EXPLORING THE BARRIERS OF SOLAR ENERGY DEVELOPMENT IN EXPANSION AREAS OF ADDIS ABABA

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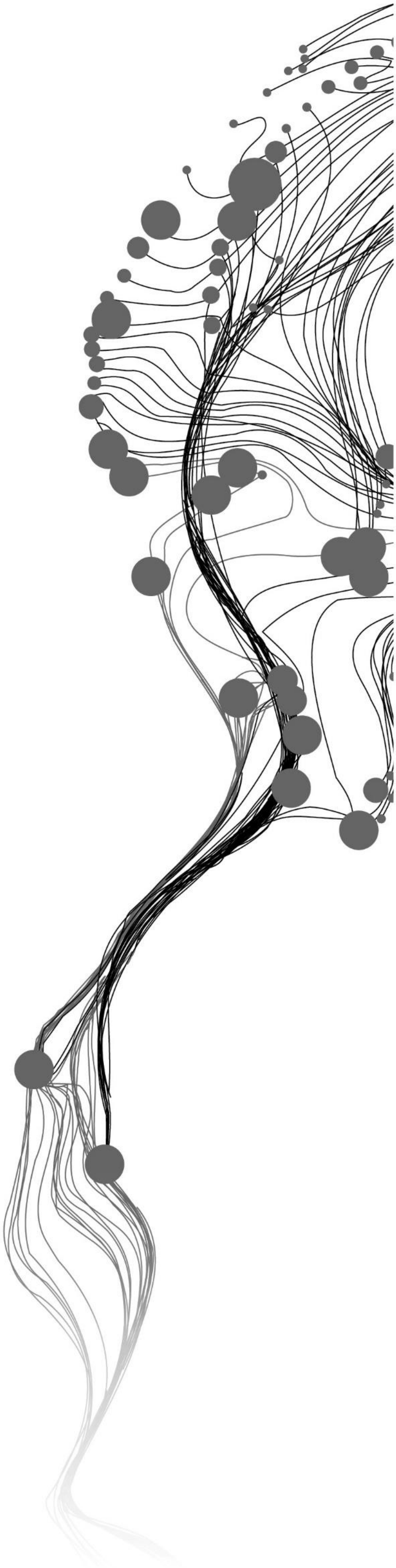

Exploring the barriers of solar energy development in expansion areas of Addis Ababa

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ABSTRACT

More than 50% of the world's people live in cities, and 75% of the population is expected to live in urban areas by 2050, so meeting energy demand sustainably is the most important difficulty for the future. Solar energy is believed as a promising source of renewable energy and an effective solution for power outages. This thesis aims to develop a framework for assessing the potential of solar energy development in the expansion condominium areas of Addis Ababa based on identified influential factors for solar energy development. First, the identified barriers are classified into economic, policy and institutional, information and human resource, technological, spatial, and societal, from various studies. Then based on data collected from Ethiopian draft energy policy document, energy sector report, household survey, KIs interview, and FGD with relevant experts, this thesis identifies the key barriers to the development of solar photovoltaic (PV) and institutional and policy barriers are separated and classified into seven categories. Then, the Best-Worst ranking method (BWM) is used to determine the importance of the identified factors and indicators to solar energy development in the condominium area. The findings indicate that policy and regulatory framework is the most influential barrier to solar energy development. Indicators such as "no clear, well-structured and unimplemented policy," "limited RE incentive (tax exemption, feed-in tariff, net metering)," and "weak energy sector institutional regulation & management" make the factor the most influential in hindering solar energy development in the context of Addis Ababa condominium areas. The economic factor is the second most influential barrier factor in the condominium areas. Indicators that make the economic factor the second most influential for the solar energy development include "foreign currency shortage & high foreign exchange spending," "limited access to financing." and affordability issue. It is recommended that the Ethiopian energy sector, decision-makers, policy makers, and concerned parties in the energy sector including, Ministry of Water, Energy and Irrigation (MoWIE), Ethiopian Energy Authority (EEA) to focus on the most relevant barriers when planning for energy to ensure a successful development of solar energy in the city.

Keywords: Solar energy, solar energy development, urban expansion, condominium, rooftop PV, BWM, Addis Ababa

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Acronyms and Abbreviations

CEO	Chief Executive Officer
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Authority
EEPCO	Ethiopian Electric Power Corporation
ETB	Ethiopian Birr (1 USD = 53 ETB)
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GHG	Green House Gas
GW	Giga Watt
GWh	Giga Watt Hours
GoE	Government of Ethiopia
Ha	Hectares
Hh	Household
IHDP	Integrated Housing Development Program
KIs	Key Informants
Km	Kilometre
Km2	Kilo Meter Square
KWh/m2	Kilo Watt Hours per Square Meter
KWh/m2/day	Kilo Watt Hour per Square Meter per Day
MoWIE	Ministry of Water, Irrigation and Energy
MW	Mega Watt
MWh	Mega Watt Hour
NGO	Non-Governmental Organization
NEP	National Electrification Program
R&D	Research and Development
RE	Renewable Energy
RET	Renewable Energy Technology
TWh	Tera watt hour
FiT	Feed in Tariff
IHDP	Integrated Housing Development Programme

1. INTRODUCTION

1.1. Background and Justification

The UNDESA (2010) notes that more than 50% of the world's people live in cities, and 75% of the population is expected to live in urban areas by 2050, so meeting energy demand sustainably is the most important difficulty for the future. In other words, as the urbanization trend continues, energy consumption increases and leads to demand for more energy, energy crises, and CO2 emissions (Wang, Wu, Zeng, & Wu, 2016). Moreover, according to the UN-Habitat (2016), rapid urbanization occurs in developing countries. Sub-Saharan Africa is experiencing rapid urbanization and is expected to be predominantly urban by 2040. Besides, Bawakyillenuo et al. (2018) highlighted 75% of energy demand will be urban by 2040. Thus, meeting the fast-growing demand with reliable and affordable energy is a major bottleneck for future prosperity (Adegoke, 2018). According to the International Energy Agency (IEA) (2020) report, over 700 million, more than half of Africans, lack access to electricity. Over 80% of the population in the Sub-Saharan region has no access to modern energy sources (Mugisha et al., 2021). Furthermore, Africa faces an electricity shortage which causes a number of power outages, and this phenomenon is worst in the sub-Saharan Africa region (Abotsi, 2016). For instance, more than 77% of sub-Saharan African firms experience frequent power outages, and the average number of power outages they experienced in 2020 in a typical month was over nine times (World Bank, 2021). The World Bank Group (2015) stated that some reasons for repeated interruptions are due to having medium voltage conductors, interrupted lines or breaking, informal connections, and a high load of demand. However, African countries are rich with untapped renewable energy (RE), including over 10,000 gigawatts (GW)[1] solar potential (African Development Bank, 2017). Also, Africa is the sunniest continent having an annual estimated theoretical reserves of solar energy potential at 60,000,000 terawatt hour (TWh)[2], which is almost 40% of what the entire world receives annually (Liu, 2015). Out of this, eastern Africa has the highest potential share, followed by southern Africa (Renewable Energy Agency, 2014). However, according to IRENA (2017), South Africa leads in solar energy development. Therefore, compared to the resources they have, solar energy potential in African countries is untapped (Manfred Hafner et al., 2018; World Bank, 2020).

Ethiopia has substantial RE resources potential with an estimated 45,000 megawatt (MW) hydro, 10,000 MW geothermal, more than 100 GW wind (Ministry of Water Irrigation and Electricity, 2018). Furthermore, due to its geographic location, Ethiopia has massive resources of solar energy (Mazengia, 2010; Belay, 2018 & MoWE., 2012); although it is highly reliant on biomass, which accounts for over 90% of the total energy consumed in the country (Japan International Cooperation Agency, 2012). The World Bank (2020) reported that 0.005% of the country's area of land, which is 5500 Km^2, could generate sufficient power to meet the existing demand. Solar irradiation intensity is a leading factor in determining the technologically developable capacity of solar energy; regions with over 1500 KWh/m^2 annual irradiation intensity are suitable for solar power development (Liu, 2015). According to the MoWE (2012) and Tucho, Weesie, & Nonhebel, (2014), Ethiopia's average radiation intensity of exploitable solar energy

[1] GW unit of power, the rate at which energy is produced from the available solar energy resource.
[2] TWh is the unit of energy, the amount of energy generated over a given timeframe.

potential received at the ground is around 5.5 KWh/m^2 per day, equivalent to 2200 KWh/m^2 annually.[3] However, only 14000 KW PV power, less than 1% of the total available potential, was exploited until 2017 (Dorothal, 2019). Moreover, it has a PV potential of 27154 TWh/year (overall sum of suitable areas) (Irena_Africa, 2014). The national energy policy encourages shifting the traditional energy usage (biomass) to modern and environmentally friendly energy sources; it also planned to use locally available alternative energy sources by prioritising hydropower. As stated by USAID (2020), the country's installed energy capacity reached 4,300 MW; out of this, around 92% of the installed energy capacity is from hydropower. However, it still faces energy shortages for electricity due to an increasing electricity demand that is forecasted to grow by 32% annually (Asmamaw, 2016). Access to electricity in Ethiopia remains among the lowest in the globe, more than half of the population lives in the dark were only 48% gets access to it (World Bank, 2019; Mugisha et al.,). This is because the significant potential of RE sources, particularly solar, is underdeveloped so far.

Over the past 20 years, Addis Ababa city has been experiencing rapid urban expansion through the conversion of farmland to development, and the economy of the city also showed growth (Koroso, Zevenbergen, & Lengoiboni, 2020). This paper further reported that the city's boundary enlarges by 19%, and the population grew by 30% between 1994 to 2007. Moreover, Zewdie et al. (2018) found that Addis Ababa city grows by 50% while agricultural land and forest cover declined by 34% and 16%, respectively, between 1984 and 2014. He further argued that the government that took over power in 1991 had brought significant urban growth because the post-1991 decentralization policy encouraged housing development. For instance, in 2005, the Ethiopian government came up with a new housing policy framework called Integrated Housing Development Programme (IHDP). It has been implementing government-led low and middle-income condominium housing, particularly in Addis Ababa (UN-HABITAT, 2011). According to the report, the initial goal of the programme was to construct 400,000 condominium units. The IHDP was introduced as a government-led intervention to address housing shortages by focusing on Addis Ababa city. According to the UN-HABITAT (2011) study, 171.000 housing units were built. Recent data gained from Addis Ababa Housing Development Corporation shows that the program has built 282.116 housing units so far, of which 42.548 are in the Bole sub-city. Since 2005, the Addis Ababa city administration started large-scale condominium housing projects and transportation infrastructure (Larsen et al., 2019). However, not all ten sub-cities expand at the same pace; Bole, Akaki kality, and Keranyo (see figure 1 & table 1) show the most rapid urban expansion (Koroso et al., 2020). At the same time, the energy demand is increasing enormously (Gaddada & Kodicherla, 2016). Currently, Addis Ababa city energy is heavily dependent on hydropower.

This over-dependence on hydropower can be ineffective because it is the most water-intensive RE type, making it very helpless against dry season, rivalry over water resources, and other water deficiencies (Jiao Wang, 2017). This brings about power outages, also known as power failure. Power failure is either a short-term or long-term condition of complete or nonappearance of electrical power at the consumer's end that may range from a few minutes to several days and weeks (Amadi, 2015; Salvador & Manalo, 2017). Even though the energy for electricity access of Addis Ababa city is close to 100%, frequent service interruption is viewed as a stress in the area (World Bank Group, 2015). For instance, the city experienced an average of 42 interruptions that happened in January 2015 in a week. As indicated by UN-Habitat (2017) report, the number of household reports because of power outages per week in the resettlement area (716 hh) was very high compared to the reports before the relocation 491 hh.
Similarly, the number of household reports because of power outages per week was 150 hh in the inner city and increased to 345 in the resettlement site in 2016. This study further states that this substantial and

[3] KWh/m^2 is unit of irradiance intensity, the rate at which solar energy falls onto a surface, not the total amount of energy.

repeated power disruption causes significant economic and social effects to dwellers of the city, affects businesses, declining economic competitiveness, and decreases the capacity of investment attractions. World Bank Group (2015) further states that sustaining the intensity of urbanization and rapid growth of population into the future requires an increased capacity and an efficient energy supply and distribution system.

The Ministry of Water, Irrigation, and Energy is the main responsible institution of the energy sector, together with the three additional institutions (Ethiopian Electricity Agency, Ethiopian Electric Power Corporation, and National Strategic Petroleum Reserve Administration) related to the energy sector (MoWE, 2012b). However, the national energy policy drafted in 2012 mentioned that unclear coordination between the responsible organs and the power sector experiences an absence of strong institutions. For instance, Tessama et al. (2013) noted that most non-governmental actors; currently working in the energy sector work in a fragmented way. Due to low local technical and institutional capacity, they follow their own objectives and policies. However, they argue that involving relevant non-state actors have a role for the energy sector in reducing implementation challenges, creating coherent policies and strategies, and attracting external funding.

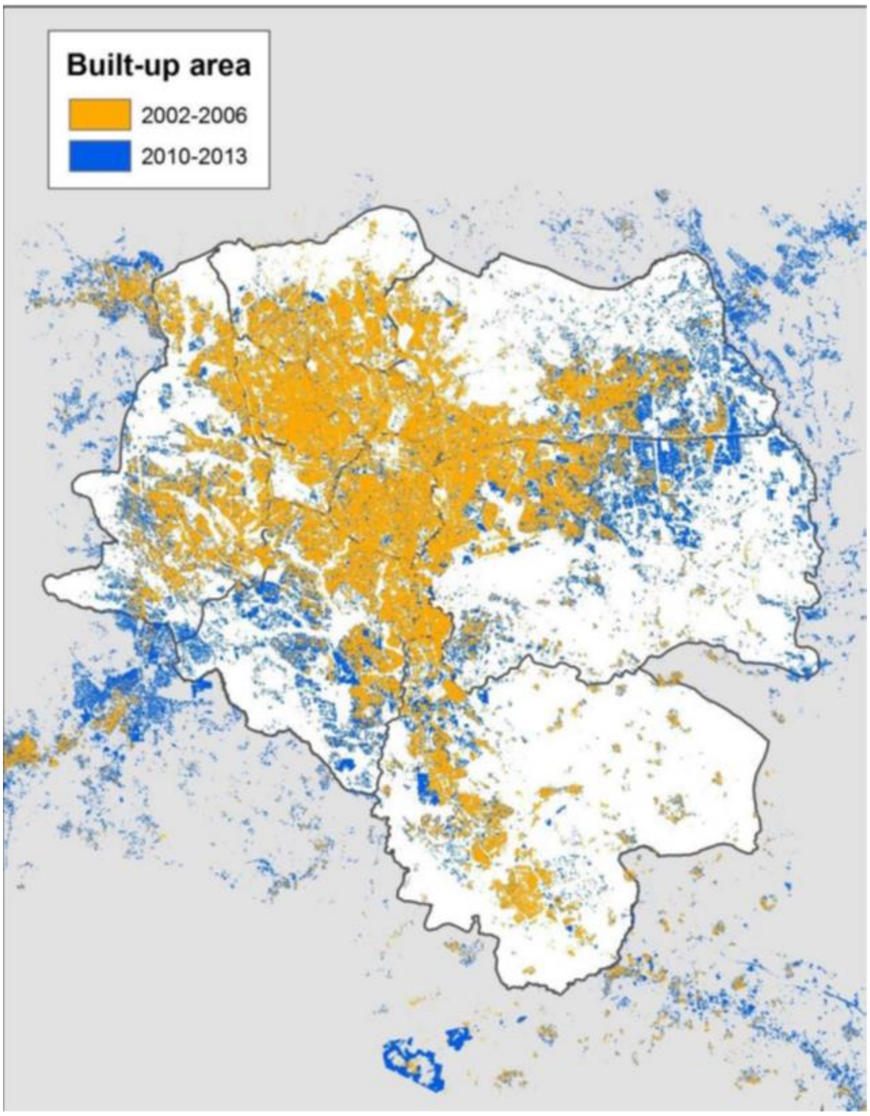

Figure 1: Addis Ababa urban expansion *source: (World Bank Group, 2015*)

Table 1: Addis Ababa population and built-up area growth (adapted from (Koroso et al., 2020)

Addis Ababa				Change		
Year	2005	2011	2019	2005-2011	2011-2019	2005-2019
Population	263,4000	326,3000	459,2000			
Built-up area (sq. km)	254	344	450			
Population growth				24 %	41 %	74 %
Built-up area growth				35 %	31 %	77 %

1.2. Research Problem

Despite having abundant solar energy potential, the IHDP in Addis Ababa has not yet integrated solar energy into the energy supply system and experiences frequent power outages (UN-HABITAT, 2011). Solar systems are environmentally sound technologies (Lobaccaro et al., 2019). Addis Ababa city is continually experiencing rapid urban expansion and population growth, requiring an increase in power generation capacity. However, due to increased energy demand, the city experiences frequent outages and interruptions (World Bank Group, 2015). Besides, for grid-connected areas like Addis Ababa, with most of its power generation capacity depend on hydropower, it may face challenging times during droughts (MoWE, 2012). Therefore, diversification of energy resources by investing in solar energy into the expansion areas is a wise decision to be less dependent on hydropower, to address energy stress and help to provide a consistent energy supply, optimal economic development, and a better standard of living (Gärtner & Stamps, 2014). Moreover, integrating carbon-free alternative energy sources to such rapidly urbanizing sites supports economic growth in a sustainable manner. For example, Kazeem (2018) argues that solar power is an obvious solution for around 600 million Africans who live without access to electricity.

Addressing the energy demand through the unexploited solar potential is stated in the drafted national policy of Ethiopia in 2012 (MoWE, 2012). To achieve this, the national electrification program launched in 2017 that focuses on achieving 65% integrated grid and 35% of off-grid power access to all citizens by 2025 (Ministry of Water Irrigation and Electricity, 2019). However, the policy and the program are vague since there is no detailed plan for the installation of solar energy in the country's urban areas. Accordingly, there is also no plan to integrate rooftop solar energy into the expansion areas, particularly in condominiums.

In Addis Ababa, large-scale condominium (condo) housing is encouraged by the national urban development policy of 2005 (Terfa, Chen, Liu, Zhang, & Niyogi, 2019). Most of these are constructed in the peri-urban areas of the Bole and Kality (Koroso et al., 2020). While these housing projects do have access to electricity, power outages are the main challenge of the resettlement (condominium site). As such, it will be ideal that solar energy could be used to address this problem. To determine this potential, it is crucial to explore what factors support and hinder the use of local energy sources (solar) in these areas.

Much literature exists regarding the various influential factors to the implementation of solar energy. For instance, Irfan, Zhao, Ahmad, & Mukeshimana (2019) found that the barriers of solar energy development in Pakistan include economic, policy, information and human resource, technological, and societal related issues. A study by Do, Burke, Baldwin, & Nguyen (2020) which was done on solar PV diffusion in

Vietnam, found that the most important barriers for PV diffusion are economic, institutional, technical, and social. Another study by Zhang, Shen, & Chan (2012) mentioned economic, technologic, societal, political and spatial issues are the main solar energy development barriers in Hong Kong. However, these factors are not all relevant in Addis Ababa, a rapidly growing city in a developing country. Most research on solar energy development studies, including those stated above, is centered on either higher income or less quickly urbanizing areas. Hence, there is the need to take a critical look at the barrier factors and indicators that can be refined in the context of Addis Ababa in determining the potential of solar energy development. Therefore, this research will explore the currently used indicators in assessing the barriers in solar energy development to better understand what could possibly hinder solar energy development in the condominiums of Addis Ababa.

1.3. Research Objectives / Research Questions

1.3.1. Main Research Objective

The main objective of this study is to develop a framework for assessing the potential of solar energy development in the condominium areas of Addis Ababa, based on identified influential factors for solar energy development. This study will focus on rapidly expanding sub-cities of Bole, Kality, Kolfe keranyo and Lafto condominium districts.

1.3.2. Sub Objectives

I. To evaluate the identified (from literature) potential indicators under each barrier factors and identify the appropriate ones in the context of Addis Ababa condominium sites.

II. To identify new potential indicators under each factor for solar energy implementation in the context of Addis Ababa condominium sites.

III. To determine and rank the contextualized and newly identified factors and indicators under each barrier, based on their relevance in hindering solar energy development.

1.3.3. Sub Questions

I. From the identified barrier indicators (from literature), which potential barrier indicators are appropriate for affecting solar energy development in the Addis Ababa condominium site?

II. What are the additional potential barrier indicators that affect solar energy development in the Addis Ababa condominium site?

III. What are the most and least important factors and indicators affecting solar energy development according to the experts who understand the context of Addis Ababa?

Figure 2: Study area & the Four rapidly expanding sub-cities (Bole, Kality, Keranyo & Lafto)
Source: (World Bank Group, 2015),

1.4. Significance of the Study

The study focuses on developing a framework for assessing the likelihood of solar energy development in the condominium areas of Addis Ababa. This study identified the potential barriers of solar energy development in the particular context and developed a framework for assessing it. Hence, it will provide understanding and academic knowledge of solar energy development's potential hindrances/supports. It could be used as a starting point to assess all other condominium developments. Therefore, other researchers can use the framework to find data and look at the most important barrier for potential solar development. Besides, the results from this study will also provide insight and relevant information for the Ethiopian energy sector, decision-makers, and policymakers to better understand on what to incorporate for the successful development of solar energy in the city. Thus, such a study will help provide the government information on what gaps may exist in solar energy development contextually and focus on

1.5. Scope of the study

More than 18 sites of condominium housing projects were constructed in ten sub-cities of Addis Ababa. According to the World Bank Group (2015) report, all the sites experience power outages. However, due to constraints of finance, Covid19 travel restriction, time, and the researcher ability, the study would be bound by Bole, Akaki Kaliti, Nefassilk Lafto, and Kolfe Keranio sub cities' project sites. Those sub-cities are purposively selected because they are the most expanding zones than any other sub-cities of Addis Ababa. To get detailed information and conduct a detailed assessment, Bole-Arabsa condominium site is selected from the leading expanding sub-city of Bole based on its area occupancy and population number.

1.6. Thesis structure

The study will comprise six chapters that will be undertaken in three phases of pre-field fieldwork, fieldwork, and post fieldwork.

Chapter 1: Discusses about the general introduction, background, and rationale of the research, the research problem, research objectives and questions, significance of the study and scope.

Chapter 2: Reviews the literature in order to explore existing knowledge in the field of study. It gives emphasis on key concepts of the study from existing studies on power outages, barriers for solar energy development, the contextual information of solar energy development, energy policy and role of solar actors, followed by a conceptual framework.

Chapter 3: Highlights the research design, study area, methods and methodology, techniques for data collection and interpretation, sampling techniques, limitations and ethical considerations.

Chapter 4: presents the findings obtained from household questionnaire, KIs interview, FGD based on the defined objectives and questions.

Chapter 5: Presents the discussion aspect of the study, which highlights the explanation and interpretation of the findings of this research in line with the literature review.

Chapter 6: Presents the conclusions and recommendations for the future scope of research.

2. LITERATURE REVIEW

This section of the study briefly provides an overview of solar energy and its ability to reduce power outages in expanding cities. It further summarizes evidence from several studies which attempt to identify the main factors for developing and transitioning to solar energy potential. Lastly, it provides an overview of the available information regarding solar energy development in Addis Ababa.

Various sources of literature were used to obtain related studies on potential factors and indicators. To easily find literature that relates to the study, keywords were employed. Examples of the keywords are Solar energy", solar power, solar radiation, sun energy, rooftop solar, PV rooftop, power outage, power cut, blackout, power failure, power down, power interruption, power cuts, electricity outages, power disruptions, transition, conversion, development, transformation, turn, hinder factors, barrier, blockade, Impediment, limit, obstacle, urban expansion, urbanization, urban development is performed using Scopus, Web of science, and google scholar. The results of the key terms include academic studies, governmental and agency reports, academic journals, and policies. Then the results are selected by their relevance to the study. Then the results are selected by their relevance to the study and the potential barriers/ supporters of solar energy development are identified from the selected literature.

In addition to this, new indicators that hinder/support solar energy development in Addis Ababa were identified from policy documents, climate-resilient green economy strategies, reports, feasibility studies, and solar energy-related literature used in Addis Ababa. This can be performed by reviewing the secondary documents and helps to identify new potential indicators under each factor in the context of Addis Ababa.

2.1. Solar Energy and Power Outages

Research to find the potential of solar power to support the reduction of impacts of power outages was conducted in 1996 by Perez et al. (1997). Since then, many studies have shown that solar energy has the potential to reduce power outages. For instance, a recent study in Malaysia by Arief, Anak Sa-Or, Mubarakah, Izzwan Saad, & Eteruddin (2020) argues that solar energy can be considered a solution to blackout by providing reliable power. Similarly, a study by Gaitov, Kopelevich, & Samorodov (2019) claims that solar energy usage decreases direct and indirect economic damages caused by a power disruption. According to the research by Khalil (2017), all sectors in Pakistan are negatively affected due to long hours of a power outage and believed this trouble could be minimized by adopting solar energy systems.

Financial incentives like government subsidies and creating a suitable economic environment for the private sector will encourage investment opportunities for solar energy, which can help minimize power disruption, thus increasing efficiency and economic resilience in Ghana (Asumadu-Sarkodie & Owusu, 2016). Okoye et al. (2016) argue that Nigeria's big business hub cities, such as Lagos, Onitsha and Kano, are known for their recurrent power outages by blocking their business and economic development. Okoye et al. (2016) further argue that standalone PV systems are the best solutions to minimize the power outage in urban residents of Nigeria and then compare it with a currently widely used diesel generator. They concluded that stand-alone PV systems are technically and economically feasible. Furthermore, Zhang et al. (2012) highlighted that solar energy is believed to be an effective solution to power shortage in Hong Kong.

In a study by Mwale and Davidson (2014), it was found that in South Africa, power outages are either planned (when the power supply cannot reach the demand because of high demand load) or forced (due to failures of the system caused by factors such as outdated equipment, trees, birds, animal, wind, vehicular accidents). To mitigate the power outage, the government spends R160 billion of money on expending and strengthening of the transmission network (Africa, 2012). It also increases the generation capacity by emphasizing local RE resources, mainly wind and solar, and reducing the dependence on coal-based electricity generation (Mwale & Davidson, 2014).

2.2. Factors Affecting Solar Energy Development Globally

Countries that are popular for solar energy development, such as US, Spain, Germany, and Italy, focus on rooftop solar installations on residences. This is because it reduces the cost of power generation infrastructure, increases energy reliability and becomes a source of money for residents (Bhasin, Saxena, Kumar, & Tirth, 2015). Therefore, this study focuses on rooftops. There is a broad range of literature that describes the factors to the development of rooftop solar energy.

The following sections will provide a general understanding of these factors according to a number of categories and an overview of the available indicators which have been used to assess them in various cases around the world. Appendix 4 indicates studies with a detailed list of hindrance factors and their indicators to solar energy development in different regions. Most of the studies are taken from developing countries. Therefore, the factors discussed in most studies are selected and can be organized according to six general categories: Economical, Policy and Institutional, Technological, Information and Human Resource, Spatial and Societal. This study is going to look at and assess these six factors for their appropriateness for use in the case of the Addis Ababa condominium site. Indicators that are appropriate for the case area are selected from the above studies to measure each barrier.

2.2.1. Economy

Several studies have highlighted economic factors that could hinder the implementation of solar energy development. The most mentioned indicators include capital incentives, level of government subsidies, initial costs, repair costs, and tax exemption mechanisms. For instance, Zhang et al. (2012) which was done in Hong Kong, highlighted the high initial cost of solar energy with reference to the expensive materials needed to install solar panels. Also, Ohunakin et al. (2014), which focused on cities in Nigeria, explained limited government subsidies as barriers because most governmental supports in the form of subsidies are given for conventional energy sources, and this has led to slow solar energy development. Luthra et al. (2015), a study in India, explained limited access to financing discourages RE investors, Small and medium scale enterprises (SMEs) towards solar energy development. Also, a study by Najafi et al., (2021) in Iran argue that limited tax exemption discourages investors from entering renewable energy development projects.

Therefore, based on the Literature (see appendix 4), the most mentioned barriers in a couple of the studies were taken, and the best way to measure the economic aspects limiting the implementation of solar energy in Addis Ababa were determined: 1) capital incentives, 2) level of government subsidies, 3) initial costs, 4) limited access to financing, 5) tax exemption mechanisms.

2.2.2. Policy and Institutional

Since the policy is the critical engine to fasten the development of solar PV (Wang, Yang, Xu, & Fei, 2021), and most of the studies reviewed are related to policies. For instance, Irfan et al. (2019), which was done in Pakistan, highlighted confusing and uncertain policies discourage businesses and the involvement of private investors in solar PV projects. Also, as mentioned by Do et al. (2020), to start a solar project in Vietnam, an investor should go across 17 administrative steps, which makes a complex and lengthy process. A study which was done in Nigeria by Ohunakin et al. (2014) argue that the incorporated feed-in tariff scheme into solar energy in the country is not attractive and encouraging for investors since it is expensive and doesn't make the investor profitable. As revealed in appendix 4, how best to gauge the institutional and policy viewpoints restricting the implementation of solar energy in Addis Ababa are examined. These factors include 1) uncertain and confusing policies related to private investors, 2) Complex administrative procedures, 3) poor structural regulation, 4) limited Feed-in tariffs (FiTs)[4].

2.2.3. Technological

Based on the different studies review technological factor is highlighted as a barrier the development of solar energy. For instance, Do et al. (2020), which was done in Vietnam, pointed out that grid unreliability is in relation to the inadequate or overload transmission infrastructure (grid). Irfan et al. (2019), which was done in Pakistan, highlighted the country is dependent on foreign technology for key solar energy parts and equipment due to no solar cells production facility at a national level. Also, (Luthra et al., 2015), which focused on cities in India, point out solar energy technologies in India are inefficient/underperforms because developmental efforts of some relevant solar technologies have not yet been initiated. As indicated in appendix 4, the best way to measure the following technological hindrances to solar energy development in Addis Ababa were determined. These are 1) high dependency on foreign technology equipment, 2) inefficient technology, 3) grid unreliability, and solar energy storage technologies.

2.2.4. Information and Human Resource

Several studies have highlighted solar energy development in different areas is experiencing information and human resource challenges. The most mentioned indicators include lack of local experts for operation and maintenance, level of government subsidies, initial costs, unreliable and inefficient solar energy data, limited knowledge of modern solar technologies, and limited investors and suppliers. For instance, Irfan et al. (2019), which was done in Pakistan, highlighted limited skilled manpower with reference to limited local and international cooperation in and limited training centers. This study also argues that the unreliability and inefficiency of solar energy data is a barrier because the government is not encouraging solar energy-related research and development (R&D) by providing funds. Also, Charles et al. (2018), which focused on Africa, highlighted limited skilled manpower with reference to the inappropriate designed solar energy policies and to the installation and maintenance of solar equipment. A study by Mostafaeipour et al. (2021) identified the limitation of investors and suppliers as barriers to the development of solar energy. The study further explained the reason for this is the lack of interest to invest in solar energy due to lack of funds and loans for investment. Similarly, Do et al. (2020) also argue that having limited investors and suppliers is due to a lack of supporting governmental policies, including FiT mechanism and tax exemption, which encourages private sectors to enter solar PV business and to invest in solar PV projects. Therefore, indicators that will determine and measure potential solar energy development in Addis Ababa based on the different countries study which is indicated in (appendix 4) selected and include: 1) lack of local experts for operation and maintenance, 2) unreliable and inefficient solar energy data, 3) limited knowledge for modern solar technologies, 4) limited investors and suppliers.

2.2.5. Spatial

Some studies have highlighted spatial factors that could hinder the implementation of solar energy. The most mentioned indicator includes inadequate rooftop space. For instance, Zhang et al. (2012), which was done in Hong Kong, argued that lack of sufficient space in individual buildings' roofs leads to a limited amount of energy generation. Also, Hosseini (2019) highlighted inadequate rooftop space with respect to population density. Therefore, indicators for spatial hindrances were determined based on the findings from the literature review contextually, which are 1) available/suitable rooftop space, inside this indicator, the type of roof, and its architectural position assessed.

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[4] FiTs are the most widely used RE policy globally to drive down the cost of REs for accelerating RE deployment by providing potential investors with the security to make long-term investments (Couture, Cory, Kreycik, & Williams, 2010; Cherrington, Goodship, Longfield, & Kirwan, 2013).

2.2.6. Societal

Several studies have highlighted societal factors that could hinder the implementation of solar energy development. The most mentioned indicators include lack of awareness and information for solar energy, limited public participation, and low public acceptance. Do et al. (2020), which was done in Vietnam, highlighted low public acceptance slow down the implementation of solar energy projects. A study by Nikas et al. (2020) argue that issues such as public acceptance may be considered as a significant barrier to the energy transition.
Therefore, this research will also determine how best to measure the stated societal aspects that hinder the development of solar energy in the context of Addis Ababa. These are 1) lack of awareness and information for solar energy, 2) limited public participation, 3) low public acceptance,

Based on the different studies reviewed, the factors affecting the successful implementation of solar energy in other places have thus already been collected and decided to organize them into six different categories as economical, policy, technological, Information and human resource, Spatial and Social Barriers. Due to having limited time, it is difficult to take all the factors and indicators reviewed in different studies. Therefore, the most repeated barriers by the majority of the studies are taken for this research. However, a study by Zhang et al. (2012) includes one additional factor, which is spatial. So that it is decided to include in this research, believing that it is relevant in the context of Ethiopia. Furthermore, some studies such as Nikas et al. (2020) and Do et al. (2020) used political and institutional barrier factors, respectively. However, the indicators listed under those barrier factors are similar to the indicators stated under policy barriers in the other reviewed majority studies. Therefore, for the purpose of this research, the policy factor is taken.

Moreover, in the literature review, the previous research, which was done about the hindrance aspects to solar energy development, has a different aspect that varies in different countries, which is dependent on the context of Addis Ababa. Therefore, the findings from the studies will give very useful information for further study to understand how we can measure the impact of these factors contextually.

2.3. Factors Affecting Solar Energy Development in Ethiopia

Solar energy in Ethiopia is underdeveloped due to different constraints in both the demand and supply sides (Kebede & Mitsufuji, 2014). This study further described only less than 1% of the country's solar potential is exploited in off-grid areas. This shows that rooftop solar PV in urban areas is not yet used. Low RE generation mix and relying on hydropower has drawbacks, so the GoE believed to develop the country's young solar PV through involving private parties(MWE) (2012). Besides, the 2011 draft energy policy recommended involving private investors and attract them through the provision of loans, grants, and various incentive mechanisms include the formulation of FiT laws (Kebede, 2015).

Reports reviewed from the Ministry of Water and Energy (MWE) (2012), national energy policy (2011), green economy strategy (2011), and feasibility studies highlighted reducing the bottlenecks in the development of RE helps to meet the demand in an efficient and reliable way. The factors found from the above-identified reports and studies are general barriers for RE at a national level and are categorized into six general categories as economic, technological, policy and institutional, information & human resource, and societal. For a general understanding, a number of categories and an overview of the available indicators are identified under each factor as follows. The detailed study is illustrated in appendix 5. The indicators for measuring the potential for solar energy development in Ethiopia found from the reports, and feasibility studies are:
Economy: Ministry of Water and Energy (2012) argued that limited access to financial support and incentive schemes leads to a decrease market size and the number of investors and private suppliers in RE.

Another study by UNIDO (2010) also explained the currency issue as a constraint for suppliers, investors, and the whole energy sector. Banks and institutions are the main actors needed to provide loans for the suppliers, investors, individual users, promoters, and designers; however, access to financial support for RE projects, including solar, is limited and at an early stage (Kassa, 2019).

In general, the main factors measuring economic aspects limiting the development of solar energy in Addis Ababa are capital intensive, low financial support, low income, high foreign currency needed, limited tax exemption and bank loans, lack of access to financing for research and development, promotion and dissemination, lack of a market link between various RE actors, lack of access to credit facility for enabling communities to use solar energy and lack of fund for solar technologies.

Policy and institutional: it is believed that having unimplemented FiT mechanisms discourage investors from entering the RE business (Ministry of Water and Energy 2012). Other barriers include not clear policy, limited institutional support, and participation, weak institutional arrangements and capacity building, poor sector management, and inadequate infrastructure, lack of stable institutions, limited private sector participation, lack of effective monitoring and evaluation strategies to develop solar PV technology.

Furthermore, the quality of the imported materials is another issue hindering solar development because the controlling quality of such products in a free market-based economy is difficult (Kassa, 2019). The study also claimed that Ethiopia lacks a "national quality regulation" agency, which leads to people importing lower-quality solar components due to the low cost. This activity obstructs product market penetration.

Technological: According to the UNIDO (2010) and Kassa (2019) studies, solar cells, batteries, and most of the technological materials needed for assembling are imported from China, Germany, and India. Kassa (2019) further highlighted due to the lack of local industry, the price of solar materials is highly affected by the increased foreign exchange rate, and most of the suppliers do not import certified quality solar technology materials.

Information and HR: Ministry of Water and Energy (2012) report highlighted lack of local skilled human power to carry out maintenance, absence of sufficient information and data, lack of feasibility studies. Also, detailed data at a specific site, town, or city level is stated in the report as a barrier. A feasibility study by UNIDO (2010) argued that due to the hard currency problem in the country, it is difficult for suppliers to import solar technologies. This study also mentioned the national and international companies involved in the energy sector also suffered because of the foreign currency shortage to import raw materials needed for assembly.

Societal: the Ethiopian energy sector report, Ministry of Water and Energy (2012) mentioned societal barriers affecting RE in general at a national level. These include a lack of appropriate media for RE advertisement, lack of motivational awareness, dependence on traditional sources of energy, low private sector participation, and lack of local community participation, ownership in RE projects were assessed.

Integration of solar energy players for promotional activities, sharing of experiences and resources would be mandatory and a better method to reap mutual benefits in a country with limited resources and such an unspoilt market throughout the country (Kebede & Mitsufuji, 2014). The study further highlighted, weak relationships between universities and businesses, suppliers and users, governmental and non-governmental groups are also barriers.

2.4. National Energy Policy

Ethiopia has had an energy policy first issued in 1994 and second drafted in 2012. The policy encourages using of sustainable, reliable energy sources and gives priority to indigenous energy resources on paper. The Ministry of Water, Irrigation, and Energy is the responsible institution for developing and implementing strategies and policies for the energy sector. According to Jica, (2009) report, the 1994 policy was not based on a detailed analysis of needs. It was formulated based on insufficient information and qualified person, strategies were not set for private sector participation, international context was overlooked, based on an insufficient assessment of energy resources and technologies. It had no strategies for the policy implementation and current concerns were not reflected. The 2011 draft policy considered solar energy as one of the important sources of future energy, however, the feed-in-tariff mechanism is unclear and has not implemented yet. The policy gives priority to hydropower than other types of RE sources. The policy also mentions the main factors to have continued outage of power at various locations are increasing demand, low transmission capacity, low technical standard, low generation mix, lack of a comprehensive plan for the distribution network.

2.5. The Role of Government, NGO, and Private Sectors in RE Development

According to the new revised National Energy Policy 2020, the Government of Ethiopia (GoE) energy sector aims to achieve universal access to RE services and become a power export hub of the region of Eastern Africa by 2025. To achieve GoE's universal electricity access goal by 2025, the National Electrification Program (NEP) was launched in 2017 and updated as NEP 2.0, brought all stakeholders and development partners together and updated grid electrification targets and cost, provide a detailed off-grid implementation framework based on best practices and consultations with private and public sector implementing agents (Ministry of Water Irrigation and Electricity, 2019). The government, with the collaboration of the Chinese government, prepared a master plan for wind and solar energy for the country, which helps to identify their gross amount and distribution conditions (Derbew, 2013). Based on this study, Ethiopia has 2.199 million TWh solar energy reserve annually, and investors are allowed to invest in off-grid rural electrification, solar PV, solar lanterns. The importers of solar equipment in the past decade were governmental offices and NGOs, and the international financing was World Bank and UNIDO (Kebede & Mitsufuji, 2014). However, both the above-stated reports do not mention anything about urban rooftop solar PV systems and related plans. NGOs such as GIZ-ECO (Germany International Cooperation - Energy Coordination Office), is the major solar actor who is active in the sector by promoting the use of RE technologies and capacity development of the private sectors (Kebede & Mitsufuji, 2014). This study further stated that Ethio-Telecom as a governmental organization takes lion share in expanding off-grid stand solar systems. Metal and Engineering Corporation (METEC), a governmental company with the coordination of American company started PV cell assembly (Osborne, 2012).

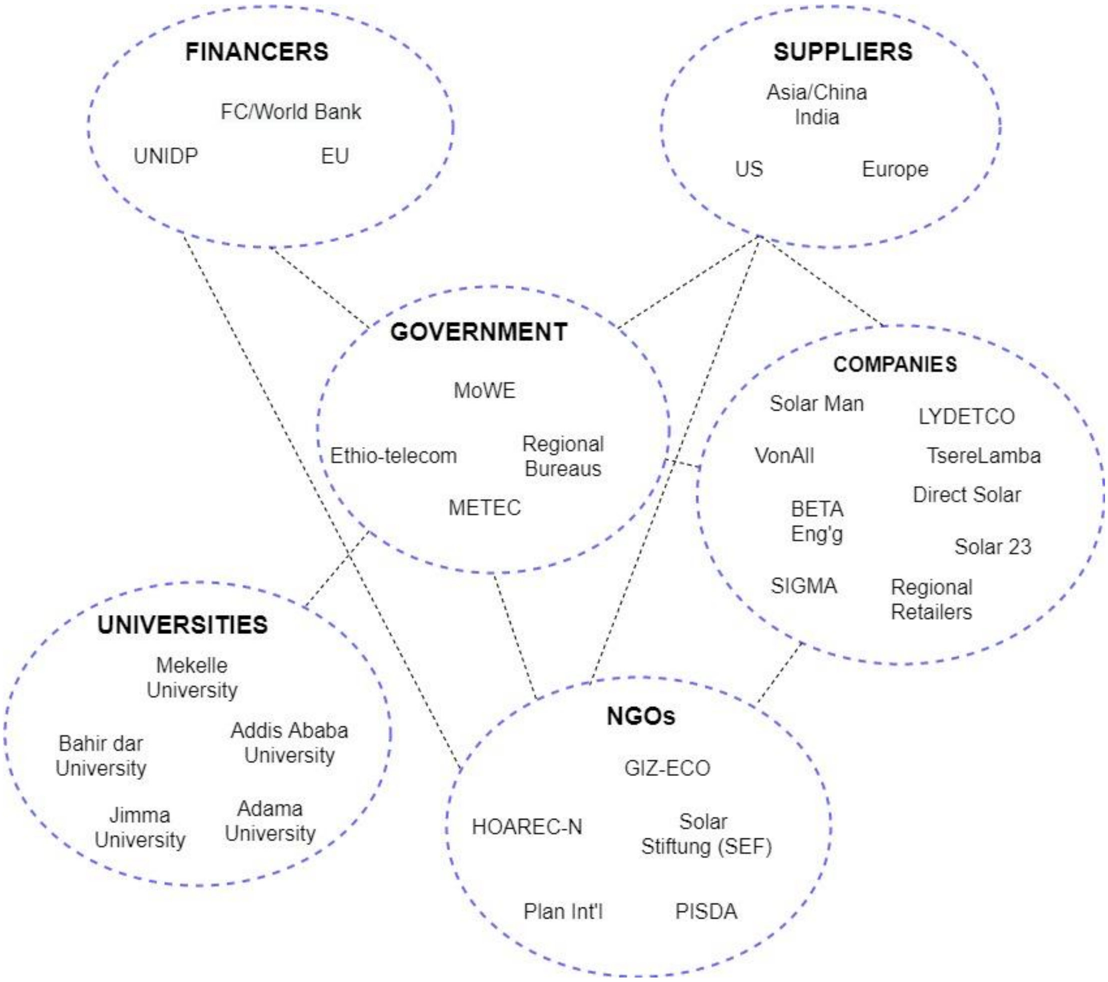


Figure 3: Major solar actors in Ethiopia *source:* (Kebede & Mitsufuji, 2014)

2.6. Solar Energy Development in Addis Ababa

There are some recent studies of solar farms in Ethiopia, but these are mostly investigated from a rural perspective. For instance, a study on modeling grid-connected solar power potential using GIS for a large-scale solar farm (Gerbo, Suryabhagavan, & Kumar Raghuvanshi, 2020). This study was conducted in Oromia Regional State. Plus, site suitability analysis of solar PV power by (Nebey, Taye, & Workineh, 2020) in south Gonder aimed to electrify 85% of the rural community.

As discussed earlier, Addis Ababa has untapped solar energy potential; however, frequent power interruptions are common and considered a serious problem in the area. UN-Habitat (2017) argues this common and regular phenomenon is due to the increased demand and reported that 1-7 days of power outages per week has occurred in Addis Ababa. Furthermore, the report by the UN-Habitat indicated the number of household reports because of power outages take place 1-2 days per week in the resettlement area that is 716 hh (55.9%), which is higher compared to the reports before the relocation, which is 491 hh (40%). Similarly, the number of households who experienced 3-4 days of power outages per week was 150 (12.2%) in the inner-city and increased to 345 (26.9% in the resettlement site in 2016 (see Figure 1). Another report by World Bank Group (2015) indicated that the city experienced an average of 42 interruptions that happened in January 2015 only in a week. In addition to this, starting from the past two decades, Addis Ababa city is rapidly expanding. Therefore, meeting the fast-growing demand with reliable, efficient, and affordable energy could be a major hindrance to the city's future prosperity. A feasibility study by Kebede (2015) on the economic aspect of a proposed 5MW PV grid-power plant in the Entoto Addis Ababa skirt area showed that the planned power plant is economically viable. However, the study emphasized that this might not be interesting to commercial investors unless the government introduces capital incentive policies like FiT.

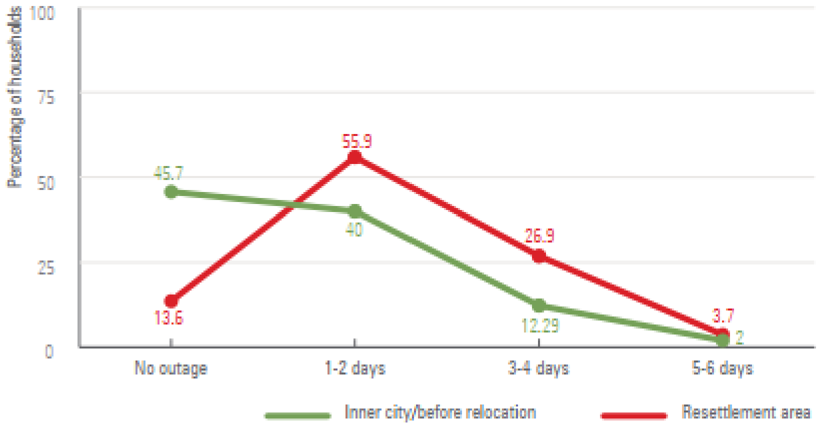


Figure 4: Electricity service dependency (in days without electricity per week) *source: (UN-Habitat, 2017)*

2.7. Conceptual Framework

The conceptual framework (Figure 5) illustrates solar energy development in Addis Ababa and the relationship between the important variables that hinder solar energy development.

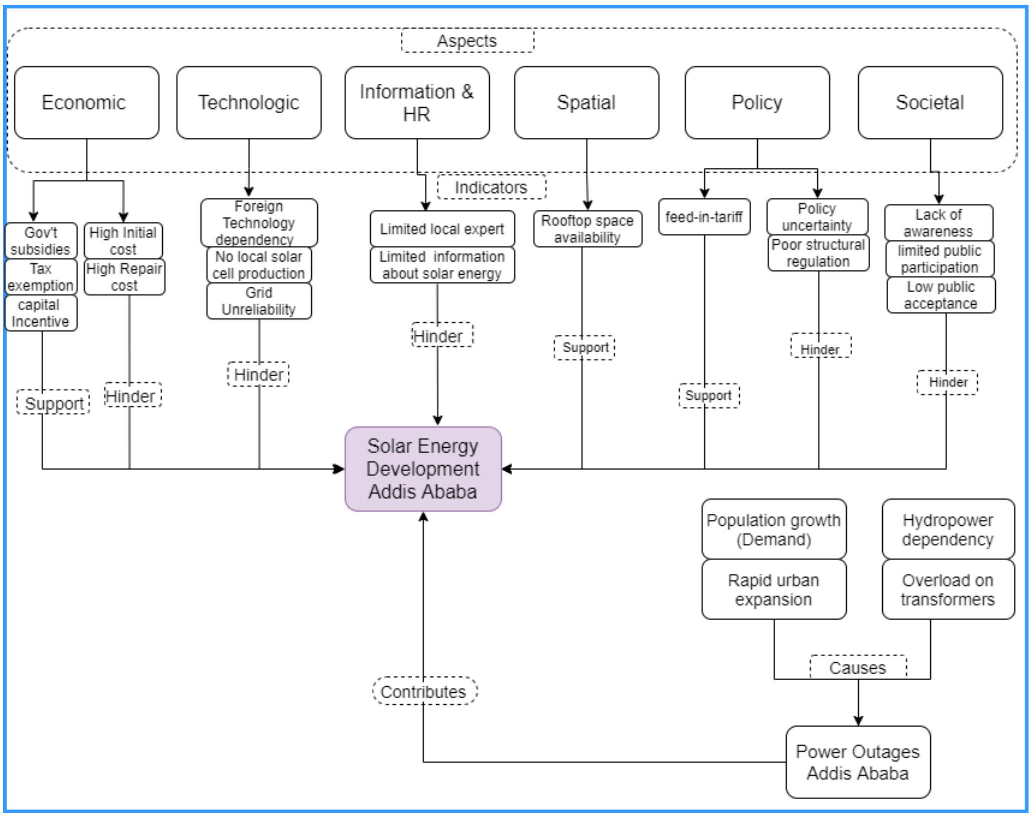


Figure 3: Conceptual diagram

3. RESEARCH DESIGN AND METHODOLOGY

3.1. Research Design (Procedure)

The fundamental research question of interest was exploring the factors affecting solar energy development in expansion areas of Addis Ababa condominium areas. The case study in this research helps to identify the important factors for rooftop solar development in peri-urban areas of Addis Ababa condo areas.

This study employed both qualitative and quantitative methods of research approach for data collection and analysis through content analysis, descriptive statistics and best-worst method. Questionnaires, interviews and focus group discussions were used to collect data. This study adopted semi-structured interviews for professionals and academics in energy-related sectors to understand factors affecting solar energy development. In this study, the selection of relevant and reliable indicators to measure the factors was through a review of literature from other countries and adjusted to the local context of the case area.

3.2. Study Area

The area of interest for this study is Addis Ababa expansion area of condominium sites, located in Ethiopia. According to Teferi & Abraha, (2017) the highest urban expansion occurred in four sub-cities, out of ten sub-cities of Addis Ababa. These sub-cities with their spatial extent of expansion between (1986-2011) are Bole (25.12 km2), Akaki Kality (21.63 km2), Nifassilk Lafto (16.56 km2) and Kolfe Keranyo (15.64 km2). Koroso et al. (2020) study also mentions the highly expanded sub-cities as Bole, Akaki Kality, and Nifassilk Lafto respectively. Koroso et al. (2020) argue that the population and built-up area of Bole sub-city grew by 21% and 83.3% between 2007 and 2019, respectively. This growth makes Bole the second biggest sub-city with area of 118.5 km^2 and 378,104 population in 2016 (Aklilu & Necha, 2018). Condominium areas found in the above stated expanded sub-cities face power disruptions from the hydropower source caused by an overload on transformers as demand increases (Gebrewold, 2015). According to the UN-Habitat (2017) report, a large number of power interruptions take place in such resettlement areas. At the same time, with the rapid expansion of the stated sub-cities, demand for energy is also increasing enormously by causing frequent power interruption. For instance, the city experienced an average of 42 interruptions in a week that happened in January 2015, and most of these interruptions happened in resettlement condominium areas. As indicated by UN-Habitat, 2017 report, the number of household reports because of power outages per week in the resettlement area (716 hh) was very high when compared to the reports before the relocation, which is 491 hh. Similarly, it was 150 hh in the inner-city and increased to 345 in the resettlement site in 2016.

To conduct a detailed assessment, however, this study focused on Bole sub-city of Bole-Arabsa resettlement condominium site from the eastern part of Addis Ababa based on the following reasons. First, Bole-Arabsa resettlement site is found in Bole sub-city, one of the sub-cities with the highest urban expansion. Second, it has a large area of occupancy with a large number of dwellers.

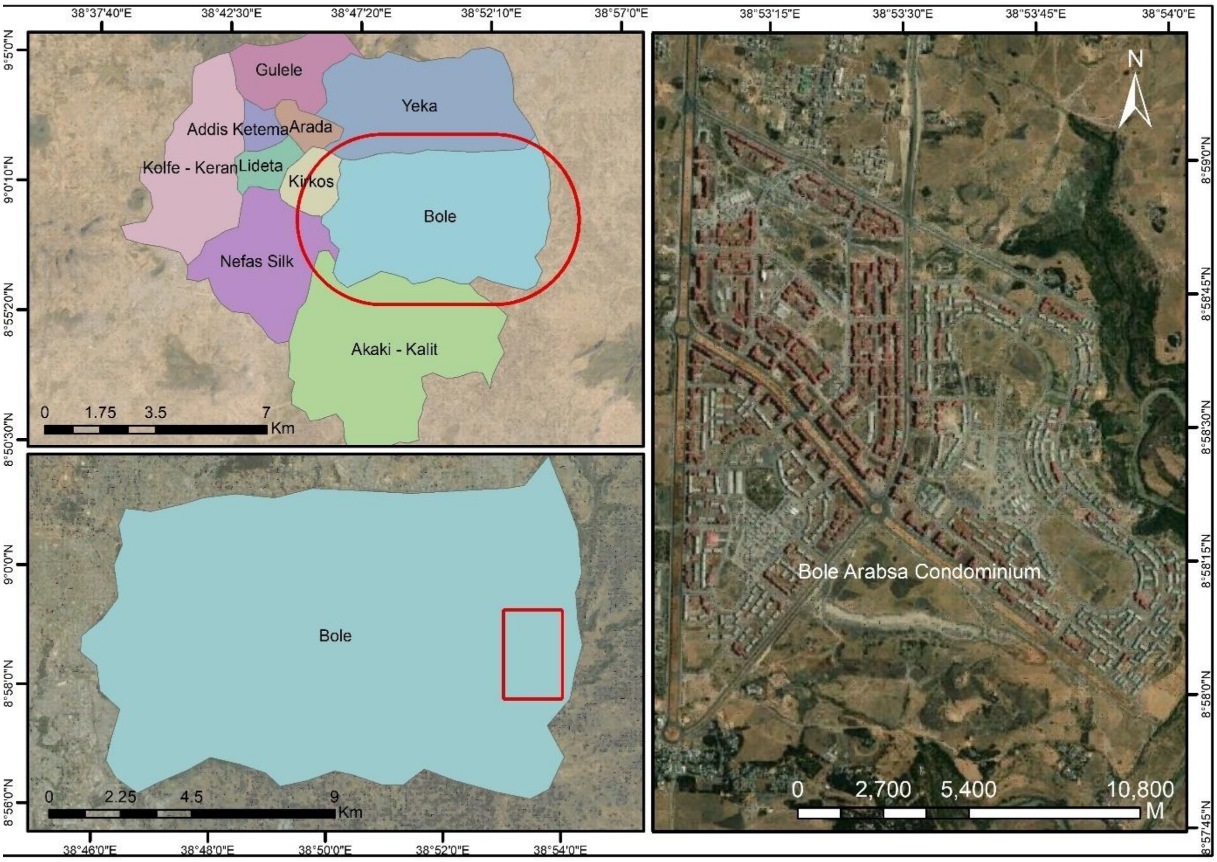


Figure 5: Study area locational map *Source: (ArcGIS Online and Esri Basemap)*

3.3. Pre-fieldwork stage

The pre-fieldwork phase involved a thorough review of existing literature on solar energy development and factors affecting it, power outages, and the relationship between solar energy development and power outages, particularly in developing nations. It comprised the research problem identification revolving on the conceptual framework and formulation of research objectives and research questions. During this stage, the study area was selected, and a map of the study area was prepared. Besides questionnaires for residents, an interview guide for KIs and FGDs has been drafted according to the research objectives and questions.

3.4. Fieldwork stage

The fieldwork was carried out in Addis Ababa, Ethiopia, using a fieldwork assistant. It involved the collection of both primary and secondary data in order to achieve the overall objective of the research. The main tasks executed during this stage are sampling strategy, training research assistant, household survey, KIs interviews, FGDs.

3.5. Target Population and Sample

3.5.1. The Population of The Study Area

According to the secondary data given from Addis Ababa Housing Development Corporation (AAHDC), Bole Arabsa condominium is the biggest site in size and population it serves, having 42,548 housing units for 40,749 households and the rest 1,799 are communal service buildings and commercial houses.

3.5.2. Sampling

Selecting a subset of individuals from a larger unit to represent the entire research population for data collection, known as sampling, is required when not all members of the study population can be surveyed in the data collection (Leonard, Bickman Debra, 2009). According to this study, drawing a sample is crucial in academic studies since the population is too large, costly to administer, time and resource-consuming for us to consider collecting information from the whole population.

The sample size is decided considering time, resources, and data management challenges. Purposive sampling is used to select the case study site. The main reason is selecting the best representative of rapidly expanding sub-cities with large areas and population numbers.

Stratified random sampling techniques were used to sample the residents. It is based on the constructed housing unit type, which are studio, one-bedroom, two bedrooms, and three bedrooms housing unit types. The decision to conduct a semi-structured questionnaire for the condominium dwellers was arrived at because semi-structured questions require a lower cognitive load on the respondents (Guest, 2019).

Key informants (KIs) are government officials and private energy sectors. Semi-structured questions were carried out to obtain the opinion of KIs who are concerned with governmental officials from AAHDC, Ministry of Water and Energy, as well as energy sectors. The semi-structured interviews involved a series of open-ended questions, enabling new ideas to be brought up during the interview. In addition, a virtual focus group discussion and interview with the Ethiopian community in the Netherlands was conducted to obtain expert feedback on the identified indicators and to get new potential indicators that affect the implementation of solar energy in Addis Ababa. Snowball sampling is used to collect data from experts. Snowball sampling is a known sampling method in qualitative research by which the data/information is collected starting from small numbers and networking to other large groups who are relevant to the research criteria (Parker, Scott, & Geddes, 2019). Therefore, the experts were found using their social networks to start initial linkage.

Bole-Arabsa is selected from Bole sub-city based on the expansion level, population size and area. According to the data from Addis Ababa Housing Development and Administration Agency, the selected resettlement site (Bole-Arabsa) is the largest site with the highest population number in the fastest expanded sub-city of Bole. It has 42,548 housing units for 40,749 households and the rest 1799 are communal utility houses and commercial houses. However, it is not clear whether the 40,749 residential housing units are already transferred to the people who deserve the house. The Addis Ababa Housing Development & Administration Agency said the exact number of people in the neighborhood is not allowed to be given because of privacy issues.

Stratified random sampling for the study was determined at 95% confidence level, 10% precision (for smaller allowable error between sample estimates and true population values), and p = 0.5 (for unknown population proportion to generate the largest sample size) following (SurveyMonkey, 2021).

Equation 1: Equation 1: Sample size formula

$$Sample\ size = \frac{\frac{Z^2 * P(1-p)}{e^2}}{1 + \left(\frac{Z^2 * P(1-P)}{e^2 N}\right)}$$

$$= \frac{\frac{(1.96)^2 * 0.5(1-0.5)}{0.1^2}}{1+\left(\frac{(1.96)^2 * 0.5(1-0.5)}{(0.1)^2(40749)}\right)}$$

$$Sample\ size = 96$$

Where;
N = population size
P= 0.5 is the assumed population proportion (taken 50% = 0.5)
e = Margin of error (percentage in decimal form, taken 10%)
z = z-score (is the number of standard deviations a given proportion is away from the mean),
For confidence level 95%, z-value is 1.96. The margin of error is a small amount that is allowed for in case of miscalculation or change of circumstances. Generally, the margin of error is taken as 5% (e=0.05), but for this study, 10% (e=0.1) is taken according to the time and resource I have. So, Z-score =1.96.
The total sample size was 97. This total sample size determined was then distributed to the condominium community by using the probability proportional to the housing unit size. Hence, out of the total 97 samples, 25 were from studio, 35 from one-bedroom, 29 from two-bedroom, and 8 from three-bedroom housing unit type.

3.6. Data Sources and Collection methods

Various studies have been conducted in different countries regarding factors affecting solar energy development. The identified factors in those studies provided very useful information for further studying these barriers in the context of Addis Ababa. Due to different weather conditions and cultures, many of the findings from these studies made in the context of other countries could not be applied directly to Addis Ababa. Therefore, a semi-structured interview, questionnaire from the relevant stakeholders, and relevant document reviews were conducted to understand the extent to which the barriers found in the literature are applicable in Addis Ababa. This involved e-mail and phone communications with 6 KIs.

To understand the phenomenon of interest, four methods of data collection were chosen: a semi-structured questionnaire, interviews with key KIs, focus group discussion, and documentary research. The data collected from documentary research includes literature review from research reports, official data, such as legal and energy policy documents, feasibility studies, green economy strategy document published by officers in energy sector office, official reports from governmental and creditable organizations is used. This research additionally used quantitative data from secondary sources. For instance, population data from the Ababa Housing Development Agency is used.

3.6.1. Household Surveys

A research assistant for the data collection was employed and trained. The criteria to recruit the assistant researcher were that she was to be a university graduate with sufficient experience on data collection and field works. The research assistant was trained on the ethics of data collection as well as on the use of the Maptionnaire[5] platform for data collection to ensure data quality. She likewise got training based on the questionnaire to make sure understanding of the questions and coming up with commonly used local languages to be used by the assistant to guarantee respondents' clear understanding of each question. Further, keeping distance to protect from Coronavirus disease (COVID-19) was taken into consideration.
After training of a research assistant on 21st April 2021, primary data for the study were gathered from household surveys. Household survey from Bole-Arabsa condominium was accompanied by careful

[5] https://maptionnaire.com/

designing of survey instruments which is semi-structured questionnaires based on the information gathered from a review of relevant literature. As structured questions require a lower cognitive load on the respondents and to cover the sample size, a questionnaire is the best way to save time and resources. The questionnaire is focused on obtaining information about factors affecting rooftop solar energy in the area and potential indicators to measure the aspects through the close-ended questionnaire (see appendix 1). The household survey was conducted through face-to-face interviews, and the Maptionnaire data collection tool was used to collect the data.

3.6.2. Key Informant Interviews

In addition to the questionnaires, a qualitative study was conducted with nominated KIs. Invitations for online interviews of KIs were sent to government agencies which are the Ministry of Water, Irrigation and Energy (MWI&E), the Ethiopian Energy Authority (EEA), and Addis Ababa Housing Development Corporation (AAHDC). Invitations were also sent to the Private sectors that are involved in solar energy installation. Out of the 11 purposively selected and invited KIs, the interview was carried out with six willing KIs, one top governmental official from AAHDC, two high-level officials from MWIE, two higher officials from EEA, and one private investor in solar energy with the language for the interviews being Amharic. The length of interviews varied from thirty to fifty minutes, with semi-structured and open-ended interview questions sent to the interviewees. Overall, six interviews were conducted to obtain an in-depth opinion from the KIs. The semi-structured interviews involved a series of open-ended questions (see appendix 2 and 3), enabling new ideas to be brought up during the interview (Bryman, 2012). Semi-structured interviews help as a source for in-depth discussions to attain detailed information and are flexible means for the researcher to ask follow-up questions. This was held by online interview using Teams[6], Zoom[7] , and WhatsApp[8] platform. All the interviews were recorded with the permission of the respondents. During the interview, open questions were being asked for the KIs to get detailed information, asking the informants to list the barriers regarding the question of what aspects and indicators affect rooftop solar energy development in the context. This technique helped to see how the public officials and private energy sectors identify the barriers. This type of approach has been recently used in other studies into solar energy development issues in Hong Kong and Vietnam (Zhang, Shen, & Chan, 2012; Do, Burke, Baldwin, & Nguyen, 2020). The interviewed KIs were kept anonymous so as to facilitate open interactions and coded them as high-level officials ABC and investor 1. The interviewees were asked to identify and discuss the barriers to rooftop solar development in Addis Ababa condo areas. Discussion points related to economic, policy and institutional, technological, information and human resources, spatial and societal, aspects, as identified from different countries study, were used to guide the interviews. The responses were then synthesized based on their relevance/repetition. Barriers mentioned by less than two of the respondents were considered irrelevant and were not adopted in the preparation of the framework. Interviewees were also asked to identify and discuss if there are other unmentioned factors that hinder the further development of Addis Ababa's rooftop solar PV.

[6] https://teams.microsoft.com/
[7] https://zoom.us/
[8] https://www.whatsapp.com/

Table 2: List of Key informants interviewed

Interview type	Office of KIs	
Key informants	Ethiopian Energy Authority (EEA)	Key informant A
	Ethiopian Energy Authority	Key informant B
	Ministry of Water, Irrigation & Energy (MWI&E)	Key informant C
	Ministry of Water, Irrigation & Energy	Key informant D
	Addis Ababa Housing Development Corporation (AAHDC)	Key informant E
Investor	High level employee at Green Scene and Board Member at Ethiopian Solar Energy Development Association (E-SEDA)	Investor 1

3.6.3. Secondary Data Collection

For the study, secondary data was collected from various national and international studies, Ethiopian 2011 draft national energy policy, national electrification programme, growth and transformation plan document, and energy sector reports. Also, Published and unpublished data sources were used to get data related to the condominium site and solar energy development in order to support and make sense of the primary data collected from the questionnaire, interview, and focus group discussion. A number of populations living in Bole-Arabsa condominium housing and related data were collected from Addis Ababa Housing Development Agency, the internet website of related offices, etc. Furthermore, solar development-related data were assessed, and factors of RE development in the whole country at a national level were identified from the 2011 draft national energy policy, feasibility studies, energy sector reports, and governmental and non-governmental reports.

3.6.4. Focus Group Discussion to Get Expert Feedback

In addition to the above-stated data collection methods, virtual focus group discussion of the Ethiopian community in the Netherlands and one expert from Addis Ababa was also used to obtain expert feedback on the identified indicators and to get new potential indicators that affect the implementation of solar energy in Addis Ababa. The experts' backgrounds were from a wide range of disciplines specialized in solar energy technologies, sociology, urban planning, economics, policy and regulation, and human resource. The purpose of the FGD was to validate and rank the barriers identified from a questionnaire, KIs interview, and literature review. The BWM technique was used to analyse the collected data. The experts were informed about the general purpose of the study in February 2021 via email, WhatsApp, and direct call in July in order to understand the context before the FGD is conducted in July. The FGD guide was designed and sent to the experts a week before the FGD is taken place to collect the data needed for prioritization of the barrier factors and indicators of solar PV in Addis Ababa condo areas (see Appendix 8).

Out of the 15 invited experts, the FGD was carried out with 12 experts due to time inconvenience. The experts of the Ethiopian community in the Netherlands who participated in the FGD were 11, and 1 was from Ethiopia. The time was inconvenient for all the 12 participants to conduct one session. Therefore, two sessions of FGD were conducted on the same day but different time on July 11, 2021. A bit explanation was given to the participants on some justification needed indicators and on why have used them as well to avoid confusion. During the two hours long focus group discussion via zoom, an attempt has been made to identify some missed important barriers and appropriate for the context, adjust names of the identified barriers, remove less important ones, and rank the major factors and indicators to the development of rooftop solar energy technologies in the Addis Ababa expansion area context. Then the two sessions of FGD came to one and agreed and decided on the rank of relevant factors and indicators based on the level of influence on solar PV development in the study area (see Appendix 9). Based on experts' opinions, some of the identified factors were adjusted, added and some were eliminated.

In general, the experts assessed the indicators as they were; then, they discussed and determined the most and least important factor. Then they gave preference, "the best criterion over all the other criteria," and the preference of "all the other criteria over the Worst" by selecting a number between 1 and 9 from the drop-box in EXCEL[9]. Rank them collectively (see example figure 14 and table 24). Finally, twenty-eight barriers were identified and categorized into seven classes, namely economy, policy and regulatory frameworks, institutional, technological, information and human resource, spatial and societal.

The weight of the factors was calculated in EXCEL sheet using the best-worst method (BWM). The reliability of the weighting result was assessed using the inconsistency ratio, and it should be less than 0.1; if it becomes over, the comparisons should be revised (Mostafaeipour et al., 2021). Using experts' opinions to identify barriers to solar energy development based on their importance has been recently used in other studies such as Mostafaeipour et al. (2021), (Irfan et al., 2019), (Zhang et al., 2012), and (Luthra et al., 2015). Using the BWM results, the relevant factors and indicators under them were analysed.

Table 3: Level of education, area of experience, and work experience of experts

No	Level of education	Area of experience and work experience	From
Expert 1	M.Sc.	Urban planner, lecturer at Mekelle university	Netherlands
Expert 2	Ph.D.	Architect-planner at EiABC- Ethiopian Institute of Architecture Building Construction and City Development, Addis Ababa University	Ethiopia
Expert 3	Ph.D.	System and network management, lecturer at university of technology, interested in solar installation	Netherlands
Expert 4	M.Sc.	Leadership	,,
Expert 5	Ph.D.	Software technology	,,
Expert 6	M.Sc.	Sociologist	,,
Expert 7	M.Sc.	Software technology	,,
Expert 8	M.Sc.	Urban planning and management, lecturer at Mekelle university	,,
Expert 9	M.Sc.	Consultant Construction management, water engineer,	,,
Expert 10	M.Sc.	Architect, lecturer at Mekelle university	,,
Expert 11	M.Sc.	Planner, Hawassa University	,,
Expert 12	Adjunct professor	A post-doctoral researcher, Consultant, Renewable energy expert, researcher in Infrastructure economics, energy policy & regulation, power systems, energy markets, and energy access (Ph.D. in engineering science, M.Sc. in Economics and Management of Network Industries)	,,

[9] https://bestworstmethod.com/wp-content/uploads/2019/07/BWM-Solver-4.xlsx

3.7. Method of Data Analysis and Interpretation

3.7.1. Content Analysis

Content analysis is used by many researchers for qualitative data analysis using codes. Akermi and Triki (2017) used content analysis to analyse green energy transition and civil society in Tunisia. It is a research method for analysing written, verbal or online communication messages (Cole, F L., 1988), and it is used to systematically summarize qualitative data in a quantitative way. It helps to transform a large amount of text into a highly organized and concise summary of key results (Bryman, 2012). It's an appropriate type of analysis method since it is used for data in many different formats, including texts, interview transcripts, and audio recordings. This study uses coding to make it easier to identify the factors affecting solar energy development and to organize textual content. The coding process was used to identify the relevant contents to the research question, and the codes were grouped together in relation to each other through their content/context as economic, policy, technological, information and human resources, spatial and societal factors. Excel tool was used to change qualitative data to quantitative using percentage and frequency.

To identify major potential indicators affecting the implementation of solar energy in Addis Ababa condominium areas, the data that were collected from the interview were analysed by applying the coding units. The results of the primary data collection might be different for the same kind of answer since different people have their own way of expressing their idea. Hence, to identify connections between the responses, coding the data was relevant. Thus, to find common ways about the subject matter, coding the data is relevant, and an analytical software known as, ATLAS. ti 9 is used to analyse and code the qualitative data. The result of this method was helpful in identifying significant potential indicators. ATLAS. ti is used by many researchers for qualitative data analysis using code. Lammers & Hoppe (2018) used ATLAS. ti to analyse institutional settings for local renewable energy planning and implementation in the European Union (See Appendix 6).

3.7.2. Descriptive statistics

In addition, the collected data from the survey using the Maptionnaire platform were downloaded as an XLSX/Excel file to process and analyse on a Microsoft Excel worksheet. The collected data was analysed and interpreted quantitatively by using descriptive statistics such as frequency, percentages, and Likert scale together, which are presented using charts and tables. Based on the frequency result, the relevant barrier factors for rooftop solar were sorted accordingly. Likert scale was used to scale the respondent's opinion with a grade of "1 to 5", 1 as less relevant and 5 as highly relevant. Many studies used the Likert scale to measure respondents' opinions with grades. For example, (Zhang et al., 2012) used this analysis method to rank respondents' opinions to study the diffusion of solar energy use in Hong Kong.

3.7.3. Ranking 7 criteria/factors and 28 sub-criteria/indicators and determining the priorities using the best-worst method (BWM)

The identified indicators from the survey and interview, along with the selected indicators from different studies were evaluated by experts. Online virtual Focus group discussion was conducted to get expert opinions regarding the factors and indicators that hinder solar energy development in Addis Ababa condominium areas. The experts' backgrounds were from a wide range of disciplines specialized in solar energy technologies, sociology, urban planning, economics, policy and regulation, and human resource.

The contextualized and the newly identified indicators under each factor were ranked by the experts with the help of the best-worst method (BWM)[10], based on their relevance/importance in affecting solar energy development in the condominium areas of Addis Ababa. BWM is recent and best to solve multi-criteria decision-making (MCDM) problems. The BWM method is a powerful MCDM method for determining the relative importance of several factors/criteria based on pairwise comparisons of the best and worst among them with other criteria (Ijadi Maghsoodi, Mosavat, Hafezalkotob, & Hafezalkotob, 2019). According to BWM, the best (i.e., most important) and the worst (i.e., least important) factors are identified first by the decision-maker (Rezaei, 2015). After ranking is done by the experts, a decision was made by the researcher to remove or to include the experts' opinions and rankings. A recent study by Mostafaeipour et al. (2021) used fuzzy BWM for identifying barriers to the development of solar energy in Iran. This method is used for weighting the identified barriers.

3.8. Ethical Considerations

Ethics in research is not only applied and used to preserve participants' rights but also to ensure the purity of the research itself by logical undertakings (McKenna & Gray, 2018). In this case, the researcher received a letter of support from the University of Twente for the study and distributed it to all relevant respondents prior to their participation. All respondents were given a thorough explanation of how the data was collected by the researcher. Respondents' informed consents were requested for their participation in the study, as well as a complete explanation of the study's consequences to the community and stakeholders for the information they provided for analysis and reporting. During the questionnaire, virtual KIs interview, and FGD sessions, the researcher also followed ethical norms. Before conducting the questionnaire survey, permission was obtained from local authorities such as the EEA and the MoWIE. Both key informants and FGD participants were given advance notice to agree on meeting times for the interview and FGD sessions. The data gathered for this study has been properly recognized.

[10] https://bestworstmethod.com/wp-content/uploads/2019/07/BWM-Solver-4.xlsx

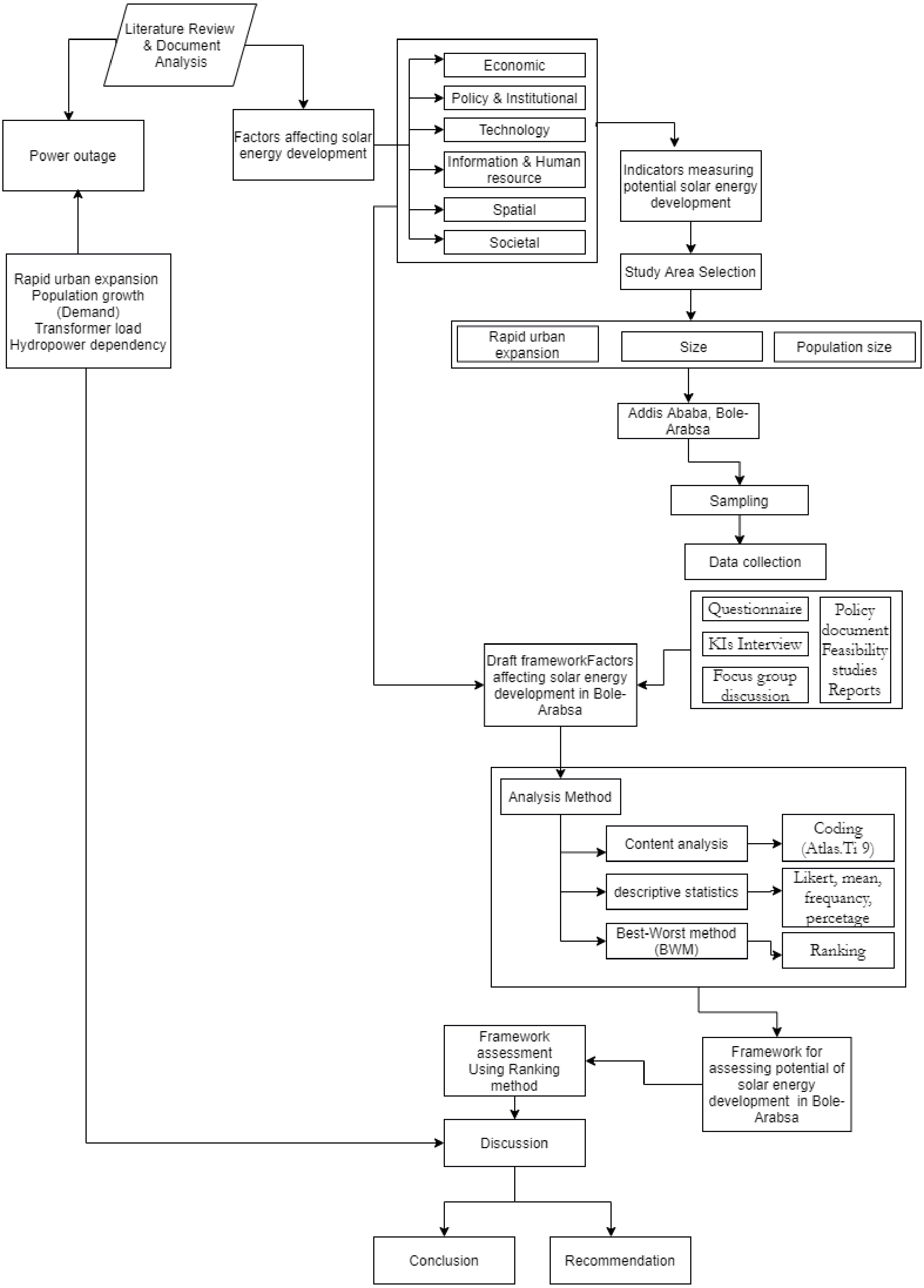


Figure 6: Overall methodology workflow

4. RESULTS

This section presents the results of the survey questionnaire from the community of Bole Arabsa condominium site and interviews from KIs on the factors affecting rooftop solar energy development in the study area. The study was conducted based on 97 household surveys, and 6 interviews with KIs and private sectors who are working in the energy sector.

Figure 7: Photo shows condominium buildings in the study area (*Source: Senayt fieldwork, 2021)*

4.1. Barriers to solar energy development in the Addis Ababa condominium site

Based on the identified barriers through extensive literature review from different developing countries such as Nigeria, Tunisia, Pakistan, Hong Kong, Vietnam, India (Ohunakin et al., 2014; Akermi & Triki, 2017; Zhang et al., 2012; Do et al., 2020; Luthra et al., 2015) and some from developed countries such as Iran, and Greece, (Mostafaeipour et al., 2021; Nikas et al., 2020) the appropriate barriers in the context of Addis Ababa condominium sites have been identified through KIs interview and household survey. To answer the first research question, "From the identified barrier indicators (from literature) (see appendix 4) which potential barrier indicators are appropriate for affecting solar energy development in the Addis Ababa condominium site?" Interview with KIs and household survey were applied to understand the factors. According to the KIs interview and community questionnaire, rooftop solar energy technologies have faced a number of constraints that have affected their rate of development in Addis Ababa condominium areas. The interview and survey result shows that thirty barriers have been identified contextually and these identified barriers have been categorized into the six dimensions that are Economical, Policy & Institutional, Technological, Information & Human resources, Spatial and Societal aspects. The KI's attempts to rank the major factors were according to their influence in hindering the adoption of rooftop solar energy in the study area. These barriers are specific to a study area, while some new potential indicators that are specific to the whole country or region were identified through deep assessment of national energy policy document, energy sector reports and feasibility studies (see Appendix 5). Overall identified indicators through the KIs interview are presented in table 4. However, the responses were presented based on their relevance/repetition and barriers mentioned by less than two of the respondents were considered irrelevant and were not considered in the preparation of the framework.

4.1.1. The effect of national policy in solar energy development

All these findings are based on the KIs' interviews conducted online through Microsoft teams, Zoom, and WhatsApp platforms. An interview with the high-level official 'A' from EEA points out that there is a draft policy that supports and gives priority to the use of energy efficient and RE technologies. However, it hasn't been implemented, no institution has been set up, and it is not yet known who will manage it. The official also mentioned that there is not any plan to install rooftop solar on such condominium areas. Regarding the FiT mechanism, the officer mentioned that it's not approved, and it is one of the problems that has kept investors from investing in the country, which is still in dispute with many investors. KI 'B' strongly believes and appreciates rooftop solar usage; however, he points out that the policy lacks the encouragement and enforcement for people to use rooftop solar, and there is no plan to install rooftop solar power in such areas. Furthermore, he indicated that there is no testing facility for the quality of solar cell materials. Furthermore, KIs A and D stated that "*although Standard and Regulation are there, they require Testing Facility, but there is not enough Testing Facility in this country. For the time being, there is an agreement underway to be made official, which is a Pre-export Verification confirmation (PVOC) process to check out and control the quality of solar products exporting from their country of origin.*" This means, according to KI 'D', the item should be checked and confirmed its quality in the country where it was manufactured before it enters Ethiopia. But this system has not yet started. Private sectors import solar equipment by use of certificate checks. The energy sector institutional regulation and lack of well-structured policies are the main issues, said KI 'B.' Additionally, there are no clear processes and mandates to follow; for example, if someone wants to invest in solar energy, it is not clear where to go and what to do. KI 'C' from MWIE points out that policy and institutional factors are most likely to negatively affect the installation of rooftop solar systems in condo areas. The official explained that the main reason for the national policy for giving priority to hydropower is due to its abundance and the low cost of energy. The officials raised an issue of not having feed-in tariff policy mechanisms for the sector. Private investor '1' from the energy sector argued that poor sector management and bad infrastructure as one factor affecting solar energy development in the city.

To date, the feed-in tariff scheme is not included in the future energy policy since Ethiopia has not connected solar PV into their national grids, said investor '1'. The investor further mentioned that if there was a viable/suitable and clear policy, private sectors would dare to enter the solar business. KIs 'B' and 'D' stated that it is possible to install a solar PV panel on the rooftop for personal consumption. However, it is difficult to transmit to the grid because there is no FiT mechanism. FiT is one of the leading problems that has kept investors from investing in the country. The investor also mentioned that there is a high level of demand for solar energy compared to the supply. KI 'D' also mentioned that hydropower is considered as a backbone in the energy sector and the national policy gives priority to it because of its cost-efficiency.

4.1.2. The effect of economic aspects in solar energy development

Findings from an in-depth interview with a KI 'A' at EEA emphasized that *"the economy has an influence on solar energy development. The government allowed suppliers to import efficient and RE technologies without customs duty, but due to hard currency and exchange rate fluctuations, the price of the equipment became high".* In Addis Ababa, there is a lack of access to the bank loan system in such a way that people pay the price of solar panels on a monthly basis. Lack of access to bank loans to investors makes it difficult to import the technology. Also cost of solar panels is not affordable for people in the condo.

According to KI 'B', the economy is a big issue for not using solar power since people, especially in condo areas, can't afford it. KI 'B' and 'D' also mentioned that investors have foreign currency problems, and this makes the investors reluctant to enter the sector. All the KIs and the investor point out that there are very few suppliers and cannot meet the national demand. There are only about 11 private companies participating in the sector, said KI 'D'. KI 'C' from MWIE pointed out that financial factors are the most likely reasons that affect the installation of rooftop solar systems in condo areas. Both KIs C&D said residents cannot afford to install solar panels on their house's rooftop without any subsidies, and KI 'D' mentioned that there are no government subsidies for the people, yet the investors are subsidized. This KI suggested that *the "government should not block incentive mechanisms to promote the technology domestically, tax should be exempt, private sectors should have access to loan facilities, technology promotion should be done by allocating budgets or by dedicating funds."* investor '1' further pointed that "*credit facilities are available. In fact, the World Bank recently approved a $500million loan to Ethiopia for the solar industry, but this loan does not include urban areas. The government thinks there is an option in the city, which is hydropower, but the countryside has no choice because they are off-grid. So, there is no access to credit facility for the city".*

According to investor '1', as soon as the hydropower goes out, residents in the city want the power to come immediately. They don't buy the backup system they want because, economically, they can't afford it. When the suppliers advertise solar technology, there is a lot of demand, but the high price of the technology is an obstacle. She pointed out that solar panels take up to 300,000 ETB to do different activities that the user requires, and the investor explained that it is not feasible. Despite having demand, it could not be converted into a market. Investor '1' also mentioned that compared to solar energy, hydropower energy is the cheapest and cost-efficient, and this is the more reason the Ethiopian energy policy gives priority to hydropower energy. The investor pointed, they didn't try to install it specifically in the condominium site because people who live in the condominium are low and middle income, and they can't afford it. However, they tried in a high-class community of some real state communities called Europac and Country Club Development (CCD). When they tell these wealthy communities to install solar energy on their rooftops, they often say it's okay since money is not a big deal for them.

4.1.3. The technological effect on solar energy development

According to KI 'A,' PV cells are not produced in Ethiopia. Only assembly works of PV cell parts are there, so foreign technology dependency is a barrier for solar energy development. There is also a technology problem with the utilities. It is difficult with the current technology unless old countertops are designed to be converted to smart meter[11] energy usage monitors. In other words, a smart meter is needed to use solar energy, but our country's system has not yet reached this level. According to private energy sector investor 1, there are legal and illegal importers who pay tax and sell poor-quality solar cells. Such type of importers does not follow the criteria of the standard authority, and they are not tax exempted.

[11] https://en.wikipedia.org/wiki/Smart_meter

Therefore, poor-quality solar panels are common in Addis Ababa, especially in Merkato, a market hub in Addis Ababa.

4.1.4. The effect of information and human resource aspects in solar energy development

According to KI 'A' from EEA, solar panel suppliers are very few, so nationally, they do not carry a large burden meaning that they don't have enough capacity in case many demands exist. The KI also mentioned that Ethiopia has no manpower problem, but specialization remains a problem until now. KI 'B' also said, investors and private companies are very limited compared to resources, population, and the area of the country. Investor '1' argued that Ethiopia has human resources, but it does not have skilled human resources. The investor also added that to install rooftop PV in a mini grid way, there are people with many years of experience, but the investors cannot find them. There is no platform to easily find them. There is no integrated and continuous work, they do not have a connection with each other, and they do not have a platform to meet.

4.1.5. The effect of societal aspect in solar energy development

KI 'B' points out that lack of awareness is one factor for not using rooftop solar energy. Limited acceptance by the people can make investors difficult to import solar technology. House ownership is one among the many indicators that hinder dwellers of bole Arabsa condominium from installing rooftop solar. According to the information from KI 'D', people living in rural areas greatly appreciate and accept solar systems. In cities, it's hard to find solar technology users. The people of the city still have a long way to go before they can accept the good and the bad. According to private energy sector investor 1, if the investor socially promotes the public, their attitude about solar is 99% positive. But when they tell them its economic aspect, they become very disappointed and leave it.

4.1.6. The effect of spatial aspects in solar energy development

KI 'A,' 'B' points out that the buildings are not designed to accommodate solar panels. He highlighted that this is because there is not any regulation or common code used to guide when the buildings are designed to construct. Similarly, KI 'E' mentioned that the roofs are faced eastward, and the government didn't consider to which direction should the slopes of the condominium building's roof face and its orientation towards the sun. Similarly, they didn't consider roofing material because "*the condominiums are designed with minimum cost to afford the low-income households*." Currently, the roof material of the building is Ega Sheet which is not strong to carry solar panels (see figure 8). Furthermore, the KI stated that the rooftops of the condo do not have enough space and are not suitable for PV installation.

Figure 8: roof type and material of Addis Ababa condo

Table 4: Table Overall identified indicators through the KIs interview

KIs	Barrier Factors	Indicators
A	Economic	High foreign currency needed to import technology High initial cost and not affordable for people in the condominium Limited bank loans provided to investors to import solar technology Lack of financial support
	Policy & Institutional	No implemented policy Unclear which body manage the policy yet Lack of Feed-in-Tariff mechanisms Material quality standard issue, no testing facility and material quality problem Lack of dedicated institution
	Technology	No local solar cell production/Foreign technology dependency Technology efficiency such as out of date (old) technology with existing utility & limited capacity
	Information & Human Resource	Limited specialized manpower Insufficient solar panel suppliers
	Societal	Lack of awareness Limited public acceptance
	Spatial	Building design code problem Inadequate roof space
B	Economic	Foreign currency problem Lack of affordability
	Policy &Institutional	Lack of policy encouragement and enforcement measure for people to use rooftop solar No Feed-In Tariff mechanism Poor energy sector institutional regulation &

		management Lack of well-structured policies No implemented policy
	Technologic	Material quality problem due to no testing facility No local solar cells production facility
	Information & Human Resource	Limited investors and private suppliers
	Societal	Lack of awareness Limited acceptance by the people
	Spatial	Building design code problem
C	Economic	High cost and lack of affordably
	Policy & Institutional	Not having feed-in tariff policy mechanisms No plan for the building integrated PV (BIPV)
	Technology	Foreign technology dependency No local solar cells production facility
	Information & Human Resource	Limited investors and private suppliers
D	Economic	Foreign currency problem Lack of affordability & low income No government subsidies for the people Limited access to loan facilities Limited tax exemptions Limited budget for technology promotion
	Policy & Institutional	Priority given to hydropower No Feed-In Tariff mechanism No material Testing Facility & quality issue
	Technology	Technology problem with Utility (old material)
	Information & Human Resource	Limited investors and private suppliers
	Societal	Limited societal promotion in Addis Ababa city
	Spatial	Insufficient roof space
E	Economic	Low income & lake of affordability
	Spatial	Insufficient roofing space Building design code problem Improper roofing direction & orientation towards the sun Roofing material quality & durability issue
Investor 1	Economic	Lack of affordability Low income High cost Limited tax exemption Limited long-term loans No access of credit facility for the city
	Policy & Institutional	Poor sector management Not having feed-in tariff policy mechanisms No plan for urban areas Complex administrative procedures
	Technologic	Standard & Material quality Foreign technology dependency
	Information & Human Resource	Limited investors and private suppliers Limited skilled human resource

	Societal	No network platform/connection between investors & PV experienced people Limited socially promotions by investor
	Spatial	Bad infrastructure & utility

The interview discussions with the KIs contribute to the analysis of the survey data. KIs are also requested to rank the individual factors based on their likeliness/importance on affecting rooftop solar PV systems development in condominium areas of Addis Ababa. A five-point Likert scale was used for the KIs to rate the relative significance of individual factors. The mean score was computed and used to evaluate the relative significance of the barrier factors.

Table 5: Mean scores of the barriers

Factor	Very likely	Likely	Neutral	Unlikely	Very Unlikely	Respondent	Mean	Rank
Economy	5	0	0	0	0	5	5	1
Policy & institutional	3	2	0	0	0	5	4.6	2
Technological	1	4	0	0	0	5	4.2	4
Information & Human resource	2	3	0	0	0	5	4.4	3
Spatial	1	3	0	1	0	5	3.8	5
Societal	2	1	0	1	1	5	3.4	6

4.2. Bole Arabsa condominium household Survey result

This sub-section elaborates factors affecting rooftop solar energy and indicators under each dimension in the expansion areas of Addis Ababa, Bole Arabsa condominium site. A community survey was conducted to understand the situation of the dwellers. The result for the question, 'which factors do you think most likely affect to not install rooftop solar PV systems in condominium areas of Addis Ababa yet?' (See appendix 1 question number 2) reveals that about 29 percent of the total respondents identify lack of financial support as the important barrier, followed by 27.5 percent representing the lack of information and practical knowledge and 25 percent lack of communication and participation about solar energy with government and institutions. Again, data from the interview and the national energy policy document support this survey result. There are no plans to install PV systems in buildings' roofs, so that no financial support is taken.

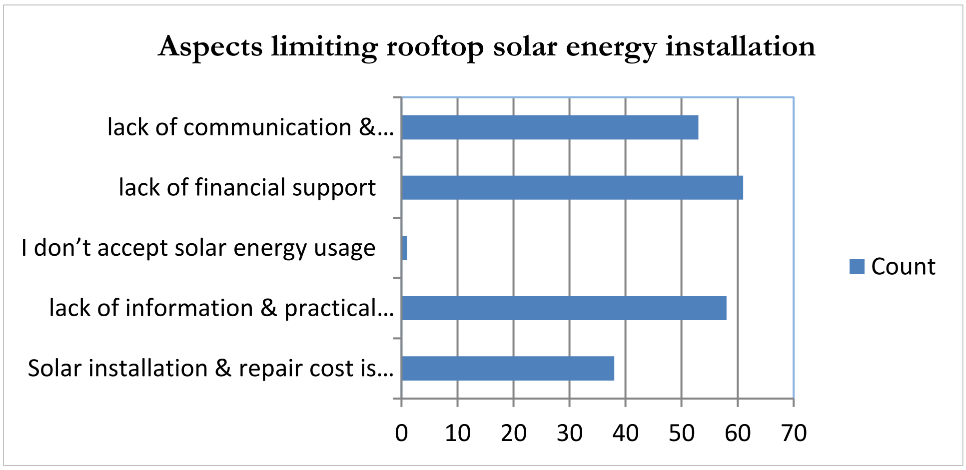


Figure 9: Aspects limiting rooftop solar energy installation in Bole-Arabsa condo area

According to the community survey result (see table 6), 79% of the dwellers are willing to install rooftop solar panels if the government or other institutions such as NGO offer them or arrange for them a bank loan and related financial supports (see appendix 1 question number 3.3). This indicates that the important barrier for not installing rooftop solar PV in the study area is the lack of financial support. Since people in the community are very disappointed by the frequent power outages the more reason, they really need to install solar PV. Investors tried to install solar for lighting and mobile charging, but this is not the main problem of the Addis Ababa residents. However, when they tell people to install solar on their roofs, they accept it without any hesitation. However, they need Long-term loans from the government and related institutions, and many respondents give feedback as *"if the government supports me financially, I will install solar power on my roof. I want the government to provide us solar panels at affordable prices. And I would like if there will no power outages."* The KIs raised the economic issue as a leading problem to the residents for not installing solar without subsidies because the majority of people who live in such areas are middle and low-income groups.

Table 6: People's willing to install rooftop solar panels if a loan is given

willingness to install rooftop solar panels if the government or other institutions gives a loan	Percent %
Yes	79
No	21

Some of the reasons for the 21% of the total respondents not being willing to install rooftop solar with the help of government loans are, some don't want loans, some are low income, and they can't afford it, and others are tenant/with no permanent house. Furthermore, graph 10 below indicates that, 37% of the community dwellers earn monthly income more than 5000ETB which is around $116. However, the majority (56%) of these households have less than $116 monthly income which means that the people in condominium areas are low-income groups and installing solar PV without any financial support is difficult in such neighbourhoods.

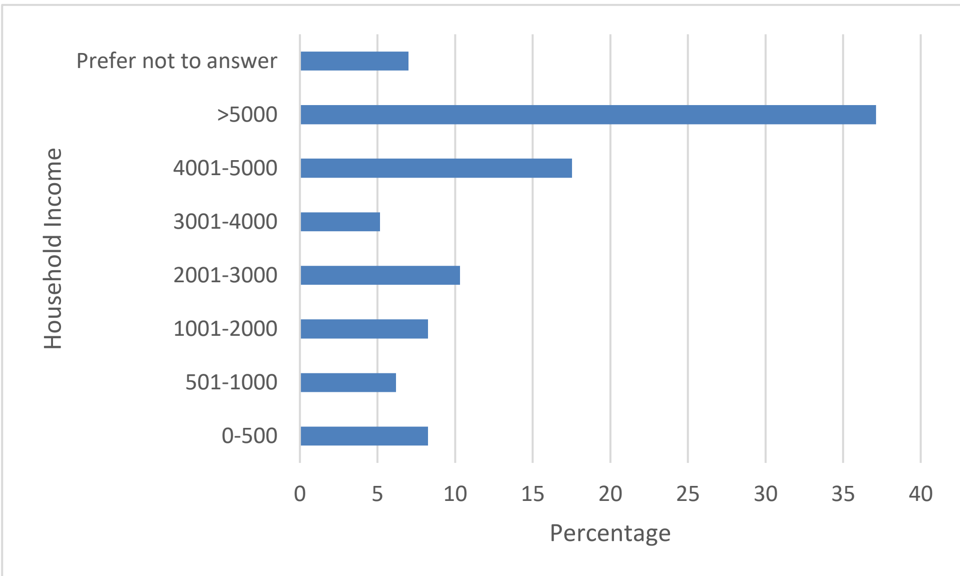


Figure 10: Total household monthly income in ETB

Figure 12 and table 7 below illustrate that 14.4% of the total respondents in the community were informed to install solar energy by their office friends, university teachers, private solar equipment importers, by government, woreda administration, ethio-telecom sector, and people from the hinterland who uses rooftop solar power.

Table 7: Government information for the community to use rooftop solar energy

Government information for the community to use rooftop solar energy	Percent %
Yes	14.4 = 13people
No	85.6

According to table 7 result, out of the total 97 surveyed people, 84 of them have not been getting any information from the government or any related institutions. This indicates that there is a lack of information about solar energy within the community.

The Likert scale result of figure 11 below reveals that out of the 13 people that were informed by the government and others, 8 of them were strongly agreeing to install PV, 3 moderately agree, and 2 of them are neutral. (See Appendix 1, questions number 3 to 3.2). This result is supported by the KIs since they did not carry out any awareness for people in the city, but they do for those who have no grid in rural areas.

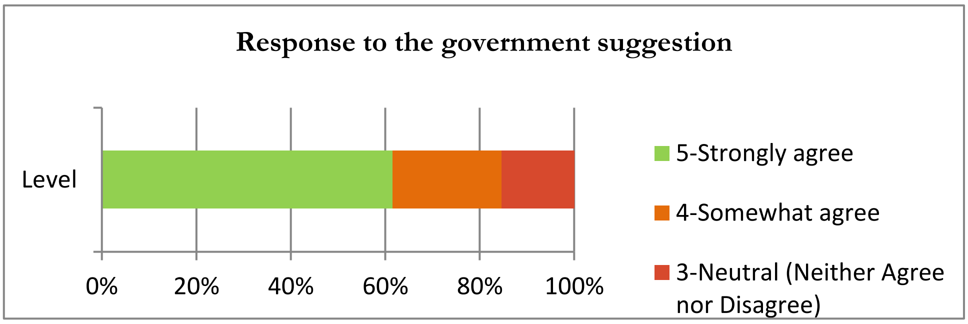


Figure 11: Respondents who are agreeing to install rooftop solar as government suggestion

According to the community survey result, table 8 below indicates that most of the inhabitants in the study area condominium have no practical knowledge on how to install or maintain solar panels.

Table 8: Residents PV Installing and maintaining knowledge

Installing and maintaining knowledge	Percentage %
Yes	12.6
No	87.4

Most of the respondents noted that condominium sites do not have enough rooftop space to put panels that serve all the households. Furthermore, the building code and their rooftops are not designed to accommodate solar panels. Also, one household highlighted the roof is collective roof, so it needs agreement with all the owners to install solar PV.

The result below (Figure 12 and Table 9) shows the level of people's awareness of rooftop solar energy in the case area. Out of the total 97 sample sizes, 55.6% of them, which are 54 people, know what rooftop solar energy is. The rest did not know solar rooftops, but they know and use solar lanterns. The reasons for the majority of the respondents knowing bout solar energy were due to private sector promotion, higher education, media, looking at other places and hinterlands, and a small number of them said by government training (see Appendix 1, question number 1 and 1.1).

Table 9: Level of rooftop solar energy awareness in Bole Arabsa condominium site

Awareness of rooftop solar panel	Percentage %
Yes	55.6
No	44.3

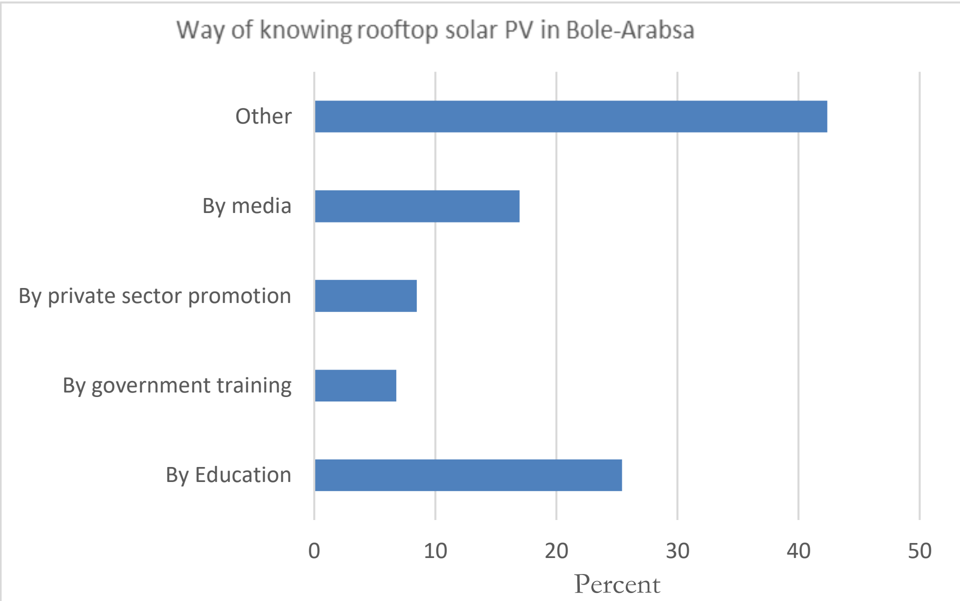


Figure 12: Percentage of way of knowing rooftop solar in Bole Arabsa condominium community

Table 10: Community willing to have solar PV

Dwellers use/having rooftop solar energy	percent %	Willingness to have rooftop solar PV
Yes	3	
No	97	Yes 90.3 No 9.7

Table 10 reveals that almost all the participants do not have solar PV on their roofs, and out of this, 9.7% are not willing to have and install rooftop solar energy because of the above-stated factors (see figure 9).

Table 11 below shows that most of the community dwellers have not participated in different solar energy meetings and training.

Table 11: Community participation in solar energy development meetings and trainings

Participating in Meeting or training	Percentage %
Yes	8.3
No	91.7

Most people in the community believe that rooftop solar PV usage help to reduce power outages. Many people are tired of the frequent power outages, and they say that it is better to see it in action beyond research. In addition to the factors specifically addressed in the questionnaire, the community participants have been asked to raise additional factors, and they mentioned different reasons for not using solar PV yet (see Appendix 1, question number 9). These include being tenant, not affordable, slope and position of the condominium are not suitable, not well-designed rooftop, low income, shortage of supply and high product price, the government pays little attention to the sector, not having long-term interest free loan, quick deterioration characteristic of the PV cell. They mentioned that they want the government to give attention to the sector, to go beyond research and apply it, formulate a policy and implement it to import high quality and durable solar PV, and encourage private sectors to do more.

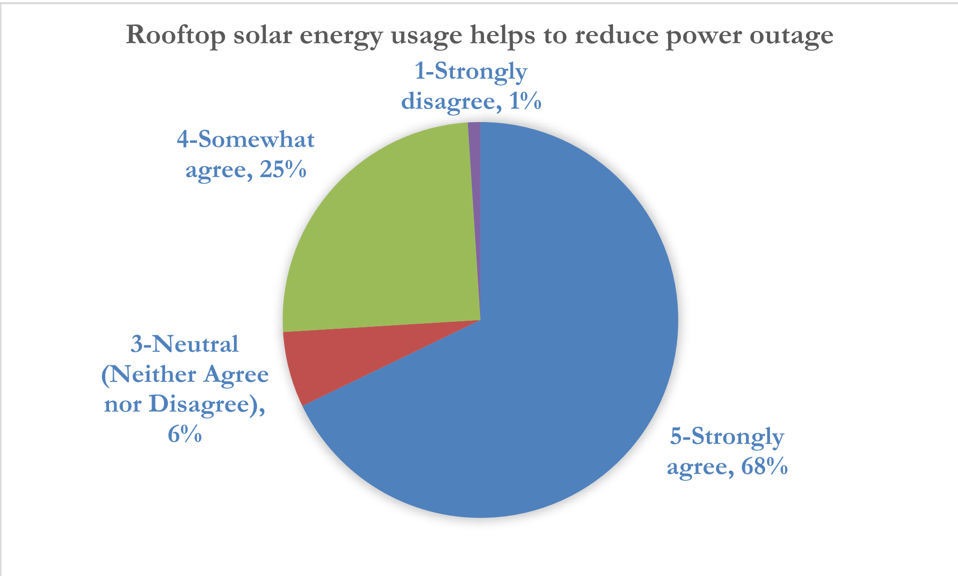


Figure 13: Participants view for importance rooftop solar PV

Furthermore, the result from the household survey is summarized in (table 12) below.

Table 12: Barriers to the development of solar PV in Bole Arabsa community

Factors	Indicators
Economic	Lack of affordability
	Lack of access to financial support
	Low-income level
	Lack of long-term & interest free loan

	Shortage of supply and high product price
Policy and institutional	Government did not pay attention to solar PV
Technologic	Not durable, a tendency to break down quickly
Information & Human Resource	Lack of information & practical knowledge on installation & maintenance
Societal	Lack of communication & participation with govt & private sector
	Awareness problem
	No engagement in solar energy meeting and training
	Tenant (no having permanent home)
Spatial	Lack of accessibility
	Slope and position of the condominium is not suitable
	Insufficient roof space

4.3. Selecting the important barrier factors and their measure indicators contextually

To answer research question two, what are the additional potential barrier indicators that affect the development of solar energy in the Addis Ababa condominium site, interviews, household surveys, policy documents, feasibility studies, and reports were used. The result shows that unimplemented policy, building design code problem, lack of testing facility for imported PV components, no plan for urban rooftop PV, lack of network platform between investors, poor infrastructure, and housing ownership problem are newly identified indicators from the collected data contextually.

The most important factors were then identified and selected to prepare a framework from KIs interview, household survey, plus energy policy, sector reports, and feasibility study assessment. The factors identified from policy documents and feasibility studies are found in Appendix 5. Based on the survey conducted and documents review, the common factors and the most repeated ones, at least by two of the sources, are selected as important barriers and summarized as follows. The factors summarized in table 13 are the important barriers expected to be assessed by the experts, so the table was employed to conduct the FGD to get feedback.

Table 13: Draft framework prepared for expert feedback

Criteria	Factors	Indicators	Denotations
C1	Economy	Foreign currency problem & high foreign exchange spending	C1- 1
		Limited access to loan from institutions & banks	C1- 2
		Lack of access to financial support	C1- 3
		High initial cost and lack of affordability	C1- 4
		Low-income level	C1- 5
		Limited tax exemption	C1- 6
		Limited budget for technology promotion	C1- 7
		Lack of access to financing for RE research & development	C1- 8
C2	Policy & institutional	No clear, well-structured and implemented policy	C2-1
		No Feed-in-Tariff mechanisms	C2-2
		standard issue, no testing facility and material quality	C2-3

		problem	
		Complex administrative procedures	C2-4
		Poor energy sector institutional regulation & management	C2-5
		No plan for urban rooftop PV	C2-6
		Priority given to hydropower	
C3	Technological	Lack of locally developed technologies & foreign technology dependency	C3-1
		Technology efficiency	C3-2
		Standard & material quality problem due to no testing facility	C3-3
C4	Information & Human resource	Limited specialized manpower	C4-1
		Limited investors and private suppliers	C4-2
		Limited of local research and development	C4-3
C5	Spatial	Building design code problem	C5-1
		Insufficient roof space	C5-2
		Improper roofing direction & orientation towards the sun	C5-3
		Roofing material quality & durability issue	C5-4
		Bad infrastructure & utility	C5-5
C6	Societal	Low public awareness	C6-1
		No network platform/ integration among solar actors	C6-2
		Limited socially promotions by investor	C6-3
		Housing ownership problem	C6-4

4.4. Expert feedback and ranking barriers of rooftop solar energy development in Addis Ababa condominium areas using BWM

The final framework is shaped by Ethiopian experts in the Netherlands during the FGD based on their feedback. The experts were allowed to add important additional barriers that are not discussed in the draft framework (look at table 13 and 14). They were also allowed to remove indicators if all the participants are agreed that the indicator is not important to hinder rooftop solar PV in the condo. Decision is made that the policy and institutional dimensions are separated into two as policy and regulatory framework and institutional dimension. Since both are different factors, policy is about guidance and direction and institution is about administration, and monitoring. Then finally proper name was given to the indicators and ranking the main factors is performed.

Table 14: Final framework assessed by experts

Criteria	Factors	Indicators	Denotations
C1	Economy	Foreign currency shortage & high foreign exchange spending	C1- 1
		Limited access to financing	C1- 2
		Affordability issue (low-income households)	C1- 3
		Limited budget for RE technology promotion	C1- 4

C2	Policy & regulatory frameworks	No clear, well-structured and implemented policy	C2-1
		Limited RE incentive (tax exemption, feed-in tariff, net metering)	C2-2
		Weak energy sector institutional regulation & management	C2-3
		Poor quality standard regulation	C2-4
		No plan for urban rooftop solar PV	C2-5
		Lack of policy to promote energy Entrepreneurship	C2-6
C3	Institutional	Complex and lengthy administrative procedures	C3-1
		Lack of dedicated institution overlooking the development of grid connected decentralized generation	C3-2
C4	Technological	Lack of locally developed technologies	C4-1
		Low-capacity factor of solar PV technology	C4-2
		Poor distribution grid infrastructure	C4-3
		High upfront capital cost of solar PV technology	C4-4
C5	Information & Human resource	Limited specialized manpower	C5-1
		Limited investors and private suppliers	C5-2
		Limited local research and development	C5-3
		Lack of maintenance and installation workshop	C5-4
C6	Spatial constraints	Building design code problem	C6-1
		Insufficient roof space	C6-2
		Improper roofing direction & orientation towards the sun	C6-3
		Roofing material quality & durability issue	C6-4
C7	Societal	Low public awareness	C7-1
		No network platform/ integration among solar actors	C7-2
		Limited socially promotions by investor	C7-3
		Housing ownership problem	C7-4

Since economy and finance are interrelated disciplines and deal with the same thing and finance is part of the economy (Zabavnik & Verbič, 2021), the economy is decided to use for this study as one of the dimensions.

Steps of the BWM method

Step 1. The seven dimensions are considered as decision criteria.

Step 2. The FGD participants define the best (most desirable, most important) and the worst (least desirable, least important) criteria. In this stage, the two sessions FGD, experts identified the most important and the least important criteria for rooftop solar PV development. The factor that was selected as the most or the least important factor by the majority of the participants has been selected as the most or the least desirable factor for solar PV development. Besides, a consensus was made on the selected factors and indicators by all the FGD members.

Step 3. The experts determined the most important over the other seven criteria by assigning a number between 1 and 9. Their importance is based on the level of their influence on solar PV development.

Step 4. The experts then determined the preference of the other seven criteria to the least important criterion using the number between 1 to 9. The same step is used to rank the indicators in each factor. Besides, weights of the factors and indicators were derived based on the comparisons of the best and worst factors or indicators to the other factors. The weights for the criteria were solved by operating the 'solver' in Microsoft Excel, and the weight and reliability scores were obtained automatically. The reliability score indicates to what extent the results are reliable, and the closer the reliability score to zero is the better (Mostafaeipour et al., 2021).

If more than one criterion/factor is selected and considered as the most or least important during the selection, one can be chosen arbitrarily (Rezaei, 2015). Based on this, the two FGD came to a consensus with policy & regulatory frameworks as the most desirable factor and societal and information and human resource as least desirable. Institutional and spatial factors have the same weights, shows that both have equal importance on hindering solar energy development contextually. Besides, societal factors have the least influence on hindering solar PV (see table 15).

Main Criteria	weights	Rank
Policy & regulatory frameworks	0.3774	1
Economy	0.2265	2
Institutional	0.1133	3
Spatial	0.1133	
Technological	0.0755	4
Information & Human resource	0.0615	5
Societal	0.0566	6

The results of weighting the factors of rooftop solar PV are presented in table 15 and see Appendix 7 and reveals that the experts give priority for policy & regulatory frameworks category. They highlighted that the most needed influential factors include “no clear, well-structured and unimplemented policy,” “limited renewable energy incentive (tax exemption, feed-in tariff, net metering),” and having “weak energy sector institutional regulation & management.”
Reliability of the weighting result was assessed using the inconsistency ratio and it was less than 0.1 which is 0.075 shows that the weighting score is reliable. In other words, it is describing the results' reliability extent.[12]

Policy and regulatory framework: the policy and regulatory framework factor is the most important factor. Table 16 indicates that unclear, well-structured, and unimplemented policy is the most critical barrier in the study area. Supports in the form of subsidies are not sufficient, and this discourages energy investors and suppliers. The direction of the policy is not clear,
They also described, solar energy technology is not locally manufactured components are imported from abroad like China, India Germany and Italy. Due to high foreign currency, the quality of the product is affected and is the main factor for material price. It is impossible to control the quality of products because of Ethiopia’s economy is based on free market. Lack of a proper level and adequate incentive schemes is identified as the main constraint during the FGD session. A barrier ‘priority given to hydropower’ was a less important factor because the policy already has a plan to mix the energy generation system with solar, wind, and related RE sources. The tax break for Res is not sufficient in Ethiopia. Low attention is also given for energy entrepreneurship.

[12] https://bestworstmethod.com/wp-content/uploads/2019/07/BWM-Solver-4.xlsx

Table 15: Importance and priority of policy and regulatory framework sub-criteria

Sub-criteria	Weights	Rank
No clear, well-structured and unimplemented policy	0.4359	1
Limited renewable energy incentive (tax exemption, feed-in tariff, net metering)	0.1282	2
Weak energy sector institutional regulation & management	0.1282	
No plan for urban rooftop solar PV	0.1282	
Lack of policy to promote energy Entrepreneurship	0.1282	
Poor quality standard regulation	0.0513	3

Economy: it is the second most important factor in solar energy development hindrance. Foreign currency shortage is the leading barrier under the economic category. From the expert's opinion, one reason to foreign currency shortage & high foreign exchange spending is due to underdeveloped industries for manufacturing of solar materials since most of the technological materials are imported. Experts highlighted that limited access to finance could be in terms of (loan, grant, equity finance). Local and international banks don't provide adequate loan for investors, users and other players in the energy business. Importing the solar components at high foreign currency increase the materials price, so this has a huge negative impact on the individual's solar energy usage because people who live in the condo areas doesn't afford the price of the solar components, said the experts. The experts also gave the same weight for "affordability issue (low-income households)" and "limited budget for renewable energy technology promotion." However, based on the literature reviewed, household questionnaire, and KIs interview the researcher decided that the affordability issue is more influential barrier than the "limited budget for renewable energy technology promotion" in the context of Addis Ababa condominium areas. Because most of the residents are low- and middle-income people. The experts highlighted Addis Ababa there is no any start-up on energy entrepreneurship for developing suitable business models the policy is also not encouraging for such activities.

Table 16: Importance and priority of economic sub-criteria

Sub-criteria	Weights	Rank
Foreign currency shortage & high foreign exchange spending	0.5	1
Limited access to financing	0.27	2
Affordability issue (low-income households)	0.14	3
Limited budget for renewable energy technology promotion	0.105	4

Institutional: these include issues related to the bureaucratic procedures and lack of dedicated institutions that overlook solar energy development. The experts highlighted the energy sector, in general, suffers from a lack of strong institutions and well-trained and skilled manpower that helps to ensure efficient power system management in the activities of planning and implementation and regulation stages.

Table 17: Importance and priority of institutional sub-criteria

Sub-criteria	Weights	Rank
Complex and lengthy administrative procedures	0.4444	1

Lack of dedicated institution overlooking the development of grid connected decentralized generation	0.1111	2

Spatial: these barriers are related to the roofing space, material, and its material quality in the study area. The experts agreed, and they gave the same score to all the barrier indicators means that all are equally important to hinder solar energy development in the study site. However, it is decided to make the "building design code problem" the leading influential barrier under the spatial factor based on the KIs interviews. This is because the buildings are not designed to accommodate solar panels since there is not any regulation or common code used to guide when the buildings are designed to construct. Therefore, the lack of a building code is considered to be a major barrier under the spatial category to the development of solar PV in Addis Ababa condo areas. The experts highlighted most of the buildings in the city are not designed to integrate with PV systems.

Table 18: Importance and priority of spatial sub-criteria

Sub-criteria	Weights	Rank
Building design code problem	0.4	1
Insufficient roof space	0.2	2
Improper roofing direction & orientation towards the sun	0.2	
Roofing material quality & durability issue	0.2	

Technological: According to the expert's opinion, the most important barrier under technological factors was 'lack f of locally developed technologies, and the others have the same importance on hindering solar PV development. The experts noted that due to undeveloped manufacturing for solar equipment, most of the solar energy technological hard wares are imported. This makes the technology expensive and difficult to afford by all income groups. The foreign currency shortage also affects the price of imported solar materials.

Table 19: Importance and priority of technological sub-criteria

Sub-criteria	Weights	Rank
Lack of locally developed technologies	0.3	1
Poor distribution grid infrastructure	0.3	
High upfront capital cost of solar PV technology	0.3	
Low-capacity factor of solar PV technology	0.1	2

Information and human resource: according to the expert's feedback, limited skilled manpower in the city and in the sector in general is the leading barrier compared the others under information and human rsource factor. According to the experts, one reason for limited skilled manpower is because there are no short-term training programs like workshops to train users, individuals, and professionals on solar energy-related technologies such as design and installations. Another reason is limited research and training institutions like university, colleges and workshops. Also, they highlighted lack of access to finance for R&D purpose, no social networking between different governmental and non-governmental institutions, universities and related bodies are also reasons for having limited specialized manpower and information in the city. The experts also pointed that the absence of well-organized and up-to-date data remains the main bottleneck for private sector participation in the sector.

Table 20: Importance and priority of information and human resource sub-criteria

Sub-criteria	Weights	Rank

Limited specialized manpower	0.4	1
Limited investors and private suppliers	0.2	
Limited local research and development	0.2	2
Lack of maintenance and installation workshops	0.2	

Societal: according to the expert's opinion, low public awareness and limited socially promotion of solar PV by investors and related solar actors are the leading barriers that hinder the development under the social aspect. They highlighted universities and colleges have no social connection and network each other and universities are not giving courses and training programs that help increase public awareness.
They described the main reason for limited social promotion of solar energy is due to limited access to finances including loan, fund, and inadequate incentive schemes.

Table 21: Importance and priority of societal sub-criteria

Sub-criteria	Weights	Rank
Low public awareness	0.3846	1
Limited socially promotions by investor	0.3846	
Housing ownership problem	0.1538	2
No network platform/ integration among solar actors	0.0769	3

Finally, the experts rank the overall barriers of rooftop solar PV development in condo area of Addis Ababa. It is possible to consider more than one criterion as best or worst, so the experts chosen more than one barrier to the same score based on their importance to hinder solar energy development. Table 22 revealed that most of the best or important factors affecting solar PV in the context are laid under the Policy and regulatory frameworks and economy aspects.

Table 22: Final ranking of the criteria (factors and indicators) using BWM

Factors	Weight	Indicators	Denotations	Rank
Economy	0.2265	Foreign currency shortage & high foreign exchange spending	C1- 1	2
		Limited access to financing	C1- 2	3
		Affordability issue (low-income households)	C1- 3	4
		Limited budget for RE technology promotion	C1- 4	4
Policy & regulatory frameworks	0.3774	No clear, well-structured and unimplemented policy	C2-1	1
		Limited RE incentive (tax exemption, feed-in tariff, net metering)	C2-2	3
		Weak energy sector institutional regulation & management	C2-3	3
		Poor quality standard regulation		
		No plan for urban rooftop solar PV	C2-4	5
		Lack of policy to promote energy Entrepreneurship	C2-5	3
			C2-6	3
Institutional	0.1133	Complex and lengthy administrative procedures	C3-1	4
		Lack of dedicated institution overlooking the development	C3-2	7

		of grid connected decentralized generation		
Technological	0.0755	Lack of locally developed technologies	C4-1	5
		Low-capacity factor of solar PV technology	C4-2	6
		Poor distribution grid infrastructure	C4-3	5
		High upfront capital cost of solar PV technology	C4-4	5
Information & Human resource	0.0615	Limited specialized manpower	C5-1	6
		Limited investors and private suppliers	C5-2	7
		Limited local research and development	C5-3	7
		Lack of maintenance and installation workshop	C5-4	7
Spatial constraints	0.1133	Building design code problem	C6-1	5
		Insufficient roof space	C6-2	5
		Improper roofing direction & orientation towards the sun	C6-3	5
		Roofing material quality & durability issue	C6-4	5
Societal	0.0566	Low public awareness	C7-1	6
		No network platform/ integration among solar actors	C7-2	8
		Limited socially promotions by investor	C7-3	6
		Housing ownership problem	C7-4	7

5. DISCUSSION

This section of the paper presents the interpretation and discussion of the findings presents in the previous chapter based on the set objectives. This chapter discussing the main factors and barrier indicators of rooftop solar energy development and their level of influence in the expansion condo areas of Addis Ababa.

5.1. Barriers to rooftop solar energy technologies development in Adds Ababa condo areas

Based on the evaluation of the solar energy barriers in Addis Ababa condominium area using policy documents, energy sector reports, feasibility studies, community questionnaires, KIs interview, and FGD, it was found out that the key influential factors to rooftop solar PV in Addis Ababa are policy & regulatory framework, institutional, economy, technological, information & human resource, societal and spatial. Regarding the studies by Akermi & Triki (2017); Irfan et al. (2019); Kebede & Mitsufuji (2014), Luthra et al. (2015); Do et al. (2020), and Zhang et al. (2012), five of the mentioned six factors were highlighted in the above studies except for the spatial related barriers. This similarity of the factors shows that most of developing countries face similar challenges in rooftop solar PV development. Hence, solar energy development barriers that cover policy & regulatory framework, information & human resource, institutional, economy, technological, and societal in other areas can be applied and considered by key stakeholders in the energy sector in Addis Ababa when planning for solar energy. On the other hand, spatial related barriers were absent in most studies except for Zhang et al. (2012), which was focused on Hong Kong, a city that has faced rapid urbanization over the years Zhang et al., (2012). The emergence of the spatial related barrier is due to the fact that most solar energy studies are centred on relatively less urbanising areas with basically little or no spatial problems. Addis Ababa, being a fast-urbanising area is presented with several spatial related problems including the erection of buildings and improper roofing design among other physical structures which in tend could affect the development of solar energy.

5.2. New identified potential barriers under the factors contextually

The finding indicates that new barriers that are specific to the context of Addis Ababa condos include building design code problems, no plan for urban rooftop PV, and housing ownership problems which are categorized into spatial, policy, and societal factors, respectively. These new indicators are from the collected data contextually, and they are not mentioned in most of the reviewed studies. The condominium housing is constructed for people having low- and medium-income level, and the result indicates that there are a lot of people in the condo as a tenant and their tenancy make them difficult for rooftop solar installation. The newly identified spatial factors like building code design are key issues in the city; however, most developing countries' studies didn’t include this barrier except a study by Zhang et al. (2012).

5.3. Most and Least Important Factors Based on Their Relevance in Infulencing Rooftop Solar Energy Development

Policy and Regulatory Framework Category

The literature highlights that policy has a significant impact on solar energy development. This study found out that policy and regulatory framework is the most relevant factor in hindering solar energy development, with a BWM weight of 0.3774. This is because it has a leading role in influencing private sectors to invest in solar by implementing tax exemption and profitable FiT. This is in tandem with the idea of Do et al. (2020) that supporting governmental policies, including FiT mechanism, encourages enterprises to enter the solar PV business and to invest in solar PV projects. Ethiopia has a draft energy policy at the national level, which encourages solar energy usage. However, not having the policy at the city level, particularly for Addis Ababa, makes efforts for solar development vague and confusing. So, the lack of a clear policy and regulatory framework has kept investors from investing and inhibiting the development of solar PV market in the city. This is in line with a study by Irfan et al. (2019), which highlighted confusing and uncertain policies discourages businesses and the involvement of private investors in solar PV projects. The findings of this study show that FiT and tax benefits are declared, but it is yet not implemented due to having an unimplemented policy. However, these incentive schemes are the most important ones in attracting private sectors to invest in solar PV. However, this is different in Iran, for example, where the policy factor is the third factor, according to Mostafaeipour et al. (2021), where the most important indicators were related to not having implemented incentive mechanisms (policy, FiT, and tax exemption). This shows that the importance of different factors does indeed vary based on the different contexts of the areas.

Economy Category

Based on the analysis, it was found that economic issues are the second most important barrier to solar energy development in the expansion areas of Addis Ababa condominiums. This category contains important factor which makes economy as the second most important factor, foreign currency shortage & high foreign exchange spending. Limited access to local and international financing institutions is another important barrier under the economy. This is because banks are not willing to give loans at low interest. This is in line with a study in Pakistan, where locals were finding it difficult to access loans (Irfan et al., 2019). the difficulty in accessing financial support was also evident in (Kebede & Mitsufuji, 2014), which highlighted that lack of interest in a loan from local banks and micro-credit institutions contributed to the problem. Additionally, the energy sector in Ethiopia is dependent on international financing packages such as the world bank. However, it is not sufficient for the development of the sector, including solar energy development.

Furthermore, a study by Irfan et al. (2019) in Pakistan, Do et al. (2020) in Vietnam, and Mostafaeipour et al. (2021) in India indicates that the economy is the most important factor in influencing solar energy development. According to Do et al. (2020) study, this is because, for instance, Vietnam has clear FiT and related incentive mechanisms. So, as a result, the economy being high on the list is quite common and is not very surprising.

Institutional category

Complex and lengthy administrative procedures are another key barrier that hurts investor motivation on solar development since it is difficult for them to go through this process. The study findings also mentioned bureaucracy as a key problem in the city. For instance, according to The World Bank Group (2019) report, Ethiopia is ranked 159 out of 190 countries mean that doing business in any sector is difficult and bureaucratic. The contextually bureaucratic structure includes top-down hierarchical communication, negligence of administrative interactions, and regulation lead to problems such as lengthy processes, which undermine investors in solar energy. Furthermore, the lack of dedicated institutions overlooking solar PV development is a major problem under this category. Although the institutional factor is not as important as the economic factor, it ranks 3rd and influences the development of rooftop solar energy. Do et al. (2020) also categorized the institutional barrier as 3rd most important one. Lengthy processes are common due to a lack of dedicated resources, which is also quite common in other cities in the global south. It would be expected that this barrier would also be found in other similar contexts.

Technological category

It was expected the technological factor would be higher; however, this factor ranked as 4th important, and the finding reveals that lack of locally developed technologies, poor distribution, grid infrastructure, and high upfront capital cost of solar PV technology is seen as the most important barrier to solar PV development in Addis Ababa. Ethiopia imports solar panels and related solar equipment's from China, the world's biggest solar PV manufacturer. This makes to have a high upfront cost of the solar PV technology. Lack of smart/modern grid and having poor existing distribution grid infrastructure is another barrier under this category. The low ranking of the technological barrier is because there is a limited use and knowledge about solar energy in Ethiopia. Also, the low ranking of the technological barrier is attributed to the dependency of technology use on economic capacities. This category is highly related to the economic costs of the technology. If the economic drivers are not present, then the necessary infrastructure etc., will not follow.

Information & human resource category

The findings of the research reveal that compared to others, this factor is not as important in influencing rooftop solar PV development. In this category, it is mentioned that specialized manpower is limited. Besides local research and development is insufficient due to lack of finance for such activities also insufficient technical schools. Based on the KIs interview result, Ethiopia has only 11 solar cell suppliers. According to Kebede & Mitsufuji (2014) solar innovations such as solar lanterns, solar cookers, and solar PV have been introduced into the Ethiopian market. However, compared to the demand, there are still few solar actors. Specifically, the active actors are local and international NGOs. The information and human resource category's low ranking could also be attributed to the dependency of the barrier on economic and policy categories.

This category can also be seen as being dependent on both the economic and policy categories. Without a dedicated or specific institution, people are not able to develop the necessary skills that are needed to support the development of solar energy. Also, without supportive incentive mechanisms, investors and private suppliers could not be interested in involving in the solar energy business.

Spatial category

The spatial factor is ranked as the second most important factor and has thus equal influence on solar development as the institutional factor. Results revealed that the buildings in the condo are not designed to accommodate solar panels. Besides, the roofs are faced eastward, and the government didn't consider to which direction should the slopes of the condominium building's roof face and its orientation towards the sun. Similarly, they didn't consider roofing material because "the condominiums are designed with minimum cost to afford the low-income households." Currently, the roof material of the building is Ega Sheet which is not strong to carry solar panels. Furthermore, the rooftops of the condo do not have enough space and are not suitable for PV installation. Comparing to the other solar energy barriers, the dependency level for this barrier seems low. Unlike other factors, this one is relatively independent and is as such not as much dependent on the general context. Aspects like the direction of the roofs could be improved when taken into consideration earlier on in the building phase.

Societal category

Lastly, according to expert opinion, societal factors form the least important category for the development of solar energy. Awareness of the local people in developing countries leads to low social resistance against the development of rooftop solar PV. Most of the people in the condominium area are acquainted with rooftop solar panels. Therefore, a societal factor has relatively less importance comparing to other factors. However, in general, this category has still influenced solar energy development. Social connection or network between the solar actors helps them for mutual benefits; however, they are not integrated so far, and this contributes to low solar energy development. This is similar to developed areas such as Iran, for example, according to Mostafaeipour et al. (2021), societal barriers are the least important factors compared to the other barrier factors. This implies that a lot of people would be willing to use solar PV.

5.4. Assessing the Framework

The first developed framework based on literature, questionnaire, and KIs interview was assessed using a ranking by experts. The feedback from the participated experts helps to remove less important factors like policies giving priority to hydropower. This barrier was found from the policy assessment; however, the policy itself included a plan to use mixed REs, then a decision was made to remove it. During the FGD most participants were confused about why the tax exemption barrier was set under the economy category. As a result, the national policy document was re-assessed, as were studies like Irfan et al. (2019), and it was decided instead to be under the policy and regulatory framework category since it is one of the incentive mechanisms.

Some missed important barriers like "lack of dedicated institution overlooking solar PV development" were also added by the participants to the final framework following the focus group session.

Applicability and Implication

The framework can be applicable both in developing and developed countries, but barriers like lack of clear policy, limited incentive scheme, and financial support should be checked because they could be different for developed countries, and these indicators could be less relevant in developed countries.

Following the focus group discussions and reflections on the framework, there are a lot of interdependencies between the different factors within the framework. This likely would lead to a higher amount of work in implementing the framework than necessary. It could be possible to check the correlations between the different factors and determining which factors could be removed because of redundancy. However, the framework is now quite complete and serves as a good basis in contexts similar to Addis Ababa.

This framework is thus particularly useful for the Ethiopian energy sector and to the key players in the energy sector including, MoWIE, EEA. Besides, it can be used as a tool by decision-makers, policymakers, and concerned parties in solar energy development. It also provides insight and relevant information for them to understand better on which factor to focus on when planning for energy to ensure a successful development of solar energy in the city.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The ultimate purpose of this study was to develop a framework for assessing the potential of solar energy development in the expansion condominium areas of Addis Ababa, based on identified influential factors for solar energy development. Bole-Arabsa community, the biggest condominium site from the current most rapidly expanding sub-cities (Bole) of Addis Ababa. The key findings of the study were concluded in the context of the sub-research objectives.

6.1.1. Sub Objective One: To Evaluate the Identified (from literature) Potential Indicators under each Barrier Factors and Identify the Appropriate Ones in the Context of Addis Ababa Condominium Sites.

Based on the different studies reviewed, the factors affecting the successful implementation of solar energy in other places have thus already been collected and decided to organize them into six different categories as economical, policy, technological, Information and human resource, Spatial and Social Barriers. Due to having limited time, it was difficult to take all the factors and indicators reviewed in different studies; therefore, the most repeated barriers by the majority of the studies are taken for this research. These categories are taken and evaluated in the context of Addis Ababa. Based on the finding, the challenges and barriers facing solar energy development in the context of condominium areas of Addis Ababa were identified through reviewing policy documents, feasibility studies, energy sector reports, questionnaires, interviews with the KIs and FGD with experts of relevant educational background to the study.

The survey and document review conducted in this paper identifies several key barriers affecting the development of solar energy in Addis Ababa expansion areas include policy & regulatory frameworks, institutional, technological, information & human resource, spatial and societal barriers. This implies that most of the barriers identified from various studies in the majority from developing countries are also barriers in Addis Ababa; however, their importance has slightly differed from place to place.

6.1.2. Sub Objective Two: To Identify New Potential Indicators under each Factor for solar energy implementation in the context of Addis Ababa condominium sites.

The new barriers facing solar energy development in the context of condominium areas of Addis Ababa were identified through questionnaires and interviews with the KIs. Based on the finding, the newly identified barriers in the context of Addis Ababa condominium areas are building design code problems, no plan for urban rooftop PV, and housing ownership. The buildings are not designed to accommodate solar panels because there is not any regulation or common code used to guide when the buildings are designed to construct. Therefore, the lack of a building code is considered to be a major barrier under the spatial factor to the development of solar PV in Addis Ababa. Furthermore, the building's rooftop slope direction and their orientation towards the sun is not taken to consideration. The finding of the study reveals that the government has no plan to integrate building-integrated PV, particularly rooftops in the city. Another context-specific barrier is housing ownership. This is because there are a lot of people in the condo as a tenant and their tenancy makes them difficult for rooftop solar installation.

6.1.3. Sub Objective Three: To Determine and Rank the Contextualized and newly Identified Factors and Indicators under each Barrier, Based on Their Relevance in Hindering Solar Energy Development.

In achieving the third objective, the FGD guide was designed and sent to the experts a week before the FGD is taken place to collect the data needed for prioritization of the barrier factors and indicators using the BWM. Some missed important barriers like "lack of dedicated institution overlooking solar PV development" were also added by the participants to the final framework following the focus group session. The key finding was that policy and regulatory framework was the most influential barrier to be considered when planning for solar energy development in Addis Ababa condominium areas with a weight of 0.3774. Indicators such as "no clear, well-structured and unimplemented policy," "limited RE incentive (tax exemption, feed-in tariff, net metering)," and "weak energy sector institutional regulation & management" make the factor the most influential in hindering solar energy development in the context of Addis Ababa condominium areas.

Another finding was that economic factors are the second most influential barrier factor in the condominium areas, with a weight of 0.2265. Indicators that make economic factors the second most influential for solar energy development include "foreign currency shortage & high foreign exchange spending" and "limited access to financing." Furthermore, Affordability issue is common in the study area. This is because the IHDP launched in 2005 was aimed to construct affordable housing for the low- and middle-income people. Other findings in this study revealed that the majority (56%) of the condominium dwellers have less than $116 monthly income, which means that the people in condominium areas are low-income groups and installing solar PV without any financial support is difficult in such neighborhoods.

Another finding was that compared to the other factors, societal factors are the least influential barrier factor in the condominium areas, and their weight is 0.0566. This is because most of the dwellers in the condominium are familiar with rooftop solar panels. So, if the other most influential factors are tackled, societal influence on solar energy development can be insignificant. However, in general, this category has still influenced solar energy development.

6.2. Limitations of the Study

Transcription of the local language (Amharic) into English was tough and requires intensive time. ATLAS.ti 9 coding process requires significant time and effort to code the interview results, thus some information might be lost in the analysis. Categorizing the KIs response into the important factors were also challenging.

Due to the Covid-19 restriction, the researcher was not able to visit Addis Ababa condominium areas for data collection.

Another limitation of the study was finding an appropriate time to have the key informants' interviews online. This was because most of the key informants had tight schedules at their various offices and, the Ethiopian timeline slightly differs from the Netherlands. Besides, more KIs and other solar energy actors could not interview due to COVID 19 travel restriction.

Internet instability was another problem during the KIs interview. So, this could limit the result on identifying more important factors and barrier indicators to solar energy development contextually.

6.3. Recommendation and Future Study

Further study is needed to identify the independent and dependent variables in order to address the problem and to understand the key factors affecting solar development.

During the online FGD, it was difficult for the experts to rank the indicators using BWM as the ranking method needs some time to understand. Also, ranking seven factors and 28 indicators and approaching consensus was time-consuming. So, conducting such focus group discussion will be very ideal if it is done using face to face approach.

The government, as a key actor, needs to have clear policies to build up local manpower through institutional programmes such as universities, technical schools, and colleges.

The finding of this study indicates that the major barriers of solar energy development in condominium areas of Addis Ababa are policy and regulatory framework and economic factors so, it is recommended that the Ethiopian energy sector, decision-makers, policymakers, and concerned parties in the energy sector including, MoWIE, EEA to focus on the most relevant barriers when planning for energy to ensure a successful development of solar energy in the city.

Similar studies could be conducted in other non-condominium areas of Addis Ababa to identify if they experience similar barriers to solar energy development. Follow the following steps.

1. Determine the most important factor and the worst (least) an important factor in the development of solar PV.
2. Express the best criteria over all the other criteria by using a number between 1 and 9. (or by selecting a using from the drop-box in Excel sheet use the link below) (see example figure) https://bestworstmethod.com/wp-content/uploads/2019/07/BWM-Solver-4.xlsx

The meaning of the numbers 1-9:
1: Equal importance
2: Somewhat between Equal and Moderate
3: Moderately more important than
4: Somewhat between Moderate and Strong
5: Strongly more important than
6: Somewhat between Strong and Very strong
7: Very strongly important than
8: Somewhat between Very strong and Absolute
9: Absolutely more important than

Table 23: Linear multi-criteria decision-making method (BWM)

Source: (Rezaei, 2016) & https://bestworstmethod.com/wp-content/uploads/2019/07/BWM-Solver-4.xlsx

Criteria Number = 7	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7
Names of Criteria	Economy	Policy and	Institutional	Technologic	Information	Spatial	Societal
Select the Best	Policy and						
Select the Worst	Societal						
Best to Others	Economy	Policy and	Institutional	Technologic	Information	Spatial	Societal
Policy and regulatory	2	1	4	6	7	4	8
Others to the Worst	Societal						
Economy	6						
Policy and regulatory	8						
Institutional	3						
Technological	4						
Information and	2						
Spatial	3						
Societal	1						

Figure 14: Example of BWM ranking method

LIST OF REFERENCES

Abotsi, A. K. (2016). Power outages and production efficiency of firms in Africa. *International Journal of Energy Economics and Policy*, *6*(1), 98–104. https://doi.org/10.2139/ssrn.2729838

Abubakar Mas'Ud, A., Wirba, A. V., Muhammad-Sukki, F., Albarracín, R., Abu-Bakar, S. H., Munir, A. B., & Bani, N. A. (2016). A review on the recent progress made on solar photovoltaic in selected countries of sub-Saharan Africa. *Renewable and Sustainable Energy Reviews*, *62*, 441–452. https://doi.org/10.1016/j.rser.2016.04.055

Adegoke, Y. (2018). World Bank recommendations on electricity in sub-Saharan Africa — Quartz Africa. Retrieved October 5, 2020, from https://qz.com/africa/1271252/world-bank-recommendations-on-electricity-in-sub-saharan-africa/

African Development Bank. (2017). *Update on Implementation*. Retrieved from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Brochure_New_Deal_2_red.pdf

Akermi, R., & Triki, A. (2017). The green energy transition and civil society in Tunisia: Actions, motivations and barriers. *Energy Procedia*, *136*, 79–84. https://doi.org/10.1016/j.egypro.2017.10.288

Aklilu, A., & Necha, T. (2018). Analysis of the Spatial Accessibility of Addis Ababa's Light Rail Transit: The Case of East–West Corridor. *Urban Rail Transit*, *4*(1), 35–48. https://doi.org/10.1007/s40864-018-0076-6

Arief, Y. Z., Anak Sa-Or, S. S., Mubarakah, N., Izzwan Saad, M. H., & Eteruddin, H. (2020). Model of grid-connected PV system in Sarawak, Malaysia Rural Area. *2020 4th International Conference on Electrical, Telecommunication and Computer Engineering, ELTICOM 2020 - Proceedings*, 250–259. https://doi.org/10.1109/ELTICOM50775.2020.9230485

Asmamaw, K. (2016). Highlights of Ethiopian Energy Sector. *69Th International Short Course on Renewable Energy and Energy Efficiency*, (September), 1–20. Retrieved from https://tu-dresden.de/bu/umwelt/cipsem/unep-unesco-bmu/previous-courses/sc69?set_language=en

Asumadu-Sarkodie, S., & Owusu, P. A. (2016). The potential and economic viability of solar photovoltaic power in Ghana. *Energy Sources, Part A: Recovery, Utilization and Environmental Effects*, *38*(5), 709–716. https://doi.org/10.1080/15567036.2015.1122682

Bawakyillenuo, S., Olweny, M., Anderson, M., & Borchers, M. (2018). Sustainable Energy Transitions in Sub-Saharan African Cities: The Role of Local Government. *Urban Energy Transition*, 529–551. https://doi.org/10.1016/b978-0-08-102074-6.00042-5

Belay, A. (2021). The Study on the SWOT Analysis of Solar Energy in Ethiopia. *Journal of Environmental Pollution and Management*, *3*(1), 1–13. https://doi.org/10.18875/2639-7269.3.105

Bryman, A. (2012). *Social research methods* (4th ed.). New York, United States: Oxford University Press.

Charles, M., Mzezewa, C., Chiteka, K., & Tsodzo, K. (2018). *Policy Framework and Programme Design for Small Hydropower and Solar Energy Development in Africa Final Report*. Retrieved from https://au.int/

Cherrington, R., Goodship, V., Longfield, A., & Kirwan, K. (2013). The feed-in tariff in the UK: A case study focus on domestic photovoltaic systems. *Renewable Energy*, *50*, 421–426. https://doi.org/10.1016/J.RENENE.2012.06.055

Cole Frank L. (1988). Content Analysis: Process and Application : Clinical Nurse Specialist. *Clinical Nurse Specialist*, (2), 53–57. https://doi.org/https://doi.org/10.1097/00002800-198800210-00025

Couture, T. D., Cory, K., Kreycik, C., & Williams, E. (2010). *Policymaker's Guide to Feed-in Tariff Policy Design*. https://doi.org/10.2172/984987

Derbew, D. (2013). Ethiopia's Renewable Energy Power Potential and Development Opportunities. Ministry of Water and Energy. *Africa Clean Energy Corridor Initiative*, 1–33. Retrieved from https://irena.org/DocumentDownloads/events/2013/July/Africa CEC session 3_Ministry of Water and Energy Ethiopia_Beyene_220613.pdf%5Cnhttp://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=30&CatID=79&SubcatID=343%5Cnhttp://www.irena.org/events/eventsar

Do, T. N., Burke, P. J., Baldwin, K. G. H., & Nguyen, C. T. (2020). Underlying drivers and barriers for solar photovoltaics diffusion: The case of Vietnam. *Energy Policy*, *144*(April), 111561. https://doi.org/10.1016/j.enpol.2020.111561

Dorothal, M. (2019). Ethiopia Solar Report. *Solar Plaza International*, (July), 18. Retrieved from https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/White_Paper_-

_Ethiopia_Solar_Report_2019.pdf
Gaddada, S., & Prashanth Kumar Kodicherla, S. (2016). Wind energy potential and cost estimation of wind energy conversion systems (WECSs) for electricity generation in the eight selected locations of Tigray region (Ethiopia). *Renewables: Wind, Water, and Solar*, *3*, 10. https://doi.org/10.1186/s40807-016-0030-8
Gaitov, B. K., Kopelevich, L. E., & Samorodov, A. V. (2019). Use of solar-wind power plants to decrease damage from power outages. *2019 International Conference on Industrial Engineering, Applications and Manufacturing, ICIEAM 2019*. https://doi.org/10.1109/ICIEAM.2019.8743040
Gärtner, H. J., & Stamps, A. M. J. P. (2014). *Ethiopian power grid*. Retrieved from http://repository.tue.nl/778636
Gerbo, A., Suryabhagavan, K. V., & Kumar Raghuvanshi, T. (2020). GIS-based approach for modeling grid-connected solar power potential sites: a case study of East Shewa Zone, Ethiopia. *Geology, Ecology, and Landscapes*, *00*(00), 1–15. https://doi.org/10.1080/24749508.2020.1809059
Guest, C. (2019). Structured vs. Unstructured Questions | Cvent Blog. Retrieved July 5, 2021, from https://www.cvent.com/en/blog/events/structured-vs-unstructured-questions
Hosseini, S. E. (2019). Development of solar energy towards solar city Utopia. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *41*(23), 2868–2881. https://doi.org/10.1080/15567036.2019.1576803
IEA. (2020). Access to electricity – SDG7: Data and Projections – Analysis - IEA. Retrieved August 2, 2021, from https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity
Ijadi Maghsoodi, A., Mosavat, M., Hafezalkotob, A., & Hafezalkotob, A. (2019). Hybrid hierarchical fuzzy group decision-making based on information axioms and BWM: Prototype design selection. *Computers and Industrial Engineering*, *127*, 788–804. https://doi.org/10.1016/j.cie.2018.11.018
IRENA. (2017). Renewable energy statistics 2017 statistiques d'énergie renouvelable 2017 estadísticas de energía renovable 2017 About I*RENA*. Retrieved from www.irena.org
Irfan, M., Zhao, Z.-Y., Ahmad, M., & Mukeshimana, M. (2019). Solar Energy Development in Pakistan: Barriers and Policy Recommendations. *Sustainability*, *11*(4), 1206. https://doi.org/10.3390/su11041206
Japan international Cooperation Agency. (2012). Energy Policy of Ethiopia Japan International Cooperation Agency. Retrieved from https://www.mofa.go.jp
Jiao Wang, L. S. and L. Z. (2017). No Water, No Power | World Resources Institute. Retrieved September 16, 2020, from https://www.wri.org/blog/2017/06/no-water-no-power
Jica International Center Tokyo. (2009). General Information on the 1994 Formulated Energy Policy and Current Available Energy Statistics. In *Energy*.
Kassa, A. B. (2019). Current Status, Future Potential and Barriers for Renewable Energy Development in Ethiopia. *Iranian (Iranica) Journal of Energy and Environment*, *10*(4), 269–274.
Kazeem, Y. (2018). Solar power plans for Africa face hurdles, say investors — Quartz Africa. Retrieved October 20, 2020, from https://qz.com/africa/1238545/the-biggest-obstacle-to-deploying-solar-energy-in-africa-is-skepticism-in-high-places/
Kebede, K. Y. (2015). Viability study of grid-connected solar PV system in Ethiopia. *Sustainable Energy Technologies and Assessments*, *10*, 63–70. https://doi.org/10.1016/j.seta.2015.02.003
Kebede, K. Y., & Mitsufuji, T. (2014). Diffusion of solar innovations in Ethiopia: Exploring systemic problems. *International Journal of Technology Management and Sustainable Development*, *13*(1), 53–72. https://doi.org/10.1386/tmsd.13.1.53_1
Khalil, I. U. (2017). *Solar PV adoption for homes (*.
Khan, B., & Singh, P. (2017). The current and future states of Ethiopia's energy sector and potential for green energy: A comprehensive study. *International Journal of Engineering Research in Africa*, *33*, 115–119. https://doi.org/10.4028/www.scientific.net/JERA.33.115
Koroso, N. H., Zevenbergen, J. A., & Lengoiboni, M. (2020). Urban land use efficiency in Ethiopia: An assessment of urban land use sustainability in Addis Ababa. *Land Use Policy*, *99*(December 2019), 105081. https://doi.org/10.1016/j.landusepol.2020.105081
Larsen, L., Yeshitela, K., Mulatu, T., Seifu, S., & Desta, H. (2019). The impact of rapid urbanization and public housing development on urban form and density in Addis Ababa, Ethiopia. *Land*, *8*(4). https://doi.org/10.3390/land8040066
Leonard, Bickman Debra, J. R. (2009). *The SAGE Handbook of Applied Social Research Methods - Leonard Bickman, Debra J. Rog - Google Books*. Retrieved from https://books.google.nl/books?hl=en&lr=&id=9_bUtEp-

bGUC&oi=fnd&pg=PA77&dq=what+is+Sampling&ots=-wP59OMSWS&sig=THnWrXF7tW1H0wfO9oIK7KDHHFM&redir_esc=y#v=onepage&q=what is Sampling&f=false

Liu, Z. (2015). *Global Energy Interconnection - Zhenya Liu - Google Books*. Retrieved from https://books.google.nl/books?id=T_MQCgAAQBAJ&pg=PA30&redir_esc=y&hl=en#v=onepage&q&f=false

Lobaccaro, G., Croce, S., Lindkvist, C., Munari Probst, M. C., Scognamiglio, A., Dahlberg, J., … Wall, M. (2019). A cross-country perspective on solar energy in urban planning: Lessons learned from international case studies. *Renewable and Sustainable Energy Reviews*, *108*(March), 209–237. https://doi.org/10.1016/j.rser.2019.03.041

Luthra, S., Kumar, S., Garg, D., & Haleem, A. (2015). Barriers to renewable/sustainable energy technologies adoption: Indian perspective. *Renewable and Sustainable Energy Reviews*, *41*, 762–776. https://doi.org/10.1016/j.rser.2014.08.077

Manfred Hafner, Simone Tagliapietra, & Lucia De Strasser. (2018). Energy in Africa: Challenges and Opportunities. In *SpringerBriefs in Energy*. Retrieved from https://link.springer.com/content/pdf/10.1007%2F978-3-319-92219-5.pdf

Mazengia, D. H. (2010). *Ethiopian Energy Systems - Potentials, Opportunities and Sustainable Utilization*. 76.

McKenna, L., & Gray, R. (2018). The importance of ethics in research publications. *Collegian*, *25*(2), 147–148. https://doi.org/10.1016/J.COLEGN.2018.02.006

Ministry of Water irrigation and Electricity. (2019). *Federal Democratic Republic of Ethiopia:National Electrification Program 2 . 0; Integrated Planning for Universal Access*.

Ministry of Water Irrigation and Electricity. (2018). *The Federal Democratic Republic of Ethiopia Ministry of Water Irrigation and E National Energy Policy The Federal Democratic Republic of Ethiopia Ministry of Water Irrigation and Electricity National Energy Policy The Federal Democratic Republic of Ethiop*.

Mostafaeipour, A., Alvandimanesh, M., Najafi, F., & Issakhov, A. (2021). Identifying challenges and barriers for development of solar energy by using fuzzy best-worst method: A case study. *Energy*, *226*. https://doi.org/10.1016/j.energy.2021.120355

MoWE. (2012a). *Federal Democratic Republic of Ethiopia Ministry of Water and Energy Scaling-Up Renewable Energy Program Ethiopia Investment Plan (Draft Final)*.

MoWE. (2012b). *Scaling - Up Renewable Energy Program Ethiopia Investment Plan. Ministry of Water and Energy,Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia.* (January), 81. Retrieved from www.h4sd.info

Mugisha, J., Ratemo, M. A., Bunani Keza, B. C., & Kahveci, H. (2021). Assessing the opportunities and challenges facing the development of off-grid solar systems in Eastern Africa: The cases of Kenya, Ethiopia, and Rwanda. *Energy Policy*, *150*, 112131. https://doi.org/10.1016/J.ENPOL.2020.112131

MWE., M. of W. and E. (2012). Ethiopian National Energy policy. In *WD info*. https://doi.org/https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/1195b.pdf

Nebey, A. H., Taye, B. Z., & Workineh, T. G. (2020). Site Suitability Analysis of Solar PV Power Generation in South Gondar, Amhara Region. *Journal of Energy*, *2020*, 1–15. https://doi.org/10.1155/2020/3519257

Nikas, A., Stavrakas, V., Arsenopoulos, A., Doukas, H., Antosiewicz, M., Witajewski-Baltvilks, J., & Flamos, A. (2020). Barriers to and consequences of a solar-based energy transition in Greece. *Environmental Innovation and Societal Transitions*, *35*(December 2018), 383–399. https://doi.org/10.1016/j.eist.2018.12.004

Ohunakin, O. S., Adaramola, M. S., Oyewola, O. M., & Fagbenle, R. O. (2014). Solar energy applications and development in Nigeria: Drivers and barriers. *Renewable and Sustainable Energy Reviews*, *32*, 294–301. https://doi.org/10.1016/j.rser.2014.01.014

Okoye, C. O., Taylan, O., & Baker, D. K. (2016). Solar energy potentials in strategically located cities in Nigeria: Review, resource assessment and PV system design. *Renewable and Sustainable Energy Reviews*, *55*, 550–566. https://doi.org/10.1016/j.rser.2015.10.154

Osborne, M. (2012). Ethiopia to get first PV module assembly plant courtesy of Spire - PV Tech. Retrieved July 2, 2021, from https://www.pv-tech.org/ethiopia_to_get_first_pv_module_assembly_plant_courtesy_of_spire,/

Parker, C., Scott, S., & Geddes, A. (2019). *Snowball Sampling*. https://doi.org/10.4135/

Renewable Energy Agency, I. (2014). *Estimating the Renewable Energy Potential in Africa: A GIS-based approach*.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega (United Kingdom)*, *53*, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega*, *64*, 126–130. https://doi.org/10.1016/J.OMEGA.2015.12.001

SurveyMonkey. (2021). Sample Size Calculator: Understanding Sample Sizes | SurveyMonkey. Retrieved June 1, 2021, from https://www.surveymonkey.com/mp/sample-size-calculator/

Teferi, E., & Abraha, H. (2017). Urban Heat Island Effect of Addis Ababa City: Implications of Urban Green Spaces for Climate Change Adaptation. In *Climate Change Management* (pp. 539–552). https://doi.org/10.1007/978-3-319-49520-0_33

Terfa, B. K., Chen, N., Liu, D., Zhang, X., & Niyogi, D. (2019). Urban expansion in Ethiopia from 1987 to 2017: Characteristics, spatial patterns, and driving forces. *Sustainability (Switzerland)*, *11*(10), 1–21. https://doi.org/10.3390/su11102973

Tessama, Z., Davis, M., Tella, P., & Lambe, F. (2013). Mainstreaming Sustainable Energy Access into National Development Planning: the Case of Ethiopia. *Stockholm Environment Institute, Working Papaer*, (February). https://doi.org/10.13140/2.1.3430.2401

The World Bank Group. (2019). Doing Business 2019 Training for reform. In *World Bank*. Retrieved from http://www.doingbusiness.org/en/reports/global-reports/doing-business-2019

Tucho, G. T., Weesie, P. D. M., & Nonhebel, S. (2014). Assessment of renewable energy resources potential for large scale and standalone applications in Ethiopia. *Renewable and Sustainable Energy Reviews*, *40*, 422–431. https://doi.org/10.1016/j.rser.2014.07.167

UN-Habitat. (2016). *Urbanization and Energy Nexus*.

UN-Habitat. (2017). *The State Of Addis Ababa*. Retrieved from http://etd.aau.edu.et/dspace/handle/123456789/2372

UN-HABITAT. (2011). Condominium housing in Ethiopia : the integrated housing development programme. United Nations Human Settlements Programme: Nairobi.

UNIDO. (2010). *Study on Local Manufacturing of Renewable Energy Technology Components in East Africa*.

United Nations. (2010). World Population Prospects: The 2010 Revision | Latest Major Publications - United Nations Department of Economic and Social Affairs. Retrieved July 7, 2021, from https://www.un.org/en/development/desa/publications/world-population-prospects-the-2010-revision.html

USAID. (2020). POWER AFRICA IN ETHIOPIA | Power Africa | U.S. Agency for International Development. Retrieved October 13, 2020, from https://www.usaid.gov/powerafrica/ethiopia

Wang, H., Yang, X., Xu, X., & Fei, L. (2021). Exploring opportunities and challenges of solar pv power under carbon peak scenario in china: A pest analysis. *Energies*, *14*(11), 1–28. https://doi.org/10.3390/en14113061

Wang, Q., Wu, S. D., Zeng, Y. E., & Wu, B. W. (2016, February 1). Exploring the relationship between urbanization, energy consumption, and CO2 emissions in different provinces of China. *Renewable and Sustainable Energy Reviews*, Vol. 54, pp. 1563–1579. https://doi.org/10.1016/j.rser.2015.10.090

World Bank. (2019). Access to electricity (% of population) - Ethiopia. Retrieved August 2, 2021, from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=2019&locations=ET&start=2000

World Bank. (2020). Solar Photovoltaic Power Potential by Country. Retrieved October 14, 2020, from https://www.worldbank.org/en/topic/energy/publication/solar-photovoltaic-power-potential-by-country

World Bank. (2021). Firms experiencing electrical outages (% of firms) | Sub-Saharan Africa Data. Retrieved July 30, 2021, from https://data.worldbank.org/indicator/IC.ELC.OUTG.ZS

World Bank Group. (2015). *Enhancing Urban Resilience*. Retrieved from www.worldbank.org/urban

Zabavnik, D., & Verbič, M. (2021). Relationship between the financial and the real economy: A bibliometric analysis. *International Review of Economics & Finance*, *75*, 55–75. https://doi.org/10.1016/J.IREF.2021.04.014

Zewdie, M., Worku, H., & Bantider, A. (2018). Temporal Dynamics of the Driving Factors of Urban Landscape Change of Addis Ababa During the Past Three Decades. *Environmental Management*, *61*(1), 132–146. https://doi.org/10.1007/s00267-017-0953-x

Zhang, X., Shen, L., & Chan, S. Y. (2012). The diffusion of solar energy use in HK: What are the barriers? *Energy Policy*, *41*, 241–249. https://doi.org/10.1016/j.enpol.2011.10.043

Appendix 1: Survey Questionnaire for Community of the Bole-Arabsa Condominium Site

Survey Questionnaire for Community of the Bole-Arabsa Condominium Site

Location/ block number Building number/code
Housing unit type □ studio □ 1bedroom □ 2bedrooms □ 3bedrooms

1. Are you aware of rooftop solar panel? □ Yes □ No
1.1. If the answer is yes, how do you know it?
□ By education □ By government training □ by private sector promotion □ by media □ other (mention)
1.2. Do you have roof top solar panels? □ Yes □ No
1.2.1. If the answer is no, would you like to have roof top solar panels in your house?
□ Yes □ No
2. What aspects are limiting you from rooftop solar energy installation?
□ Solar installation & repair cost is high
□ lack of information & practical knowledge
□I don't accept solar energy usage
□lack of financial support
□lack of communication & participation about solar energy with government & institutions
3. Does the government or anyone else inform you to use solar energy in your home's roof? □ Yes □ No
3.1. If the answer is yes, by whom?

3.2. what was your response to the government suggestion?
□ 5 - Strongly agree
□ 4 - Somewhat agree
□ 3 - Neutral (Neither agree nor Disagree)
□ 2 - Somewhat disagree
□ 1 - Strongly disagree
3.3. Will you install rooftop solar panels if the government/institutions offer you or arrange for you a bank loan?
□ Yes □ No
3.3.1. If your answer is no, could you tell me your reason

4. Have you ever participated in solar energy development meetings or trainings?
□ Yes □ No
5. Do you have any knowledge on how to install or how to maintain solar panels?
□ Yes □ No
6. Have you ever trained by gov't or other institutions about solar energy installation & maintenance? □ Yes □ No
7. Do you think Rooftop solar energy usage helps to reduce power outage?
□ 5 - Strongly agree
□ 4 - Somewhat agree
□ 3 - Neutral (Neither agree nor Disagree)
□ 2 - Somewhat disagree

□ 1 - Strongly disagree

8. Which of these describes your total household monthly income in Birr?

□ 0-500 □ 501-1000 □ 1001-2000 □ 2001-3000 □ 3001-4000

□ 4001-5000 □ >5000 □ prefer not to answer

9. Is there anything else that you would like to add about things which prevent you from using rooftop solar energy?

Appendix 2: Survey with High level officials

Hello Sir /Madam

Currently, due to the rapid expansion of Addis Ababa city, the demand for energy is constantly increasing, and there are frequent power outages. However, the city has untapped solar potential.

Besides, solar energy is reliable, affordable, and environmentally sound energy type and helps to minimize outages. Study shows that countries such as China use massive rooftop solar energy to meet their energy demand in a sustainable way and Rooftop PV development has been strongly supported by Chinese policy. People in China also use rooftop PV as a source of income.

So solar PV is a perfect way to meet demand and secure, consistent energy by minimizing interruptions. Thus, this interview questionnaire's main focus is to collect information on the main barriers of rooftop solar energy development in condominium areas of the city, particularly in the Bole-Arabsa site.

The conduction of this study on exploring the barriers of solar energy development contextually will provide understanding and knowledge to the energy sector, decision-makers and policymakers to understand better what to incorporate for the successful development of solar PV in the city. It will also help the government on what gaps may exist in solar energy development and to focus on taking measures.

Please be assured that any information provided would be treated with the privacy it deserves and used only for this academic purpose. The interview questionnaire is therefore scheduled to last for about 30-45 minutes.

Thank you for your willingness and for giving me your precious time.

II. Interview questionnaire to government officials (Ethiopian Energy Authority (EEA) & Ministry of Water, Irrigation and Energy (MoWIE)

1. What is your role in this institution?
2. In the national energy policy, it is mentioned that the government planned to use mixed energy sources to minimize power interruption so,
   - 2.1. What are the plans for Bole Arabsa condominium site related to rooftop solar energy?
   - 2.2. When are you planning to start installation of the rooftop solar panel?
   - 2.3. Is there a specific reason that the planned work has not started yet?

3. Which factors do you think most likely affect to not install rooftop solar PV systems in condominium areas of Addis Ababa yet?

	Very Likely	Likely	Unlikely	Very Unlikely
Economy	○	○	○	○
Policy/Institutional	○	○	○	○
Technological	○	○	○	○

Information & Human resource	○	○	○	○
Spatial	○	○	○	○
Societal	○	○	○	○

4. How is the people's awareness and acceptance for solar technologies?

5. Do you think the residents can afford to install solar panels on their house's rooftop without any subsidies? □ Yes □ No
   5.1. If the answer is No, does the government has a bank loan or other means of financial support for such economic difficulties?

6. Do you motivate people in the condominiums to install solar energy? □ Yes □ No
   6.1. If the answer is yes, how? could you give me an example.

7. Do you think there is a lack of information & technical skill for modern solar energy technologies in Ethiopia?
8. Do you encourage & motivate private sectors/investors to participate in solar energy projects? Could you please explain?

9. Does the government encourage private sectors/importers involved in RE technologies by creating a suitable economic environment like subsidies, bank loans, tax exemptions, and feed-in tariff policy mechanisms?

10. Why the national energy policy of Ethiopia gives priority to hydropower but not to solar energy? Could you please explain?

11. What are the reasons for the national energy policy giving more subsidies to fossil fuel than solar energy?

12. Is there solar cells production facility in Ethiopia? □ Yes □ No
    12.1. If no, so do you import them from abroad?

13. Do you think there are enough solar panels market and suppliers?

14. Are there structural regulations for solar energy?

15. Which of the following technological factors influence solar energy development?
    □ dependency on foreign technology □ life span of the cell □ technology efficiency
16. Do the gov't have standards and regulations to control material quality of the imported solar panels?
    □ Yes □ No
17. Do you think inadequate transmission capacity is a barrier for solar energy development in condominium areas?
    □ Strongly Agree □ Somewhat agree □ neutral □ somewhat disagree□ Strongly disagree

18. According studies the government believe that solar is too costly and not a viable option to reduce power outage. Could you explain from what direction do you say it costly?

19. Is there anything you feel I didn't or should have asked that you would like to mention as solar energy development barrier?

Appendix 3: Survey with private sector working in the energy sector

III. Interview questioner to the private sector working in the energy sector

1. What is your role in this sector/organization?
2. Are there solar panels produced in Ethiopia? □ Yes □ No
3. Can you tell me the cost of one solar panel?
4. Studies show that residents in condominium sites don't install rooftop solar panels; which factors do you think most likely affect to not install rooftop solar PV systems in condominium areas of Addis Ababa yet?

	Very Likely	Likely	Unlikely	Very Unlikely
Economy	□	□	□	□
Policy/Institutional	□	□	□	□
Technological	□	□	□	□
Information & Human resource	□	□	□	□
Spatial	□	□	□	□
Societal	□	□	□	□

5. There are frequent power outages in expansion areas of new resettlement zones, especially in condominium sites. Have you tried to install solar panels in such areas?
   □ Yes □ No
   5.1. If your answer is yes, what was the community's response and acceptance for such technologies?
6. Do you promote and encourage people in condominium sites to use solar energy?
   □ Yes □ No
   If the answer is yes, could you give me some examples on how you encourage them?
7. Which of the following social factors do you think influence rooftop solar energy development?
   □ lack of communication with local community
   □ lack of awareness □ No public acceptance□ lack of relation with local & state actors
8. Do you have access of credit facility for enabling communities to use solar energy?
9. Does the government invite you to participate in different energy projects?
   □ Yes □ No
10. Which of the following does the government/institutions encourage you by creating a suitable economic environment?
    □ subsidies □ bank loans □ feed-in tariff system □ tax exemptions
    □ other (mention)
11. Do you think there is a shortage of technical experts and manpower for operation and maintenance of solar energy?
12. Do you carry out installations for customers at additional cost?
13. How is the solar cells quality & transmission capacity?
14. What would you consider as an issue in the solar PV market?
15. Are there many suppliers regarding solar technology? □ Yes □ No
    15.1. If yes, do you have market link with them and other RE actors?
    15.2. If no, what is the reason for not involving in such sectors?

16. Is there anything you feel I didn't or should have asked that you would like to mention as a solar energy development barrier?

Appendix 4: factors affecting solar energy development & indicators globally

Studies	Case study area	Methode used	Main barriers to solar energy	Indicators
(Irfan, Zhao, Ahmad, & Mukeshimana, 2019)	Pakistan	semi-structured interviews	Economic	Solar energy projects are capital intensive. Buying solar energy needs high installation costs. Government subsidies are limited Limited bank loans for solar energy projects.
			Policy	Government policies are confusing. Solar energy projects have limited feed-in tariff. Low priority for RE technologies.
			Technologic	Local technology is unreliable. The production of solar cells is limited in the country. There is a huge dependency on foreign technology for core parts and equipment. There is a lack of local personnel to operate large solar farms.
			Information Human Resource	The information regarding modern solar technology, markets, and suppliers is limited. Human resource potential is limited to the installation and maintenance of solar energy projects. The collection of solar energy data is unreliable and inefficient.
			Societal	Social acceptance and participation of solar energy products are limited. Local users lack practical knowledge to fix solar energy systems if they suddenly some problem occurs.
(Nikas et al., 2020)	Greece	Stakeholder interview Ensemble	Economic	Lack of financial resources, High investment costs, high initial and repair costs

		modeling	Political	lack of Government policy and financial support
			Societal	Problematic relations with state actors Public acceptance
(Akermi & Triki, 2017)	Tunisia	Qualitative approach/content analysis	Economic	Lack of financial resources Tax exemptions
			Human Resource Barriers	Lack of human resources
			Policy	Lack of institutional support
			Technologic	System failures
(Do et al., 2020)	Vietnam	an inductive approach using semi-structured interviews Ranking barrier	Economic	High upfront costs Fossil fuel subsidy Low foreign investment attractiveness
			Technologic	Inadequate transmission capacity Lack of technical information and assistance
			Institutional	Complex administrative procedures Institutional Policy uncertainty
			Societal	Lack of communication between developers local community Lack of engagement with local communities
(Zhang et al., 2012)	Hong Kong	Questionnaire survey for expert opinions Pilot study	Economic	High initial and repair cost, Long payback period
			Technologic	Relating to structural problems concerned with existing buildings Lack of technical skill
			Societal	Legal and regulation barriers Lack community/ stakeholder participation
			Political	Lack of Government policy and financial support
			Spatial	Insufficient installation space
(Ohunakin et al., 2014)	Nigeria		Economic	High initial investment cost Operation and maintenance costs
			Societal	Lack of awareness and information
			Technologic	Grid unreliability solar energy storage technologies
			Policy and	Low policy support for solar energy
			Institutional	Ineffective quality control of products
(Charles et al., 2018)	Africa		Economic	Underdeveloped RE markets Low private sector participation (by bank, financial institutions)
			Policy & Institutional	Poorly formulated policies Weak institutions

			Technologic	Dependence on imported technologies
			Information Human Resource	Lack of data Low technical skill
(Hosseini, 2019)	US	Measuring appropriate roof top area (%)	Spatial	Rooftop total suitable /available area for solar installation
(Luthra et al., 2015)	India	Expert opinion and Analytical Hierarchy Process (AHP)	Economical & Financial	High initial capital cost Lack of financing mechanism Transmission & distribution losses Inefficient technology Lack of subsidies
			Market	Lack of consumer awareness to technology Lack of sufficient market base Unable to meet electricity power demand alone Lack of paying capacity
			Awareness & Information	Need for backup or storage device Unavailability of solar radiation data Lack of IT enablement
			Technical	Lack of awareness of technology Less efficiency Technology complexity Lack of research & development work Lack of trained people & training institutes Lack of local infrastructure Lack of national infrastructure
			Ecological & Geographical	Scarcity of natural & renewable resource Geographic conditions Ecological issues
			Cultural & Behaviora	Lack of experience Rehabilitation controversies Faith & Beliefs
			Political & Government Issues	Lack of political commitment Lack of adequate government policies Lack of public interest litigations
(Mostafaeipour et al., 2021)	Iran	Expert opinion questionnaire and questionnaire using fuzzy best-worst	Technical factors	Poor technology Shortage of manufacturers Poor quality of solar system equipment Inability to meet peak energy demand
			Legal factors	Arduous and costly legislation process Bureaucratic barriers Lack of standards and organizational

		method (BWM)		frameworks Power storage limitations
			Economic factors	High investment risk Low fossil fuel prices Lack of fund for investment High investment and operations costs
			Sociocultural factors	Lack of ambition Low priority of efficiency in energy purchases Low risk-taking Herd behaviour Resistance to change or new paradigms Low public awareness Low investment motivation
			Support factors	Tax exemption International and national relations Fossil fuels subsidies

Appendix 5: factors affecting solar energy development & indicators Contextually (Ethiopia context)

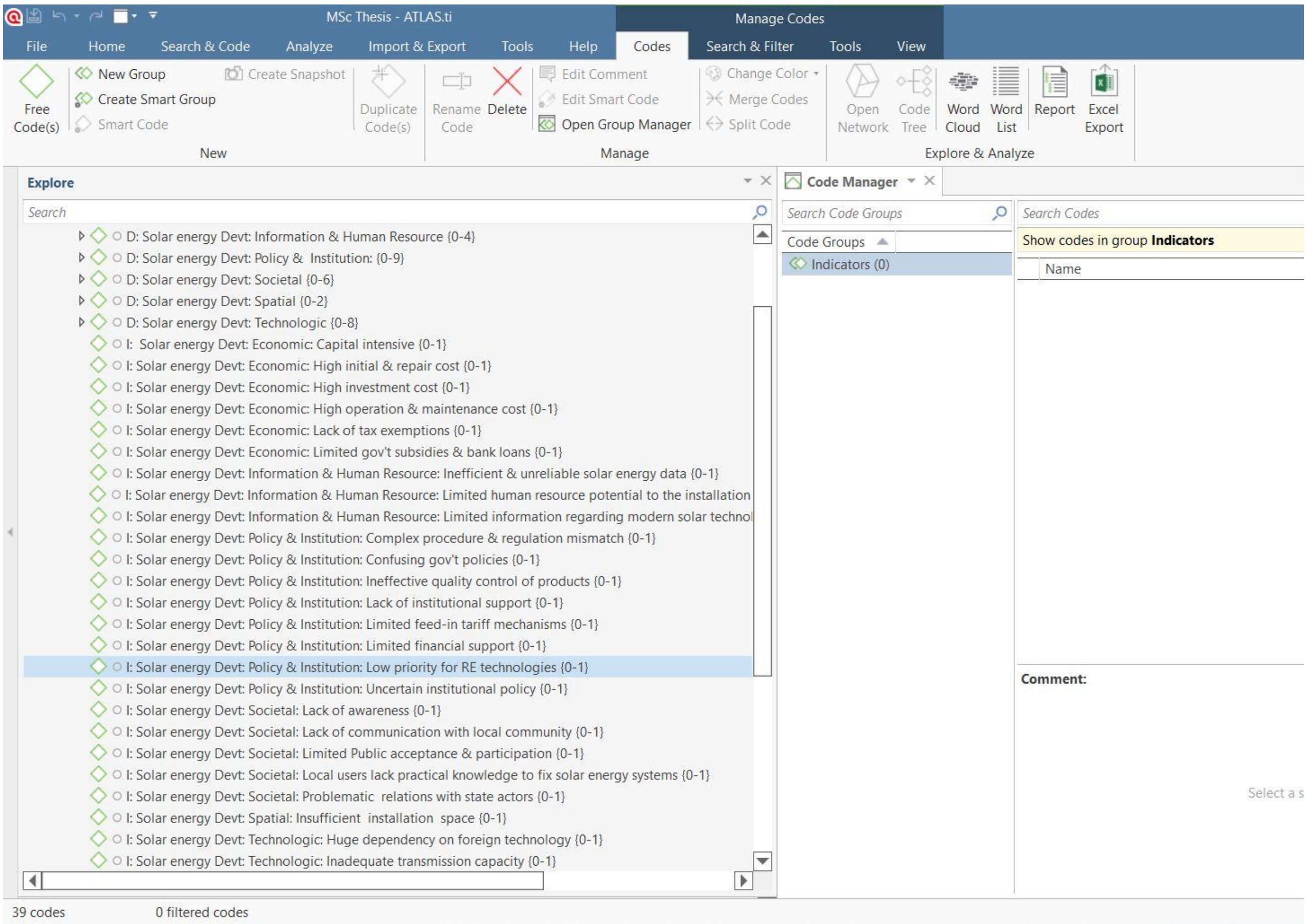
Studies	Main barriers to solar energy	Indicators
(Kassa, 2019): Article	Financial	High investment cost Lack of loan from institutions & banks Capital intensive High foreign exchange spending Financing for RE is at early stage
	Technical	Lack of technical capacity (local knowledge & skill) Low equipment quality & standard Depend on Foreign technological hard wares
	Policy & regulations	Not clear policy & policy problem Limited awareness & information (users, designers & promoters) Low implementation rate Limited institutional support and participation
	Human Resource Barriers	Lack of knowledge & skill gap No data
	Societal	Lack of local community participation & ownership in RE project

Ethiopian National Energy Policy (2nd draft). (2013).	Financial	Capital intensive (high investment cost needed) High initial cost High foreign currency needs to import technology Limited tax Exemption Low income Lack of access to financing for research and development, promotion and dissemination Lack of market link between various RE actors Lack of access to credit facility for enabling communities to use solar energy Low energy sector financing Not having "energy fund"
	Institutional	Weak institutional arrangement and capacity building Poor sector management & inadequate infrastructure Lack of stable institution Lack of promotion (from traditional to modern energy) No quality assurance & control Lack of proper regulations, standard and enforcement measures
	Technologic	Limited technological capacity High dependence on imported petroleum fuels High degree dependence on traditional energy sources (Biomass) Inadequate transfer of technology and localization Lack of localized supportive industries Low technical standards & inadequacy of distribution network Low technological transfer and localization
	Information & Human Resource Barriers	Limited human resource potential & capacity Absence of sufficient information & data Lack of reliable and up-to-date data
	Societal	Low private sector participation Limited promotion the transition (traditional to modern) Low participation of investors Lack of infrastructure to mobilize and develop RE resources Lack of awarness
	Policy & legal frameworks	Weak enforcement of standards and regulations More subsidies for fossil fuels as compared to solar energy and other renewable technologies High dependence on biomass resources & lack of structural regulations for RE. Weak introduction on efficient technologies No financial support policies such as loans and seed money Limited encouragement of public and private sector investment.

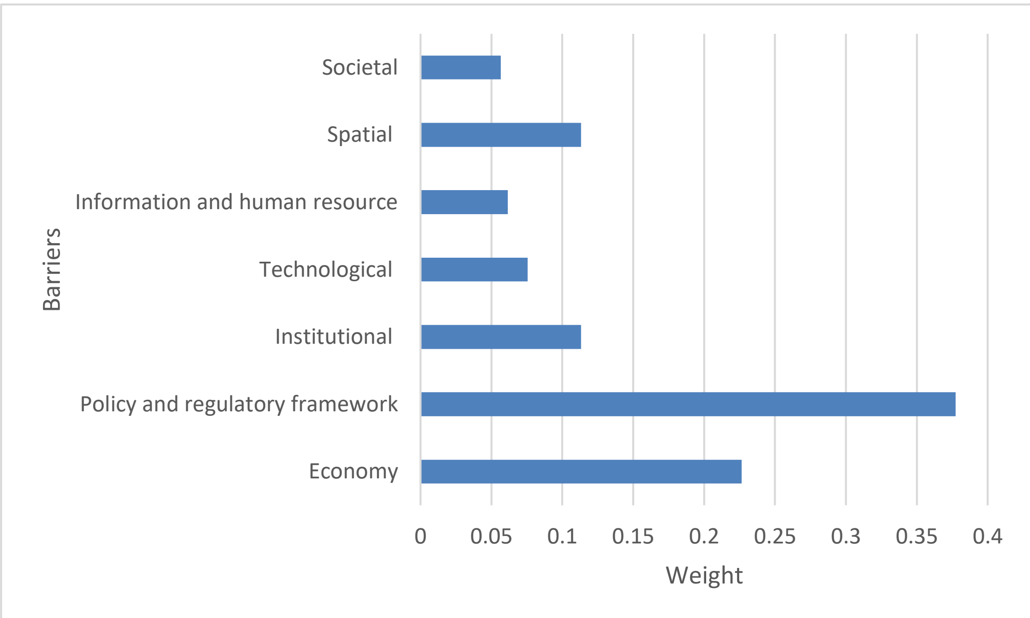
		Limited local research & development
Green economy strategy 2011, (Report)	Economic	Lack of funds for expensive technologies
	Technological	Low quality material
MoWE, 2012 (Report)	Financial	High cost of RE technologies Lack of available finance
	Technologic	System losses Lack of locally developed and adapted technologies Poor distribution network design
	Policy	No private sector participation Lack of Feed-in-Tariff mechanism
	Human resources	Limited Skill & knowledge
	Societal	Lack of awareness and information
(Kebede & Mitsufuji, 2014)	Economic	Financial problem High upfront cost of solar PV Lack of finance for investment by local companies Unavailability of loan (micro credit) systems and institutions Poor promotion Less investment interest from existing financial institutions
	Institutional	Unclear standards and regulations Tax exemption problem Working culture and lack of trust b/n users and suppliers, and among companies
	Societal	Lack of integration among solar actors Poor interaction b/n users and suppliers
Feasibility study by (Kebede, 2015) Article	Policy	No tax incentives, financial loans, grants and formulation of favorable Feed-in-Tariff laws to attract private investors. Lack of education & awareness about traditional sources of energy Priority for hydropower
	Institutional	policy makers in Ethiopia believe that solar is too costly and not a viable option
	Societal	Lack of awareness Dependence on traditional sources of energy
(Khan & Singh, 2017)	Economic	Lack of government subsidies Less financial sources Initial cost & no bank loan
	Technologic	Lack of technical training Scarcity of system capacity Excess System Losses

	Policy/institution	Low organizational efficiency weak management Lack of regulatory framework Improper management of power sector Reliance on hydropower No supporting framework to private investors Dependence on fossil fuels
	Information & HR	Lack of skilled human power to maintenance
	Societal	Lack of motivational awareness
(Abubakar Mas'Ud et al., 2016)	Economic	Lack of source funding for solar PV High initial & maintenance cost (on-grid) Lack of budgetary allocations or dedicated funds for RE promotion
	Policy/institution	No clear policy strategy for feed-in-tariff scheme Insufficient funding instruments. Lack of political will from the government to pursue energy policy implementation Inadequate research and development Lack of an enabling environment to encourage local entrepreneurship in the sector Lack of effective monitoring and evaluation strategies to develop solar PV technology Lack of government support &encouragement for private sectors Poor management
	Information & HR	lack of technical capabilities & information lack of having accurate solar resource data Insufficient technical expertise in that region to accelerate solar PV developments. Lack of local technical skills Lack of feasibility studies
	Societal	Lack of appropriate media for RE advertisement
(Jica International Center Tokyo, 2009) policy report	Policy	High priority to hydropower dev't High dependence on imported petroleum fuel No emergence of modern technology
	Technologic	Limited capacity
	Information & HR	Lack of recent information

Appendix 6: Coding Using ATLAS. Ti 9



Appendix 7: Importance of main factor/criteria on solar energy development in Addis Ababa condos



Appendix 8: Focus Group Discussion

Hello dear,

My study aims to develop a framework for assessing the potential of solar energy development in the condominium areas of Addis Ababa. To understand the context, I did some research, I looked at literature, surveys, and key informants' interviews were conducted, and the indicators mentioned in the table below are what I think the most important barrier aspects to rooftop solar energy development in Addis Ababa expansion areas.

The table below is a draft framework that I developed for assessing the potential of solar energy development in the condominium areas of Addis Ababa, based on identified influential factors for solar energy development. Thus, I want you to look at them and tell me what do you think about it? Do you want to add other important barriers that are not discussed here? Feel free to ask me if you think the barriers are confusing. Also, if you feel they are not important contextually, don't hesitate to remove them. Then we will do the following.

1. Rank the factors based on their relevance in hindering solar energy development (see table below). Using the best-worst method (BWM)
2. Rank the contextually identified indicators under each barrier factor, based on their relevance in hindering solar energy development.

Thank you for your willingness and for taking your precious time.

Criteria	Factors	Indicators	Denotations
C1	Economy	Foreign currency problem & high foreign exchange spending	C1- 1
		Limited access to loan from institutions & banks	C1- 2
		Lack of access to financial support	C1- 3
		High initial cost and lack of affordability	C1- 4
		Low-income level	C1- 5
		Limited tax exemption	C1- 6
		Limited budget for technology promotion	C1- 7
		Lack of access to financing for RE research & development	C1- 8
C2	Policy & institutional	No clear, well-structured and implemented policy	C2-1
		No Feed-in-Tariff mechanisms	C2-2
		standard issue, no testing facility and material quality problem	C2-3
		Complex administrative procedures	C2-4
		Poor energy sector institutional regulation & management	C2-5
		No plan for urban rooftop PV Priority given to hydropower	C2-6
C3	Technological	Lack of locally developed technologies & foreign technology dependency	C3-1
		Technology efficiency	C3-2
		Standard & material quality problem due to no testing facility	C3-3
C4	Information & Human	Limited specialized manpower	C4-1

	resource	Limited investors and private suppliers Limited of local research and development	C4-2 C4-3
C5	Spatial	Building design code problem Insufficient roof space Improper roofing direction & orientation towards the sun Roofing material quality & durability issue Bad infrastructure & utility	C5-1 C5-2 C5-3 C5-4 C5-5
C6	Societal	Low public awareness No network platform/ integration among solar actors Limited socially promotions by investor Housing ownership problem	C6-1 C6-2 C6-3 C6-4

Appendix 9: Focus Group Discussion first attempt ranking for solar energy barriers.

Factors	FGD1 (Expert 1-7)	GD2 (8-12)
Economy	1	2
Policy & institutional	2	1
Technological	4	3
Information & Human resource	3	5
Spatial	4	4
Societal	5	6