Addis Ababa University

Addis Ababa Institute of Technology (AAiT)

School of Mechanical and Industrial Engineering

Value Chain Mapping and Analysis of Ethiopian Wind Energy Technology

By

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A Thesis Submitted to the Addis Ababa University, School Of Mechanical and Industrial Engineering in Partial Fulfillment of the Requirements for the Degree of Masters of science in Industrial Engineering

Advisor

Kassahun Yimer (PhD)

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Addis Ababa University

Addis Ababa Institute of Technology

School of Mechanical and Industrial Engineering

This is to certify that the thesis prepared by Anteneh Hulluye, entitled Value chain analysis of Ethiopian wind energy technology and submitted in partial fulfillments of the requirements for the degree of Master of Science in Mechanical Engineering with the specialization of Industrial Engineering complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

By Anteneh Hulluye

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Declaration

I, Anteneh Hulluye, student of School of Graduate Studies of Addis Ababa Institute of Technology, declare that this research, entitled ***"Value Chain Mapping Analysis of Ethiopian Wind Energy Technology",*** is my original work and not the work of others. All sources of materials used in this research have been duly acknowledged.

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Anteneh Hulluye (Candidate) Date

This is to certify that the above declaration made by the author is correct to the best of my knowledge.

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Dr.-Ir. Kassahun Yimer (Thesis Advisor) Date

Dedication

I am dedicating this thesis to my beloved sister who has to mean and continue to mean so much in my life. Though your life was short, I will make sure your memory lives on as long as I shall live. May you find peace and happiness in Paradise!

Acknowledgment

I would like to take this opportunity to thank those people who have made this study possible. I owe a great debt of thanks, first and foremost to my advisor Dr.-Ing Kassahun Yimer for the sacrifices, continuous and unreserved support throughout the research work, for his invaluable advice and technical support in strengthening the work to be completed. His guidance helped me in all the time starting from research title selection up to completing of this thesis. I am so fortunate to have him on my side!

Further, I would like to extend my thanks to all AAiT, Industrial Engineering Department staffs and my fellow friends for their unreserved help directly or indirectly during my study at Addis Ababa University.

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Finally, I would like to thank all my family for their love, contributions and moral support throughout my research. I can't ever say this enough, but thank you.

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Abstract

With the rising of the world's energy demand, efforts have been directed towards maximizing the utilization of renewable energy resources. In order to meet such rising levels of energy demand, renewable energy technologies have been promoted as they have less environmental impact and contribute to the sustainable development of societies. In this regard, wind energy is mentioned as a genuinely promising source of renewable energy and it is one of the few green energy systems having an everlasting nature and abundance. The purpose of this study is to map and analyze the wind energy technology value chain in Ethiopia. The data was collected from government organizations, private sectors and wind farms made through questionnaire, interview and site visits. Descriptive statistics approach was deployed to analyze the collected data. Despite the tremendous potential of the wind energy and green development plan of the country, the manufacturing and deployment of wind energy technology is still in its infancy stage in Ethiopia. The results of this research showed that most of the micro-grids components could be designed, sourced, manufactured, installed and operated domestically with little support of skilled foreign experts. Also, in large scale wind technologies, there is promising local capacity potential to provide less complicated components and downstream services of wind power plant segments which can be taken as the first tier of the wind industry. And later, it would be possible to upgrade and move towards the upper end of the value chain with the involvement of the private sector participation in the short and medium terms. The weak integration and collaboration of actors, lack of and incentive schemes, low engagement of private sectors, lack of skilled work force and others are identified as barriers facing on the development wind energy value chain of Ethiopia. To overcome these challenges, local capacity building, local content requirement, initiating active community participation, promotion of mini-grade wind technologies, designing inclusive energy framework and road maps, and different financial incentive mechanisms are recommended as the top measurements to strengthen the development of Ethiopian wind industry and enhance the socio-economic benefits obtained from the sector.

Key words: Sustainable development, Renewable Energy, Wind Technology, Ethiopia, Value Chain.

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List of Acronyms

Acronym	Definition
P4G	Partnering for Green Growth and the Global Goals
CRGE	Climate Resilience Green Economy Strategy
NDC	National Determined Contribution
NEP	National Electrification Program
IRENA	International Renewable Energy Agency
qsp	Quality service price
DIWA	Danish Wind Industry Association
SWT	Small Wind Turbines
LSWT	Large Scale Wind turbines
MWE	Ministry of Water and Energy
OEMs	Original Equipment Manufacturers
IC	Innovation Capability
R&D	Research and Development
GWEC	Global Wind Energy council
AFDB	African Development Bank
GTP	Growth and Transformation Plan
FDI	Foreign Direct Investment
GoE	Government of Ethiopia
LCR	Local content requirement
IEA	International Energy Association
WPP	Wind Power Plant

List of Units

Units	Definition
GW	Giga watt
GWh	Giga Watt hour
MWh	Megawatt hour
Rpm	Revolution per minute
KV	Kilo volte

Clarification of Concepts

Renewable energy	For the purpose of this thesis the term renewable energy refers to the energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.
Conventional energy	This refers to the dominant energy sources that currently generate electricity including fossil fuels (coal, oil and natural gas), nuclear energy and large hydro energy.
Value chain	The linked set of value-creating activities all the way from basic raw material sources for component suppliers through the ultimate end-use product delivered into the final customers' hands.
Local content requirements	Local content requirements are policy measures that require foreign or domestic investors to source a certain percentage of intermediate goods from local manufacturers or producers.
Large scale wind turbines	Utility-scale wind turbines range in size from 100 kilowatts to as large as several megawatts.
Small scale wind turbines	The term refers to the wind generation systems with the capacity to produce up to 100 kW of electrical power and is typically used in remote, off-grid locations for residential, public organizations, and small business applications where a connection to the utility grid is not available.

CHAPTER ONE

BACKGROUND OF THE STUDY

1.1. Introduction

In this modern era, energy security is central factor to sustainable development and prosperity of a society in any nations (Sarakika, 2015). It is fundamental to the continued survival of a people: their socio-economic and political development; propensity for future growth, including the rate of growth of infrastructural facilities; level of agricultural and industrial production; state and level of delivery of social services; etc. (Igoni, 2016).

However, despite being the leading factor on the development of any nation, the traditional energy sources are also criticized for rising of greenhouse gas emissions and climate changes. The existing global demand for energy is mainly met by conventional source of energies like coal, natural gas and oil. This heavy dependence on fossil fuels results in a set of global environmental challenges. Hence, the global efforts have been directed towards increasing the share of renewable energy sources to address the energy poverty and alleviate environmental effects. Among the different renewable energy options, wind technology appears to be first in the future in resolving energy security issues and environmental concerns. Based on its abundant in nature and zero environmental impact the generation of electricity by wind energy is considered to be one of the most genuinely promising source of energy resources in the future. The improvement of production methods and accelerated innovation of wind turbines in the recent years have resulted in the significance reduction of investment costs and increasing in deployment of wind energy plants. During the last two decades, the global wind power market has continued to grow exponentially with an average annual rate of 21.3% and has reached 622,704 MW in 2019 (IEA, 2019). According to various researches conducted in the sector the future wind market is expected to grow at both national and global level, and has estimated the total installed capacity of wind power to 6000 GW, that would cover 35 precent of the world electricity demand in 2050 (GWEC,2019).

Ethiopia is one of the least developed countries in the world and has the lowest rate of access to modern energy services. Its energy supply is primarily based on traditional biomass and only about 45% of the country population has access to electricity (Bekele S. , 2017). As more than 80% of the country's population is engaged in the small-scale agricultural sector and live in rural areas, traditional energy sources represent the principal sources of energy in the country, followed by oil and hydropower. Currently the total installed capacity of electric generation is about 4.5 GW (2019) mainly generated by hydro (90%) and followed by wind energy (7.6%) (Kalbessa, 2020).

The population is growing at 2.6% annually and projected to reach 130 million in by 2025. Furthermore, the demand of energy production in Ethiopia will keep increasing because of accelerating industrialization, urbanization and fast growing economy. Consequently, the future energy demand of the country is expected to rise by a rate of 10 -14 % per year till 2037 and reaches 54.8 TWh/year in 2030 (EEP, 2019).

In order to address these challenges as well as to meet the growing demand, the Ethiopian Government has launched the country's Climate Resilient Green Economy Strategy (CRGE), National Determined Contribution (NDC) and National Electrification Program (NEP), with the policy objective of expanding electricity generation from renewable sources of energy for domestic and regional markets (Alam H., 2018). Accordingly, the government has set a target towards universal access by 2025 through integrated planning of 65% access by grid and 35% access by off-grid energy system. In achieving these programs and assuring the sustainable development of the country, a priority is given for the development of the renewable energy sector and particularly the wind source (Elizabeth Bryan, 2018).

Despite the tremendous potential of the wind energy and green economy development plan of the country, the manufacturing and deployment of Wind energy technology is still in its infancy stage in Ethiopia. Studies have shown that the local manufacturing of wind technologies is not only important for the development of wind energy, but has the potential to create high value-added employment opportunities, reduce cost of energy technology and develop local economies having wider benefits than just the electricity it provides (Gebreslassie, 2019). With lack of local wind technology value chain, all components of wind turbines of Ethiopia are imported to fulfill the local demand. In this respect, this paper aim to explores the barriers and opportunities for local manufacturing and deployment of wind energy technologies such as availability of resources, manufacturing capacity, project deployment capacity, research and development capacity, skilled workforce, government policies and regulations.

1.2. Statement of the Problem

Among more than 110 million people living in Ethiopia, 55% of the populations in the country have no electricity infrastructure (Massaro, 2020). These households depend on inefficient and polluting energy sources such as biomass for cooking, kerosene and wax-wick for lighting, the shortage of electricity generation capacity will be a major obstacle to development in the country. Ethiopia, is faced with the challenge of generating more power to meet existing and the future growing demand in relation to the industrialization program of the country. Despite this and the added fact that the country is well endowed with wind energy resources and has an economically feasible potential of 1000 GW which constitute plausible solutions to address existing power shortages with a high degree of reliability. However, in exploiting this vast potential, still resources remain largely untapped and underutilized, does not exceed 0.5% of national capacity and only contribute about 7.5% in the current electric power consumption. At the same time the installed wind power plants turbines are not operating full potential, due to poor supply of spare parts. As the two wind farm annual energy production report shows: the total estimated loss of energy in Adama one and Adama two wind power plants in 2009/2010 was estimated 27.01Gwh and 10,924.175 MWh respectively.

The disparity between potential and extent of exploitation raises questions about constraints to development of wind energy in the country. Unfortunately, though the cost of energy delivered through such systems is relatively low over the lifetime of a system, but the upfront capital cost of technology is still remains exceedingly high, due to the tight supply of towers and other components, as well as the high prices for transportation of components (IRENA., 2015). They represent the major fractions, in the range of 60 to 75 percent, of a wind farm total installed cost. The transportation costs of wind technology components and parts have also taken as one barrier for such countries which have great potential of the resource.

Accordingly, it suggest that local manufacturing of most of the wind turbine components would probably lower the cost of wind energy, especially since it reduces the transportation cost of components ((Joern, 2014). Studies have also demonstrated that local production of wind energy components could reduce the power plant costs by 25% in the long term (Razavi, 2012). Furthermore, the local manufacturing of wind technologies and its components could have a bigger role to play through socio-economic benefits and is perceived as an opportunity for industrial diversification, new value-chain activities and technology transfer which are expected to create substantial employment opportunities for the country's growing population and power for income-generating activities.

Hence, a detail mapping and analysis of the full range of activities along the value chain involved in supply of raw materials, manufacturing of components, installations and operations to the maintenance and decommissioning is absolutely crucial for the development of wind power plants and industry. This research work aims to analyze and examine the current situation of Ethiopia Wind industry along the phases of upstream and downstream activities of the value chain.

The following basic research questions were presented as guiding questions to find solution for the problem stated in the statement of the problem.

- What is the Status of the value chain of wind energy technology in Ethiopia?
- Which parts of the wind energy value chain can be substituted locally and offer the best prospects for generating local benefits?
- What are the potentials and challenges of locally developing wind energy technology?
- Which government policies and incentive mechanism could adequately support wind energy technology localization?

1.3. Objective of the Study

1.3.1. General Objective:

The general objective of this research is to map and analyze the value chain of Ethiopian wind energy technology and identified the obstacles and enablers that restrain the development of local wind energy in Ethiopia.

1.3.2. Specific objectives

- To examine the current local value chain of the wind energy in Ethiopia
- To assess the competitive position and manufacturing potential of the key components and services of the wind energy value chain in Ethiopia
- To analyze and identify the various gaps and barriers hindering the development of local manufacturing capacities
- To identify the opportunities and challenges and set recommendations to enable the wind energy value chain localization in the country

1.4. Significance of the Research

The significance of this research is to explore the opportunities and challenges in the wind energy technology value chain in Ethiopia. In doing so, it may:-

- Recommend a new value chain system that the can improve problems in the existing value chain of wind power technology
- Create initiation on investors and stakeholders(materials suppliers, manufacturers, assemblers, installation, maintenance etc.) to participate in the sector by showing the advantages in the value chain
- Recommend policies to government's policy makers which can be used as bases to construct support policies to help stakeholders to improve their value chain
- Provide information on findings and results for future studies of researchers.

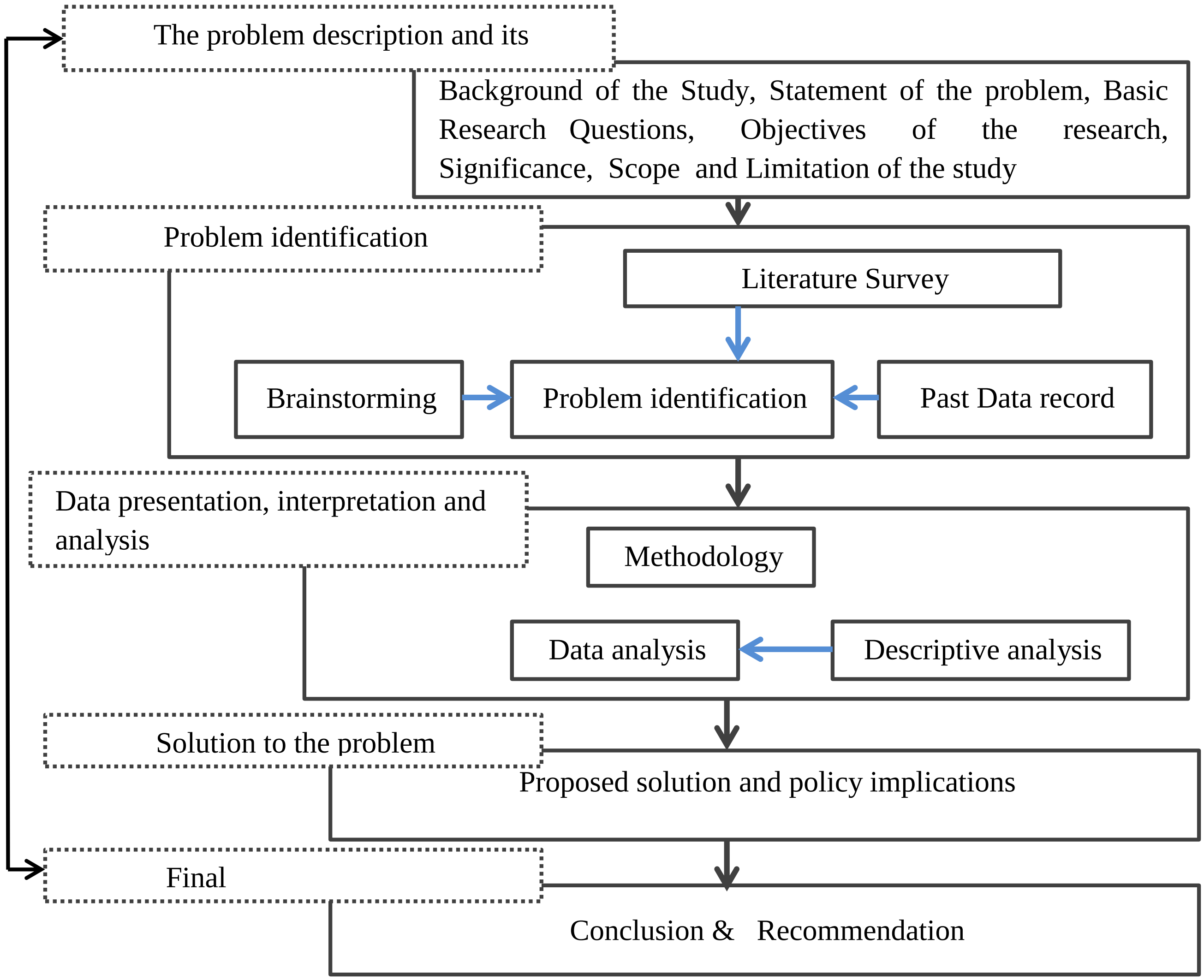
1.5. Scope and Limitation of the Study

Generally this Research focuses on value chain of Ethiopian wind energy technology. It covers the whole value chain segments starting from designing and planning, manufacturing, installation, operation and maintenance. Furthermore, the technological capability of the country has been evaluated with respect to wind turbine and component manufacturing, project execution and innovation capability. However, the capability of individual firm with respect to each specific activities and component were not measured and evaluated due to time and financial constraints.

1.6. Organization of the Study

The research consists of five chapters. Chapter one introduces the research by discussing the main problems of the study and different approaches to it. Chapter two gives insight to the wind energy technology, the global and national status overview, the global industry's value chains and technology innovation systems. This chapter also comprises the literatures reviews related wind energy technology value chain and technology innovation systems and analysis to identify the research gap. The third chapter deals with the methodology used to collect data for the research. The fourth chapter present the data collected through different methods and makes the analysis and propose the most appropriate value chain model for Ethiopian wind energy technology. The fifth chapter gives conclusions and recommendations with proposed

Future research works. Finally, References and Annexes are included in the last part of the research. More specifically the contents of the chapters have been organized as follow:


The problem description and its
Background of the Study, Statement of the problem, Basic Research Questions, Objectives of the research, Significance, Scope and Limitation of the study
Problem identification
Literature Survey
Brainstorming
Problem identification
Past Data record
Data presentation, interpretation and analysis
Methodology
Data analysis
Descriptive analysis
Solution to the problem
Proposed solution and policy implications
Final
Conclusion & Recommendation

CHAPTER TWO

LITERATURE REVIEW

2.1. Concepts and Definitions of Value chain

2.1.1. Introduction

Chains composed of companies or individuals that interact to supply goods and services are varyingly referred to as production chains, value chains, marketing chains, supply chains, or distribution chains. These concepts vary mainly in their focus, in the activity that is emphasized, and in the way in which they have been applied. However, they all describe the interactions of firms and processes that are needed to deliver products to end users, and they all aim to identify opportunities for and constraints against increasing productivity. Although it is impossible to make fine distinctions among these often overlapping concepts, it is still worthwhile to provide some basic definitions. For example, a value chain describes the full range of activities required to bring a product or service through the different phases of production, including physical transformation, the input of various producer services, and response to consumer demand (Porter M. , 1985). As such, value chains include the vertically linked interdependent processes that generate value for the consumer.

2.1.2. What is Value Chain?

According to Philp Kotler and Kavin Lane Keller, value reflects the perceived tangible and intangible benefits and costs to customers (Keller, 2006). It can be seen as primarily a combination of quality, service and price (qsp) called the "customer value triad." It is a capability provided to a customer of the highest quality, at the right time, at an appropriate price as defined by the customer. Michael Porter, has described value is the amount buyers are willing to pay for what a firm provides them. Accordingly, the consumer is viewed as the source of value. Creating value for buyers that exceeds the cost of doing so is the goal of any generic strategy.

A value chain can be defined as the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final customers, and final disposal after use. Value activities are the physically and technologically distinct activities a firm performs. According to Porter, a value chain consists of two sequences of activities, i.e. primary and support activities. Primary activities include inbound logistics, operations, outbound logistics, marketing and sales, and service. Support activities include firm infrastructure, human resource management, technology, and procurement.

2.1.3. Why is value chain analysis important

The value chain concept was first introduced and popularized by Michael E. Porter in 1985 (Porter M. , 1985). Porter (1985) propounded value chain theory in his book "Competitive Advantage", with the model identifying value chain as an interlinked chain of activities and subsystems that bring value to the customers while yielding competitive advantage for the enterprise. Porter (1985) introduced the concept of value chain as the basic tool for examining the activities a company performs and their interactions with a view to identifying the sources of sustainable competitive advantage. It separates the activities of a firm into a sequential stream of activities and is used to analyze and establish the importance of the different activities in delivering the final product/service, thereby facilitating the identification of core and non-core activities. The value chain is therefore a logical way of looking the overall business activities with purpose to mobilize these various strategic impacts.

Value chain analysis is useful research approach for identifying constraints and opportunities for the provision of products and services. The value chain analysis involves breaking a chain into its constituent parts to better understand its structure and functioning. Thus, the analysis consists of identifying chain actors at each stage and discerning their functions and relationships; determining the chain leadership and sustainable production, to facilitate chain formation and strengthening; and identifying value-adding activities in the chain.

An approach used in value chain analysis various from researches to researches depends on the research questions. The most common approaches of value chain study includes Value chain mapping; identifying the distribution of benefits of actors in the chain; examining the role of upgrading within the chain; and the role of governance in the value chain are commonly employed in renewable energy technologies value chain analysis in general (Kaplinsky and Morris, 2003). Value-chain analysis systematically maps the actors participating in the production, distribution, processing, marketing, and consumption of a particular product. The value chain analysis involves steps like mapping the core processes in the value chain; identifying and mapping the main actors' involved in these processes; mapping flows of products, in formation, and knowledge; mapping relationships and linkages between value chain actors; and mapping supports and services that feed into the specific value chain. The global value chain analysis of renewable energy technologies is particularly important for developing countries to explore opportunities for local value creation and upgrading (Anna Bruce, 2007). An analysis of the value chain localization and upgrading process includes an assessment of the capability of actors within the chain as well as the government policies. Governance issues play a key role in defining how such a local value creation and upgrading occurs. Besides, the structure of regulations, financial incentives and standards can influence the localization of any products and services. Hence, governance is import ant from a policy perspective by identifying the institutional arrangements that may need to be targeted to improve capabilities in the value-chain and increase value-added in the sector by systematically understanding these linkages within a network; one can better prescribe policy recommendations.

2.2. Wind Turbine Technology

2.2.1. Wind Power Harvesting System

Initially wind is formed from expansion and convection of air as solar radiation is absorbed on Earth. The uneven earth's terrains get unequally heated by the sun's rays. Because the earth's surface is made up of different types of land and water, it absorbs the sun's heat at different rats. This makes some region of the earth warmer than the others. The hot air in the warmer regions becomes less dense and light and thus rises up. This upwardly movement of the hot air creates a vacuum which is immediately filled up by cold air from the adjacent cooler realms. This movement of air creates wind which is called kinetic or motion energy. It can be either converted into electrical energy by power converting machines or directly used for pumping water, sailing ships, or grinding gain.

Wind energy conversion systems (WECS) are designed to harvest the wind by convert the energy of wind movement into mechanical power. With wind turbine generators, this mechanical energy is converted into electricity and in windmills this energy is used to do work such as pumping water, mill grains, or drive machinery (Gilbert, 2004). Today's wind-harvesting technology includes blades connected to a rotor, a gear box, a braking system, a turbine, and a generator (see fig 2.4). The blades are aerodynamically designed to create a lifting force as the wind flows towards the turbine, which causes the rotor to spin. The rotational speed of the turning blades is not fast enough to generate electricity, so a gear box is needed to increase the rotational speed of the shaft. The gear box connecting the low-speed shaft to the high-speed shaft and increases the rotational speeds from about 30-60 rotations per minute (rpm), to about 1,000-1,800 rpm; this is the rotational speed required by most generators to produce electricity (Hau, 2013). A nacelle and the rotor is used to houses the generating components of the wind turbine and to connects the blades to a shaft within the nacelle, which connects to a generator respectively. An anemometer and wind vane connected to the top of the wind turbine measure wind speed and direction to send signals to a yaw- and pitch-system. These mechanisms ensure that the wind turbine is facing the incoming wind flow (yaw) and the blades are tilted enough (pitch) to cause efficient lift force from the wind. Additionally, if the wind speed becomes too turbulent, the anemometer sends a signal to the braking system to prevent damage to the rotor, gear box, and generator.

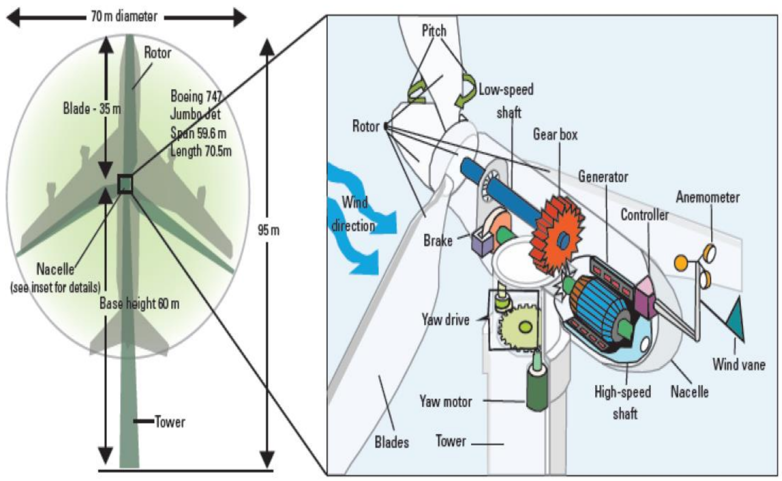


Fig 2.1: Composition of a typical large turbine and key components source (dti, 2015)

2.2.2. Current status and future prospect of global wind Energy

The global wind power market continued to grow exponentially since 2000 with an average annual rate of 21.3% (IEA, 2019), as a result, wind power has quickly become part of the mainstream in the global electricity supply. According to IRENA, the worldwide wind energy capacity has reached 622,704 MW and accounts 4.8% of worldwide electric power usage. The vast majority of this capacity has been located on land; offshore wind capacity surpassed 51 GW at the end of 2018, with accelerated growth expected in the future, especially in Europe and Asia (GWEC, 2019). In 2019, the cumulative installed wind power capacity was increased by 59 GW worldwide including nearly 51 GW onshore and 8 GW offshore, witnessing the massive development of this sector. The Global cumulative installed wind power capacity grew from 23,900 MW to 622,704 MW during 2001–2019 as shown in figure 2.2.

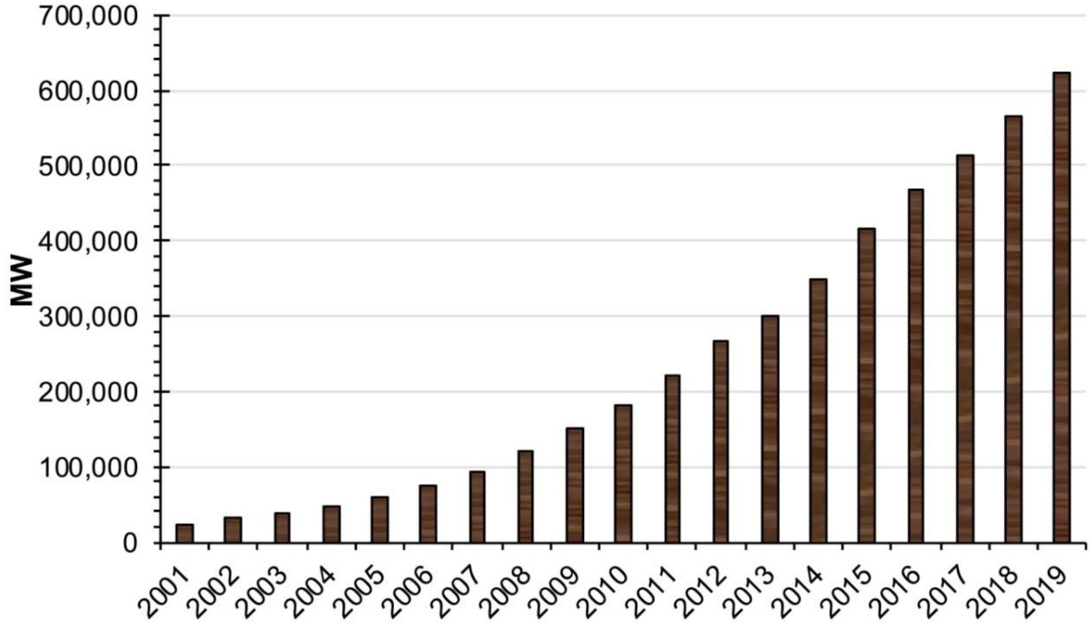


Fig. 2.2. Global cumulative installed wind capacity from 2001 to 2018, (GWEC, 2019)

The Global Wind Energy Council Report on “The global wind power outlook” witnessed the development of wind power market in the next decades all over the world. The market for wind power is expected to grow at a cumulative growth rate of approximately 7.9% during in the next five years, which makes it the world’s most rapidly growing energy source, whether conventional or renewable. By 2030, wind power is expected to reach 1787GW and supply up to 20% of global electricity. According to the International Renewable Energy Agency report entitled as “the future of the wind” and released in October 2019, in 2030, “wind energy will be a major modern energy source, reliable and cost competitive in terms of cost per kWh, therefore the future of wind power is looking bright”. In the same report the organization has estimated the total installed capacity of wind power to 6000 GW, which would cover 35 percent of the world electricity demand in 2050.

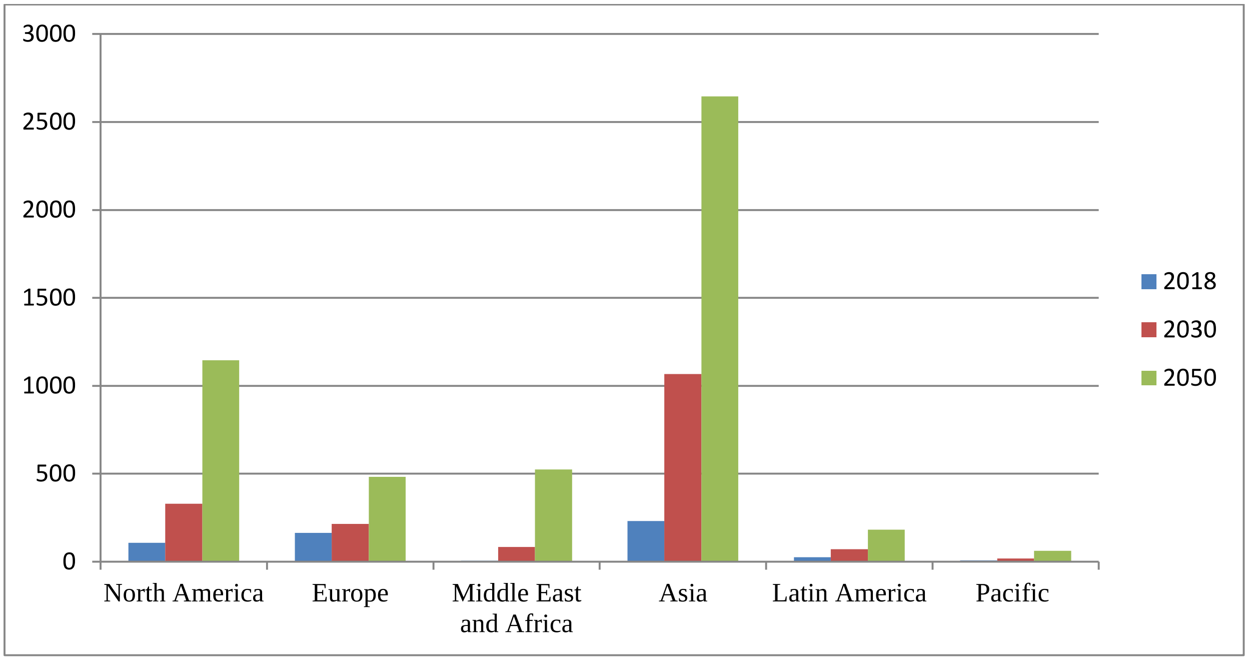


Fig 2.3. The installed and forecasted onshore wind capacity by region (GWEC, 2019)

Installed capacity to harness wind energy in Africa is expected to increase 12-fold over the next decade, in line with the global trends and technological innovations now characterising the wind market (AFDB, 2017). The continent is tipped to emerge as a wind energy development hotspot, especially considering new developments in Ethiopia, Tanzania, and Mauritius, as well as commitments made in South Africa and Morocco (GWEC, 2016). It will be a key technology to produce cost-competitive, sustainable energy, transform the region's energy system and to ensure access to modern electricity for all, create skilled jobs and drive local economic growth.

The sub-Saharan Africa wind market is also beginning to awaken and this should come as a major boost for wind energy in Africa. Persistent droughts within sub-Saharan Africa pose a major functional risk for most hydro-power generation projects that most countries have often prioritized. There is also some pressure to reduce the reliance on fossil fuels as a power source due to the environmental ills resulting from heavy reliance on these sources. As a result, most African countries, especially within sub-Saharan Africa where most wind power laggards.

Some of the major factors attributing to the forecasted global and regional wind power growth are:

i. The increasing population and economic development, global energy demand is rising rapidly. Many countries across the globe have been experiencing an energy gap, which is being broadened by the deliberate depletion of fossil fuels, which needs transformation of the world's traditional energy system with excessive uptake of energy-efficient renewables. In turn, this is expected to enhance the development of renewable energies like wind power that is clean, environmentally sound and, as long as the sun keeps shining and winds are created, completely renewable (Gilbert, 2004).
ii. Rapidly falling costs per kilowatt have made wind energy the least-cost option for new power generating capacity in a large and growing number of markets around the world. This is due to increasing economies of scale, more competitive supply chains and further technological improvements. According to the various researches conducted in this area, the growing size of wind turbines will provide opportunities for further reduction in the cost of wind energy.
iii. Targets for renewable energy and for reductions in CO2 emissions also continue to be important drivers of wind power.
iv. The favorable government policies, the increasing investment in wind power projects and the reduced cost of wind energy which has led to an increased adoption of wind energy, thereby, positively contributing to the demand for wind energy
v. Wind energy supports a strong domestic supply chain (create socio-economic benefits). Wind has the potential to create job opportunities for local skilled and unskilled labors along manufacturing and deployment chains like in manufacturing, installation, maintenance, and supporting services.

Generally, Recognizing the above-mentioned driving factors, it is believed that in the next decade wind energy could grow to a fully-competitive mainstream energy source globally instead of using it as an alternative energy source like today’s trend.

2.2.3. Wind power turbine types

The modern wind turbines fall into two basic groups based on the axis in which the turbine rotates:

a. Horizontal axis wind turbines (HAWT)

b. Vertical axis wind turbine which is with blades that spins around a vertical axis (VAWT).

The horizontal- axis wind turbines in which the axis of rotation is horizontal with respect to ground (and roughly parallel to the wind stream) , and the vertical-axis turbine in which the axis of rotation is vertical with respect to ground (and roughly perpendicular to the wind stream). All the Horizontall-axis wind turbines and the vertical wind turbines can be built with two or three blades. However, the the three blade horizontal axis wind turbines the most common type installed in wind farms (including the offshore wind farms) as more electricity can be produced from a given amount of wind. More than 90% of wind turbines in use today are thought to be of HAWT design (GWEC .. , 2018). While, Vertical axis wind turbines are communally used on sites where the wind direction is highly variable or has turbulent winds. With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier.

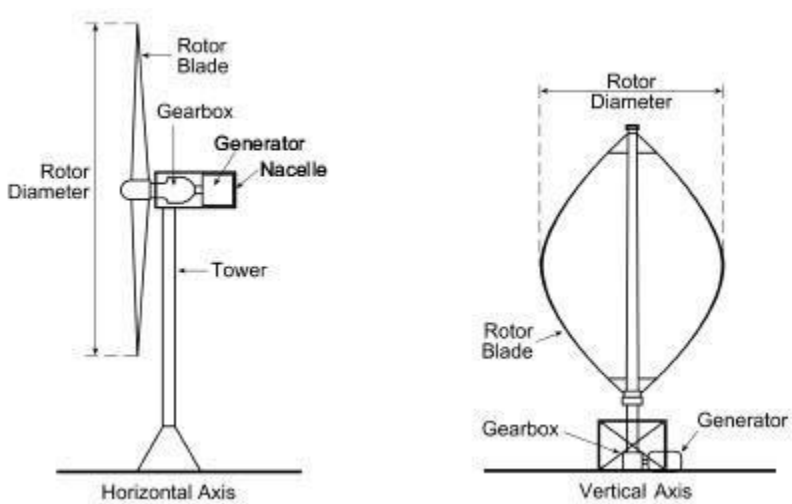


Fig 2.4. The horizontal and vertical axis wind turbines form left to right respectively

Apart from the above classification of wind turbines the distributed wind market also includes wind turbines and projects of many sizes. These can be classified into three turbine size segments: wind turbines up through 100 kW (in nominal capacity) referred to as "small wind," mid-size wind turbines 101 kW to 1 MW, and large-scale wind turbines greater than 1 MW (U.S Department of Energy, 2015).

The small wind turbines (SWT) are specially designed for small rural village electrification without high-grid connection in terms of small-grid or off-grids , aiming to take advantage of wind potential in the urban, near -urban, or the built environment as well as in populated areas where the implementation of large turbines would not be possible or preferred. More rarely the produced energy can also be consumed or stored in order to provide energy autonomy or an auxiliary energy source, as shown in fig 2.4. These can be used for various applications such as generating electricity, charging batteries, pumping water, or communications for homeowners and remote villages.

Intermediate-sized wind power systems often incorporate additional generating systems like photovoltaic, small-scale hydro and/or storage systems. These "hybrid" systems provide improved reliability of power supply and operational flexibility. When the power from the wind turbine is not sufficient to operate the load, the alternate power source comes on-line. These systems have significant potential for rural electrification. These systems can provide more cost-effective electricity than diesel and transmission line extension for communities in the remote areas with good wind resources and no utility grids.

The large scale wind turbines are usually built and operated close together forming "wind power plants "or "wind farms" to supply electricity for large grid-connected systems. This large grid-connected wind turbines are more common in the global wind market and takes the largest share of the total installed capacity among the previous two categories.

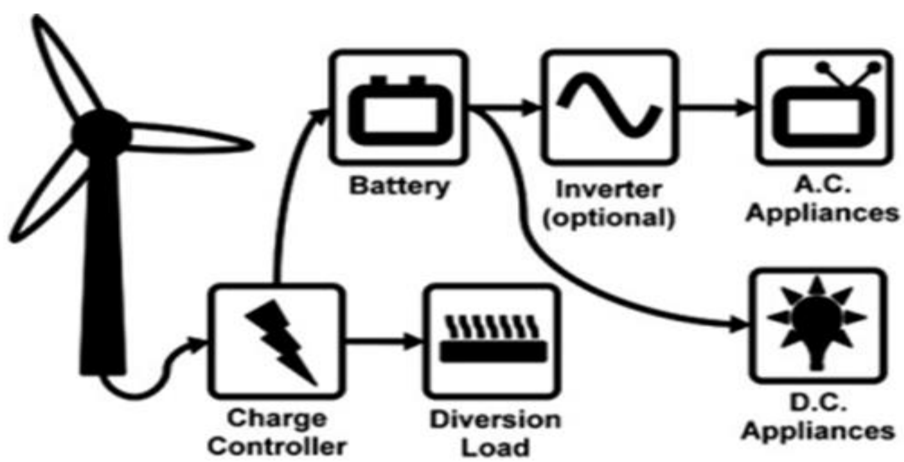


Fig 2.5 Schematic of the power flow in a typical off-grid wind power system (Eales, 2013)

2.2.4. Main complements of wind turbines

As it is mentioned in the previous section wind turbine are made of wide range of components that include mechanical, electrical and civil construction. The primary components in a wind energy generating system are described here below with special reference to three blade horizontal wind turbines which is also already installed in Ethiopian wind farms.

Rotor and Blades

The rotor works as collecting the energy from the wind, the rotor and its blades convert the wind power to a rotational mechanical power. The rotor includes the most important components of wind turbines such as blades and hub, and it makes up 10 to 14 percent of the weight and 22% of the total costs of the wind turbine (Huenteler, 2015). Different materials are used for the production of rotor blades. Resin, glass fiber, carbon fiber, steel and balsa wood are some of the most common materials in blades (AWEA, 2009). The turbine rotor and hub assembly spins at a rate of 10 to 25 revolutions per minute (rpm) depending on turbine size and design (constant or variable speed). The blades of the rotor are designed to spin in the wind, driving the turbine generator. Sometimes gearing is used to increase the frequency for electricity generation. The hub is the component holds the transmission motion and the rotor together to nacelle and it transmits the loads that which are generated by the blades.

Nacelle

This is the main structure of the turbine used to housing the main turbine components. The nacelle case contains the drivetrain components (bearings, coupling, gears, generator, and shafts) and the analytical and auxiliary equipment (anemometer, brakes, controller, convertor, cooling system, sensors, and yaw drive system). The Nacelle are made of fiberglass and other components are constructed from aluminum, cast iron, copper, plastic, stainless steel, and steel alloys (AWEA, 2009).

The drive train (Gearbox, shafts and Generator) convert the rotating force in to electrical power. The gearbox increases the rate of rotation of the rotor from a low value typically below 100 rpm to a rate between 1200 – 1800 rpm, suitable for driving a standard generator. Then the generator converts this mechanical energy to electrical energy. Typically, generators operate at 690 volt and provide three-phase alternating current (AC). The Doubly-fed induction generators are more common in wind power plants than other generator types used for direct-drive designs, this is due to advantage of induction generators is that they are rugged, inexpensive, and easy to connect to an electrical network. A yaw mechanism also housed in the nacelle to constantly ensure that the turbine constantly faces the wind.

The turbine's electronic controller monitors and controls the turbine and collects and record operational data. The computer-based central control panel of the wind turbine is typically mounted inside the tower. This control system collects operational data and monitors a vast number of parameter like gearbox and generator temperature, wind speed (if wind speed is above some set limit, the wind turbine may be stopped for safety reasons), vibration, and so on. The wind farm operator is therefore able to have full information and control of the turbines from a remote location.

Tower and foundation

Tower is a vital part of wind turbines that keeps the turbine up in the air. It provides the support system for the turbine blades and the nacelle and serves as the conduit for electrical and electronic transmission and grounding. Towers are most commonly tapered, tubular steel pole. However, concrete towers, concrete bases with steel upper sections and lattice towers are also used (Hau, 2013). Tower heights tend to be very site-specific and depend on rotor diameter and the wind speed conditions of the site to optimize wind energy capture, typically 1 to 1.5 times the rotor diameter, but in any cases normally at least 20 m (Huenteler, 2015).

2.2.5. Technological Trend

The technology of wind turbines has evolved a great deal over 20 to 30 years, with innovation accelerating in recent years and it comes to matured. This makes wind turbines more efficient, helped to drive down costs due to technological advancements of wind turbines, and helped to put wind energy on a stronger footing to compete with other energy sources.

The most significant technological trend is the continuing up-scaling of machines. Thirty years ago, the largest wind turbines were typically rated 100-200 kW, with some rated a bit higher and many rated lower. Twenty years ago, the largest wind turbines were rated 300-600 kW. Ten years ago, the largest turbines were rated 1.5-2.0 MW. Nowadays, the nominal rating for an onshore turbine is 2.0-4.0 MW, but many OEMs are pushing the envelope to 5 MW and beyond. Offshore turbines are rated 5 MW to 7 MW, with new turbines approaching or exceeding 10 MW.

Electricity production efficiency is also rapidly improving, owing to higher towers, larger rotors and design improvement. The physical size of rotor diameters and towers length has grown to 110 -130metres from 40-90 meter of 20 years ago and up to 150 meter height of rotor length from

50-100 meter of 20 years ago respectively. These increased size and efficiency of wind turbines access better wind resources, higher average wind speeds and reduced wind turbulence that lead directly to increased annual energy output per square meter of land occupied and also substantially reduced the cost of wind energy. A single modern wind turbine annually produces roughly 180 times more electricity per year and at less than half the cost per kilowatt-hour than its equivalent of 20 years ago (IEA, 2016).

In addition to the rapid increment of wind turbines physical size discussed above the design aspect of turbine has also improved over the years to produce more power out of less mass. New wind turbines are being produced with an increased use of strong, light, corrosion-resistant composite materials for wind turbine blade, tower, such as carbon fiber or advanced fabrics. Advancements in blade design of new wind turbine blades optimize performance by maximizing energy production capacity, optimizing the flow of wind turbine blades, and decreasing drag. The latest trends in global wind turbine technology include augmenting wind power with energy storage, integrating smart grid technology into turbine operation.

Today's, advanced wind turbines and farms use more sophisticated power control systems. During the intervening years, programmable computer configurations were introduced, as computer technology and miniaturization continued advancing. Variable speed constant frequency systems utilized newly developed power electronics, improving energy capture, and proactive mechanical turbine hardware loads management software was introduced. Industrial smart systems in new, advanced tech wind farms send data to wind farm operators, allowing operators to predict wind strength, times of stronger wind activity, and wind direction; so that operators can program the optimal position for turbines based on the forecasted wind speed, time, and direction. In addition, renewable energy storage technologies store excess electricity when more energy is produced by the wind than what is needed, and feed it back into the grid when the wind slows down, or the wind stops blowing for a time.

Table 2.1: Wind turbine improvement trend; source (IEA, 2019)

Years	1980-90	1990-95	1995-2000	2000-05	2005-10	2010-2015	2015-2020	Future
Hab Highet (m)	20	30	50	70	80	100	130	150
Rotor dimeet (m)	17	30	50	70	80	100	125	150
Rating (KW)	75kw	300kw	750kw	1500kw	1800kw	3000kw	500kw	10000kw

2.2. Wind Energy Technology Value Chain

The wind energy value chain consists of a number of specific and distinct steps - from the supply of raw materials to the transmission of electricity. This can be divided into several segments/phases comprising related activities, pertaining to core and supporting activities. The core activities that are specific to renewable energy development include project planning, procurement of raw materials and intermediary products, manufacturing of components, transport of equipment, project installation, grid connection, operation and maintenance and decommissioning. For analytical purpose, it was also classified in two-pronged value chain: a manufacturing chain concerned with producing the key equipment and a deployment services chain concerned with all aspects related to deployment and utilization (Lema et al., 2011). This distinction takes into account that there are normally two lead firms involved in the process: wind turbine generator assemblers in the manufacturing chain; and utilities or other types of project developers in the service chain. Other activities from the various sectors that support deployment include consulting, financing, education, research and development, policy making and administrative activities.

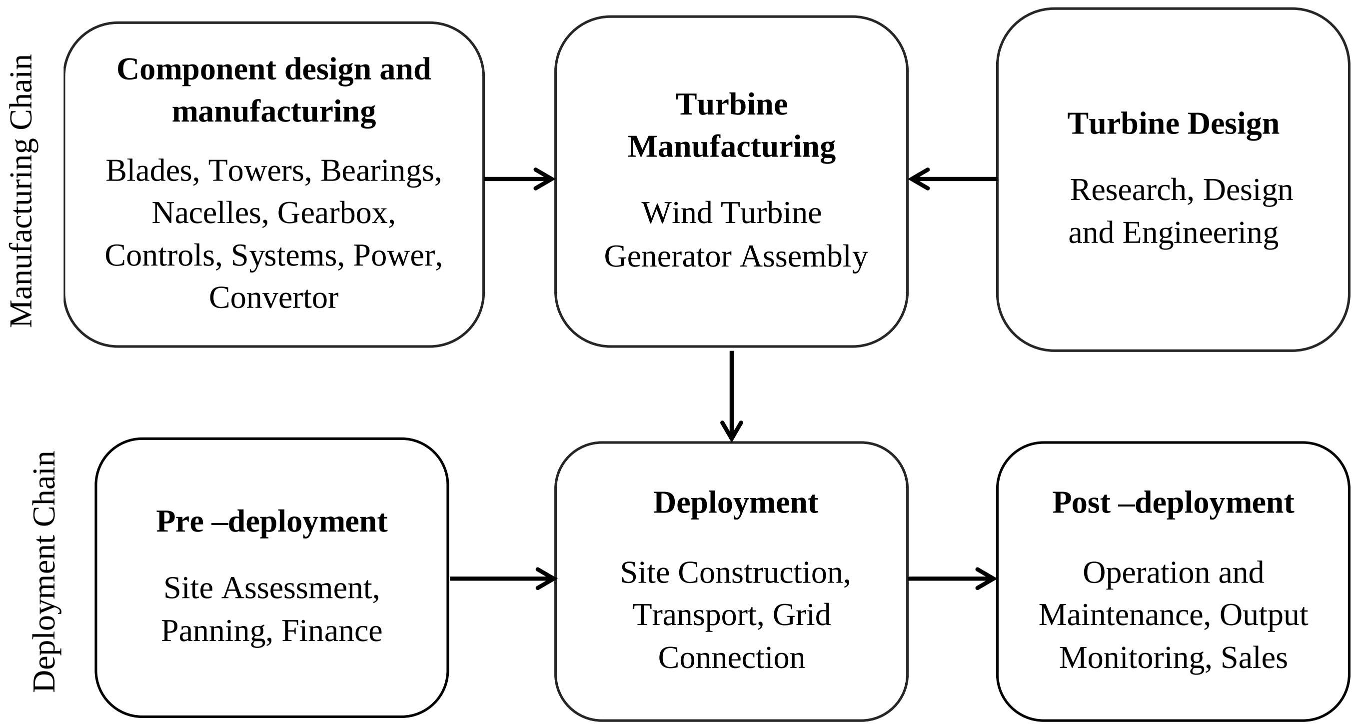


Fig 2.6. Basic structure of wind energy technology value chain (source: (Lema et al., 2011))

2.3.1. Project Planning

The project planning phase comprises the initial activities of a wind project, including site selection, technical and financial feasibility studies, engineering design and project development. In the first two activities, the resource potential of a site is measured and the environmental and social impacts of the project are assessed. Engineering design covers the technical aspects of the mechanical and electrical systems; the civil engineering work and infrastructure; the construction plan; and the O&M model. Project development consists of administrative tasks, such as obtaining land rights, permits, licenses and approvals from different authorities; managing regulatory issues; negotiating and securing financing and insurance contracts; contracting engineering companies; negotiating the rent or purchase of the land; and managing the procurement processes.

2.3.2. Raw material supply

A wide range of materials are used for wind turbine components Manufacturing and wind farm construction. Steel is one of the most important materials for main components manufacturing because of its strength and durability. A typical wind turbine is reported to contain 89.1 percent steel, 5.8 percent fiberglass, 1.6 percent copper, 1.3 percent concrete (primarily cement, water, aggregates, and steel reinforcement), 1.1 percent adhesives, 0.8 percent aluminum, and 0.4 percent core materials (primarily foam, plastic, and wood) by weight (EAI E. a., 2008). As the use of wind turbines increases and research leads to the development of new technologies, may result in the development of wind turbines with mixes of materials different from those widely used today.

2.3.3. Component manufacturing

The wind turbine consists of several critical components that have a huge influence either on the performance or on the investment costs of the whole system. Local companies would also be able to produce bulky parts that are not high technology products like main electrical components, cables, towers, blades and parts of the generator in the short or medium term by following specifications and standards imposed by the main manufacturing company. Towers and blades are often outsourced to local manufacturers due to the complications in transporting them, especially when there is domestic steel or fiberglass industry avoids transportation challenges (IRENA, 2015). However, the production of the technologically advanced subcomponents, such as the gearbox, the generator and bearings requires highly specialized skills, which may not always be easy to source locally. To ensure a high quality, the manufacturing of these components is often done by the OEM Companies, with high quality standards.

2.3.4. Construction and installation

This phase of the value chain includes wide variety of tasks starting from site predation up to grid connection. These tasks are usually performed by the engineering, procurement, and construction (EPC) contractor. The EPC contractor is responsible for the whole plant construction. As project manager, EPC contractors select all the suppliers and awards most of the jobs to subcontractors. EPC contractors are usually subsidiary companies of industrial groups and can resort to building companies and engineering consultants in their own company group. The civil works for the total plant are also often closely connected to the EPC contractor, as many companies have their own subsidiaries or joint ventures to undertake these tasks. For these civil works, and for the assembly and installation of the collectors, a large number of low skilled workers is required on the construction site. In current projects the EPC contractor even serves, in part, as financer and owner, and for the first years is also responsible for the operation and maintenance (O&M), which binds him to the plant.

2.3.5. Operation and Maintenance

The operation and maintenance phase of a wind farm covers the expected lifetime of about 25 years. The tasks for operation and maintenance can be split into four different groups: Plant administration, operation and control, technical inspection of the power block, and the solar field operation and maintenance. Operation includes regular site personnel, observing and operating the turbine operation, dealing with local failure and coordinating with the utility. This is usually undertaken by the wind turbine manufacturer during the warranty period, afterwards the local companies may subcontract it and operators perform these services.

2.4. The Global wind Technology Value Chain

The global wind industry resembles a so-called producer-driven value chain (Gereffi, 2016), in which lead firms coordinate the production networks of component suppliers, and where competition is mainly based on technological progress through continued R&D. The industry structure is dominated by a few large lead firms mainly based in the major markets share of installed wind energy capacity and production countries. As outlined in figure 2.8, USA and Europe but increasingly also from Asian countries, in particular China, Germany,Denmark, Spain, and India account for the biggest market share of wind turbine manufacturing. The large lead firms include Vestas, Siemens, General Electric, Gamesa, Sinovel, Goldwind and Suzlon. As shown, the leading Denmark wind turbine manufacturing firm accounted for at least 21.3 % of the new global installed capacity in 2018 followed by the leading Chinese and Spain companies with 13.8% and 12.3 % respectively (GWEC, 2019).

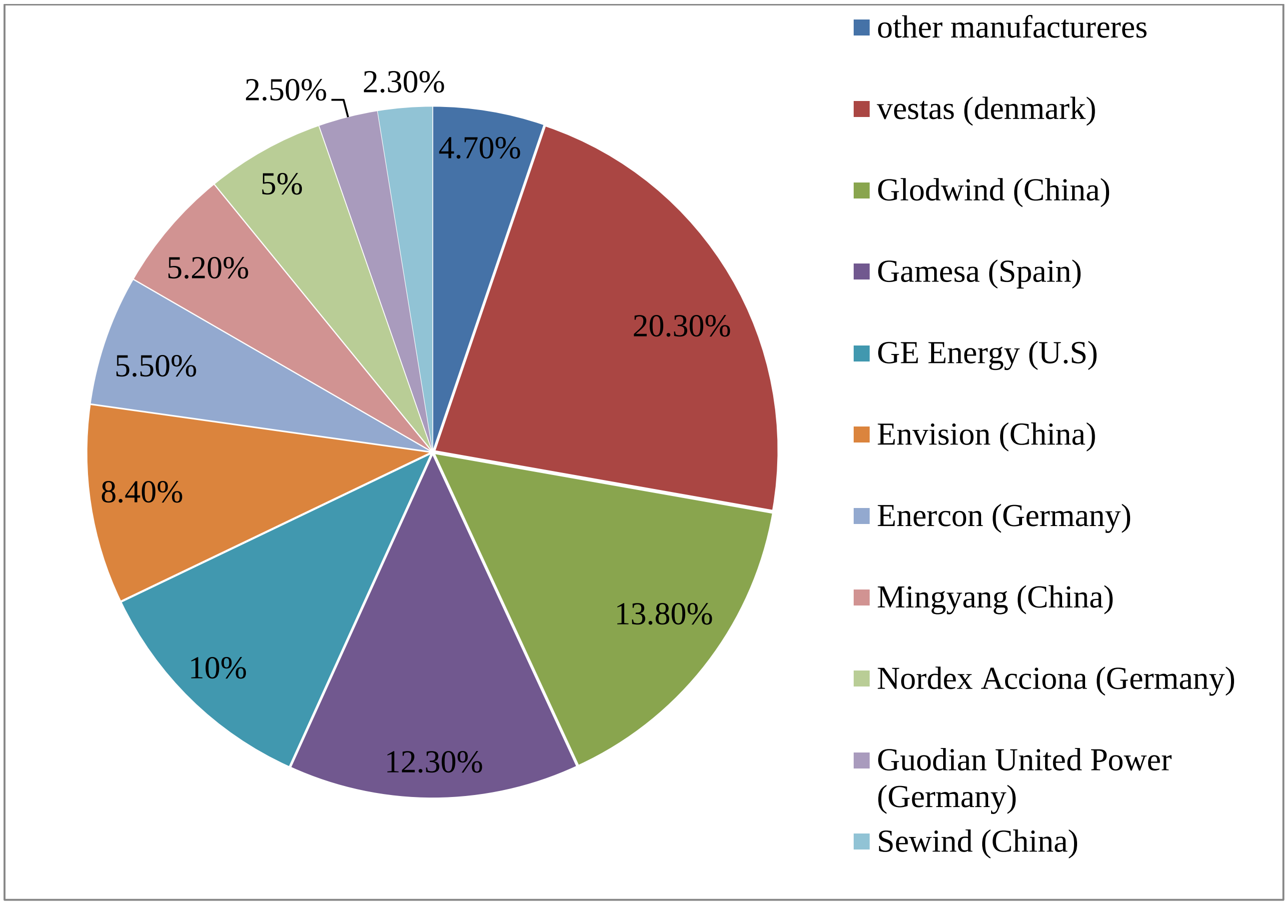


Fig 2.7. Global market share of the world's leading wind turbine manufacturers in 2018 (GWEC, 2019)

The tendency among these lead firms is to focus their activities increasingly on the parts of the value chain with the highest value-added, such as R&D, engineering and other knowledge-intensive activities (Lema, 2012). Over the years, though, lead firms typically retain in-house control of the development and production of key wind turbine components, such as the main control system, the generator and the converter, while the remainder of the up to 8,000 components that a standard turbine consists of are outsourced to an extensive global network of external sub-suppliers. This entails that the manufacturing of such components provides a window of opportunity for the insertion and upgrading of external sub-suppliers in the GVC for wind turbines.

Hence, the global wind turbine industry is generally experiencing increasing levels of local production facilities in the form of outsourcing to export markets either to reduce costs or to serve local market demand or both (Davide, 2017). New Turbine manufacturers are entering into the global markets through joint ventures, technology licensing, establishing wind farm developing subsidiaries, facilitating access to finance, or by acquiring a local company. In this regard the recent development shows many new market entrants and expanding of the global wind industry. The localization and establishing of local production of wind turbine and its components is commonly supported by the sufficient and sustainably large wind energy market in the emerging country and the global wind energy demand as well. The less complicated and bulk wind turbine components but very costly and difficult to transport are considered as the first tier in the global wind industry integration. Also, countries with low labor costs might have an advantage for localization of labor intensive activities like final assembly of nacelle.

2.5. Wind Energy Technology Development and key stakeholders in Ethiopia

2.5.1. Wind Energy Development in Ethiopia

Ethiopia has one of the most ample wind resources in Eastern Africa. The average wind speed in the whole country is greater than 6.5 m/s, with favorable locations where the average wind speed achieves 10 m/s. Its total wind energy resource reserve of 3,030 GW and the potential exploitable quantity of is 1,350GW with highest potential in the Somali (1,060 GW) region followed by the Tigray (78GW), Oromyia (75 GW) and Amhara (59Gw) region (MWE, 2012). There have been several researches conducted in the resource mapping the wind potential of the country include, (Bekele G. &., 2010), (GTZ, 2006), (AWF., 2008), which estimated the same amount of GWs. However, in practical all these potential wind resources and sites cannot be utilized for wind energy generation. Because the estimated wind resources described above does not take account some of unsuitable and reserved areas like national parks, water bodies, forest lands, wild life reserves, settlements and cities, road sides, airports and etc. The country has over 20,000 square kilometers potential areas that are favorable for grid based wind electricity generation, which is estimated about 100GW (EREDPC, 2007).

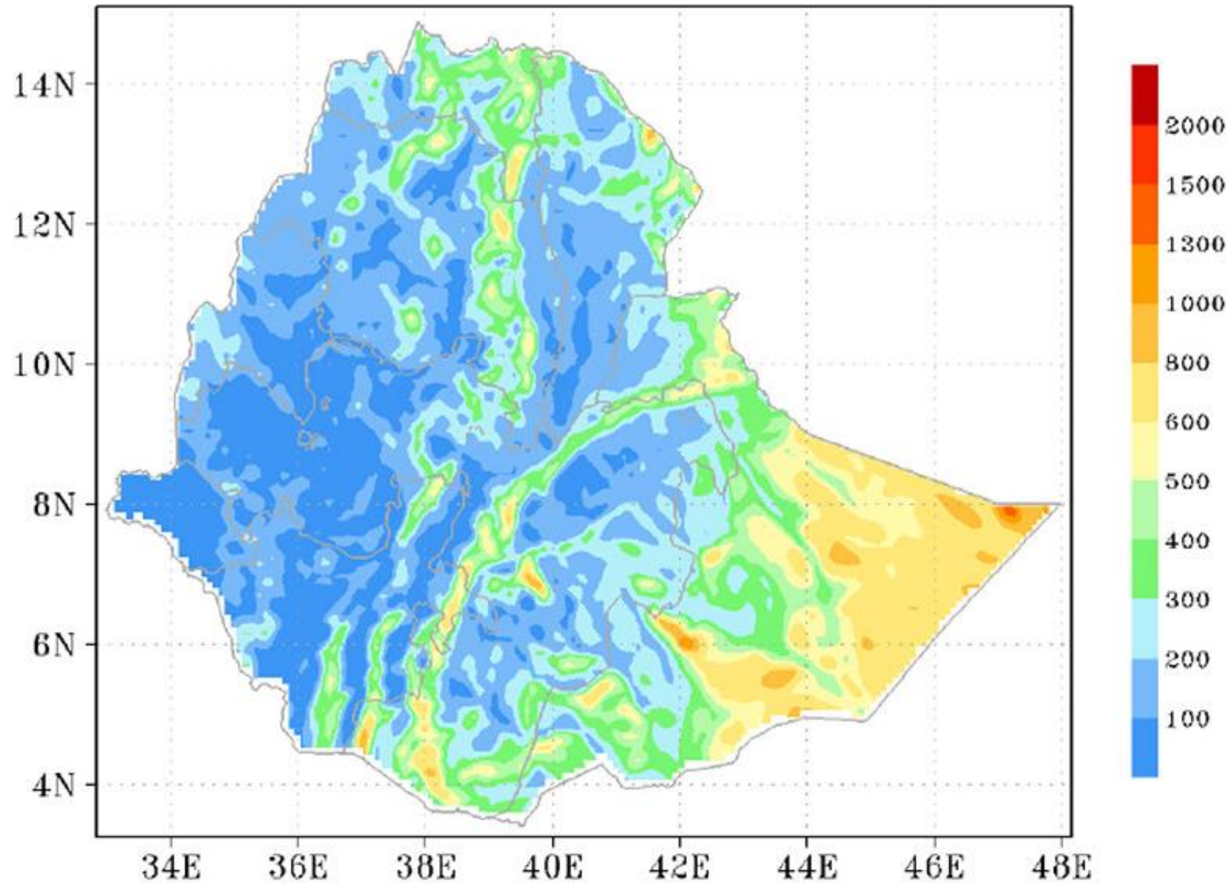


Figure 2.8: Ethiopian annual mean wind power density at 50 m height without excluding protected areas (Source: Master plan report of MWE, 2012)

However, The development of wind farms has emerged in the country very recently as another alternative energy source and the total installed with power generation capacity is 324MWs. At present different wind farm project are under way in the country and the government has plans to install additional wind power plants up to 2,400MW in 2025 and 3,600MW in 2030 (NPC, 2016).

Table 2.2: Existing and upcoming wind power plants (WPP) with their capacity (Derbew, 2017)

No.	Project	Generating Capacity	Annual Energy Production
Connected to grid			
1	Adama I WPP	51	157
2	Adama II WPP	153	479
3	Ashegoda WPP	120	450
	Total	324	1,086
	Upcoming projects		
4	Aysha WPP	300	592
5	Messobo WPP	42	104
6	Assela WPP	100	197
7	Debre Birhan WPP	100	197
	Grand Total	866	2,176

2.5.2. Institutional Dimensions and key stakeholders

There are a number of supervised institutions that are directly related to the energy sector. These are National Strategic Petroleum Reserve Administration, Ethiopian Electric Power (EEP), Ethiopian Electric Utility (EEU) and Ethiopian Energy Authority (EEA).

- ***Ministry of Water, Irrigation and Electricity:-*** The Ministry oversees the sector and sets energy policy. Its Procurement Committee sets the guidelines for awarding EPC contracts and licenses. The Ministry also sets the electricity tariff at grid level.
- ***Ethiopian Energy Authority (EEA):-*** The EEA was created as a regulator in 2003. It is responsible for issuing investment permits and licenses for generation, transmission, and distribution. It also approves plans for the import or export of energy. The EEA sets the tariff for off-takes from the grid. Renewable energy investors can apply for investment licenses for 25 years for hydropower and geothermal, and 20 years for wind, solar, biomass, and energy from waste technologies (Fulbright, 2016).
- ***Ethiopian Electric Power (EEP):-*** EEP is responsible for generation and transmission. Private operators will need to partner with the EEP via a Power Purchase Agreement.

- ***Ethiopian Electric Utility (EEU):-*** EEU is responsible for the distribution network. It purchases power from EEP, and can still be an off-taker for Independent Power Producers (IPPs).

Beyond these key institutions included with the ministry of water, irrigation and electricity which are vital for the promotion of energy access and security, there are also further organization and programs with relevance of the energy sector. Some of these are:

- Alternative Energy technologies program conduct research in technology development and promotion of rural energy technologies such as improved stoves, PV solar, and biogas.
- Environmental protection agency regulates environmental aspects of Energy
- Ministry of Finance plays a great role by oversees public finance for projects
- Regional energy agencies which are government bureaus responsible for promoting and facilitating modern energy technology programs.
- Universal electricity access program oversees universal electricity access activities, with responsibility of supporting and promoting off-grid rural electrification projects by cooperatives and private sector operators operating outside the national grid.

Source: (Senshaw, 2014), p. 52-53 & (Asnake, 2015)

2.6. Technological learning and local capability formation

Studies from the fields of international technology transfer and catching-up have found that successful industry localization and technology innovation in developing countries depends on the presence of the desired level of technological capabilities in the country (Bell M. , 2010). In this study technological capability was described as a very important component for technology utilization, technology adoption and production, and technology modification and innovation processes also.

The term Technology Capability has been given by many scholars in several ways (Kim, 2004), (Adler, 1999), (Bell M. a., 1995), (Lall, 1992) and (Satio, 2010). According to these authors, technology capability is broadly defined as the combination of means such as institutional structures and linkages (organizational systems), equipment(physical) and knowledge and skills (know-how) which are required to utilize technologies that have been developed elsewhere (i.e. other countries or other organizations) as well as to be able to adapt, improve and create new, own technologies. These studies has also argued that technological capabilities can be accumulated and embodied through the complex process as the result of interactive learning and networks established between a numbers of actors along the value chain. In addition to a capability formed from continuous participation in ordinary activity toward higher value-adding activities; the literature on international technology transfer has identified many different transfer channels, ranging from licensing, foreign direct investment, joint ventures and subcontracting to overseas training and education (Kim, 2004), as the best mechanisms of technological learning that permits companies, industrial sectors and countries to accumulate their own capabilities to carry out production-related and diverse types and levels of innovative activities over time.

2.6.1. Functional Categorization of Technological Capabilities

Following to the above definition, increasing amount of research has been conducted over several years to analyze the technological capability of nations and firms in several sectors and technologies. In this regard different author has classified "technological capability" in various ways; and designed frameworks with different approaches in their research works. Initially, (Hayami, 1971), (Thee, 1997) and (Kim, 2004) has classified the technological capability of firms from imitation up to innovation based on the degree of complexity or difficulty of technology as a trajectory of progress (or at least of potential progress) running from using given (and imported) technologies through their local reproduction to their adaptation and improvement : the level at which the firm is able to acquire, use and operate the existing/given technologies; the level at which the firm has mastered the existing technology and is able to maintain stable and continuous operation over time, and able to reproduce of the existing technologies, and the innovative level at which the firms is able to improve on the existing technology and generate technological changes.

On the other dimension, (Figueiredo, 2002), (Amsden, 2001) and (Ariffin, 2004) has tried to show and categorize the technological capability of firms in line with the concept of value chain and chain of functions of firm activities which encompass pre-production (market research, concept creation, product development and design), production, and post-production (branding and marketing) as sequence of steps in developing capabilities in these functional areas. In these two study approaches only one of these dimensions is addressed.

Based on these two approaches Yuri S. and Mai F. built a framework by setting together the two dimensions in a single one dimensional list that more broadly includes both functions and levels.

They particularly classified the technological functions in to different stages in the life cycle of industrial projects as a sequence of capabilities running from production capability, via investment capability to innovation capability (Fujita, 2009). Thus, within each of the stages of technological capability development, there is also differentiation between levels of capability running from Basic through Intermediate to Advanced, and these categories were associated with types of activity like utilization, adoption and production duplicative or Innovative that were reminiscent of the spectrum of rising capability levels. Furthermore; As pointed out by (Fujita, 2009), contrary to the conventional TC literature which regards the capability levels as a procedural sequence, they argued that firms might bypass certain levels of capabilities and develop high level of capability by using chains firms that are capable of making modifications to product designs while the firms had not established assimilative (maintenance) levels of capabilities as a practical example.

Table 2.3 Technological Capability Classifications

<table>
<tr><th></th><th>Amsden (2001)</th><th>Lall (1992)</th><th>Bell & Pavitt (1995)</th><th>Yuri S. and Mai F.(2009)</th><th>Figueiredo (2008)</th></tr>
<tr><td>Basic</td><td>Production</td><td>Basic Routine</td><td>Basic production capabilities</td><td>Using and Operating</td><td>Technology using, acquisition, assimilation, operation,</td></tr>
<tr><td>Intermediate</td><td>Project Execution</td><td>Adaptive duplicative</td><td rowspan="2">Generating and managing technical change</td><td>Design and Engineering</td><td>Technology reproduction</td></tr>
<tr><td>Advanced</td><td>Innovation</td><td>Innovative risky</td><td>Research and Development</td><td>Adaptation & modification</td></tr>
<tr><td>Sector of observation</td><td>General</td><td colspan="2">General</td><td>General</td><td>Agriculture technology</td></tr>
<tr><td>Country</td><td>Singapore</td><td colspan="2">General</td><td>Developing countries</td><td>Developing countries</td></tr>
</table>

Based on the literatures that were synthesized here above, various frameworks have been designed in different researchers in several sectors and countries. However, there is thus no "one correct way" in all circumstances, as most analytical frameworks were developed specifically to study the potentiality and ability of domestic firms wind energy technology manufacturing and deployment activities. Therefore, for the purpose of empirical analysis of Ethiopian wind energy technology value chain; the researcher has designed owns' analytical framework by incorporating, modifying and adding his own emphasis on the previous research frameworks and by taking in consideration nature the complexity of activates along wind energy technology manufacturing and deployment segments.

This framework overcome the shortcomings of the existing frameworks and has a unique future to assesses the depth of capabilities across the whole range of activities and maps capabilities in a two dimensional surface, the width of function and the depth of capabilities dimensions as an analytical framework matrix. It is based on the two streams of literatures, i.e. the nature and trends of wind energy technology value chain literatures and the technological capability literatures covered previously. Functions of activates (represented in the columns) are aligned along the value chain of wind energy technology from project planning, manufacturing, installation, grid connection to operation and maintenance. The rows represent the depth of capabilities from basic capability level to use the existing technologies, and the latter is that level to adopt and produce components and parts up to the advanced level that needs a deeper capability to improve, innovate and generate technological changes.

In assessing and measuring the existing technological capability level of the country, past literatures indicate there are two main approaches that are used globally (Gardsi, 2012) – a qualitative method using questionnaire survey and interview, and a quantitative method using numerical data collection and benchmarking with the target level. The qualitative method has been used in this research to measure the current level of the nations' technological capability of wind energy technology.

2.7. The Potential Benefits of wind industry localization

Beyond using domestic wind power technology as a symbol of both national technological success and pride, there are many potential benefits makes the local manufacturing of the wind energy value chain. In their study of wind manufacturing around the world, Lewis and Wiser (Lewis, 2009) highlight three most important potential benefits of developing a local manufacturing industry: local job creation; export of domestic manufactured wind products to international markets and cost savings.

2.7.1. Local Job Creation

The development of local wind industry creates vast domestic job opportunities for both skilled and unskilled labors. Relatively the wind energy is often found to create more jobs per kWh generated than fossil fuel power generation. In the study conducted on United States case estimates that wind power creates 27 percent more jobs than the same amount of energy produced by a coal plant and 66 percent more jobs than a natural gas combined-cycle power plant (W, 2005).

In wind power, employment is relatively low in the operation of the generating plant but higher in both the supply chain of the industries producing and servicing the plant and equipment, and during the construction phase of the project. Direct jobs are usually created in three areas: manufacturing of wind power equipment, constructing and installing the wind farm, and operating and maintaining the wind farm over its lifetime. Based on European Wind Energy Association estimates of the share of employment allocated across different stages of the wind industry, this study approximately estimates that two-thirds of the labor requirements are in the manufacturing of the wind power equipment which includes turbines, blades, towers and other components, and the remaining one-third is accounted for by installation, services, transport and development. According to the report components like rotor blades are identified as the most labor-intensive and therefore are a crucial element of local manufacturing of wind turbines since they will bring the most jobs (EWEA, 2009).

International organization and studies have estimated the total jobs created by the wind industry, including the international renewable energy agency's report on renewable energy and employment (IREA, 2019) calculated the total number of direct and indirect jobs created by the wind industry (including manufacturing, installation and maintenance) to be 1.2 million for 2018 increased by 3.5% from 2017, with categories of 33 percent construction, 24 percent professional services, and 24 percent manufacturing. The wind energy industry has become a major job generator globally: China, Brazil, Unites States, India and EU countries remain lead the industry's Jobs and representing the world's largest renewable energy employers. The environmental and energy study institute in 2019 estimates that there currently are a total of 510,000 jobs in the wind industries of China, United states and European union, as detailed in the chart below (EESI, 2019). While (W, 2005) estimates the global average of jobs from wind power is estimated up to 21 per MW of installed wind capacity.

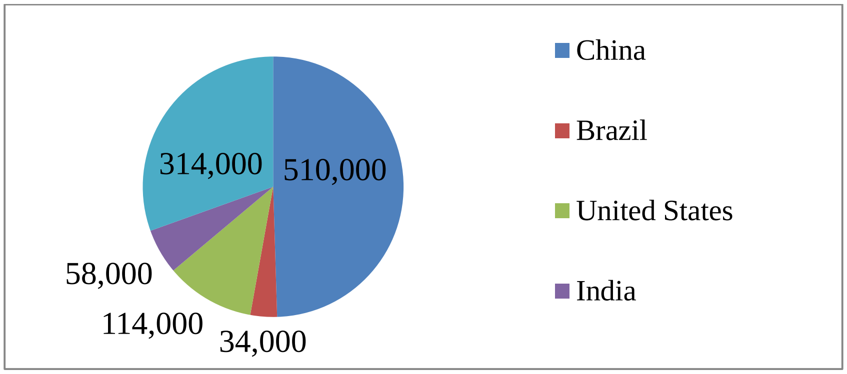


Fig 2.9. The Global Wind energy job creation potential (IREA, 2019)

2.7.2. Cost savings

The total installed capacity costs for wind energy have followed a decreasing trend in recent years driven by 1) growth in economies of scale as new yearly installations increased globally, from almost 7 GW in 2001 to over 60GW in 2019; 2) continued technological advancements like increases in hub heights and rotor diameters; 3) domestic substitution of some segments of the wind power value chain. Local manufacturing of wind turbines or wind turbine components can potentially reduce costs through: a reduction in labor costs; a reduction in raw materials costs; and a reduction in transportation costs. The improved servicing and response times that come from local manufacturers may further reduce costs and/or improve operations.

The wind turbines are the critical factors in the large wind farm development. They represent the major fractions, in the range of 60 to 75 percent, of a wind farm total installed cost. Wind turbines are composed of more than 8,000 individual components, and about 90% of the value is captured in three main parts: blades, towers, and nacelles (IRENA, 2016). The remaining costs primarily include construction costs (foundations, grid connection, roads, and sea cables), development and legal costs and land acquisition costs, and there will be variation in these remaining costs depending on the location of the wind farm site.

Therefore, domestic manufacturing of wind turbines and components in developing countries like Ethiopia with lower wage rates expect to be able to realize cost savings compared to developed countries such as Europe, Asia and America. Though this cost reduction is potentially significant for those turbine components that are particularly labor intensive. Turbine towers manufacturing, for example, is labor intensive and could thus benefit from lower labor costs, towers are also not as technically sophisticated as other components and it can be developed locally (Veena, 2017).

In the case of wind turbines, bigger is better from a financial, energy production and sustainability standpoint, which is one of the main purchasing criteria of customers. Associated with this, turbines have been doubling in size every four years, and components are much greater and heavier. As the wind components have grown, transportation of these components from OEMs to project site accounts up to 15% of the total cost of a wind farm project (Caduff, 2012). According to the reports made in the sector domestic production of wind turbines could provide opportunities for host country's to reduce the transportation cost by 2-5% of the entire system cost for imported turbines. Reduced delivery lead times for wind turbines and components are another cost-saving factor in local manufacturing. Better customer service and faster access to customer service staff and technical staff as well as spare components in case of mechanical problems may further reduce costs or improve project operations.

Generally, the actual cost reduction that can be realized through localizing production will vary greatly from country to country depending on the availability of local components, and the local cost of labor and materials. Initial studies have estimated that local production of wind turbines could reduce the cost of the technology by anywhere from 20 to 40% (Joanna Lewis, 2005).

2.7.3. Technology and Knowhow Transfer

Unlike the traditional technology transfer approach which focuses mainly on training, know – how transfer comprises various elements like regulations and policies, local market segment, finance management and etc. The collaboration of local manufacturers and service providers with international companies will provide better experience through the transfer of know-how along the value chain segments. Specially, in the early stage of the wind industry value chain localization both the upstream and downstream activates of the value chain are commonly handled by international companies and foreign experts, and then local companies will progressively take over the manufacturing process. In this scenario, the technology and know-how transfer plays a great role in the development of local wind value chain and can be taken as a key factor of success. Furthermore, the establishment of a local wind industry value chain will facilitate the know-how transfer by attracting the international OEM's to establish joint ventures with local companies/manufacturers in the country.

2.7.4. Market Benefits potential

Many countries developed domestic wind turbine manufacturing industry not only to produce and use turbine for local markets but also to export their turbines overseas and tap into the expanding global market for wind energy. According the global wind industry report of 2019 a total of 22,893 installed wind turbines from 33 manufacturers with a combined capacity of 63 gig watts (GW)(GWEC,2019). Vestas, Gamesa, Gold wind and General Electric were the largest suppliers in the consolidating global market for wind turbines.

Table2.4. Global market share of wind turbine manufactures in 2019, (GWEC, 2019)

Manufacturers	Home country	% of global market share
Vestas	Denmark	18%
Gamesa	Spain	15.7
Goldwind	China	13.2
GE renewable energy	USA	11.61%
Envision	China	8.57%
Mingyang	China	5.72%
Nordex Acciona	Germany	4.91%
Enercon	Germany	2.99%
Senvion	Germany	2.54%
Suzan	India	2.11%

2.8. International Experience with Wind Technology Development

2.8.1. The Case of India

India is one of the countries, with the most extensive production of energy from wind sources and the country had a total installed wind power capacity of 35.6GW (as on 31st March 2019), according to the IRENA report. The Indian government has also the plan to exploit up to 60GW by 2022 from a gross wind power potential of 302 GW of the country. The expansion of the wind industry has resulted in a strong ecosystem, project operation capabilities and manufacturing base of about 10,000 MW per annum.

Parallel to utilization of the indigenous wind resource potential, India has built a strong wind manufacturing industry, with over 7.5 GW of manufacturing capacity. There were more than 25 wind turbine manufacturers in the Indian market in 2017 including Suzlon, Enercon and Vestas which are a leading global manufacturer continues to maintain the majority share of the Indian market. Most of Indian wind turbine industry was largely formed through business diversification of local firms through technical collaboration agreements (joint venture or license agreement) with the manufacturers on the technology frontier.

In terms of wind power project execution, skills and know-how of project planning, site assessment and site development India has built great capability since the mid-1990s through joint venture and license agreement collaborations. However, In terms of in-house innovation capacity building by manufacturers, Enercon India and Suzlon built the R&D facilities in India, but their main R&D activities still remained in Europe. In wind industry innovation capability greatly advanced at the frontier with various high technology developments since 1990, none of the significant innovations were carried out in India.

In this regard the government of India has provided significant supporting wind industry related policy measures and regulations to the wind energy development since 1980s in order to establish an indigenous industry and exploit further its wind energy potential. The federal governments promote the entire country wind power sector development mainly through private sector investment by providing various fiscal and financial incentives such as Accelerated Depreciation benefit; 5 years tax holiday, concessional custom duty exemption on certain components of wind electric generators. Besides the financial incentives stated above, the following major actions also have been taken a local content requirement that mandates a certain percentage of local content for wind turbine manufacturing in some or all projects within the country to promote establishment of domestic capability for the manufacturing, installation and innovation of wind technology in the country.

2.8.2. The Case of China

China is one of the latecomer countries to the world wind industry. Wind energy utilization, especially onshore grid-connected wind power generation, has a history of 30 years in China. With the increasing attention to renewable energy development in recent years, wind energy has become the focus of academic research and policy-making. The capacity of the Chinese wind power sector has increased rapidly over the past half-decade, essentially doubling every year since 2005. Now, China is the leading wind producing country in the Asia Pacific region, with an installed capacity of 211.6GW in 2018 grown from 342 MW in 2000. In the future the Chinese government has set a plan to have 400 GW and 1000 GW of wind capacity in 2030 and 2050 from its estimated exploitable capacity of 2,380 GW of on land and 200 GW on the sea.

On the other hand China has able built internationally competitive largest domestic wind turbine manufacturing and installations companies with in a very short period of time. China's wind turbine manufacturing industry is now the world's largest industry in the manufacturing and export of wind turbine components. China's wind energy industry has attracted large domestic wind turbine manufacturers such as Goldwind, Sinovel and Dongfang as well as international manufacturers, including companies such as GE Energy, Vestas, Gamesa and Siemens.

Beyond a clear expression of political will of the government, China has been taking considerable steps combined with a set of effective support measures to develop such massive domestic wind industry. The Renewable Energy Law that came into force in 2006 introduced nationwide renewable energy targets, offered a variety of financial incentives, such as a national fund to foster renewable energy development, discounted lending and tax preferences for renewable energy projects, and a requirement that power grid operators purchase resources from registered renewable energy producers.

To this end the Chinese government has been extremely successful at fostering a domestic manufacturing industry due to the strong and stable demand for wind energy, and to strong government support for the domestic manufacturing sector through policies such as local content requirement, sharing the burden of extra costs related to wind power, and by setting a mandatory market share for big utilities. To encourage local wind turbine manufacturing, Chinese state has implemented policies to encourage joint-ventures and technology transfers in large wind turbine technology and mandated a 70 percent share of local content for all wind concessions which was enforced by the authorities through 2009, most international manufacturers set up assembly and production facilities in China.

2.8.3. Summary of Experiences

From the analyses China and India have similarities that are useful for comparison. Both countries have a large and rapidly growing internal market and used policy support mechanisms that have been employed to directly and indirectly promote wind technology manufacturing find that in many instances there is a clear relationship between a manufacturer's success in its home country market and its eventual success in the global wind power market. Whether new wind turbine manufacturing entrants are able to succeed will likely depend in part on the utilization of their turbines in their own domestic market, which in turn will be influenced by the annual size and stability of that market. Consequently, policies that support a sizable, stable market for wind power and the local content requirements, in conjunction with policies that specifically provide incentives for wind power technology to be manufactured locally, are most likely to result in the establishment of an internationally competitive wind industry.

2.9. Literature Summary and Gap Identification

2.9.1. Identification of journal Article for Revision

The first step of the analysis consisted of searching for articles relevant to the purpose of the study and the search was limited to academic journals. The articles were gathered from well-known publishers such as: Emerald, Elsevier, science direct and research gate. Key words "Wind Energy Technology Value Chain" and "Technological Capabilities" which are mostly related with value chain analysis in wind energy technology were used to gather related articles. Though there are high numbers of published articles in the international journals related to of wind technologies with different approaches , the focus of this study has been entirely on mapping and analysis of wind energy technology value chain for local fabrication of components and services. Among the high number of the studies in this area, 34 most related studies with wind energy technology value chain analysis were identified and reviewed. By scanning further through reading the full text of the articles to eliminate those articles that are not strongly related to the study, 17 articles were found to be more relevant to the survey. The relevancy of the articles was checked based on their purpose, methods used for the study, and the final findings .The order of representation of the studies is from the studies published previously up to the recent one, those published between 2010 -2019.

2.9.2. Gap Identification and Survey analysis

The reviewed researches about the wind power technology mainly focus on the following three research streams. The first stream analyzes its development status, the socio economic effects, existing problems, and solutions from the various perspectives. Wagner and his friends explored the global Wind Energy Market, Industry and Economic Impacts (Wagner et al, 2015). They emphasized on the positive economic impacts of wind energy industry in terms of its employment, incomes and taxes and production of goods and services. In the other study conducted in Brazil, the factors which influence the performance of wind farms were analyzed and identified (Marllen S. & Mario G, 2019). This study verified that the performance of wind farms is mainly influenced by 5 factors: (1) Reliability of prospecting studies, (2) Construction quality and assembly, (3) Organizational learning, and (5) Coordination of the value chain. The second stream tries to analyze the wind power industry from the aspects of industrial chain, and explores challenges to its competitiveness. Yudi et al. investigated the challenges and identified as internal (supplier involvement, knowledge, infrastructure, technology and top management) and external challenges (investment cost, government policies and social acceptance) (Yudiet al, 2018). Hui-Ming et al. has also explored the renewable energy supply chains, performance, application barriers, and strategies for further development (Hui-Ming et al, 2012). The conversion cost, location constraints, and complex distribution networks are identified as barriers of the generation and utilization of REs.

Finally, the third stream studies the challenges and opportunities in localization of wind technologies, and explores ways and requirements to join the wind industry value chain. [(Joern et al., 2016) and (Rasmus et al., 2018)]. Rasmus et al. studied the renewable electrification and local capability formation: Linkages and interactive learning (Rasmus et al., 2018). They classified the renewable energy electrification and local capability linkages in to three types of interactive learning's (i) interactive learning between contractors and local suppliers (ii) Local labour learning to 'use ' the new installations (iii) Public authorities learning to manage major projects for renewable electrification capability formation. In the study entitled by Joern et al, the effect of local and global learning on the cost of renewable energy in developing countries was analyzed (Joern et al., 2016). They investigated the conditions enabling local learning, such as a skilled workforce, a stable regulatory framework, and the establishment of sustainable business models, has a more significant impact on the cost of renewable energy in developing countries than global technology learning curves. From those literatures reviewed, some of the studies failed to analyze wind energy technology from the perspective of the overall value chain, while the others failed to analyze the wind technology value chain with combination of technological capabilities. Despite the large number of researches conducted on the area, to the best of my Knowledge there are no researches conducted on the subject with Ethiopian context. So, the need to research on value chain analysis Ethiopian wind energy technology arises from this perspective to fill the gap.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

This chapter presents the research design and methodology used in the study. It gives a general description of the research approaches and steps of the study, then follows by showing a quantitative approach and data sources employed in the research.

3.1. Research Design

Choosing an appropriate design for a research is study entails a careful consideration of the feature of the phenomenon under investigation. Such features dictate both the type of empirical data as well as the method that is going to be applied in the analysis (Hannås, 2007). In this study descriptive analysis has been done to analyze the value chain of wind energy technology in Ethiopia with the use of collected data through the survey done to participants in a value chain. To achieve the desired objective the entire content of paper is designed as follows:

- First, examine the current wind energy technology value chain of Ethiopia. This aims to assess the competitive position and manufacturing potential of the key components and downstream activities of the wind energy value chain in Ethiopia.
- Second, analyze local capabilities in supplying of components and providing downstream activities. This requires analyzing and identifying the wind energy technology value chain segments and activities that can be suitable for local value creation. For this outcome a new wind energy technology value chain model is designed and proposed.
- Third, identify the opportunities and challenges and set recommendations to enable the wind energy value chain localization in the country.

3.2. Research Framework

The research framework of the study is designed based on considerations of the concepts reviewed literatures, expert opinion and different data sources. The general framework of this research is shown in Figure 3.1.

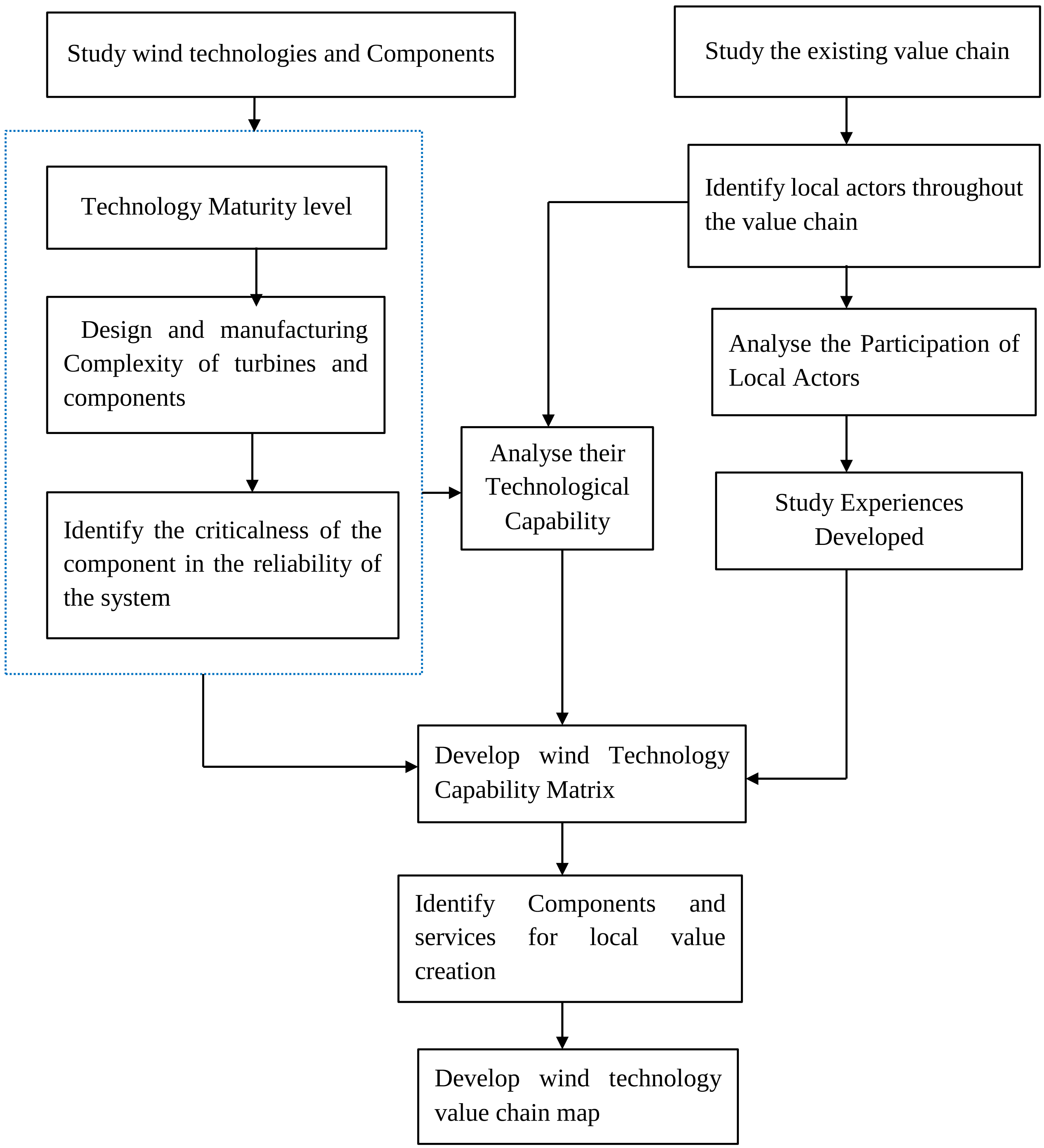


Fig 3.1: A framework to develop wind energy technology value chain roadmap in Ethiopia

3.3. Research Methodology

To address the key research objectives, a combination of primary and secondary sources and both the qualitative and quantitative methods ware used. The different methods deployed in this paper are explained below:

3.3.1. Literature Review

Literature review was conducted in order to increase the understanding about the research topic and to form a theoretical foundation for the empirical part of the study. The literature review consisted of an examination of academic literature, organizational reports, government documents, and different official statistics regarding value chain analysis, technological capability, wind energy technology, global trends and experiences, Ethiopian energy sector and about the wind power resources potential in Ethiopia. The literatures were referred from electronic media, journals and books such as articles, periodicals, proceedings, books, magazines, reports and websites. The analysis and discussion of the articles is carried out based on their context, the structures and methods used for the study, and the final findings.

3.3.2. Data Collection

Following the extensive literatures surveyed to strength the theoretical background of the study area and to identify the research gap; the data were collected from the key stake-holders in the sector including governmental institutions and business organizations. Specifically the researcher has collected data from Ministry of Water, Irrigation and Electricity of Ethiopia, Ethiopian Electric Power, Ministry of Trade and industry, Ethiopian Energy Authority, Adama I and II wind power plants, Ethio-Resource Group, Green Energy development, METEC, Ministry of innovation and technology, Mesfin industrial Engineering Plc., and Metal industry development institute through observation, interview, questionnaire and secondary data.

3.3.2.1. Observation

Observation is a vital facet of science. The observation is tightly connected to information assortment, and there square measure totally different sources for this: documentation, repository records, interviews, direct observation and participant observation (Yin, 1994). There square measure several positive aspects of the data-based analysis approach, namely, observations square measure sometimes versatile and do not essentially would like to be structured around a hypothesis. For instance, before enterprise a lot of structured kind of analysis, a scientist could conduct observations in order to kind analysis queries. Data-based analysis findings square measure thought-about sturdy in validity as a result of the scientist is ready to collect a depth of data a few specific behavior. During this study the scientist used observation as a tool for collection data and information.

So, to have firsthand information and to understand the existing situations of wind energy technologies, operational practices, existing problems and challenges, the researcher has selected and observed three wind power plants (Adama I, Adama II and Mehal Meda mini- grid wind plant) to understand the existing situations of wind energy technologies, operational practices, problems and challenges.

3.3.2.2. Interview

The use of individual and cluster interview could be a common observe in qualitative analysis. as a result of interviews address advanced subjective analysis problems, are comparatively economical in terms of time and resources (Silverman, 2007). There are three styles of interview: (1) structured interview during which associate degree enquirer physically meets the respondent, reads them the same set of queries in a planned order, and records his or her response to every; (2) Semi-structured interview could be a kind during which the enquirer commences with a collection of interview themes however is ready to vary the order during which queries are asked within the context of the analysis state of affairs; and (3) unstructured interview that involves loosely structured and informally conducted interview that will begin with one or a lot of themes to explore with participants however while not a planned list of inquiries to work.

This study applies a combination of a semi-structured interview and an in-depth (unstructured) interview in retrieving primary data. Key informants interviews and focus group discussions are conducted with members of management, and with officer and experienced staffs which are selected from governmental and non-governmental organizations mentioned above. In this study, the interview process is conducted to collect general information regarding the Ethiopian wind energy technology value chain sector with the aim to:

- Understand the overall current wind energy technology value chain in Ethiopian
- Assess the current technological capability of the country to localize the value chain
- Identify the value chain segments that will be substituted locally
- Generate a possible solution and map the new wind energy value chain

3.3.2.3. Questionnaire

The main tool for gaining primary information in practical research is questionnaire, due to the fact that the researcher can decide on the sample and the types of questions to be asked (Harris and Brown, 2010). The primary data can be gathered through a self-completion questionnaire. Essential advantages of collecting primary data were the connection of this information to the specific research question. The researcher will gain insight into first-hand information and experiences from selected respondents and, to this end, encourages respondents to express their opinions or to give feedback beyond the scope of the set questions (Veal, 2005).

In this research, the data was also collected through questionnaires distributed to organizations those are engaged in the wind technology value chain. The questioner only targets manufacturing companies and service providing organizations which can in principle contribute with their competences and know-how to a part of the value chain of the wind technology. The respondents were selected based on their educational background, working experience and job position (employees who has 5 year experience and minimum of first degree and working at middle/top management level were selected). The questioner was used in this study with the aim to explore the existing wind technology value chain practices in Ethiopia, actors involved, experiences developed, challenges and constraints faced in the deployments and manufacturing segments, assessing the potential domestic companies in manufacturing of wind turbine components and delivering supporting services, investigating the governmental and non-governmental organizations future plan (including short, medium and long term plans) in the sector and so as to identify the value chin segment (wind turbine components) which would be submitted locally by considering the technological capability of the country and its relative benefit as a whole (see Appendix A for a full list of interviewees).

3.3.2.4. Secondary data

Secondary data were also assessed as part of the desk research; use the existing information from the website, related organizations data and sources, journals, Articles, senior thesis work, magazine or other published and not published sources. Secondary data entail the proactive seeking of existing data in both qualitative and quantitative research.

3.4. Data analysis and synthesis

The data obtained through physical observation, interview, and questioner and from secondary sources were synthesized and analyzed using the Microsoft Excel (2007 version) program, which is one of the most commonly used data analytical techniques in qualitative researches. Descriptive statistics such as frequencies, measures of central tendency and dispersion were used to provide the general overview of the localization potential of the country along the wind energy technology value chain segments. Qualitative data was categorized and analyzed using content analysis.

3.5. Reliability and validity

Methodological triangulation through the use of structured questionnaires, semi-structured questionnaires and key informant interviews were adopted to improve on the validity and reliability of the study. The objective of triangulating the research methods is to check if similar conclusions can be drawn from the various methods of data collection. In combining the various methodological data collection and analysis techniques, triangulation seeks to increase confidence in the research data, create innovative ways of understanding a phenomenon, reveal unique findings, challenging or integrating theories, and providing a clearer understanding of the research problem (Thurmond, 2001).

The way in which different organizations and employees perceive the situations, opportunities and challenges are most likely to vary depending on the level of education, technical competency and technological awareness, hierarchy within the organization, and other vested personal and professional interests. As a result, effort was made to select employees with random purposeful sampling technique from focal organizations during the sample selection. Furthermore, to capture the diverse opinions obtained from different stakeholders, multiple data collection and analysis methods were deployed in this thesis.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1. The wind technology value chain practices in Ethiopia

Currently, there are three large-scale and one mini-grid wind power plants installed in Ethiopia. The manner in which these wind power plant turbines and related components are manufactured transferred and deployed in Ethiopia varied from project to project, depending on the detailed contractual structure used. Nevertheless, all the three large-scale government owned projects developed follows typically includes four phases: identification, development, construction, and operation. In the identification phase, the project owner (EEP) contracted with international companies to conduct a feasibility study and selects potential projects for development. During the development phase, the project owner selects the EPC contractor through open tender, closed tender, or tender negotiation, based on prices, experience, financing, and technology. This phase also includes civil works, such as access roads, turbine foundations, transmission lines, and substations. After construction is completed, the wind farm is transferred to the project owner for operation, per the terms of the Operations and Maintenance (O&M) agreement.

In the value chain of large scale wind power plant projects, lead firms such as Vergent and Hydro-china are in cooperation with international construction and engineering companies typically involved as total system suppliers - in so-called engineering, procurement and construction (EPC) contracts -under which they are responsible for the detailed engineering design of the project, the procurement of all the equipment and materials necessary, and the construction and delivery of a fully operational plant to their clients. This is also one part of the requirement imposed by external financial lenders in the loan agreement. For instance, there was a prerequisite for the BNP Paribas loan that more than 50 percent of the supplies must be of French origin (Yanning, 2016). Hence, all of the main components, such as blades, towers and nacelle comments, are imported, and assembled on-site by the lead firms from their , who handle and control the entire value chain of the projects. The participation of local actors in those projects was mainly limited to higher education institutions hired by the project owner, served as consultant throughout the project life cycle to ensure that the contractors are adhering to the project specification (see Table 4.1).

Table 4.1: The existing Ethiopian wind Technology value chain and actors involved in the segment

<table>
<tr><th></th><th colspan="2">Ashegoda wind farm</th><th colspan="2">Adama Wind Farm I and II</th><th>Mehale-Meda</th></tr>
<tr><td>Feasibility study</td><td colspan="2">Lahmeyer</td><td colspan="2" rowspan="2">Hydro-China</td><td rowspan="3">ERG (project owner)</td></tr>
<tr><td>Project designer</td><td colspan="2" rowspan="2">Vergent</td></tr>
<tr><td>Procurement</td><td>Hydro-China</td><td>CGC</td></tr>
<tr><td rowspan="5">Manufacturing</td><td colspan="2" rowspan="5">Ecotecnia
Supply 54/74 wind turbines with all components and controlling systems
Vergent
Supply 30 turbines with all components and accessories</td><td colspan="2">Gold wind
Supply components (Blades, Tower and Nacelles)</td><td rowspan="5">Foreign technology suppliers
All turbine components and accessories were imported</td></tr>
<tr><td colspan="2">Baoding Tianwei Electronics Co.
transformer</td></tr>
<tr><td colspan="2">Hengshui Shuangli Wind Electric Equipment Co.
Wind mast manufacturer</td></tr>
<tr><td colspan="2">Hydrochina Northwest Institute
Monitor and automatic system</td></tr>
<tr><td colspan="2">Shanghai Dingxin Electric Co.
Diesel generator</td></tr>
<tr><td>Transporter</td><td colspan="2">Vergent used their own shipping line</td><td colspan="2">Sinotrans and Ethiopian Shipping Line</td><td>Ethiopian shipping line</td></tr>
<tr><td>Installation</td><td colspan="2">Vergent</td><td colspan="2">Hydro-china</td><td>Ethio-Resource Group</td></tr>
<tr><td>Construction</td><td colspan="2">Local construction companies</td><td colspan="2">CGC Overseas Construction Eth. Ltd.</td><td>Local construction company</td></tr>
<tr><td>Grid connection</td><td colspan="2">Vergent</td><td colspan="2">Hydro-China International Engineering Co., Ltd</td><td rowspan="2">Ehio-Resource Group</td></tr>
<tr><td>Operation & Maintenance</td><td>Vergent</td><td>EEP</td><td>Hydro-China</td><td>EEP</td></tr>
</table>

Consultant	Lahmeye	Mekelle University	Adddis Ababa University	Mekelle and Adama University	Components manufacturer

However, the development of these wind farms provides many short-term employment opportunities for local residents and companies throughout the project life cycle. According to Yanning Chen, Vergent subcontracted logistics such as, insurance, and customs clearance, electromechanical works and civil works to local companies in the development of Ashegoda wind farm; and Hydro-China also subcontracted shipping, insurance, and customs clearance works, to local companies. Additionally, in the construction phase of those projects over 18000 local workers were employed, about 1000 job was created in Adama wind farm. From the employees participated in the development of wind plants; 35 engineers from Ashegoda and 60 Engineers in Adama (I &II) wind farm were trained and gained a lot of knowledge working in specially designed class-room training, onsite training and touring international wind farms, manufacturing facilities, and control centers to take over the wind farm during the operations Phase.

In the mini grid wind farm, the participation of local actors was high and captured large shares of the value chain, predominantly in the deployment phase activities. Initially, in the identification phase, the project owner ERG, through a feasibility study, selects potential sites for mini grid wind power development. Since this project was the first private owned and mini grid wind power in the country's history, the identification process also involves prolonged discussion and negotiation between the project owners, communities and concerned governmental bodies to gate permissions and supports. But the participation of local actors in the manufacturing and or supplying of wind turbines and components were poor; and Wind turbines were imported as fully operational, pre-fabricated systems from renowned wind turbine suppliers abroad. The wind turbines and its systems installed by the project owner (ERG) with support from civil contractor and from the wind turbine manufacturer. The operation and maintenance activities are also provided by the project owner for the last three years. In addition to the periodic monitoring visit make by ERG engineers to inspect system components and oversee sustainable operation, one local electrical technician is employed to operate the operation system and provide routine operation and maintenance in short distance.

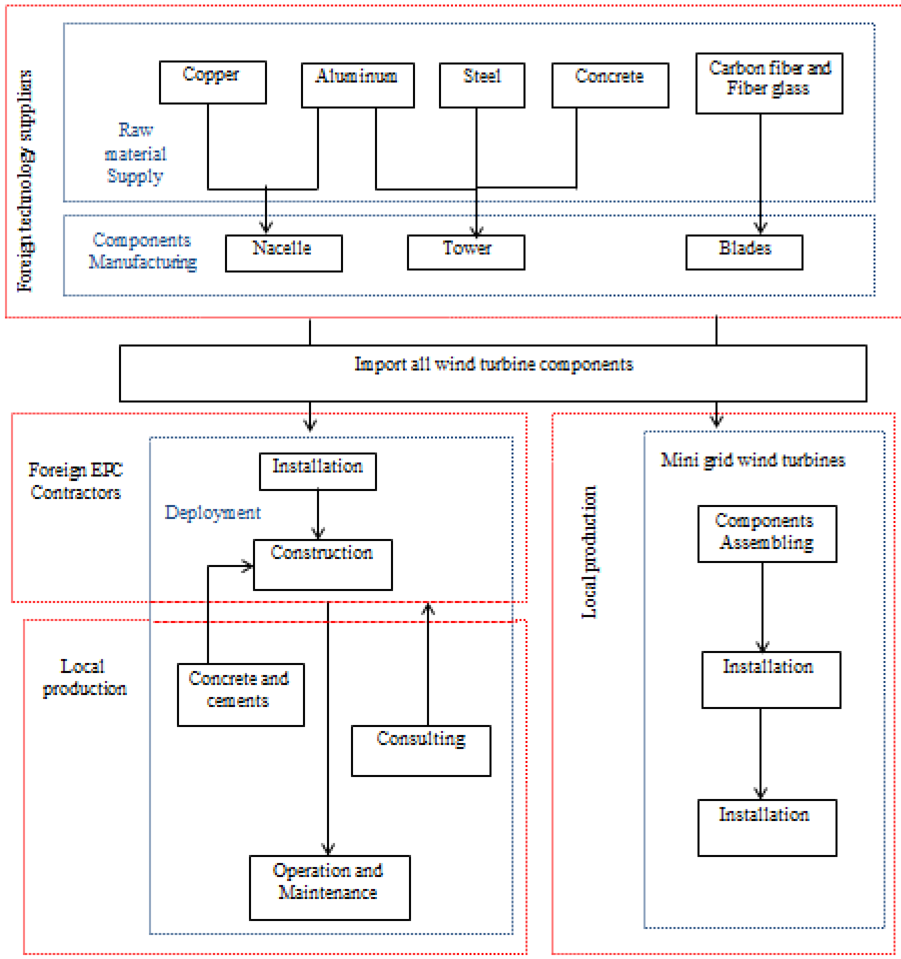


Fig 4.1. Value chain of wind energy technology in Ethiopia

4.2. Contents of Data analysis

In the assessments made earlier the overall market potential, the current situation of wind energy in Ethiopia and actors involved along the wind energy technology manufacturing and deployment segments in the installed wind power plants were analyzed and discussed. From this literature survey, the researchers understand the potential of the wind industry to incorporate on several industrial sectors and generate income and create jobs along the value chain. In addition to understanding the technology, the industry value chain and the global trend, the researcher noted that the potential of the market in the country as wells as in the region that relies the local manufacturing of wind technology components in Ethiopia.

The assessment domestic technological capabilities for manufacture of parts and components and associated services were also supported by the data collected through questioners and interviews made with governmental and non-governmental organizations which are mentioned in the methodology part.

Accordingly, considering the existence of a sizable, protected and stable market in short and long run in the country as well as in the region as evident; this chapter presents, interprets and analyze the domestic technological capabilities in the wind technology value chain with respect to the manufacture of parts and components and associated services (production and project execution capabilities), as well as knowledge creation and R&D potential (innovation capabilities). The assessment of level of technological capabilities for wind technology value chain localization in Ethiopia relies on the data gathered using a questionnaires and interviews as well as on the surveys made on the existing vale chain and technology maturity. The data's were collected from manufacturing companies, governmental and non-governmental stakeholders. Ethiopian wind energy technology for the individual segments, activities and services over the whole project life cycle is given below, starting with the project development phase, followed by the realization phase (covering the complete manufacturing phase) and the operation and maintenance phase until the end of facilities life time.

Although the wind power is made up of a number of segments, the industry can also be broadly divided into upstream activities (related to developing and manufacturing the components itself) and downstream activates (related to deployment of the wind turbine and gird connection). In order to allow an easier analysis of each activates and a component of wind energy technology, the value chain of Ethiopian wind industry was is divided into three different sub-chains:(1) upstream activities, (2) downstream activates and (3) supporting activities.

4.3. Domestic Wind technology capabilities in Ethiopia

4.3.1. Production Capability

The upstream segment of the wind energy value chain includes various activates starting from supplying of raw materials up to manufacturing of tower, blades, gearbox, generator, bearings, power converters, screws, yaw and pitch systems, and control systems.

4.3.1.1. Raw Material Production

Wind turbines are majorly made of steel, Aluminum, copper, fiberglass and concrete. The raw materials used in the construction phase such as aggregate, steel and cement, which is used to construct concrete foundations for wind turbines, is available locally and can be supplied by conventional companies working in the domain. The tower is fully made of steel and concrete that can be delivered by local companies, which are engaged in production of these components without a huge additional investment by modifying the manufacturing the existing manufacturing process. According to the interview made with Ethiopia electric power and ministry of industry, the local companies have experienced in supplying different concrete articles in large hydropower projects. Local specialist companies could also be involved with project development. Although the country is known to possess a wide variety of mineral resources. However, their utilization is yet to be realized, mineral exploration and exploitation still being in its infancy. Information gathered through a key informant interview with metal and industry development Institute also supports this finding. According to these interviewed institutes, despite the limitation of quantity produced in relation to the country demand, there are capable steel manufacturing industries like East steel and Kality steel manufacturing company to produce the required quality of products in the construction of wind towers and basements.

4.3.1.2. Wind turbine Component Manufacturing

The wind turbine with its installation components are the main components in wind project development followed by project planning and civil works. Most commonly, the wind turbines account for between 64% and 74% of the project's total installed cost globally and about 65% of total project cost of the previous Ethiopian wind power plants (IRENA, 2016), (CHEN, 2016)). In the utility scale onshore wind power plants, turbines comprise of vast components, ranging from simple to sophisticated components and parts (critical components), that are technologically advanced and extremely complex and require highly specialized skills to ensure a high quality, and often manufactured by the OEMs company with high quality of standards. Despite these complicated components of the wind turbine, due to the fact that wind turbines are made of large components, there are also simple and bulky but costly components, which are supplied by non-original equipment manufacturers globally, and provide opportunities for local value creation with an already existing production line.

Furthermore, the most important components for the wind turbine are the rotors and blades, the nacelle and tower, generator and electronic components including all necessary sub-components. The feasibility of localization of these individual components in Ethiopia has assessed and analyzed by taking in consideration: the knowledge and skill transferred and experience obtained from the previous wind power plants establishment; the existence of capable domestic organization, facility and human power; costs and logistical challenges related to transporting, government policies and strategies and incentivizing towards local manufacturing and value creation; the socio-economic opportunities that will be obtained as follows.

i. Tower

The tower is one of the largest and expensive components from wind turbine components that account from 25-30 percentage cost of all the major wind turbine components (GLWN, 2014). But also, the tower and tower basement are one of easily manufactured of steel or concrete or hybrid from the wind turbine components. The literatures surveyed has also confirmed; due to large, expensive, less sophisticated manufacturing process, and difficult to transport, wind turbine towers are commonly outsourced and supplied by non-OEMs (GLWN, 2014). Local production of towers has generally progressed furthest and reaches more than 100 tower suppliers in the world.

In Ethiopian context, the manufacturing of wind turbine could tend to be localized first and taken as precious entry point for establishing a local production with the following justifications.

- ✓ Towers are not high technology products and have low technical requirements. The production of wind towers used machines that are also required in other industrial sectors such rolling and welding. So, it can manufactured locally by the existing well developed heavy mechanical engineering industries (E.g. METEC, Yesu metal works, Akaki steel factory and Mesfin industrial engineering) by licensing a pre-certified designs from specialized foreign companies.
- ✓ The raw materials used in tower manufacturing like concrete and steel can be sourced locally, hence it encourage the vertical value creation and local production of towers.
- ✓ Can generate large job opportunity since it highly labor intensive, it accounts 34% of the total human resources required to manufacture main wind turbine components; a tower manufacturing facility would occupy up to workers to produce 100mw of wind turbine towers (IRENA. I. R., 2017).
- ✓ Moreover, as the information obtained from ministry of water, irrigation and energy, the country is doing aggressively in irrigation works and the government of Ethiopia has a plan to sustain in long term. Therefore, manufacturing of wind towers locally will create capability in the country in the manufacturing of irrigation components also.

Despite the production of steel towers discussed above, the concrete type of towers is further affirmed for Ethiopia, since the concrete towers are cost effective, have the potential to create more jobs along its value chain compared to those of other technologies such as steel towers (IRENA. I. R., 2017). According to the interviews made with ministry of trade and industry, and metal industry development institute; there are capable firms to produce steel with size and quality required for the tower production, but the country have high demand of steel in relation to rapid development of construction industry, which is till fulfilled by imported materials (the country imports about 70million tons of steel per annum). So, manufacturing of wind towers from concrete materials would be more economical and solve the challenges mentioned above. It can be provided by the existing well established general concrete construction industries that are experienced in subcontracting megaprojects in the country, by taking the license from original equipment manufacturers. According to the survey shown below almost 90% of respondents replied that the country is capable to manufacture wind towers.

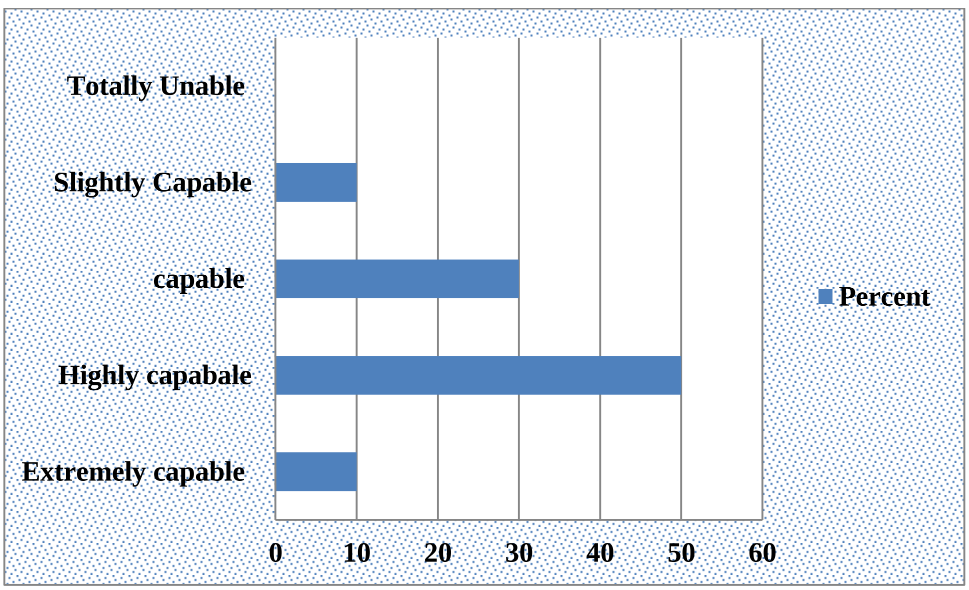


Fig 4.2: Local capability for tower production

ii. Blades

Wind blades are one of the most critical and expensive components of the wind turbine, which are typically made of glass and carbon fiber materials. One three-blade set (often used commonly in wind power plants) comprises the second highest percentage cost of major wind turbine components at 15-26 percent (GLWN, 2014). The global trend in establishment of local capabilities in the manufacturing of blades is also relatively common among OEMs, provided the market has sufficient demand; however, blades manufacturing requires large investments and access to know-how.

Furthermore, since the geometry and the inner setup of the blade are crucial for the efficiency and the energy output of the wind turbine, it is extremely requires in-depth knowledge and skilled labour force, special design methods, and advanced and précised industrial processes and highly specialized equipment that include molding and assembly systems, laser tracking and ultrasonic inspection (DTI., 2015). Although this would require engineering and development centers to test the composites used to manufacture the blades and to improve the selection of materials.

Therefore, manufacturing of this component locally is not an easy task in Ethiopia with the exiting manufacturing facilities and workforce that the country has. The feedback received from Ethiopian metal industry development, which has a mandate to support and assess the local metal industries during in the interview; at present it would be difficult to manufacture the wind blades, since there is lack of raw material, advanced industrial equipment and facilities, expertise and R&D centers to ensure good quality products. The first heavy mechanical manufacturing industries in country such as Mesfin Industrial Engineering and METEC companies also have no facilities, equipment and expert workforce to produce this component. But, manufacturing of this component locally in long run make sense to reduce challenges and costs in the transportation of thus large and heavy wind blades by initial acquisition of license or joint venture agreement with specialized foreign companies. However, the significant investment needed to create new production lines is a barrier. This would require investing in new production lines, expanding industrial facilities, improving industrial processes, and training for human resources.

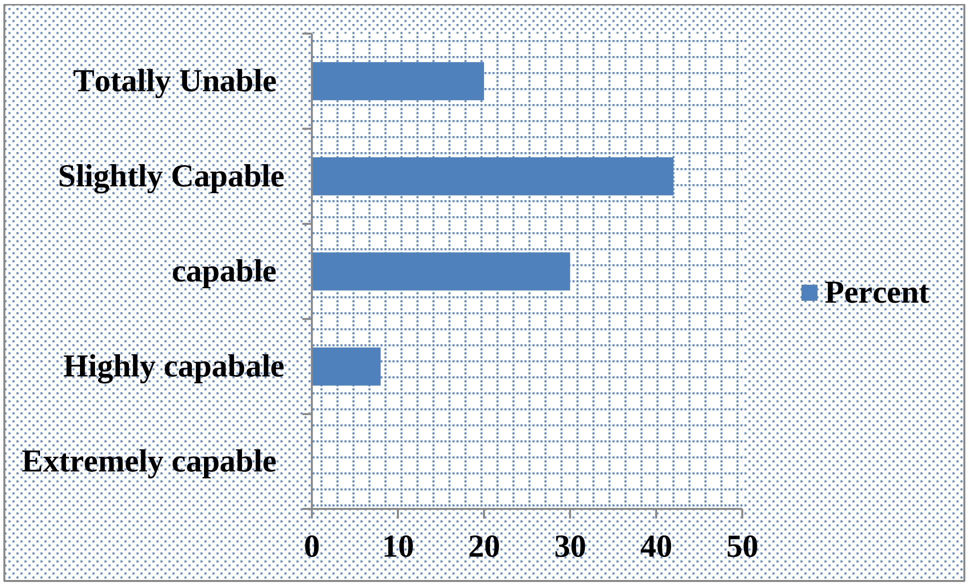


Fig 4.3. Local capability for blades production

The result of the survey shows that the local potential for manufacturing of blades is weak. 42 percent of the respondents argue that the country slightly capable; 20 % respond that it is totally unable to manufacture wind turbines locally with exiting domestic firms and technologies; 30% respond the country is capable; and rest of the few respondents argues that the country is highly cable. The overall assessment of the existing technological capability of domestic firms is not sufficient to manufacture the wind turbines as per the required quality level. It need further investments in the sector and know-how development or joint ventures with international manufacturing companies.

iii. Nacelle

Aside from the main shaft, the nacelle includes extremely complex and are technologically advanced sub-components such as gearbox, generator, bearings, power converters, screws, yaw and pitch systems, and control systems, which are critical in the entire system as they affect reliability of the wind turbine. The manufacturing of these components requires highly specialized skills and precise processes to ensure a high quality, and needs significant investment associated with local technology deployment, therefore it's often produced in-house by OEMs with high quality of standards. Furthermore nacelle components are less bulky and involve lower transportation costs compared to towers and blades; therefore they can be transported more easily international manufacturers. Hence, as the incentive for lead firms to localise production of these components is lower, nacelle components are often imported directly from limited number of highly specialised manufacturing companies globally.

All in all, the potential present for local manufacturing these components in Ethiopia is limited by the complexity of the process that requires highly specialised labour and by the concerns over quality and high inputs costs. Based on the interview conducted with government institution and non-governmental business organization; instead of manufacturing of those components, the assembly of the nacelle would be the easiest step to start; with the objective of establishing local capability for manufacturing of nacelle sub-components in long run. Although the country is seeing opportunity to localize it by inviting international OEM companies to invest in the sector and to set up manufacturing facilities through foreign direct investment. According to the information obtained from Ethiopian Electric power, the chines wind turbine manufacturing company "Gold-wind" is also in progress to establish wind turbine manufacturing plant in Ethiopia by considering the countries and the regional market opportunity.

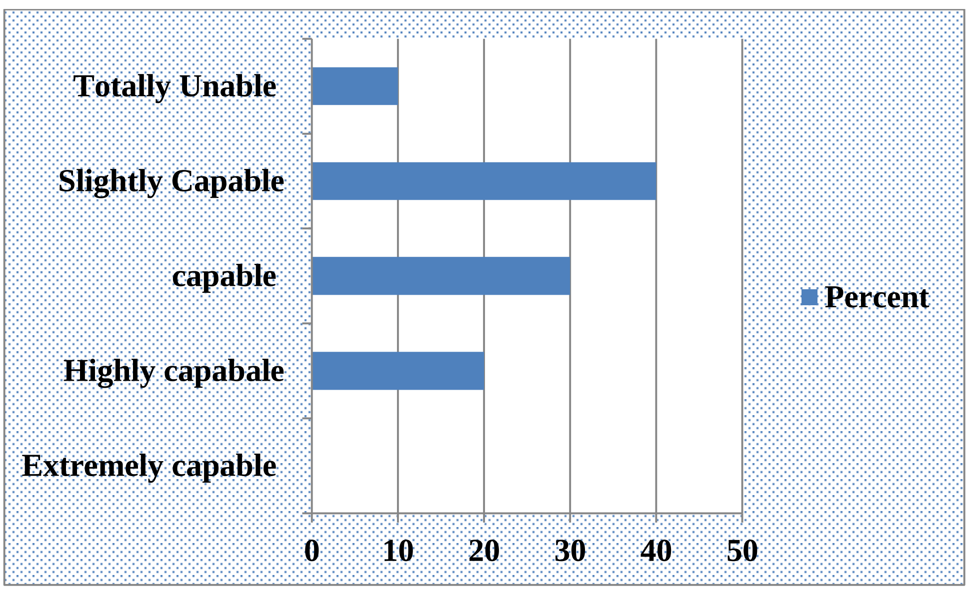


Fig 4.4. Local capability for nacelle production

iv. Electrical components

In addition to the main wind turbine components discussed above; the wind turbine plant also incorporates electronic components such as transformers that are used to transfer the energy generated by the turbine to a higher voltage to feed it into the distribution network; and cables that are required to connect wind turbines to the inverters, transformers and grid. These components are not limited to the use in wind turbines but also required in other energy power plants and industrial sectors. Information gathered from the interviews also revealed that the country has capability to produce power cables and step-up transformers. Local companies such as METEC, Euro Cable PLC and Elsewedy cable Ethiopia has considered for manufacturing of these components, as long as they are able to adapt their production processes to the special needs of the wind turbine company. In the previous wind power plants deployed in Ethiopia, the government owns company METEC has been involved in repairing the unit transformers. Local manufacturing of these items will provide large potential for domestic value creation in the first stage, depending on existing capacities used in other industries that can provide expertise, raw materials and intermediary products.

4.3.2. Project Execution Capabilities

Pre- Deployment Phase

The project planning phase of the wind turbine incorporates different activities starting from site assessment and selection to project development. In the previous installed wind power plant, this segment of the vale chain has predominantly undertaken by foreign companies with little involvement of local actors. In fact, some of the activates needs specialized professionals from different disciplines like environmental science, renewable/wind energy and social science for economic valuation of high-quality renewable sources, which are not available in locally. But there are many activates that would be performed by local professionals and actors. During the project life cycle different services like feasibility studies, technical and legal advisory works are necessary. Besides the technical also local know-how is necessary to perform these services. Also during the construction several companies are active concerning civil engineering and logistics.

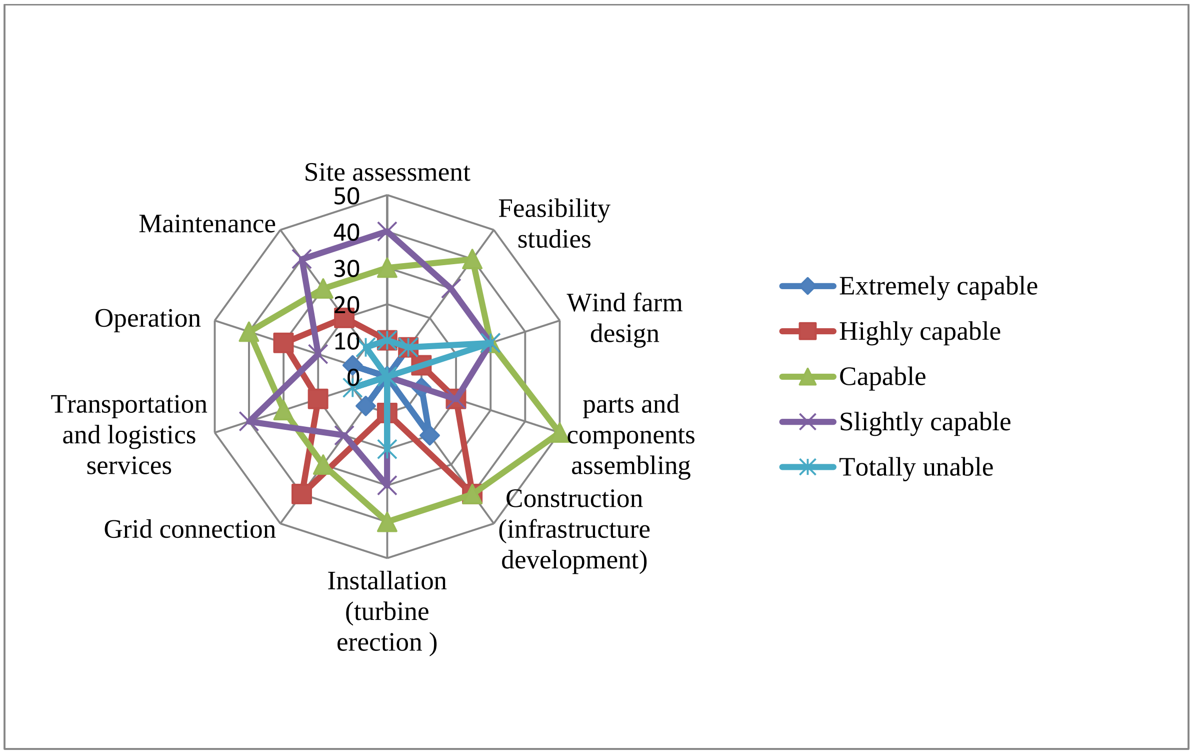


Fig 4.5. Localization Capability for downstream Activities

In this regard the capability were collected using the questionnaire was assessed as shown above. The result indicates that the local firm's capability to carryout site assessment activities including wind resource assessment, environmental assessments and social assessments activities is weak. On the other hand, the local firms have a capability to conduct feasibility studies of wind power plant projects. The result also shows that local firms have weak capability to design wind power plant.

Deployment Phase

The deployment phase of the wind energy includes the construction of infrastructure to permit physical access to the site to facilitate the transport of equipment, and components and wind farm construction, assembling and installation of components, and grid connections. The installation and construction with other activities involved during the wind turbine deployment represents between 25-30 percent of the total project cost, based on the soil characteristics of the wind farm site and the distance components transported (IRENA, 2017). As it is was described in the literature review part in detail, local companies and individual have been involved in the previous wind projects deployment services like transportation, civil works and electro-mechanical works. Therefore, this phase is typically, an effective segment for localization as several companies and individual have been involved in the previous wind projects deployment; they have developed experiences and capabilities well. AS per the fact obtained from the two ministry offices namely ministry of water, irrigation and Energy and ministry of trade and industries; those services can be provided by local, experienced and sufficient companies that are already well established. In this particular regard, the government of Ethiopia is also committed to support the involvement of local companies by implementing local content requirement in the contract agreement in the ongoing projects. However, assembling different components on-site might require investing in human resources and training programs.

Post- Deployment

The operation and maintenance process of a wind farm is the latest stage of the development of wind projects. The operation and maintenance (O&M) covers the expected lifetime of about 25 years and accounts 20-25% of the total cost of wind projects. In the existing wind power plants, the first five years of operation and maintenance activities are commonly under taken by the project developers as per the agreement in the contract, to ensure a specific level of performance. After the period is completed, all the management and activates of operation and maintenance works would be performed the project owner (Ethiopian Electric Power). In this regard, the first wind power plant Adama one is a typical example that is fully operated, managed and maintained by local workforce. According to the interview made with Adama I and II Power plant managers, the local engineers who has obtained special training during in the installation phase and work for long period in the plant are able to perform these activates potentially. Although, localization of these activities will provide opportunities, to create large local employment possibilities and labor force skills within country, to develop skills and experiences so as to participate in the installation and assembling works, for the future projects. So, it could be taken as an effective segment for localization and local job creation along the wind deployment activities.

4.3.3. Supporting Activities

The supporting segment of the wind value chain includes activities like consulting, research and development, education and training.

Government polices

Government policies are considered as a key driving factor in promoting the wind industry value chain localization and domestic capability development. The encouragement of a wind power policy measures and supporting mechanisms will have a positive impact on both wind power development and industry localization. As it illustrated in the previous section (lessons from the case countries), government policy has been central to successful domestic wind industry development and technology diffusion.

Lewis and Wiser classified the policy measures used to the wind industry development in two main categories: direct (policies that specifically target local wind manufacturing industry development), and indirect measures (policies that support wind power development in general), which is indirectly create an environment suitable for a local wind manufacturing industry (Lewis and Wiser, 2005). The strategies used in the direct and indirect support of wind industry development includes polices like feed-in tariffs, utility quota obligations, local content requirements, favorable custom duties, investment subsides, tax incentives and financial incentives. But still, there is no one unique and best policy option to adopt and implement.

The Current Ethiopian energy policies and strategies are not sufficient enough to promote the local wind industry development. The government needs to show, invite and convince the opportunities and profitability of the sector to the global and local actors to participate actively in the sector. Despite promoting the wind resource potential and the high market demand, the government should also design policies that support provided economic incentives like tax exemption and duty frees to create better investment motivation. This should help to attract local and international investors to engage in the wind industry, noting that the vast resources and the highly demanding market in the country and the region should favor the investment.

Education and R& D

Education and training be crucial to the success of a domestic wind industry development. The wind power industry engages workers from a wide range of fields. In Ethiopia there are around 42 universities and more hundreds of technical colleges that annually graduate many engineers and technicians. But the problem in this area is not with the number of graduate students, rather the graduate students are not enough trained and skilled. According to the questioner collected the local capacity skilled worker is poor and it is being one of the key challenges in the industry. Therefore, it is essential to establish a local capacity building system and train qualified professionals by cooperation with the universities, research institutions, and manufacturing industries.

On the other side, the development, manufacturing and adaptation of wind turbine technologies needs different sets of research capacity and technical skills. Research and Development has critical role in supporting the adaptation of technologies to local needs and in developing the capacity of local companies. The research and development activates can also be classified in three ways (1) Basic researches (2) applied research and (3) experimental researches. Unlike other researches the basic research types requires highly skilled experts, high level technologies and huge financial resources, and mainly focus on generating new ideas and technologies. In this regard the current capacity of the country in the basic and experimental research was very limited.

4.4. Summary of Results

Despite the weak policies and unclear frameworks used to promote this sector, the analysis showed that there is promising local capacity potential to provide simple components and services of wind technology value chain segments which can be taken as the typical procedure of the first tier of the wind industry and to upgrade through time with the involvement of private sector participation in the short, and medium term. Table 4.1 summarizes the findings obtained from the above analysis and shows existing capabilities along the wind technology value chain.

Table 4.1: Wind Technology Value chain capability Matrix in Ethiopia

Levels of Capability	Production capabilities	Project execution capabilities	Supporting Activities
Basic	✓Tower construction with standardized deign ✓ Gear box assembly ✓ Electric cable and wires manufacturing ✓ generator Assembly ✓ Transformer construction with standardized design	✓ Transportation ✓ site assessment ✓ Construction of basic civil works ✓ Grid connection ✓ Operation ✓ Maintenance	✓ Consulting ✓ Policy developments
Intermediate	✓blades manufacturing with standardized deign ✓ Tower construction with naturalized design ✓ gear box construction with standardized design ✓ generator construction with standardized design	✓ Detailed Engineering design ✓ feasibility studies and environmental assessment ✓Repowering ✓ Installation	✓ Training and education ✓ technology transfer
Advanced	✓ gear box construction with naturalized design ✓ Blades construction with naturalized design ✓Product innovation and related R&D	✓ Basic process design and related R&D	✓ Research and development

In the upstream side of the wind technology value chain, the country is capable to provide non critical and matured components such as towers, electronic wires and cables, gearbox assembly and generators with the standardized OEM's specifications. The vertical conditions in the value chain also encouraging for the local production of towers due to the low barriers to entry arising from the high level of capabilities in the domestic supply and the high modifiability and low complexity of transactions. However, the potential for local production of core wind turbine components: blades, control panels and gearbox are very limited. Several researches and innovations were made this area to increase the efficiency of the wind turbine and quality is critical in the reliability of the system. Therefore, the manufacturing of those components requires high investment cost, advanced technologies and highly specialized experts. The development of know-how also needs concerted national efforts in training and education at different levels, as well as partnerships with foreign companies and organizations that are difficult to build in a short time frame. In the long-term these would be made by creating partnership and collaboration with global manufacturers to setting up local production directly or indirectly through local partners. Building local knowledge capabilities in these activities

Among the downstream activities, the wind resource assessments and feasibility studies, component assembling, infrastructures development, logistics and transportation, operation and maintenance activities were identified as the potential areas for localization. Ethiopia has a good local truck record by localizing these activities in previous installed wind power plant projects. Several local companies have been involved in the wind projects and have developed know-how in this sector. The finding of the analysis shows that the local potential for the installation, research and development, engineering design and environmental assessments is limited.

4.5. The Proposed wind technology value chain map in Ethiopia

Considering the local potentials for the different components and services described above, the wind technology value chain map of Ethiopia is developed. This was done by combining the results obtained from the data analysis and the literature survey. The proposed value chain will provide opportunities to the stakeholders by identifying the potential value chain segments for domestic value creation. The implementation of the proposed value chin map shown in the figure below will enhance the development of the wind technology in the country.

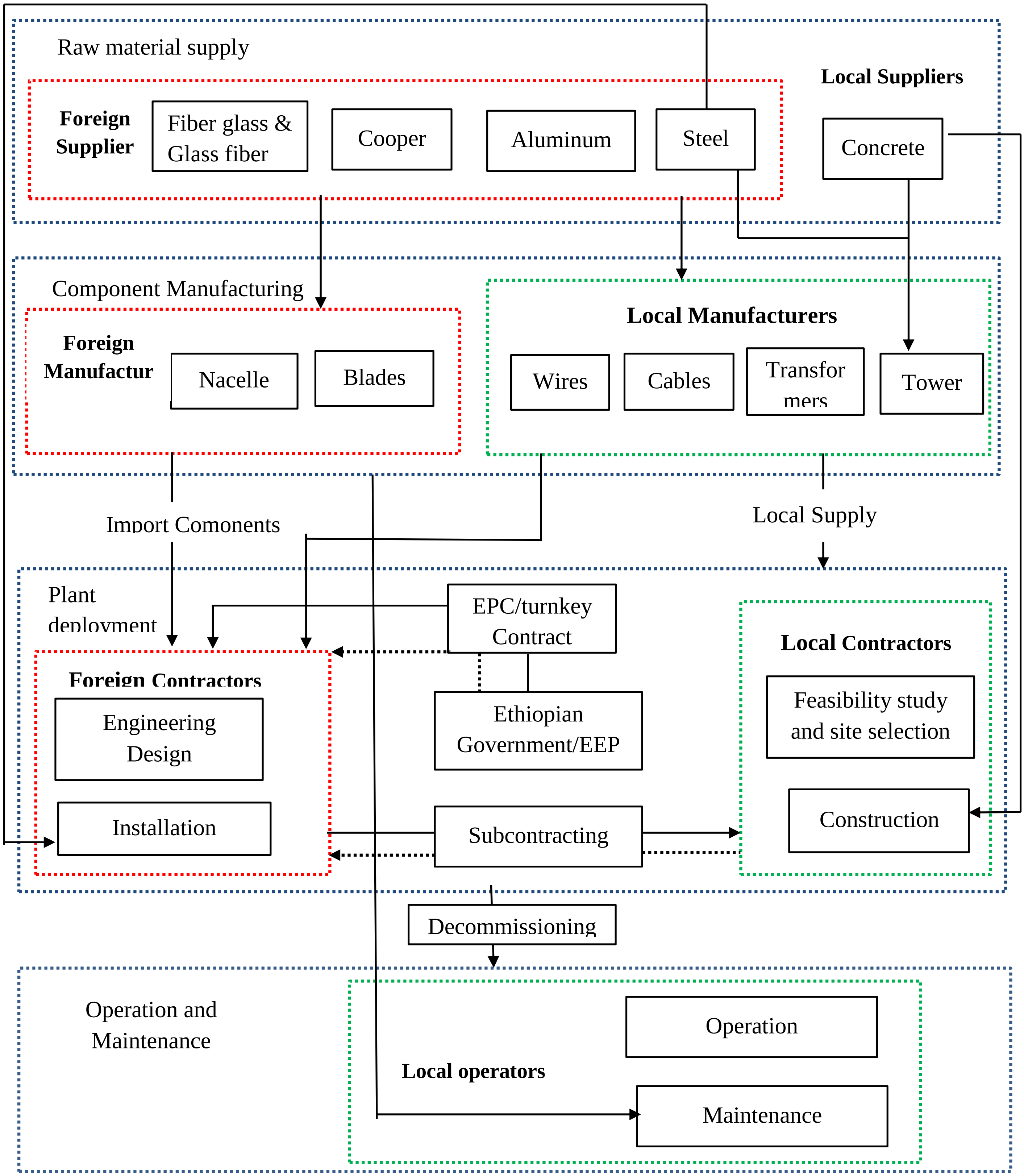


Fig 4.6. Wind energy technology value chain mapping in Ethiopia

4.6. Proposed Solution and Policy Implication

Despite the apparent potential for localizing the production of components and services the wind technology investigated in this paper, the government policies and incentive mechanisms adopted by the government are still be necessary for local value creation in the chain. Therefore, to support the development of Ethiopia's wind technology development and the localization the value chain segment as expected level, the following solutions were generated and proposed.

4.6.1. Local Content Requirements

Local content requirement is one of most common approach used to promote the development of a local wind manufacturing industry is by requiring the use of locally-manufactured technology in domestic wind turbine projects. A common form of this policy requires a certain percentage of local content for wind turbine systems installed in some, or all, projects within a country. Such policies force wind companies interested in selling to a domestic market to look for ways to shift their manufacturing base to that country or to outsource components used in their turbines to domestic companies.

As it was described there are wide varieties of components and supporting services which is roughly estimated up to 30-40 percent of the whole value chain segments can be substituted domestically. In this regard, the government should set the minimum local content requirement and appropriately considered as one element during in the contract for wind power plant project development to get the desired level technology transfer and socioeconomic benefits from the sector. By doing this the country can generate economic benefits in short and long term goals.

4.6.2. Possible Incentive mechanisms

Defining special set of investment incentives for targeted investors is a good strategy to market investment within the development and producing of technologies for the energy sector. Thus, various incentives mechanisms should be adopted and still be necessary for wind power to penetrate the electricity market. Therefore, to attract and potentially support private sectors involvement in the development and manufacturing of wind turbine technologies in Ethiopia, the following incentive mechanisms are and proposed to Ethiopian government.

i. Financial incentives

The cost of renewable energy investment is higher and typically has longer payback periods than that of typical energy investment. This obstacle will affect the chance of the wind energy investment in developing countries like African nation. Therefore, monetary incentives area unit important investment attraction and enlargement of the event and preparation wind energy. Monetary incentives of assorted forms, whether or not supported electrical production, or capital investment, and whether or not paid as a direct money incentive, or as a positive loan program, also can be accustomed encourage renewable energy development. a number of the potential instruments accustomed overcome the challenges are:

Capital grants: the capital grant provided by the governments for long-term finance to investors reduces project costs and allows investors to obtain loans from banks more easily. Furthermore, grants are not only limited to capital grants; project preparation grants are also available for resource assessments and preparation for the project. This will make obtaining loans when the project is in the preparation stage easier. .

Soft Loan and Project Financing Different loans provided by the public sector such as soft loans, loan guarantees, and project financing reduce project costs by providing long-term finance.

Resource Insurance: There are different types of insurances that reduce different risk for investors such as resource insurance and political insurance. The resource insurance guarantees return to investors if renewable energy generation is not sufficient, for instance, the investors of hydro power plants can obtain insurance during dry years. Political insurance guarantees protection against political or regulatory risks. This guarantees protection against risks from changes in policy and regulatory commitments by the host economy.

ii. Tax Incentives

Tax incentives can take the form of a tax credit, a cash payment, tax holidays, an exemption from tax obligations, or a low VAT rating. Tax incentives can come in many forms and can also be used to support local manufacturing. These incentives may take the form of capital- or production-based income tax deductions or credits, accelerated depreciation wind energy equipment, property tax incentives, sales or excise tax reductions and VAT reductions. Governments provide these incentives allowing taxpayers to deduct a certain amount of tax by investing in renewable energy projects. Many countries like Japan, china, India and US used different tax-based incentives to drive the wind energy and solar energy markets.

iii. Feed in tariffs

A feed-in tariff is policy tool designed to promote the investment of renewable energy resources. Feed in tariffs are designed to extend preparation of renewable energy technologies by giving long purchase agreements for electricity generation at a given value per kilowatt-hour, thereby providing market certainty for developers (Couture et al. 2010). And this makes FITs one of the most effective tools in establishing the rapid and sustained deployment of wind energy and to facilitate local manufacturing. The global experiences obtained from Spain, Germany and Denmark also suggest the potential of feed in tariffs policy in establishing the rapid and sustained deployment of wind energy. Furthermore, a feed in tariff polices are very vital to encourage the development of mini-grid and off-grid wind energy systems to countries who have scattered population distribution like Ethiopia and when main grid electrification system are not economically feasible. The Ethiopian government has been trying to develop enclose tariff schemes however it's not nevertheless materialized. Considering its significant co-benefits of promoting the utilization of renewable energy technologies and consequently being a catalyst for developing the capability of native producing and its indirect potential for energy security by promoting the utilization of suburbanized systems, it's suggested that the policy is enforced as quickly as potential.

4.6.3. Building institutional and human capacity

Since the industry is in infancy stage the domestic professionals and engineers participation in the sector is very weak. The shortage of wind power professional talent is one of the main factors that repeatedly reported by the stakeholders. At present, only three universities have established degree programs that are relate to the sector. Therefore, in addition to placing local content requirements for the future projects, the government should also consider the professional development works. This would be made by establishing domestic technology center specifically in wind power at one local university and promoting cooperation with the state, society, research institutions, and enterprises. On the other hand the government should establish a protocol regulatory framework to assure the participation of domestic experts is newly emerged wind power plant projects from the beginning, as such, professionals can develop know-how and skills.

The wind power plant development includes different units of governmental and non-governmental organizations form different sectors like suppliers, manufacturers, education and training, supportive service providers and etc. In this regard it is important for government policymakers to work in conjunction with industries and educational institutions for establishing guidelines and criteria for clean energy training. With practical experiences, industry partnerships can create effective standards for certification and are often well suited to provide training on key topics.

Therefore, communication and consultations between government, industries, and educational institutions are important for developing an appropriate renewable energy training program that can cultivate a professional workforce to satisfy the need in the market.

4.6.4. Research and Development support and Demonstration

Many studies have shown that the sustained public support of analysis on wind turbines can be crucial to the success of a domestic wind trade. R&D is commonly only once there is a few degree of coordination between personal wind corporations and public establishments, such as national laboratories and universities. Significantly in the case of wind rotary engine technology, demonstration and development programs will play a crucial role in testing the performance and liableness of recent domestic merchandise before these turbines go into business production (Lewis and Wiser, 2005).

As it is shown in the previous discussions parts there are a significant amount of wind power segments that are potentially substituted domestically. However, insertion of domestic firms in all future wind power plants development is not such easy task, because it may have high risks and requires high financial investment. To avoid this contradictory options the government should design one pilot wind power plant that would be developed majorly by domestic firms with high care and tight follow up of the government. Likewise, research and Development requires huge financing and most of the private investors are not involved in research and development because of its long term benefits for the investors. Most investors in this region are focused on short term returns, which make it difficult for them to be involved in research and development. Therefore, the government is required to establish well equipped national R&D platform and provide incentive packages to the research and development sector in order to develop the country's capacity of manufacturing its own technologies at the local level.

4.6.5. Formulate inclusive regulatory frameworks and Road Maps

A clear national wind energy strategy that allows the individual power producers would make it easier for foreign and local investments in wind energy technology components manufacturing and providing services. This would help existing industries to adapt to market demand and, depending on market need, upgrade or create production lines. To this end, the government should revise the existing regulatory framework and make it open to the privet sector to participate in the manufacturing and deployment wind power plants.

The wind power industry includes large activities that range from low technology intensive up to highly sophisticated manufacturing processes and services. In this regard, the government should set a clear plan for wind energy component manufacturing in the short, mid and long-term to achieve its targets, and have to be supported via policies and implementation strategies. It is more feasible to start with delivering components and services domestically in which local firms are capable and procedurally to high technology intensive activities in long term in collaboration with international manufacturers.

4.6.6. Promotion of mini-grids and use as alternative power source

Due to the topography of the country, the scattered small villages and the high investment cost, the large wind power plant (central grid) seems uneconomic and it is not attractive for investment especially for local business organizations. As an alternative the government has the plan to use decentralized off-grid systems for rural areas electrification. In this regard the mini grid wind power plant is perceived a promising alternative in power supply. The pilot hybrid (wind/solar) micro-grid power plant developed by Ethio-Resource group in the Menz Gera wereda of the Amhara regional state which serves up to 124 households is one key example to show the commercial, socio-economic viability of the wind power micro-grids. Therefore, the government must give the required attention like large power plants to support and expand this experience to use social benefits including increased participation of local actors in downstream activities in the value chain.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

In this thesis, the value chain of wind energy technology in Ethiopia was mapped and analyzed. Different phases of upstream and downstream activates of the current Ethiopia wind energy value chain have been presented, discussed and analyzed. The result presented pointed out the weak integration and collaboration of actors, lack of incentive schemes, low engagement of private sectors, lack of skilled work force as a main barriers facing on the development wind energy value chain of Ethiopia. Potentially, most of the micro-grids components could be designed, sourced, manufactured, installed and operated domestically with little support of skilled foreign experts. Also, in large-scale wind technologies, there are a variety of components that could be adopted, and fabricated by the existing firms without further investment and capacity buildings. Whereas some of component manufacturing and downstream services of wind power plant segments like blades, nacelles and engineering designs, that are highly technology intensive needs significant investment and a skilled workforce to guarantee high quality products are considered in the long-term. On the other hand, the country capability in modification and innovation large-scale wind power technologies is identified as weak. The expected socioeconomic benefits that could be obtained from localization of the wind energy value chain have also been illustrated in terms of job creation, cost saving, technology transfer, market formation.

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5.2. Recommendation

Based on the overall analysis, the following recommendations have been made for Ethiopia wind energy technology value chain localization.

i. The country has the energy sector development, regulatory framework as a whole, but to create conducive environment for the local wind industry development, it needs to revise the existing regulatory framework and ensure strong and adequate government supporting policies that promote the private sector engagement in the wind industry value chain.

ii. From the data gathered and analyzed in this research work, it was identified that the country has the potential to provide products and services that don't require high skills and sophisticated manufacturing processes. Therefore, taking this into consideration, the Ethiopian government should introduce Local content requirements (LCRs) and foster partnerships with global leaders though forging direct investment and joint ventures to encourage the domestic wind power value chain and bring benefits in employee creation, currency reeducation and local capability building.

iii. The small-scale wind energy technologies are identified as the potential area for local value chain creation. So, the researcher recommends the Ethiopian government to give the required attention for this sector like solar and other renewable energies that can improve the electric access in mall violets and geographically disadvantaged places and societies.

iv. The local manufacturing and deployment of wind energy technology is highly dependent on availability of skilled labor. So, the government should set a strategic plan for the education and training of Engineers and technicians to provide local manufacturing companies with highly skilled workforce.

v. The government should provide more support for research and development activities related to wind energy technologies through financial supports and tax privileges.

vi. This research work aimed to analyze the wind energy technology value chain as a whole and to show opportunities for value creation along the value chain. So, the detail of each component like cost and quality was not considered in this the research; it would be a potential research in future.

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APPENDIX A: QUESTIONER

Addis Ababa University

Addis Ababa Institute of Technology (AAiT)

School of Mechanical and Industrial Engineering

Graduate Program in Industrial Engineering

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Thesis Title: Value Chain Analysis of Ethiopian Wind Energy Technology

Advisor: Dr. Kasahun Yimer

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Acknowledgement to the respondent

Hereby, I would like to express my gratitude for your dedicated cooperation. Had it not been your genuine cooperation of completing this questionnaire, it would have been difficult to conduct this research. This questionnaire is part of a Research work required by the Addis Ababa Institute of Technology (AAiT) as a partial requirement for the award of a Master of Industrial Engineering degree. The questionnaire is designed to solicit your independent views on “Value Chain Analysis of Ethiopian Wind Energy Technology”. All information provided shall be treated as confidential and used strictly for Academic purpose and will not be disclosed to other parties for any other purpose. Please contact the research advisor or School of Mechanical and Industrial Engineering, AAiT for further questions.

1. For government institutions

1. Can you give a general overview of Wind Energy industry (RET) in Ethiopia?

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____
____.

2. How is the affordability wind power cost relative to other power sources?

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____.

3. Who has undertaken the wind power plant development projects contract? If foreign companies, please explain the reason.

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____.

4. Does the wind power projects contract have the local content requirements? If yes, please explain the activities or components/materials supplied locally.

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____.

5. What are the challenges and constraints faced in the deployments and operation of the previous wind power plants?

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____.

6. What are the lessons taken from the previous wind power plant projects? Please mention the strengths and weaknesses observed in each of the three wind farms.

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_____________________________.

7. What are the governmental and non-governmental organizations and financial institutions supporting the development of the sector?

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__________________________________.

8. What are the major incentives the government (your institute) has in promoting the wind industry and for supporting stakeholders in the sectors?

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9. Is there appropriate Renewable energy development regulatory framework before? If yes please justify it.

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10. What has been done so far by the government or specifically in you organization to encourage the wind power development and business organizations working in the sector?

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________________________.

11. What is the government plan to increase the Ethiopian wind industry?

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________________________.

12. Does the government create the environment to encourage and attract investors in the wind industry? If yes, Please explain it including the policy, strategy, financial incentive and legislation aspects also.

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_____________________________.

13. Are there some important breakthroughs? if yes, please justify it

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____.

14. Does the country have the plan for wind energy technology manufacturing? If yes please describe the detail of the plan.

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____.

15. How do you see the feasibility of the technology localization in terms of improving the challenges in the sector?

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____.

16. Do you think that local manufacturing firms are capable to manufacture, assemble or supply the wind energy technology components and parts? Please mention the firms.

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____.

17. Do you think that local knowledge institutions are matching the knowledge requirements for the wind industry and research? What are the institutions? If not, how do you close the gap?

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____
_____________________________.

2. For Business Organization

1. Name of your Organization ____
2. How long you involved in the sector? ________________________________
3. How you are involved in the wind power industry in Ethiopia? Can you please explain your firm's main industrial or commercial activity? Include examples of your main products and or services).

   ____
   ____
   ____
   ____________________________________.
4. How would you describe the wind power market opportunities and challenges

   ____
   ____
   ____
   ____________________________________.
5. What challenges and risks or constraints do you face in making this investments/business?

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   ____
   ____
   ____________________________________.
6. How do you finance your business?

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   ____
   ____
   ____________________________________.
7. What opportunities do you see in future for your business?

   ____
   ____
   ____
   ____________________________________.
8. Do you have a plan to engage in the other segment of the wind energy technology? If yes, in which areas do you see new opportunities?

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____.

9. Does your organization have strategic alliances with wind power industry? Which are those types? If not, why you don't have those?

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____.

10. How do you consider the government policies towards promoting the industry?

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____.

11. What government policies/regulations are obstacles to growing your business?

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____.

12. What government policies/regulations benefit your business (registrations, inspections, subsidies, incentives, etc.)?

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____.

13. What factors are seen as an opportunity/facilitator for the wind power industry development?

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14. What should be done as a solution to facilitate the wind industry in Ethiopia?

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____________________________________.

15. What are the barriers that alter the development of the sector?

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____________________________________.

I have the following further comments

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My contact details:

Phone: ___________________________________

Email: ___________________________________

The following organizations (persons) should also receive this survey

Name: ___________________________________

Email: ___________________________________

Name: ___________________________________

Email: ___________________________________

Thank you for your valuable participation!

ANNEX B: WIND FARM SITES SELECTED IN ETHIOPIA

Name of site	Capacity (MW)	Area (km^2)	Grading in preliminary selection	Region
Ch'ach'a wind farm	100	56	86	Amhara
Debre Markos East v	200	143	87	Amhara
Gonder North wind farm	200	65	80	Amhara
Dangla wind farm	200	170	67	Amhara
Dabat wind farm	100	61	56	Amhara
Weldiya wind farm I	100	43	70	Amhara
Nazret wind farm	300	254	100	Oromiya
Sheno wind farm	100	56	88	Oromiysa
Iteya wind farm I	100	66	95	Oromiysa
Sulalta wind farm	100	60	92	Oromiysa
Sendafa North wind farm	100	70	88	Oromiysa
Senadafa South wind farm	100	70	88	Oromiysa
Iteya wind farm II	100	70	95	Oromiysa
Bolo wind farm I	100	60	90	Oromiya
Asela wind Farm	50	71	93	Oromiya
Bolo wind Farm II	500	300	90	Oromiya
Hula wind Farm	300	220	64	Oromiya
Debre Markos West wind Farm	200	150	87	Oromiya
Ambo wind Farm	200	130	72	Oromiya
Dilla East wind Farm	300	268	96	SNNP
Soddo wind Farm	200	160	84	SNNP
Jacho wind Farm	600	330	73	SNNP
Dilla East wind Farm	300	230	96	SNNP
Aysha wind Farm	100	60	83	Somali
Mekelle South wind Farm	100	77	85	Tigray
Mekele North wind farm	200	185	85	Tigray