal 15). Moreover, most households cook food with inefficient stoves providing less than 10% useful energy (Bhattacharya and Abdul Salam, 2002; MacCarty et al., 2010). Meeting the cooking demand thus requires an ample amount of firewood. This will have huge implications on the availability of biomass for energy, which may impose households to substitute with crop residues and dung. Substituting firewood with crop residues and cows dung is a common practice in highlands of Ethiopia with up to 30% of their cooking energy demand (Duguma et al., 2014). Primarily, these resources are used as a substitute for inorganic fertilizer and soil mulching, thus affects the availability of nutrients for crops (Mekonnen and Köhlin, 2009). The use of crop residues for energy reduces soil nutrients to be available for crop and its productivities. Reduction in crop yield and productivity affect food sufficiency and efforts of poverty alleviation (goal 1).

Lack of availability of sufficient biomass and using inefficient stoves can have many social, economic, and health impacts. During the scarcity of firewood, women and girls are enforced to spend many hours traveling and collecting firewood from distant places. They spend about 2–4 h per day for the collection of firewood at the expense of their productive time to be used for education and other activities (Blackden and Wodon, 2006). In particular, women in Africa are enforced to work over 12 h per day, where more than 50% of them are time-deficient (Blackden and Wodon, 2006; Arora and Rada, 2014). When women are deprived of time, they will have less time to look after their children, take care of their family and other social and economic activities. Lack of time for these activities can affect the development of children, their health, the ability to generate income and time for schooling. Achieving goal seven will have a lot of effects on ensuring girls to attend their school (goal 4) and women equality (goal 5).

Combustion of biomass in less efficient biomass stoves during cooking produces polluting gases involving debilitating health consequences (Fullerton et al., 2008; WHO, 2016). The World Health Organization (WHO) report shows that more than four million people die prematurely per year due to illness associated with household air pollution, caused by the inefficient use of solid fuel for cooking (WHO, 2016). Besides, most rural households use kerosene wick lamps for lighting with the risks of exposure to hazardous byproducts like black carbon and other volatile organic matters having serious human health effects (Lam et al., 2012). The health effects of incomplete combustion byproducts and other indoor air pollutants are significant on women and young children who spend most of their time in the kitchen. The collection of firewood over long distances itself has significant health effects and physical injuries. Moreover, women and girls in charge of firewood collection can be at risk of rape, sexual harassment, and attacks of wild animals during firewood collection from the distant forests. The provision of modern energy as outlined in goal seven contributes to the achievement of goal three aiming to ensure health and wellbeing to all. By solving energy issues, it is possible to save time for women to look after their children and generate income, and save time for girls to go to school and contribute to the nation's economic development.

It is important that improving access to modern and sustainable energy supply system is not optional but a definite part of sustainable development agendas (Nerini et al., 2018; Armin Razmjoo et al., 2019). Nevertheless, improving access to cooking energy technology requires a better understanding of local socio-economic and livelihood conditions potentially affecting the sustainable implementation of the programs. Lack of local justice recognitions, disregarding the roles, relations, and importance of local actors have a lot of effects on the achievement of the goal (Munro et al., 2017). Study shows that many challenges are attributed to the effectiveness of different cooking energy technologies available in developing countries on achieving the goal (Rosenthal et al., 2018). Improved biomass stoves can achieve 20–30% fuel saving and reduction of related health problems, but are not motivating due to the use of scarcely available biomass energy (Kooser, 2014; LaFave et al., 2019).

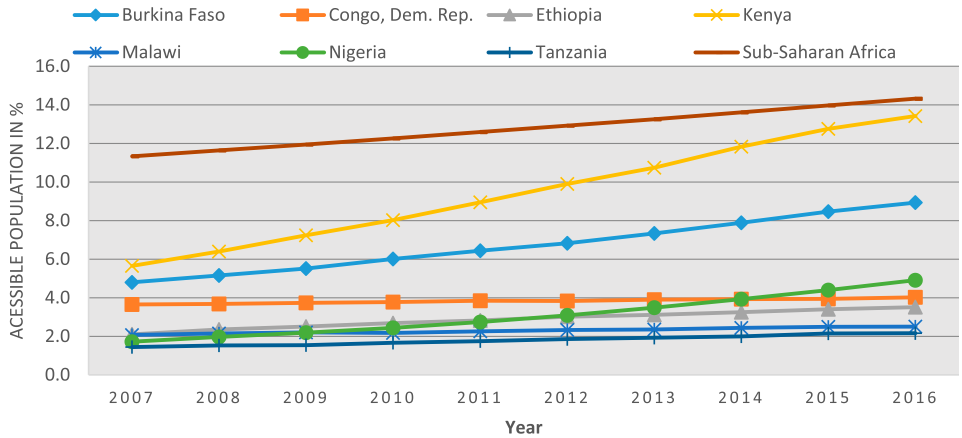

FIGURE 1 | Proportion of population access to clean fuels and technologies for cooking (% of the population) (World Bank, 2017).

A lot of efforts have been made in the last 3–4 decades to introduce the currently available improved cooking energy technologies in Sub-Saharan Africa. However, many of the efforts and implementation programs were not effective to achieve successful adoption of the technologies. Today, only less than 15% of the people in the region have access to improved cooking energy technologies (**Figure 1**). Many studies have indicated hindering factors attributed to specific technologies and programs (Brew-Hammond and Kemausuor, 2009; Kowsari and Zerriffi, 2011; Ruiz-Mercado et al., 2011; Mwirigi et al., 2014). Despite all those challenges and unsuccessful stories, goal seven aims to ensure affordable, sustainable, and modern energy access to all households irrespective of their socioeconomic and living conditions. Hence, it is important to revisit some of the significant local factors potentially affecting the implementation of this goal, in particular from the perspectives of socioeconomic, cultural, and technical conditions. This review paper aims to analyze the socio-economic and socio-technical challenges attributed to adoption and sustainable use of improved cooking energy technologies which is the main agenda of this goal in developing countries. Understanding these factors provide an insight into the possibility of achieving this goal and the required policies and strategies to help its achievement. The energy for productive and public services are not the focus of this study, since they are less likely affected by the aforementioned factors. The discussion focuses on Sub-Saharan Africa with a particular emphasis on Ethiopian energy access situations.

METHODS

This review considered relevant studies on energy access situations, its determining factors in relation to achieving Sustainable Development Goals 7 (SDG 7), and on other related goals in Africa, published in English. Studies were reviewed regardless of the year of publication and there were no restrictions by type of setting. Most recently published reports and some gray literature were included. Systematic reviews, case studies, analytical cross-sectional studies, policy review papers, and available relevant experimental studies were also considered.

The databases including Scopus, Web of Science, PubMed, ScienceDirect, DOAJ, JSTOR, and Google scholars were used for accessing published scientific articles, and Google was used for gray literature and reference lists to the papers reviewed. Then, retrieved papers and abstracts searched through different strategies were screened for inclusion. For this, we used search terms including cooking energy, renewable energy, biomass energy, cookstove, renewable energy technologies, socio-technical factors, sustainable development goals, SDG 7, energy policy, Sub-Saharan Africa, and developing countries. Although there are several works of literature available on the topic, this review fine-tuned to specific studies relevant to access to cooking energy in Sub-Saharan Africa and sociotechnical factors potentially affecting the achievement of SDG seven and related goals.

For the ease of summarizing the findings by thematic area, the pieces of evidence were synthesized and presented section by section. Accordingly, information on household energy access situations in developing countries was presented in section three of the paper. The fourth section discusses whether renewable energy technologies can meet cooking energy demands and achieve goal seven and other related goals. Socio-technical challenges affecting accessibility to modern cooking energy services and goal seven are summarized in section five. Factors related to energy policy are presented in section six, and concluding remarks are forwarded in the last section.

ENERGY ACCESS SITUATION AND ITS PROGRESS IN SUB-SAHARAN AFRICA

Sub-Saharan Africa is a place where many people do not have access to improved energy technologies. About 45% of the people without access to improved and clean cooking facilities in the world are living in this region. It was estimated that over 70% of the people living in the region will continue using unimproved biomass energy technology, and 50% without having electricity access by 2030. When the target for the sustainable development goals set in 2015, the average electricity coverage in Sub-Saharan Africa was 32% compared to the world average of 83% (IEA, 2015b). The country's energy data also showed that between 2009 and 2013, people without access to improved cooking energy technologies increased by 15% (IEA, 2015a). Over half of the people deprived of access to improved cooking energy technologies and without access to electricity in Sub-Saharan Africa are living in Ethiopia, Nigeria, the Democratic Republic of Congo, Burkina Faso, Tanzania, Malawi, and Kenya. The 10 years (2007–2016) energy access data in these countries are shown in **Figure 1** (World Bank, 2017). All of these countries are below the Sub-Saharan African average (about 15%) and do not show good progress, except Kenya and Burkina Faso which both are making promising progress toward the average. Reaching the goal of provision of universal access to improved energy with moderate consumption of electricity for Africa by 2030 may require up to ten-folds of the present production (Bazilian et al., 2012).

In the last 3–4 decades, several programs and initiatives have been implemented to provide improved cooking stoves, in particular, efficient biomass-burning stoves and biogas across the developing region. Major development progress in clean cooking energy started in the 1970 and 1980s when the issue of deforestation came into attention (Allen and Barnes, 1985; Ruiz-Mercado et al., 2011). Nevertheless, the issues of firewood and deforestation remain unsolved and the mitigation efforts are still going on with different energy policies. Implementations of most of these programs were performed centrally as a top-down approach mainly neglecting local practices and user interests (Ni and Nyns, 1996).

The biogas program is one of the energy initiatives implemented in Sub-Saharan African. Countries like Ethiopia, Kenya, Tanzania, Uganda, and Burkina Faso have implemented their program through the Africa Biogas Partnership Program (ABPP). ABPP is a global Public-Private Partnership engagement program aiming to provide improved energy access to households through the installation of biogas plants. ABPP together with its main partners SNV and GIZ benefited about 320,000 households from the involved counties until the end of 2018 (Clemens et al., 2018). The biogas program aims at providing clean and efficient energy for cooking, and its slurry for soil fertilization. Asian countries like India and China are pioneers in developing cost-effective biogas digesters and disseminating to other developing countries (Bond and Templeton, 2011), including African countries where only a few success stories have been reported (Parawira, 2009; Mengistu et al., 2015). Still, over 85% of people in Sub-Saharan Africa do not have access to improved cooking energy technologies (**Figure 1**). Without a coordinated and enabling policy, about 660–820 million people in SSA will remain to stay on traditional biomass energy by 2030 (Dagnachew et al., 2020). However, success in other Asian countries would help SSA countries if better and integrated policies are considered. Integration of income generation, technological subsidies and awareness creation into energy policy would be a promising option to increase adoption of improved cooking energy technologies (Schuenemann et al., 2018; Dagnachew et al., 2020).

Adoption and installation of biogas digesters provide a lot of opportunities, but its implementation and sustainable use have been affected by several barriers (Rupf et al., 2015). For instance, the National Domestic Biogas (NBPE) of Ethiopia plans to install 15,000 biogas digesters by 2014, but only about two-thirds of it was installed (Mengistu et al., 2016). Besides, the government has attempted to distribute improved biomass burning stoves especially for baking the local staple food "Injera, but the success of adoption is low including urban areas (Dresen et al., 2014). In Ethiopia, more than 92% of the population (and over 99% of the rural population) still depend on biomass energy for household basic cooking (Tucho et al., 2014). The condition is similar in other Sub-Saharan African countries endeavoring to distribute improved cooking stoves to their people (Muneer, 2003; Adkins et al., 2010; Ruiz-Mercado et al., 2011; Malla and Timilsina, 2014; Jagger and Jumbe, 2016). Many of these countries are not willing to adopt the technology or unable to use sustainably, the majority of them are still relying on traditional stoves of three stones open fires. Only a fraction of households mostly living in urban areas and economically better-off use electricity for cooking (Prasad, 2011; Rahut et al., 2016). A large number of poor urban households depend on biomass energy for cooking despite having access to the grid and off-grid connection. When the household's economy improved, access to grid electricity increased with affordable costs, young generations aware of the benefits of improved energy access, and more women become educated; socio-cultural and technical factors may not be a challenge. Hence, in the long-term, more and more people will be expected to use improved cooking energy technologies.

In addition to low access to improved cooking energy technologies, the lighting and appliances energy demands in Sub-Saharan Africa are mainly met with kerosene and dry cell batteries. Kerosene and dry cell batteries provide low-grade light and power services in addition to the emission of harmful indoor air pollutants like black carbon (ERG, 2013). The provision of lighting energy access is in good progress including in remote areas due to increasing mobile phone penetration and low energy demand for lighting. It can be easily met with a simple solar photovoltaic (PV) technologies integrating Light Emitting Diode (LED) (Zhou and Narendran, 2005; Mills and Jacobson, 2011). Light Emitting Diode (LED) technologies are very popular in rural areas of developing countries remote to grid connection. These technologies are technically suitable to meet the mobile phone charging and home lighting demands. Nevertheless, still, large proportions of the population do not have access to this technology due to its cost and technical support, particularly in remote rural areas. About 24% of the population in Ethiopia have access to electricity through off-grid solutions (Padam et al., 2018). Providing access to the remaining section of the population in the near future is not promising with the grid connections due to the low uptake of the technology in rural areas and connection challenges. Only 33% of the population is connected to the grid despite the impressive grid electricity expansion in the country. The off-grid electrification is the

TABLE 1 | Ethiopian suitable renewable energy potential.

	Theoretical potential (PWh/yr)	Geographic potential (PWh/yr)	Suitable potential (PWh/yr)
Solar	264	192	7
Wind	110	80	4
Hydro	0.95	0.29	0.14
Total	6.23	75.4	11.7

Source (Tucho et al., 2014).

main promising option to reach out to a large proportion of the population without access to clean lighting services.

The provision of improved cooking energy technology is very challenging due to many prevailing factors (detail will be provided in the following sections). Knowing the level of energy access situation is very indicative of the feasibility of proposed program implementations and challenges ahead. One can think of the challenges related to hindering factors, costs and implementation strategies, and guiding policy to provide modern energy to everybody as presented in goal 7.

RENEWABLE ENERGY RESOURCES AND TECHNOLOGIES

Hydro, Wind and Solar Energy Technologies

The energy for household demands can be met with the energy obtained from renewable and non-renewable energy resources. In developed countries, the energy for household demand is still met with non-renewable resources. None-renewable resources are not a realistic option for developing countries due to increasing environmental concerns (climatic changes) and depleting fossil fuel resources. Moreover, most countries without access to modern energy systems are net oil importers at the expense of scarcely foreign currency; hence fossil fuel sources cannot be an option to meet their demand. However, most of these countries are living in a warm climatic region and endowed with abundant renewable energy resources. In this study, renewable energy resources refer to energy from hydro, solar, and wind resources. These energy sources are not equally distributed to meet demand (Hoogwijk, 2004). Their technological efficiencies are also on the progress of development, a huge gap exists between the amount potentially and practically available for use. For instance, Ethiopia is among Sub-Saharan African countries with tropical climatic conditions having abundant renewable energy resource potentials from solar, hydro, and wind (**Table 1**). The country's electrical energy system is dominated by hydropower, but only a tiny portion of the available potential is exploited yet for the large scale grid system (Tucho et al., 2014). The hydro potential is not yet exploited for small scale applications. The amount of energy obtained from wind resources are affected by existing wind speed. The prevailing wind speed is affected by climatic, topographic, and vegetation conditions. The available wind speed in the country is not evenly distributed and sufficient to generate electricity, only a few areas have enough wind speed to generate sufficient electricity (Tucho et al., 2014). Most areas of the country have a low wind speed below 3 m/s (cut-in) to move the turbine and generate electricity. The Ethiopian renewable energy exploitation condition could be similar to other Sub-Saharan African countries having abundant renewable resources to be harnessed for large and small scale applications (Kaunda et al., 2012; Korkovelos et al., 2018).

The potential for solar energy is determined by the average solar radiation arriving on the earth's surface (Tucho et al., 2014). Most tropical climates have a solar radiation potential of 5–7 kWh/m^2 throughout the year. Solar radiation availability in local areas is less prone to changes with geographic and meteorological conditions and is, therefore, more or less evenly distributed during daylight hours. The availability of solar radiation is not an issue for tropical climates. The technology can be installed anywhere for direct conversion to electricity, or concentration into heat energy.

The amounts of electrical energy produced by hydro and wind power systems are determined by the mechanical power provided by the amount of water and wind (Hoogwijk, 2004). In particular, the amount of energy produced by hydropower is determined by the amount of water collected behind the dam and regularly released to a turbine head. The dam can be constructed at one location and connected to households throughout the grid system. The availability of the grid system is not determined by the local availability of the energy sources, rather by the accessibility of the areas to grid installation and affordability of the sources. However, several rural areas in developing countries are either remote to the grid, or it is not feasible to connect to the grid due to the sparseness of a settlement. Furthermore, the availability of these resources for small scale applications is highly dependent on local geographical and meteorological conditions.

Small scale hydro has a technical efficiency ranging from 60–80% (Paish, 2002), which is about three-folds of the technical efficiency of the wind turbine. Moreover, most small-scale hydropower does not need the construction of a dam. A small-scale hydro unit installed on running water relies on the level of precipitation regularly maintaining the volume of flowing water, and on the local topography creating a natural water head (pressure). Small hydropower operating on naturally running water are vulnerable to climatic change and frequently suffer power outages. As a result, small hydro plants are less likely appropriate to provide the amount of energy needed to meet the demand. This means that hydro sources are not uniformly distributed everywhere for small scale applications like that of solar. Moreover, a lot of costs are involved in hydro energy production and distribution due to the need for a grid connection to each house. Nevertheless, hydro and wind energy with off-grid can be a better option for populated remote villages having sufficient and reliable water and wind resources throughout the year.

Solar energy resource is much different from hydro and wind energy resources. Solar energy is more or less evenly available everywhere to be harnessed with different solar energy technologies. It can be converted to electricity in solar Photovoltaic or concentrated on heat and electricity in concentrated solar power. Solar Photovoltaic (PV) can be installed on rooftops, facades, and lands closer to buildings to produce and distribute electricity. Solar PV is less prone to damage compared to wind turbines due to the lack of moving parts. Solar radiation is converted to electricity through semiconducting compounds varying from amorphous silicon to thin-film materials (Parida et al., 2011). The compounds from which PV is made determine its solar-to-electricity conversion efficiency varying from 5% to more than 19% efficiency. Amorphous silicon PVs are technically mature and less costly but relatively inefficient compared to thin-film materials. Most commonly installed solar panels have a technical efficiency of up to 15% (crystalline silicon materials). This means that large size PV system (about 6 m^2 PV/household) is needed to meet the cooking energy demands (Tucho et al., 2014). Building such a size of PV may be economically inconceivable in rural areas, and is unlikely to be affordable to the majority of the households. The availability of solar energy for the cooking energy service is determined by the efficiencies of the technology, its suitability, and acceptability for local cooking, and affordability to local poor households relying on a subsistent non-monetarized economy. Hence, households may not afford the costs of large sizes of PV with seasonal and subsistent agricultural income. Households may afford a PV of moderate size (about 0.7 m^2 of PV panel) which can be sufficient to meet the lighting and phone charging demand of the household (Tucho and Nonhebel, 2017). Meeting the cooking energy demand with solar energy, in particular with PV technologies is out of reach with the present efficiency and cost.

Solar energy can be used for household cooking energy if concentrated with a solar cooker. Solar cookers are a mature technology that emerged around four centuries ago (Saxena et al., 2011). Solar cookers directly concentrate the incoming solar radiation into heat for cooking. The technology can be developed from local materials which makes it cost-competitive and cheap relatively to solar PV made of expensive materials (Regattieri et al., 2016). The main problem of solar cookers is its low thermal efficiency and related longer cooking time. Cooking in solar cookers requires about 2–4 h (Ahmad, 2001), but a recent study shows a promising thermal efficiency improvement (Coccia et al., 2018; Saxena and Agarwal, 2018). A solar cooker design modification with integrated thermal energy storage is one of the better designs providing flexible cooking time in addition to solving cooking inefficiencies (Muthusivagami et al., 2010). Despite all the limitations, solar cookers can be an alternative in areas installation of other cooking energy technologies are not possible. Solar cookers can be a better option at arid and semi-arid areas with high solar radiation and a shortage of water.

Biomass Energy Technologies

Biomass is considered a renewable energy source because of its self-replenishing in a short time through the process of photosynthesis. In the process, plants convert carbon dioxide to biomass with the help of sunlight. Plants release the same amount of carbon dioxide to the atmosphere when died and decomposed. The process of up taking and releasing carbon dioxide theoretically keeps the carbon cycle in balance. Nevertheless, the carbon cycle balance can be disturbed when extraction (burning or cutting) of the plants exceeds its growth.

Biomass used for energy comes from any plant materials grown for certain purposes or on naturally occurring common lands. The availability of biomass energy obtained from common lands (natural forests) available around a certain community depends on the level of exploitation. In most areas, these resources are already over-exploited and scarce, thus its availability for the cooking demand relies on the time spent on obtaining the biomass. Households may need 2–4 h to travel and obtain the amount of biomass required for their cooking demand. Therefore, common resource pools cannot be an option to provide cooking energy services even if improved stoves are available to use.

Biomass energy can be obtained from the own land (resources) as planted trees and/or crop residues. The availability of biomass from individual resources relies on the amount of land and its output, which is determined by the availability of land and its productivity (Berndes et al., 2003). However, resources are usually unevenly distributed among households, where households with sufficient land resources can meet their energy demands. Besides, households also use their bio-waste for different purposes, like soil fertility, construction, forage, and household purposes. For instance, in Ethiopia over 80% of the households own a small area of land (less than 2 ha) (Tucho and Nonhebel, 2015), which may not be enough to produce residues available for different purposes. Moreover, the availability of owned resources will be reduced with increasing populations, due to the sharing of lands among family members.

The conversion of biomass for energy can be achieved through the use of different technologies. These technologies range from simple combustion in open fires stoves to sophisticated technologies like combined heat and power (CHP). A traditional three-stone open fire used by most households provides low thermal energy for cooking (about 8–12% of the energy contents) (Bhattacharya and Abdul Salam, 2002). Biomass burning stoves with higher conversion efficiency are available in different types to alleviate the cooking energy issues and related health and environmental consequences (Ruiz-Mercado et al., 2011). Ethiopia is among developing countries trying to adopt improved stoves and disseminate to households. These stoves have varying efficiencies with the biomass consumption saving potentials of 10–57% (Dresen et al., 2014; Beyene et al., 2015). However, the dissemination of improved stoves is mainly limited to urban areas although most poor urban households are unable to access due to the costly price of the stoves. In addition, adoption and use of these stoves require biomass coming from scarce and depleting forest resources, as well as from agricultural lands. Improved biomass stoves are a better alternative compared to open fire stoves, but efforts are needed to solve issues associated with accessibility to the stoves and availability of the biomass for fuel. These stoves are not enough to achieve sustainable development goals although contribute to reduction of indoor air related health implications and climate change (Rosenthal et al., 2018).

Biogas plants are another means of biomass conversion technology promised to provide clean cooking energy and fertilizers by installing different sizes of anaerobic digesters (Amigun and von Blottnitz, 2010). Nevertheless, the continuous functionality of the digester requires the availability of feedstock produced from household resources. Annually, each household needs about 5–7 GJ of useful energy (16 MJ per day) for the cooking demand (Tucho and Nonhebel, 2015). To meet this demand about 11 tons of fresh dung (about 5–7 cows) and 16 m^3 of water are needed (Tucho et al., 2016). However, most households do not have sufficient land to own a large number of cows or do not have the economic capacity to own with a traditional farming system. The application of biogas technology requires a sufficient amount of feedstock and water for its continuous operation. Biogas production cannot be a better alternative from labor perspectives when transportations of feedstock, water, and slurry are involved (Tucho et al., 2016). Despite that, biogas technologies are well developed and adapted to local cooking conditions with locally available materials. Application of the technology (biogas) also does not require trained human power; households can manage. Biogas is one of the cooking energy technologies that is promised to provide clean energy and reduce related health and climate change problems, thus to achieve SDG 7 (Rosenthal et al., 2018). The effectiveness and sustainability of the system to achieve the goal relies on the possibility to provide affordable technology to priority households economic activities, and operational and maintenance technical support.

SOCIOECONOMIC, CULTURAL AND TECHNICAL FACTORS

Increasing accessibility to modern energy technology is also determined by prevailing socio-economic and cultural factors (Ni and Nyns, 1996; Urmee and Gyamfi, 2014). The amount of energy required for cooking, lighting, heating, and powering of appliances varies among households of different regions. Most households without access to modern energy services are living in tropical climates where the need for cooking energy dominates the other energy services.

The energy demand variation is not only between services but also exists between rural and urban households. Households in rural areas relatively need a high amount of energy for cooking because of the consumption of unprocessed food that requires long cooking hours. Also, households cook frequently due to a lack of storage for cooked food. Long cooking hours, together with frequent cooking leads to a high energy share of the demand. The energy for the cooking demand for rural households and poor urban households may account for about 90% of the demands. Urban households are potentially accessible to grid connection and use their energy for cooking. They also have more access to semi-processed food which requires less energy compared to unprocessed food. However, charcoal remains the main energy supply for regular cooking services and cooking local foods. Moreover, poor urban households who are not connected to electricity or cannot afford the cost still depend on biomass energy (CSA, 2012).

Cooking unprocessed local and culturally preferred food requires suitable cooking stoves satisfying local cooking needs and culture. Adoption and sustained use of improved energy technologies depend on local energy use conditions, cooking behavior, and culture (Kowsari and Zerriffi, 2011). The study report indicates that the household's decision to continue using firewood for cooking is influenced by local cooking habits and culture, food types, and gender norms (Malakar et al., 2018). Accessibility to modern cooking energy technology is largely determined by local socio-cultural practices, technological suitability, and perception of individuals (Kowsari and Zerriffi, 2011). The impacts of local socioeconomic and cultural conditions on the decision to adopt the technology and its sustainable use have been reported almost for more than two decades (Masera et al., 2000; Kowsari and Zerriffi, 2011; Mwirigi et al., 2014). Most previous studies reported socioeconomic factors as the main determinant for the adoption of improved household cooking energy technologies, but the characteristics of the stoves and their specific design also vital for consumer choices (Johnson and Takama, 2012). Energy technologies unable to meet local socioeconomic and cultural conditions are less likely acceptable among users. Hence, the suitability of the cooking technologies for local cooking is determined based on the possibility of their modification with local materials to match the needs of the users. This means that the intended technology should have improved conversion efficiency in addition to fitting local demands expectations. This could be identified in the energy program evaluations, but rarely made in most energy projects or programs. Identifying efficient local technological innovation encourages income generation while helping to increase access to improved energy technologies meeting the demand expectations.

The provision of appropriate energy technology requires a better understanding of the local energy resources, available energy infrastructure, and characteristics of the demands in addition to local expectations. Nevertheless, finding appropriate technology with renewable energy resources is very challenging. Renewable energy resources are available in abundance for the generation of electricity on both large and small scales (Tucho et al., 2014). However, their acceptance and usability for the cooking demand depend on household incomes and the suitability of the electricity source for their cooking needs. Urban households are involved in the national economy, either in the form of running a business or through employment. It is easy to use grid electricity and use electronic appliances if a household can afford the costs of the electricity bill and electric appliances. However, still most urban and peri-urban households are resistant to pay for electrical energy, which is largely determined by socioeconomic conditions of the households, their accessibility to firewood at shorter distances, and accessibility to formal economy (Arega and Tadesse, 2017).

In contrast, a large number of populations deprived of access to improved cooking energy technologies rely on seasonal subsistent farming incomes from selling crops and livestock which are not connected to the formal money economy. The income from such income sources may not be sufficient to afford monthly electricity bills and the costs of electric appliances, even if households are connected to the grid. Moreover, selling livestock for purchasing energy appliances may not be feasible since livestock also serves as a food and manifestation of socioeconomic status. These factors generally prevent rural households from using energy systems and technologies that are available in urban and money-regulated settings. Thus, energy technologies that are usable in rural settings should rely on local (non-monetized) resources. This means that biomass energy sources will remain alternative to meet the cooking demand due to their availability for free and fitness of the biomass energy stoves to rural cooking demands. However, current biomass energy sources are not sufficiently available to meet the demand and are not clean to achieve the targets of goal seven and related goals. Ensuring access to affordable, reliable, sustainable, and modern energy for all households seems highly ambitious and far from a realistic situation existing in developing countries. Moreover, existing global and national energy policies could have significant implications on the achievement of the goal.

ENERGY POLICY

Many energy transition policies have been implemented to transform the traditional energy system to improved and efficient energy technologies. The energy ladder model has been widely used to explain the household energy transition with socioeconomic conditions of the households (Leach, 1992). This model has been criticized for its notion of linear transition mode that complete transition from traditional system to modern energy cannot be achieved by increasing household income (Masera et al., 2000; van der Kroon et al., 2013). Improving household income could help to buy the technology, but sustained use of technology depends on the local conditions and cultural preferences (Masera et al., 2000). Differences could exist between rural and urban households to value local and cultural conditions. Urban households are more aware of technologies, are connected to the formal money economy, and economically better-off to use improved energy technologies compared to their rural counterparts (Heltberg, 2003). Energy transitions in developing countries are complex by which improving the economy alone cannot achieve it.

The sustainable development goal is another global agenda with 17 goals having synergistic applications. Among these, SDG seven aims to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030. This goal aims to address five important and critical issues related to the ability to buy, reliability of the technology as well as the sustainability of the system from environment and resource perspectives, the supply of better and improved technologies to all humanities. Achieving this goal needs to improve the socioeconomic status of all citizens to have purchasing capacity to the modern energy technologies or provision of low-cost technologies the poor can afford to buy. The big question is what different policy strategy is devised to assist the government in developing countries to specifically address this issue and make modern technologies accessible to their people. In 2011, IEA projected an annual investment of $48 billion to provide universal energy access to all by 2030 which mainly focus on access to electricity (IEA, 2011). The projected investment focuses on the expansion of the grid and off-grid and was not on addressing the issue of affordability associated with the household's capacity to buy. The second issue the SDG seven aims to address is the provision of reliable energy for all. It is related to increasing efficiency and upgrading the system to provide clean energy without interruption. This requires bringing down the current energy system loss to zero or integrating a back-up system compensating the loss. Improving reliability extends to upgrading the old system while investing in new infrastructure helping accessibility, which may require additional investments. The issue of sustainability is related to the provision of clean and efficient energy services with less environmental impacts. It is about the use of renewable energy resources development, which entails the question of availability, distribution, and suitability. Issues related to renewable energy technologies are well discussed in *Renewable Energy Resources and Technologies* of this paper. The term modern energy is also vague and not contextualized with reference to socio-cultural situations and expectations in developing countries. The term needs to be operationalized with local contexts, thus the definition for the western countries may not fit developing countries' situations. Moreover, the issues of increasing energy access to all people including remote areas also remain unrealistic with the current socio-economic and settlement situation which off-grid energy cannot solve with feasible costs.

Particular emphasis needs to be given to clean cooking energy technology which is directly attributed to goal seven and other Sustainable Development Goals, such as goal 3: aiming to ensure good health and wellbeing for all; goal 5: aiming to ensure gender equality; goal 13 and 15 focusing on climate action and life on land respectively (Rosenthal et al., 2018). Achieving sustainable development goals related to energy requires changes in other development goals. In particular, improving the local economy and reducing poverty would have a positive impact on increasing access to improved energy technologies although not sufficient to achieve the complete transition. Nevertheless, energy policies in developing countries mostly focus on large-scale grid electrification directly contributing to growing industries which frequently linked to foreign donations. Depending on foreign donation involves a lot of challenges attributed to donor's interests and objects which could compromise local interests. In addition, some researchers argue the impacts of post-colonial legacies and political agendas where local traditions of thought and realities are overlooked (Broto et al., 2018). Such discrepancy would have huge impacts on the effectiveness of the donations to achieve local development and interests (Dreher et al., 2015). In this regard, achieving sustainable development goals requires a better understanding of the link between access to energy and socioeconomic justice characterized by the household's economic and social independence.

Achieving sustainable energy transition in a developing country requires an integrated policy involving considering local resources and viable technologies fitting to local demands and contributes to socio-economic development and livelihood improvement. Nevertheless, what different energy policies are devised to break these complex factors and make everybody accessible to modern energy at both the global and country-level? A lot of energy policies in developing countries are mainly focusing on the large-scale grid connection to enhance energy supply to growing industries. The grid expansion may include rural villages, but involves a lot of issues related to affordability and technical feasibility to use for cooking.

The energy transitions processes also need to consider and address the questions of justice and equity. The question of justice can be associated with a fair distribution of energy infrastructure and provision of equal and equity access including marginalized groups in the population. Without considering energy justice for the poor, gender, and disadvantaged groups, achieving energy transition cannot be possible (Jenkins et al., 2018). Energy justice focuses on the evaluation and identification of the affected groups to provide sustainable solutions and reduce injustice through equal participation in decision-making processes and distribution of benefits (Jenkins et al., 2018). Recognition of the diversity of needs, values, and interests of the locals has paramount importance in ensuring energy justice (Williams and Doyon, 2019). The dream of energy for all in sub-Saharan Africa would become a reality in 2030 if productive uses and income generation activities are integrated with any available resources (Brew-Hammond and Kemausuor, 2009). With improved income, households can improve their livelihood and better purchasing power, which can reduce a vicious circle of low incomes leading to poor access to modern energy services. This requires sufficient mobilization of local and global resources and enabling pro-poor policy strategy integrating energy provision into socio-economic development.

CONCLUSION

Sustainable development goal 7 (SDG 7) is expected to ensure all households get access to affordable, reliable, sustainable, and modern cooking energy by 2030. Achieving this goal directly contributes to the achievements of goals 1, 3, 4, 5, and 15. However, many programs have failed to improve cooking energy access in most least developing countries, particularly in sub-Saharan Africa where only less than 15% of the households have access to improved cooking energy technologies. Low accessibility to improved energy technology is attributed to the interrelated socio-economic, cultural, and technical factors. Without breaking these barriers and having better integrated economic and social policies, achieving this goal cannot be possible. The policy reform should focus on easing the socio-cultural issues and the socioeconomic opportunities creating income and improving livelihood. Energy policy integrating energy provision into productive activities and income generation would help to break the vicious circle of the low economy leading to poor access to improved energy services. Renewable biomass for cooking for all households, biogas for livestock farmer households, and micro solar PV for household appliances can be some of the recommended options. Otherwise, achieving SDG 7 may remain ambitious without success, leaving over 70% of people in Sub-Saharan Africa to remain dependent on traditional use of biomass energy by 2030 as forecasted by the International Energy Agency (IEA). Although this study recommends an enabling policy integrating productive services and income generation, forwarding clear and specific policy direction on system integration and effectiveness requires further studies.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article.

AUTHOR CONTRIBUTIONS

Both GTT and DMK involved in the conceptualization and designing of the study, writing of the manuscript, and finalization.

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