Innovations

The Potential of Wind Power Energy, Utilization Level, Challenges and Opportunities in Ethiopia

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Abstract

The main objective of this systematic review is to identify the potential of wind power energy, utilization level challenges and opportunities in Ethiopia. Regarding the methodology ofutilization of the study, a systematic review was used to collect data. Data were collected from selected articles and journals based on inclusion and exclusion criteria; mainly based on their level of relevance to the topic under study. Hence, this paper was prepared by reviewing the findings of empirical research results which were conducted on wind energy utilization in different parts of Ethiopia. Literature was collected thoroughly from main scientific databases like the Web of Science, Journal of citation report, Scopus, Google Scholar, citation tracing and science direct. Those articles dealing with wind power energy utilisation have been considered for the selection process by using inclusion and exclusion criteria. The criteria employed to incorporate different related studies into a systematic review were the time of publication, similarity, type of publication and scope of the journal between 2010 and 2023 years. From the total of 127 articles assessed, only 11 were identified for this systematic review. Most of the articles included in the study were case studies and qualitative and mixed studies. The analysis result of this research shows that increasing the participation of wind power energy in the renewable energy market requires raising awareness regarding its benefits; increasing the research and development of new technologies; implementing public policies and a program that will encourage wind power energy generation.

Keywords: *Potential, Wind, Energy, Utilization, Ethiopia.*

1. Introduction

1.1Background of the Study

Wind power is the flow rate of kinetic energy carried by moving air [21].Wind power is expected to be one of the main contributors to a worldwide and sustainable energy system. It was already one of the most affordable sources of new electricity by 2015, and it could provide in large quantities. Over the course of a wind farm's existence, wind power, as it is often acquired, enables consistent electricity production prices, avoiding the increasing volatility in fuel prices [3].

By 2018, wind energy in Africa had increased from 0.74 GW (GW) in 2009 to 5.5 GW, a 740% increase. This has been made possible by ongoing cost reductions, advanced technologies, and political commitment. Despite having competitive costs and speeds capable of establishing utility-scale wind farms, Africa had erected only around 1% of its expected wind capacity as of 2018.Between 2010 and 2019, the average cost of LCOE for wind in Africa decreased by 30%, from US cents 10 per kWh to 7 per kWh. Furthermore, the development of wind energy across the continent is intermittent and disproportionately concentrated in southern and northern Africa[2].For the past 20 years, modern wind turbines have been utilized to efficiently harness the wind, and the technology is well-established, dependable, and efficient [27]. The use of wind turbines to generate energy has grown recently as a result of technological improvement, stable pricing, and environmental concerns [16]. To meet the rising energy demand and ensure sustainable growth, Ethiopia plans to employ wind power plants in addition to its current hydropower facilities. Consequently, EEPCO's (Ethiopian Electric Power Corporation) system will incorporate large-scale wind farms [4]. Ethiopia would need to make investments in the creation of other energy sources to deal with the effects of the drought on the generation of hydroelectric electricity[10].

Ethiopia has historically generated most of its electricity from hydropower, but it now wants to diversify its energy mix from other renewable sources to boost climate resilience. As a result, the Government of Ethiopia (GoE) has outlined plans to create 5,200 MW of new wind energy through the private sector, specifically through Independent Power Producers [24].In Ethiopia, a major obstacle to more widespread adoption of alternative energy sources including solar, wind, geothermal, and biomass electrical energy is the upfront capital investment required. To increase the availability of electricity in rural areas where renewable resources abound but financial resources are scarce; the best course of action in Ethiopia would be to offer financial incentives to cooperative, household, or private organizations to utilize sustainable resources. Capital subsidies and other related policies should focus on lowering the costs of initial capital investments to produce alternative renewable resources similar to hydroelectric power in price[19]So, this study is intended to review the potential of wind power energy, utilization level, challenges and opportunities in Ethiopia

1.2 Statement of the Problem

Wind energy is among the most affordable sources of renewable energy, with significant annual growth in installed capacities all over the world[17].Wind energy is a capital-intensive technology, with permanent assets (wind turbines, grid connections, and civil works) accounting for up to 80% of the total cost. Operations and maintenance (O&M) account for another 10% of expenditures, but because so few wind turbines are at the end of their useful lifespan, any analysis' accuracy is severely limited [8].African states generally lack specific renewable energy legislative, legal, and regulatory frameworks, which is a problem for the continent's wind energy. Incentives and support for the development of renewable energy sources are insufficient in Africa. There is a shortage of reliable and comprehensive information about wind resources as well as a lack of a wind map, which affects key groups in the public and corporate sectors[1].

Ethiopia's national energy policy has to be completely revised because, the main finding is that it doesn't address how much energy is needed for development and subsistence, particularly how much energy is needed in rural areas for contemporary productive activities [34]. Determining Ethiopia's full potential for renewable energy sources remains a major challenge, especially given the lack of local content development in the context of creating an industrial base. The Ethiopian government has made some notable moves in favour of the Sustainable Development Goals, the Green Growth model, and the Paris Climate Accord. However, the top-down approach of establishing general objectives for the various regions is not a workable solution to the issue of energy poverty [25].

In terms of cost, impact on the environment, and usability, wind energy competes with other energy sources. Wind power is the only renewable energy source, except hydropower, that is closest to commercial viability, however improving the project economy remains a significant obstacle for wind power [12]. Ethiopia offers a wealth of potential renewable energy sources that, if developed, may drastically change the country's energy industry and lead to a future where the entire country is electrified rather than burning biomass[20]. In the Ethiopian highlands, precipitation may increase rather than decrease, which may increase water availability for hydroelectric power generation. However, if increases in precipitation only occur during the rainy season this may not translate to increased hydroelectric energy production as water scarcity normally arises during the dry season. Hence, increased precipitation may not necessarily benefit hydroelectric production unless it occurs during the dry season. Increases in the intensity of precipitation may increase the risk of flooding, siltation, and sedimentation, which directly affect the capacity of hydroelectric reservoirs. Ethiopia needs to invest in relatively expensive renewable energy resources in pursuit of green energy development, poverty alleviation, and energy security; however, such an effort is hindered due to the high capital costs of alternative energy resources [10].
Since wind energy is a renewable energy source, it has numerous advantages over fossil fuels, and biomass energy whose supplies are running out [33].Several studies are conducted regarding wind renewable energy utilisation in Ethiopia. This review aimed to identify the potential of wind power energy, utilisation level challenges and opportunities in Ethiopia.

1.3 Objectives of the Study

1.3.1 General Objectives of the Study

The main objective of this systematic review is to identify the potential of wind power energy, utilisation level challenges and opportunities in Ethiopia.

1.3.2 Specific Objectives of the Study

- To identify the main challenges in utilizing wind energy in Ethiopia
- To assess wind energy potential and development opportunities in Ethiopia
- To examine the Status of Wind energy utilization in Ethiopia

1.3.3 Research Questions

Key research question, which the study seeks to find an answer for:

- What are the main challenges in utilizing wind power energy in Ethiopia?
- How many wind power energy potentials and opportunities exist in Ethiopia?
- To what extent does wind power energy utilization exist in Ethiopia?

1.4 Significance of the Study

The study is significant because it provides information on current wind energy utilization in Ethiopia. Also, provide information on how wind energy technologies are used in the country to light homes, produce hot water, heat homes, and generate electricity. And it can also demonstrate the country's wind power energy potential.

2. Methods

This section aims to show how journals were identified, the search strategies, the eligibility criteria i.e., inclusion and exclusion criteria, information sources, assessment of quality studies and analysis of data. A systematic review can be designed to provide an exhaustive summary of current literature relevant to a research question. Hence, this systematic review was prepared by summarizing and synthesizing the findings of empirical research results conducted in different parts of the study area. This review is composed of a comprehensive search for reliable databases on a specific topic, followed by an appraisal and synthesis of those studies according to a predetermined method.

2.1 Search strategy and design

The Web of Science, Journal of Citation Report, Scopus, Google Scholar, Citation Tracing, and Science Direct were among the major scientific databases from which a full collection of literature was made to conduct this systematic review. Data were thus retrieved from chosen publications and journals based on inclusion and exclusion criteria, mostly based on the degree of relation with the issue under investigation, published year, and study area. The particular keywords and phrases associated with the topic under investigation were used to exclude studies from the evaluation process. The selection method took into consideration articles that addressed the usage of wind power energy.

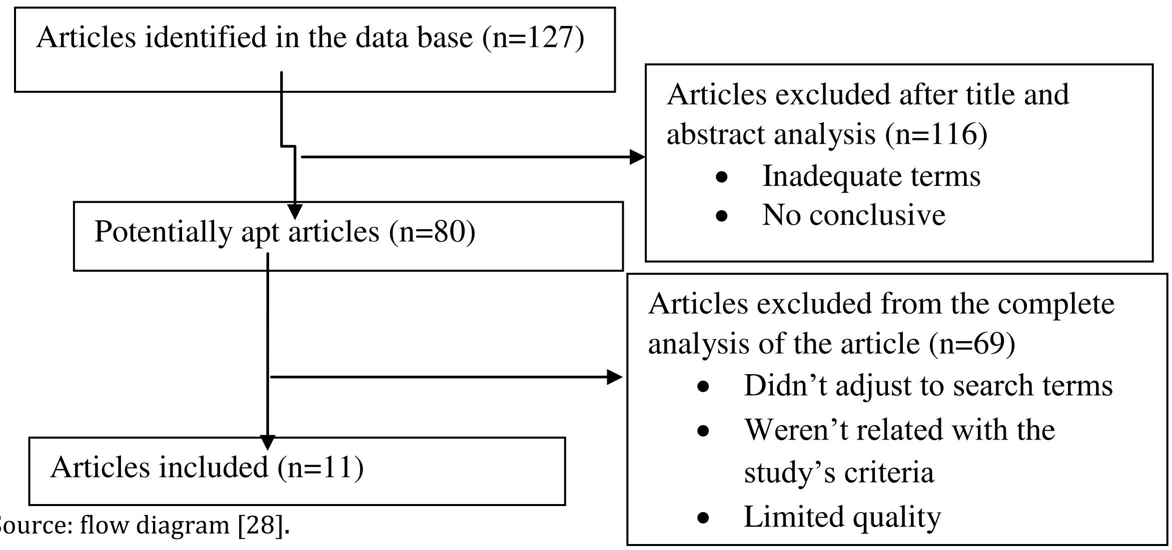
2.1.1**Inclusion criteria:** The criteria employed to incorporate different related studies into this systematic review were time of publication, similarity, type of publication and scope. The studies considered in the review do have the characteristics like their relation to the objective of the review, conducted within the scope of the review and published in a their-reviewed journal between 2010 and 2023 years. Moreover, an outstanding emphasis was given to the research works resulting from the scientific database consultations and even selected one from another within the same search engines based on the quality or position of the journal and its rankings.

2.1.2 Exclusion criteria: The studies published before 2010, conducted outside of the target area, with differences in objectives with similar topics and journals which were not well recognized by the Ethiopian Ministry of Education were excluded to be part of the systematic review. Besides, the review also ignored the journals which were not peer-reviewed and had a poor-quality position in its rankings.

2.1.3 Data collection: Different information like author/s name and publication date, journal name, type and category of publication, study settings, methods and key findings were collected and extracted systematically from the identified studies.

2.1.4 Quality assurance mechanism: To promote the reliability and validity of the systematic review, the [28]. flow diagram was strictly applied. As mentioned in Figure 1 below, the issues related to the review's objective, adequate terms, conclusiveness, inclusion/exclusion criteria, method of data analysis and concrete data presentation were strictly checked and controlled. Hence, taking into account all the aforementioned key procedures and criteria, from the total of 127 articles assessed, only 11were identified for this systematic review. To promote the validity of the findings of the study and to strengthen the triangulation of the data obtained, research conducted in the different parts of Ethiopia was fairly entertained. Most of the articles included in the study were case studies and mixed studies. But for the study, mixed studies aspects were selected to synthesize using the thematic analysis.

Figure 1. PRISMA flow diagram



Source: flow diagram [28].

3.2 Method of Data Analysis

Conducting a periodical systematic review of a given field of study enables us to comprehend the conceptual development of a discipline. This review is, therefore, executed to systematically analyze wind power energy research articles published in the previous 13 years, reassess the past, understand the present, and envisage the future of wind power energy utilization and development. Thematic and summative content analyses were employed to examine the contents of each publication. The current study provides up-to-date insight into the wind power energy utilization and development literature by highlighting the main themes and trends of wind power energy utilization and development research over the last thirteen years.

2.3 Description of the study area(Ethiopia)

Ethiopia is located in the region of Eastern Africa called the "Horn of Africa. "Ethiopia's boundaries are 3° to 15° north of the equator and 33° to 48° east of the Greenwich Meridian.GMT+3, the time zone [26]

Ethiopia, a nation of 1.1 million km2, is situated in the northeastern part of the Horn of Africa. With Somalia to the east and southeast, Djibouti to the east, Eritrea to the north and northeast, Kenya to the south, South Sudan to the southwest, and Sudan to the west, the landlocked country has shared borders [15].

Ethiopia has a substantial amount of terrain variation and a tropical monsoon climate. There are three major climatic zones: the hot lowlands below 1500 meters, the temperate zone between 1500 and 2400 meters above sea level, and the cold zone comprising the central regions of the western and eastern high plateaus. The mean annual temperature in the cool zone varies from less than 7 to 12 C in the cold lowlands to more than 25 C in the warm lowlands. The mean annual potential evapotranspiration in arid and semi-arid areas ranges from 1 700 to 2 600 mm, whereas in dry sub-humid areas, it ranges from 1 600 to 2 100 mm [15]. Ethiopia's 2022 population totals 123 million and is growing at an annual rate of 2.6 per cent,1 making it the second highest in sub-Saharan Africa [32].

3. Findings of the Study

3.1 Location, Study approach, Objectives and methods of the studies

Table1, Location, Study approach, Objectives and methods of the studies

Author(s) Year of publication	**Location, Setting**	**Study approach**	**Main objectives**	**Methods**
[17].	Tigray region(Ethiopia)	Mixed	Wind energy potential and cost estimation of wind energy conversion systems(WECSs) f	present value of cost (PVC) method
[11].	WolytaSoddo and Dilla(Ethiopia)	Mixed	To assess the wind power potential of six sites in southern Ethiopia	Weibull distribution function
[14].	Amhara Regional State (Ethiopia)	mixed	Wind energy potential assessment in Nifas Mewucha, Amhara Province, Ethiopia	a comprehensive geographic information system (GIS)-based site-selection
[35].	Ethiopia	Mixed	To investigate techno-economically viable wind energy system that supplies electricity and Heat for a given residential community in Ethiopia.	HOMER software
[6].	Somali Region of Ethiopia	Mixed	To assess the suitability of stand-alone wind-solar PV hybrid power.	HOMER & MATLAB software
[23].	Tigray, Ethiopia	Mixed	Statistical scrutiny of Weibull parameters for wind energy potential appraisal in the area of northern Ethiopia	Paramount two-parameter Weibull function

[29].	Tigray, Ethiopian	Mixed	Wind energy potential and economic evaluation of WPS using WECSs in three selected locations of Northern Ethiopia	Weibull probability density function.
[18].	Tigray, Ethiopia	Mixed	Wind Energy Data Analysis and Resource Mapping of Geba Catchment, North Ethiopia	Wind Atlas Analysis and Application Programme (WAsP)
[7].	Ethiopia	Mixed	To review the current state of wind power utilization in Ethiopia	Different materials review
[9].	East Gojjam Zone, Amhara Region, Ethiopia	Mixed	To analyze the available wind energy data in East Gojjam Zone, Amhara Region, Ethiopia and develop a resource map	Wind Atlas Analysis and Application Programme (WAsP)
[36]	Mossobo-Harena area, North Ethiopia		Wind resource assessment and wind farm modelling	Wind Atlas Analysis and Application Program

Table 1, Location, Study approach, Objectives and methods of the studies[17,11,14,35, 6, 23,29,18,7,9,36]

3.2 The status of wind power energy utilization, development Opportunities and challenges in Ethiopia

Table2,The status of solar energy utilization, development opportunities and challenges in Ethiopia

Author Year of publication	**Findings of the studies/The selected articles**		
	Development of level wind power energy in Ethiopia	Potentials and Opportunity	Challenges/ and Limitations
[17].	The VESTAS V110-2.0 at Mekele achieves the maximum capacity factor of 7.873%, while the POLARIS P15-50 at the Shire achieves the lowest capacity factor of 0.002%. The lowest average cost per kWh was obtained at Mekele using VESTAS V110-2.0, while the highest average cost was found at the Shire using POLARIS P15-50.	For electrical and mechanical purposes, Atsbi, Chercher, Mekele, and Senkata were the most lucrative hydropower plants in the nation.	Lack of policy implementation, financial and technicalassistance
[11].	suitable for large-scale grid-connected wind. , all the sites have more than a 50% chance that the wind speeds are greater than 4***ms***-1and hence are suitable for stand-alone electrical and mechanical applications, such as battery charging and water pumping.	All the sites have more than a 50% chance that the wind speeds are greater than 4***ms***-1and hence are suitable for stand-alone electrical and mechanical applications.	The capacity of energy/Applicability is limited only tobattery charging and water pumping.

[14].	The monthly mean wind speed is range from 4.3 to 9.1 m/s while the annual mean wind speed ranges from 6.23 to 6.65 m/s. The annual mean value of the Weibull shape parameter is between 2.41 (in 2019) and 5.92 (in 2016). The highest mean power density with the value of 152.921 W/m2 was observed in 2016 and the lowest mean power density with a value of 125.738 W/m2 observed in 2017.	NifasMewucha is a fairly good location in terms of wind generation potential.	The variation of air density, wind speed, and slope impact.
[35].	The loads necessary for community services including water pumps, clinics, schools, milling houses, business centres, and administrative offices are calculated in addition to residential loads. For a Moyale village with 100 households, a total of 369.45KW load, or 1417.5 KWh/year, is required.	The possibility for broad usage of renewable energy systems is created by the demand for clean power sources and alternative energy technology.	difficult to find nighttime data in Ethiopia while investigating the wind potential area.

[6]	The PV-generator-battery-converter setup is the most economical system or the system with the lowest net current cost. The setup has a total net present cost (NPC) of $155,875, an energy cost (COE) of $0.415/kWh, and a 91% contribution from renewable resources.	According to the study, the region has a lot of solar energy potential (6.12 KWh/m2/day).	wind potential is not as promising
[23].	The energy pattern factor method, the method of moments, and the mean standard deviation are the least effective approaches to fitting the Weibull distribution curves for the evaluation of wind speed data, particularly for four selected locations.	N/A	All of the chosen places have noted poor-quality wind power.
[29].	all the selected locations fall into the Class 1 category; hence they can be considered marginally for water pumping and small-scale electricity generation.	It is noted that the POLARIS P 12–25 and the POLARIS P 15–50 are the most economical options for electricity generation and water pumping applications in the region.	The capacity of energy/Applicability is limited only to battery charging and water pumping.
[18].	The average wind speed at 10 m above ground level(a.g.l.) varies from 3.7 m/s to 6.64 m/s. The mean powerdensity at 10 m a.g.l varies from 64 W/m2 to 301 W/m2. The prevailing wind directions are East and South East directions.	The catchment has goodwind power potential having mean wind speed and power density of 6.5 m/s and 288 W/m2,respectively	The capacity of energy/Applicability limitation

[7].	The utilization of those lands for the location of massive wind farms is made appealing by government assistance and the presence of enormous unpopulated areas in nations like Ethiopia.	Ethiopia has substantial potential to generate electricity from wind, geothermalandhydropower	One of the causes of Ethiopia's low use of wind energy is a lack of accurate wind data across the entire nation.
[9].	Debre Markos location has an average wind speed of 2.44 m/s, whereas the Motta site has a speed of 2.41 m/s. In the Debre Markos and Motta sites, the mean power density at 10 meters was found to be 17.82 W/m2 and 16.20 W/m2, respectively. North East, South East, South West, and North West are the predominant wind directions in the area.	there are some potential sites in the zone with class 2 and 3 sites with mean power densityreaching up to 400 W/m2.	most of the area of the zone is covered by Class 1 sites with a power density of less than 200 W/m2
[36].	The mean wind speed at the measuring site is 5.12 m/s at 10 meters above ground and 6.41 m/s at 40 meters above ground. At 10 and 40 meters above the ground, the mean power density of the measuring location was found to be 138.55 and 276.52 W/m2, respectively. About 60% of the wind at the location was measured to be blowing from east to southeast.	The site's average turbulence intensity was found to be 0.136 at 40 meters, indicating that the level of turbulence there is moderate.	Lack of policy implementation, financial and technical assistance

Table 2, The status of solar energy utilization, development opportunities and challenges in Ethiopia[17,11,14,35, 6, 23,29,18,7,9,36]

3. 3 The status of wind power energy potential in Ethiopia

Ethiopia is resolved to be able to develop, transform, and utilize its energy resources for the best possible economic development, even though the country currently has a limited capacity for power generation. Since less than 50% of rural communities in the nation have access to electricity, wood is still the primary traditional fuel used for cooking and heating in the majority of these places. In light of this, the Ethiopian government is actively building a sizable number of wind and hydroelectric facilities[7].

This systematic review was produced using eleven research articles that were conducted in various locations across the Ethiopian regional states, as shown in the aforementioned two tables. Ethiopian regions include Somali Region, WolytaSoddo and Dilla, Amhara Regional State, and Tigray Region. The findings of these chosen studies confirmed that the area has a high potential for wind energy and is endowed with renewable wind resources that will be essential to its future economic growth and provide significant environmental advantages by lowering the nation's consumption of biomass and fossil fuels. Ethiopia has a significant potential for wind energy due to its location, it continued. The country's wind energy potential may be a result of its location and the high Altitude of the region. Additionally, Ethiopia's future use of hydroelectric power as a source of energy may result in foreign exchange earnings and the attraction of foreign energy companies, which may lay the groundwork for the growth of wind energy in the nation. Innovative off-grid renewable energy-producing methods have arisen to supply low-cost electricity to rural populations.

3.4Actual status of wind energy site in Ethiopia

Ethiopia, a nation that generates the majority of its energy from hydroelectric dams, is currently expanding significantly its wind energy capabilities. One of the reasons for Ethiopia's poor use of wind energy is a lack of accurate wind data spanning the entire nation, although recent studies have revealed that Ethiopia has significant potential for producing electricity from wind, geothermal, and hydropower. The government has committed to generating power from wind farms by building eight wind farms with a combined capacity of 1116 MW along with several hydropower plants over the five-year Growth and Transformation Plan (GTP) period from 2011 to 2015. This is due to the significant wind resource in the nation[7].

By gathering information from various sources and utilizing a software program to analyze it, the wind energy potential at four different sites in Ethiopia—Addis Ababa (09:02N, 38:42E), Mekele (13:33N, 39:30E), Nazret (08:32N, 39:22E), and Debrezeit (8:44N, 39:02E)—has been examined. In terms of the monthly average wind speed, wind speed probability density function (PDF), wind speed cumulative density function (CDF), and wind speed duration curve (DC) for each of the four chosen sites, the results of the wind energy potential are provided. In short, for measurements made at a height of 10 m, the results suggest that the wind energy potential is reasonable for three of the four locations, with average wind speeds of about 4 m/s. The fourth site has a lower mean wind speed[5].

3.5Actual and Underdevelopment wind power in Ethiopia

Ethiopia is by far the fifth largest investor in Africa and has invested 100 million dollars in renewable energy. By 2020, Ethiopia hopes to have 5.2 GW of installed wind capacity, making it the wind capital of Africa[13].

Table 3, The wind power energy utilization and underutilized projects in Ethiopia since 2023.

Name of power plant	Installed capacity	Date of commissioning
Adama I	51 MW	2012
Ashengoda	120 MW	2012
Adama II	153 MW	2014
Underdevelopment		
Adama III	150 MW	Not applicable
Ayisha	300 MW	Not Applicable
Dabre Brihan	100 MW	Not applicable
Assella	100 MW	Not Applicable
Messobo	42 MW	Not Applicable

Table 3, Show us, we, can understand there are many wind power energy utilized and underutilized projects in Ethiopia since 2023 [13].

Ethiopia: Adama II Wind Farm (153 MW)
Photo credit: Ethiopia Broadcasting Corporation (2017)

According to Tiruye et al, [30]. Modern energy sources are a necessary input for social services like water supply, health care, and educational institutions, therefore a lack of access to them indicates a loss of opportunity for these services. The utilization and advancement of renewable energies in Ethiopia are hindered by several issues. The biggest obstacles to integrating renewable energy sources in Ethiopia can generally be divided into the following categories: Human and technological limitations, Financial and economic obstacles, Rural energy markets and infrastructure are underdeveloped, Informational obstacles, and Political obstacles.

3.6The challenges of renewable wind power energy Production in Ethiopia

This portion discusses Ethiopia's potential for renewable energy, as well as the difficulties and challenges it faces. Hydropower and wind power are currently Ethiopia's most potential renewable energy sources, with a combined installed capacity of about 7000 MW. It is believed that this analysis would clarify how Ethiopia may best utilize its plentiful renewable energy sources[1].

Except for hydropower, which is less than 9% of the national reserve, Ethiopia uses resources like solar, wind, and geothermal energy at less than 1% of their capacity. The study revealed that the primary obstacles to the development of renewable energy are financial, technological, legislative, and regulatory. Strengthened financial institutions, the establishment of capacity-buildingcentres, the inception of active community engagement, and the organization of institutions to assist the development of renewable energy are key indicators. Reducing the operation and maintenance cost is one of the potential actions that could reduce the cost of energy produced by offshore wind farms [8]. Based on the evidence that the country faced, these suggested measurements and policy challenges[22].

Table 4, Implementation barriers of wind energy technologies in Ethiopia

Technical	**Capacity**	**Information**	**Economic**	**Institutional**	**Policy**
Lack of creation of local content	Inadequate technology development	Inadequate dissemination efforts	Lack of affordability brought on by extreme poverty as seen by a low GDP per person	Institutional deficiencies at all levels regarding research infrastructure and research outputs, such as patents and publications that address the process of converting discovery into innovation	The policies are outdated especially the Energy Policy document from 1994
Lack of training facilities	Lack of technical expertise in the context of the STEM fields	Inadequate feedback mechanism	High-interest rates	Lack of a laboratory inventory between various Institutions	Lack of updated electricity master plans
Lack of maintenance facilities	Tripartite structure of Government, Academia, and Industry not fully realized	Lack of awareness	High payback period	Lack of capacity building programs at the various Institutions	Lack of appropriate Feed-in Tariff mechanisms
Lack of standards for	Outsourcing and	Lack of a common	Lack of a comprehensive	Lack of cooperation between	Lack of roadmaps

solar and wind energy	brain drain	database of data for replication	techno-economic assessment	Institutions in the context of fragmented researches	and standards for solar/wind technologies for embedded generation
Lack of a structured know-how exchange	Lack of state of the art manufacturing companies in solar/wind	Lack of quality assurance and control mechanisms	Lack of innovative and cost-efficient technologies	Lack of appropriate technology	Lack of an energization plan
Lack of qualified and competent engineers	Lack of solar and wind test stations and facilities	Fragmented coordination including weak linkages	High product cost due to lack of scale	Lack of supercomputers and advanced facilities	Lack of comprehensive wind/solar resource maps
Lack of frugal engineering practices	Lack of pilot projects for replication	Lack of modern ICT facilities	inferior imported goods	insufficient production of solar panels and wind turbine blades	Applying a top-down approach, energy targets were set without first analyzing the energy situation.

Table 4, Implementation barriers of wind energy technologies in Ethiopia [13].

4. Conclusion and policy recommendations

4.1 Conclusion

This paper has confirmed that Ethiopia has a significant wind energy potential. Additionally, it has proven that Ethiopia has access to enough wind energy to meet its energy requirements. To promote green energy, reduce poverty, and ensure energy security, Ethiopia must invest in relatively inexpensive renewable energy sources; yet, this effort is hampered by the high capital costs of alternative energy sources. Future energy investment pathways in Ethiopia are predicted to heavily rely on technological and efficiency advancements. Through the growth of local technological capacity and skill sets, policy actions could specifically target innovation. what kind of welcome they could get in possible host towns. Technological and efficiency advancements can be a growth driver in a world with limited resource availability. Due to their role in lowering resource scarcity, technological and efficiency advancements have positive economic effects. The price, accessibility, availability, and acceptability of clean energy to both rural and urban communities would be improved by such policies, which would also present Ethiopia with prospects for green growth.

Different studies are carried out regarding to wind energy potential in various regions of the country, including the Somali Region, Wolaita and Dila Ethiopia, the Tigray Amhara Regional State, and South Ethiopian countries and ethnicities. The findings of these chosen studies confirmed that the area has a high potential for wind energy. Renewable wind energy resources play a significant role in the region's future economic growth and provide significant environmental benefits by lowering the nation's consumption of biomass and fossil fuels. Future wind energy is also something that will be there. Because the installation material for wind energy in Ethiopia must be imported from abroad and costs significant sums of foreign currency, wind energy utilization is generally quite low.

4.2 Recommendations and policy implications

According to the review literature, Ethiopia must invest in quite costly renewable energy sources to create green energy, reduce poverty, and provide energy security. This effort is hampered, however, by the high capital costs of alternative energy sources. Future energy investment pathways are predicted to heavily rely on technological and efficiency advancements. The following policy implications and recommendations will be helpful for Ethiopia's effective and efficient use of wind energy: Government should subsidize the cost of importation of Renewable Energy Technologies (RET) Especially wind power energy to reduce the high energy cost in Ethiopia and make it affordable.

- More research into the techno-economies involving the initial and subsequent costs of wind power energy plants and their power efficiencies should be encouraged.
- Private individuals and organizations should be encouraged by appropriate authorities to invest in wind power energy supply.
- Government should create more awareness of the advantages derivable from Renewable Energy Technologies (RET) such as wind power energy technologies.
- Government can also consider placing restrictions on the importation of diesel and petrol engine generators because of their adverse effects on the environment even as the global community gear toward clean (green) energies.
- Loans should be provided with low-interestrates to motivate the establishment of renewable energy sources
- Foreign investment should be motivated by ensuring the easy acquisition of licenses for energy generation
- Policy framework, to incentivize renewable energy installation and discourage new fossil fuel projects can be formulated.

4. Declarations

4.1 Ethical Approval

Not applicable

4.2 Consent to participate

Not applicable.

4.3 Consent for publication

Not applicable

4.4 Availability of data and materials

- All data generated or analysed during this study are included in this published article (and its supplementary information files).

4.5 Competing interests

The authors declare that they have no competing interests.

4.6 Funding

Authors declare that they can afford the payment for the article publication fee at the payment time.(Self-sponsor)

4.7Authors' contributions

a. Ashenafi Bekele is writer of the article.

b. Workneh Ayall is Editor.

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