Development and manufacturing of solar and wind energy technologies in Ethiopia: Challenges and policy implications

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Development and Manufacturing of Solar and Wind Energy Technologies in Ethiopia: Challenges and Policy Implications

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Abstract

Ethiopia has one of the most ambitious energy expansion programmes but to achieve these goals, policies must be aimed at localizing the development and manufacturing of energy technologies. However, the country is dependent on importing solar and wind energy technologies. The aim of this paper is therefore to explore the challenges of locally developing and manufacturing solar and wind energy technologies, the necessary assets and policy instruments that can facilitate localization of energy technologies. This was achieved through survey questionnaire and interview from different stakeholders. The results show that the region has very limited capability of developing and manufacturing of solar and wind energy technologies because of lack of investment capital, under developed solar and wind supply chain, lack of skilled workforce and others. To overcome these challenges, financial incentives for research and development, solar and wind based power generation, manufacturing are considered as the top policy instruments with other policies included in this paper. Therefore, a proper implementation of the internationally proven policy instruments recommended in this paper are urgently needed in the region in order to achieve one of the sustainable development goals that stipulate facilitation of the implementation of modern, affordable and sustainable energy to the society.

Keywords: Solar; Wind; Policy; Manufacturing;Incentives

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1. Introduction

The growing of worldwide energy demand together with the unsustainable sources of conventional energy have led to considerable interest in renewable energy development over many years. As part of this effort, African leaders have agreed on two energy policy goals [1], with one being the provision of universal access to modern energy and energy services [2, 3], and the second focusing on complete decarbonisation of the energy sector limiting the climate change to well below 2^0C [4, 5]. Many has doubted achievement of these goals citing the financial challenges facing Africa but this has changed as the state of renewable energy technologies has improved, and their costs have fallen. However, just because the costs of renewable have fallen, and will likely fall even further, does not mean that their deployment in Africa will be easy. The Intergovernmental Panel on Climate Change has noted that the heightened risk of investment in African countries operates as a major barrier to the deployment of inexpensive renewable energy, because of renewable energy's relatively larger up-front investment costs [6].

As part of the global effort in the development and deployment of renewable energy, Africa is aggressively working to increase the share of clean energy in their energy supply. Many of the African countries such as Ethiopia are introducing and developing renewable energy power plants to address the energy poverty prevalent in the continent. Ethiopia finds itself at a momentous economic transformation and social development crossroads. The Government of Ethiopia's Growth and Transformation Plan (GTP II) aims to continue improvements in physical infrastructure as part of the aim to transform the country into a major manufacturing hub and to address some of the intractable development and poverty challenges the country faces. Widening energy access and securing reliable energy services are fundamental to this effort. Ethiopia faces energy challenges on four fronts: (i) meeting the energy needs of large numbers of people who lack access to modern energy carriers, such as electricity; (ii) meeting the energy requirements of a fast growing economy while delivering power to neighboring countries; (iii) balancing on-grid and off grid electricity for a variety of human settlement patterns; and (iv) exploring an array of financing, regulatory, and institutional modalities for a wide range of energy situations. Underpinning these challenges is the pursuit of a carbon neutral pathway to mitigate the threat of climate change, which is encapsulated in the country's vision of sustainable and resilient development.

The Growth and Transformation Plan (GTP II-2015/2016-2019/2020) had the important goals of reaching universal electricity access in the country in the medium term and positioning Ethiopia to become a power hub in the eastern Africa region. These are goals that will require a variety of different approaches, as well as resource allocation and policy attention. Even though Ethiopia has made significant headway in widening electricity access at both grid-based and off-grid ends of the spectrum, there has been a discrepancy between planned and achieved targets. The key targets of GTP II was a total grid connected power generation of 17,346 MW from diversified resources with 13,957 MW from hydro, 1,222 MW from wind, 300 MW from solar, 577 MW from geothermal, 50 MW from Waste, 474 MW from Biomass, 258 from sugar waste and the rest coming from diesel based generators but only 4,392 MW power generation have been achieved. This shows an increase of 2171.5 MW from the baseline power generation of 2,220.5 MW with the contribution from wind being 324 MW and from solar zero, which is far behind the target. Because of such low performances, currently energy access in Ethiopia stands at 44% with 33% supplied through the grid system and 11% supplied through off-grid system according the Multi-Tier Framework (MTF) energy access household survey conducted in 2017 [7].

In order to fulfill the growing demand, the Ethiopian government has launched National Electrification Program (NEP) in 2019 laying out the country's ambition towards universal access by 2025 through integrated planning of 65% access by grid and 35% access by off-grid energy systems. As part of this plan, Ethiopia is mobilizing resources for large-scale power generation systems from diversified energy sources. With the country's development plan mainly focusing on green economy, the need for the development of renewable energy technologies such as solar and wind is paramount as there is strong support by the policy makers and the public for the development of for example, wind energy [8]. A similar study on the willingness of the public to acquire solar energy technologies showed that they are interested to buy it but lack of local development and manufacturing of the technologies was cited as the key challenge and reason for the high initial investment of the technologies making it not affordable by the general public. A study by [9] showed that Ethiopia has large domestic market for solar technologies and could create 50,000 full time skilled jobs by 2020 by developing Photovoltaic (PV) manufacturing and distribution industries but it lacks adequate sector set-up to achieve this vision.

With the lack of local development and manufacturing of the technologies, many of the African countries including Ethiopia are dependent on importing solar and wind energy technologies in order to fulfill the local demands. In the period 2009-2013 alone, African countries (mainly South Africa, Ethiopia and Egypt) collectively imported wind turbines to the amount of USD 342 million from other countries [10]. They have also imported PV cells and modules from China worth of

USD 869 million in the same period [10, 11]. However, the conventional purchase and import of capital good hardware such as solar PV modules and wind turbines may only support the electrification plan of the respective countries, but it may not necessarily contribute to the technological capability building effort of each country [12]. According to the Ethiopian customs guide 2017, the import tariff rate varies from 0-35% with an average of 17% and has no preferential tariff rates for renewable energy technologies. To encourage local production of goods to replace imports, special privileges with zero tariff rates are given for the importation of raw material.

National and international crisis such as the COVID-19 can heavily affect the global supply chain of energy technologies halting any imports. This reinforces the need to develop effective policy to support and stimulate the manufacturing sector to locally developed the much needed energy technologies. There have been recent studies arguing that developing countries need to have the absorptive, adaptive and improving capacity through local technological learning and exploiting local market [13, 14]. It is known that there are different levels and types of learning to build local capability. In the context of developing countries, learning by doing, using and interacting are recommended to build local capacity and incremental innovations [11, 15].

If a country is not well equipped to develop and manufacture technologies by its own capacity, the flow of foreign direct investment is one of the key ways of developing a country's capacity by way of knowledge and technology transfer. However, this will only be successful if the country is able to develop effective policies to facilitate the knowledge and technology transfer. There are evidences that foreign employees in high tech investments can be an excellent means for knowledge and technology transfer [16]. Creation of joint ventures is also indicated as one way of enhancing knowledge and technology transfer from foreign direct investment to local firms, but implementation of this is very limited in Ethiopia [17].

In order to develop the local capacity, Ethiopia needs to have favorable policies aimed at localizing the manufacturing of energy supply chains and strengthening technological capabilities at various levels. The country's Growth and Transformation Plan (GTP II) stipulates that accelerating human capital is key to enhancing productivity, growth, and development, which needs to be underpinned by policies regarding technological advancement and innovations in science and technology [18]. Specific to the energy sector, technological capabilities can be grouped into production capabilities (the skills needed to transform inputs into outputs); project execution or implementation capabilities (the skills needed to expand capacity);

and innovation or research and development (R&D) capabilities (the skills needed to design entirely new products and processes). Ethiopia is also opening up the electricity sector to private investors recognizing them as independent power producers (IPPs). This will encourage the involvement of private sectors including foreign direct investment, which will support the government's endeavor to facilitate local manufacturing. In order to encourage this initiative, the World Bank Group has approved the launch of its Renewable Energy Guarantee Programme (REGREP) in Ethiopia that could generate 1000 MW electricity from renewable energy by private investment [19]. However, an economic viability study of a 5 MW PV grid-connected power plant showed that such solar PV system is economically viable though it is not sufficient to attract for commercial investors [20]. This indicates that investment by private sectors in Ethiopia is not sufficiency attractive making it the domestic and foreign direct investment very low.

This research therefore explores the challenges and critical assets for local manufacturing of solar and wind energy technologies such as ease of permitting process, policies and incentives, political leadership, availability of resources, regulatory climate, workforce climate, research and development capacity, manufacturing capacity and logistical issues. It also investigates and recommends the necessary policy instruments that can facilitate building required capabilities to locally develop and manufacture energy technologies.

It is clear from this study that there is lack of comprehensive data that has explored the challenges of the manufacturing sector in Ethiopia and other African nations. It is therefore hoped that this research output can hugely contribute and utilized by developers and companies to understand the key challenges facing the industry and devise solutions to overcome those challenges in collaboration with the policy makers. This research output should also provide valuable insights and evidence based policy recommendations to policy makers in order to support and facilitate the development of local industries to the level that they will be able to manufacture solar and wind energy technologies.

The paper is structured in different sections with section 2 briefly presents the methods employed in this research work including description of the study are, data collection methods and data analysis procedures. Section 3 presents the key challenges for the growth of local development and manufacturing capacity, while section 4 presents the key assets that support and facilitate local manufacturing of solar and wind energy technologies. Section 5 discusses the critical policy instruments that can facilitate the development of the manufacturing sector while section 6 presents conclusions of this research results.

2. Methodology

2.1. Description of the study area

This study was conducted in the Tigray regional state, which is located in the Northern part of Ethiopia. The study focused on companies, universities, and Technical and Vocational Education and Training (TVET) that have the potential to develop and manufacture full and/or components of solar and wind energy technologies.

2.2. Source of data

Both primary and secondary data were used as a source of data for this study. Primary data was collected through questionnaires from the companies, Universities, policy institute and TVET colleges. In addition, secondary data was gathered from national and international research results and reports.

A total number of 40 questionnaires were collected from companies,universities, policy makers and TVET colleges. There were 55% of participants from 22 companies, 12.5% of participants from five TVET colleges, 30.0% of participants from three universities, and 2.5% participants from the Tigray Institute of Policy Studies. The companies and TVET colleges were selected based on their potential for locally designing and manufacturing solar and wind energy technologies, the university participants were selected based on their active participation in research and development of solar and wind energy technologies, and the Tigray Institute of Policy and Research was selected based on its huge involvement in the development of policies in the region. As the survey covered all potential companies, TVET colleges and Universities that are either active or have the potential to participate in the development and manufacturing of solar and wind energy technologies, the data is statistically representative of the region.

2.3. Research Approach

This study implemented the two basic research approaches called quantitative and qualitative approaches. The quantitative data was collected using closed-ended questions by a structured questionnaire. The researchers directly interviewed each respondent using each closed-ended questions as guidance instead of distributing the questionnaires. The interviewing approach provided the opportunities to closely interact with the respondents and ask follow up questions what they meant when they select from the pre-defined choices for each questions. The follow up discussions and interactions were used as a way of collecting the qualitative data based on the opinions of the respondents. This interactive approach with the respondents and further literature review of similar studies were the key methods used to collect the general and subjective information that is not addressed in the quantitative form.

2.4. *Survey instruments*

The study employed a structured questionnaire to gather the necessary information from the companies, Universities, policy institutes and TVET colleges. There was study conducted in the United States by the International Economic Development Council and in few of the Middle East and Mediterranean countries by the International Renewable Energy Agency focusing on the critical assets and policy tools that affect the growth of companies [21–23]. Some part of the survey instruments utilized in these studies was adapted to the local context and informed the development of the assets and policy tools parts of the questionnaire utilized in this study. The questionnaire was pilot tested by undertaking a pretest to assess the level of understanding of the enumerators and respondents clarity of the questions. Based on the result of the pilot testing, the content, logical flow, layout and presentation of the questionnaire was amended. The questionnaire was developed using the on-line LimeSurvey tool and the data collection was conducted by visiting and interviewing each companies and TVET colleges and through on line system from University researchers and developers.

2.5. *Data analysis procedures*

The responses obtained from the different survey participants were feed-in to the on-line LimeSurvey tool and the data was automatically analysed on-line within the LimeSurvey tool. The analysed data in the form of percentages and frequencies were exported to MS Excel. The data was then manually edited, summarized and rearranged according to the obtained responses. After having done such process it was converted to percentages that finally lead to data interpretation and description of the entire problem using tables and graphs.

3. Challenges for the Growth of Local Development and Manufacturing Capacity

In order to assess the required assets and policy priorities for the local development and manufacturing capacity of companies and developers, a survey was conducted and respondents were asked to rank their top challenges for growth. The key parameters that significantly affect the growth of local development and manufacturing capacity of companies and developers are shown in Tables 1 & 2.

According to the survey results, lack of investment capital is considered as the top challenge with nearly with 22.2% and 20.4% of the respondents for the development of solar and wind energy technologies respectively. Underdeveloped solar and wind supply chain was rated second with 16.7% and 18.8% of respondents respectively.

Pressing Challenges	Percentage
Lack of investment capital or financing	22.2
Underdeveloped Solar supply chains	16.7
Lack of research and development capacity	14.8
Unclear policy and strategy	13.0
Lack of skilled workforce	11.1
Regulatory uncertainty	9.3
Inaccurate perception of solar capacity	7.4
Lack of adequate logistics or transportation	5.6

Table 1: Pressing challenges for the local technology development and manufacturing capacity of solar energy technologies

The other key challenges showed varying degree of impact with lack of research and development capacity rated third for the solar technology and lack of skilled workforce rated third for the wind energy technology shown in Tables 1 & 2. This is a crucial indication of the different requirements of the solar and wind industry. Logistics or transportation is ranked as the lowest challenge among the other assets for both solar and wind energy technology developments.

3.1. Lack of investment capital or financing

Lack of investment and financing is ranked as the top challenge and key binding constraint in most of the companies and developers based on the qualitative data collected during discussions with the firms. A study in Jordan, Lebanon and United Arab Emirates also proved that manufacturing of solar and wind energy technologies require significant capital investment [22]. This shows that firms need to be able to access finance to invest more and to engage in high-tech manufacturing business such as in the manufacturing of solar and wind energy technologies. There is a shortage of national and regional financial institutions that provide loans for

Pressing Challenges	Percentage
Lack of investment capital or financing	20.4
Underdeveloped Wind supply chains	18.8
Lack of skilled workforce	16.6
Inaccurate perception of wind capacity	15.5
Lack of research and development capacity	10.5
Unclear policy and strategy	9.4
Regulatory uncertainty	5.5
Lack of adequate logistics or transportation	3.3

Table 2: Pressing challenges for the local technology development and manufacturing capacity of wind energy technologies

investors. The only existing financial institution providing credit for investors is the Development Bank of Ethiopia (DBE). Moreover, the bank does not have enough resources to satisfy the demand of investors. Therefore, unavailability of private and other alternative financing, lengthy, costly & stringent processes, challenging pre-conditions to get loans, centralized decision making, limited power of regional DBE offices, differentiated and discouraging financial products of DBE, and corruption (over-valuation) are challenges in investing in the manufacturing sector. Furthermore, shortage of foreign currency, instability of exchange rate cause problems in the price of resources (raw materials, machinery equipment, and spare parts) and the logistics costs which make investment unpredictable and difficult.

The high interest rates linked to export targets at an early stage before full efficiency is achieved disrupts projects pre-maturely. If targets are not achieved in a given period of time, interest rates increases from 9 to 12%. Investors in the manufacturing sector are forced to pay the interest even at the initial stage of the projects. While the policy encourages the export-oriented investment, the financial regulations impose additional constraints on these investors according to the information from the different government offices.

3.2. Underdeveloped solar and wind supply chain

Effective forward and backward linkage among raw material developers, intermediate product developers, and manufacturing sectors is the secret for growth of the sector. Shortage of raw materials in terms of quantity, quality, sustainability and competitive price is one of the critical bottlenecks for the development of the manufacturing sector in the region. Improving the trade logistics to ease exporting and importing necessary raw materials and intermediate inputs and developing locally available raw materials for the manufacturing of solar and wind energy technologies is therefore paramount urgency to develop the capacity of the manufacturing sectors.

Inadequate penetration of the domestic and export markets are other major weakness of the manufacturing sector in the region. In other words, the manufacturing firms are not able to tap the domestic market adequately. The binding constraints in this regard are poor quality of products, poor import and export logistics, and weak market linkage along the supply chain. Yet there are no adequate support programs (for example, linkage program, export capacity and quality improvement program) to address these bottlenecks.

3.3. Lack of skilled workforce

Another challenge apparently is the limited educational preparedness of Ethiopian labour force to take up leading roles in locally manufacturing of solar and wind energy technologies. The industrial workforce in the region lacks the skills and competency to make the development and manufacturing sectors competitive, which is also proved in other studies [22] that a specialized workforce is key to advance industrial capacities. Inadequate supply of labour, poor working discipline, low employees technical and soft skills, high turnover, poor employee benefits package (salary, food, residence, etc.), low productivity and lack of productivity-oriented training are some of the bottlenecks in the sector. Low productivity and high turnover of employees are particularly pronounced that erode the competitive advantage of investment ventures in the region. Besides, the managers of the majority of the domestic investments do not have the experience, qualifications, knowledge, and skills to profitably run the sectors, compete at national and international market, and create linkages with international companies and investors to strengthen and expand their investments. Manufacturing in the region is trapped in the vicious circle of low wage-low productivity.

Moreover, the supporting institutions (universities, TVETs, and related training institutions) are not producing enough competent human resources that fulfill the requirement of the domestic and international development and manufacturing sector. There is also lack of sector-oriented training centers. Hence, investors are forced to train their employees with additional cost and time which affects the competitive and comparative advantages of investment negatively.

During the survey, the majority of respondents (95%) showed that finding sufficient skilled workers in the labour market is difficult in addition to the lack of adequate and advanced infrastructure for manufacturing the energy technologies.

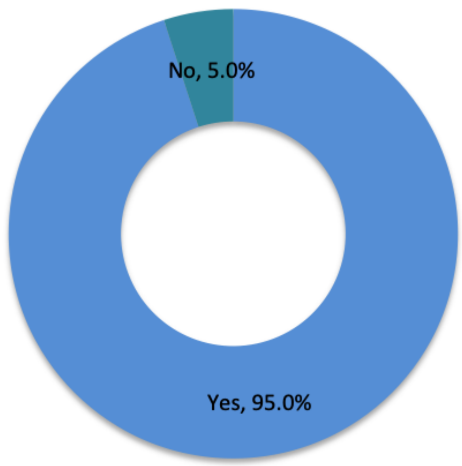

Figure 1: Difficulties in finding sufficient skilled workers for solar and wind technology development

The limited availability of skilled human power was evidenced by the lack of skilled employees at the companies and research institutions surveyed, which was rated as neutral by 82.5% of respondents with 15.0% indicated that employees are unskilled as shown in Figure 2. According to the World Bank (2012), Chinese companies investing in Ethiopia prefer to hire Chinese lead workers with more than 12 years of education while Ethiopian hires in the Chinese firms dominantly have less than 9 years of education. Even though on site training exist, the pace of skill transfer does not appear to be satisfactory.

The level of preparedness of the employees to involve in the manufacturing of technologies got mixed response with 65% indicated that they are somewhat prepared and 15% said insufficiently prepared with 17.5% responded that employees are well prepared.

The lack of skills appears to be on electrical and mechanical knowledge and CAD drawing skills with 77.50% of respondents indicated that these technical skills are critical for the manufacturing of solar and wind energy technologies (Table 3). Having good mathematical and verbal skills is rated second with 75%

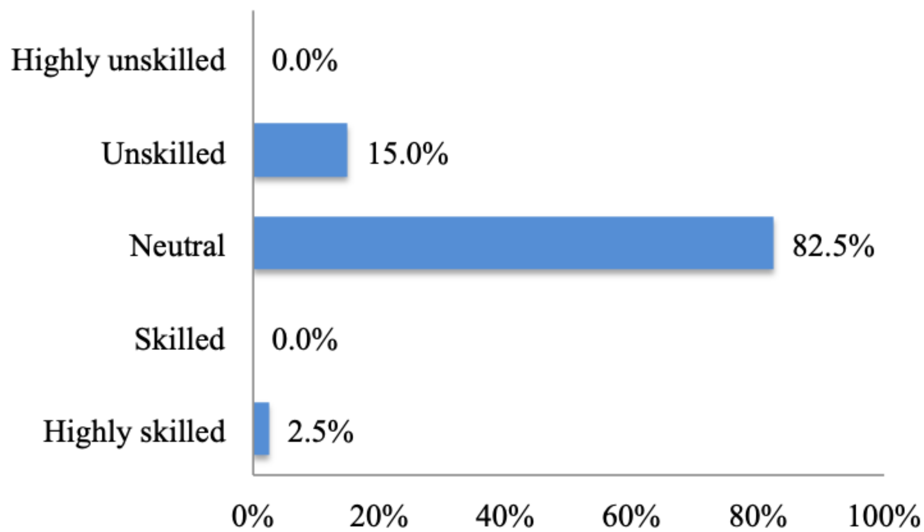

Figure 2: Rate of the skills of employees in the companies and universities to manufacture all or components of the technologies

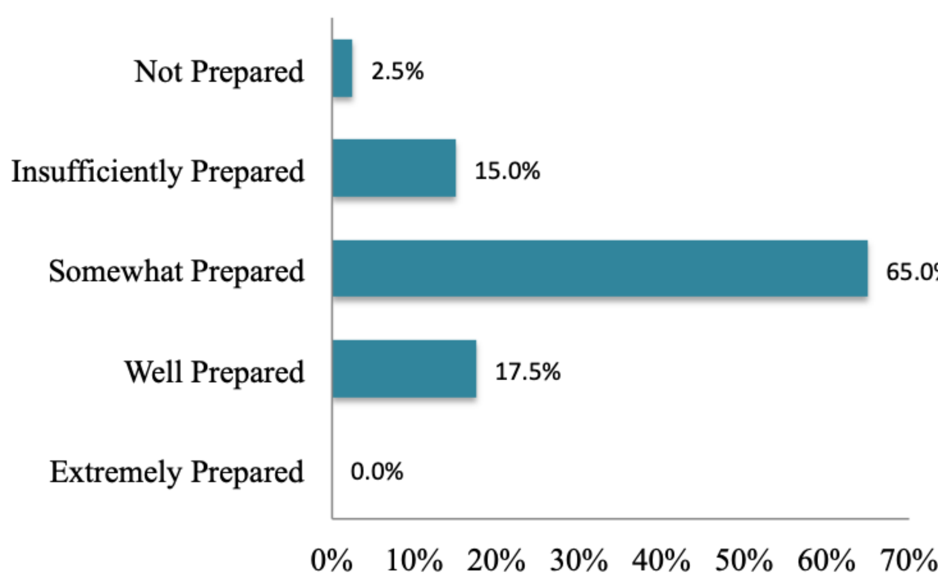

Figure 3: The level of preparedness of employees in the companies and universities to manufacture all or components of the technologies

indicated its importance. In addition to these skills, welding and machining and blueprint reading skills are key for the manufacturing capacity of companies and developers.

Necessary skills	Percentage
Electrical and mechanical knowledge	77.50
CAD drawing	77.50
Good mathematical and verbal skills	75.00
Blueprint reading	35.00
Welding and machining skills	20.00
Other	12.50

Table 3: Required human skills for the development and manufacturing of technologies

In addition to the above skills,the respondents indicated that there are technology knowledge gap, basic design gap, manufacturing skills gap, the lack of trained manpower on the specific technologies, and lack of raw materials.

4. Assets for Local Manufacturing of Solar and Wind Energy Technologies

The preparedness of a country in terms of skilled labor, clear policies and legal frameworks are the key assets for a country to accelerate manufacturing capacity either locally or through knowledge and technology diffusion from foreign direct investment flows. In the case of Ethiopia, the contribution of foreign direct investment to improve the capacity of the country is very limited because of their focus on resource and labour intensive operations that do not encourage the transfer. Over emphasis on the capital inflow and employment opportunities seems to undermine the benefits of knowledge and technology transfer from foreign direct investment.

There are internationally recognized and proven critical assets that are the foundation for a country to develop its own capacity of developing and manufacturing technologies. Some of these assets were discussed with the developers and manufacturers in the region. Considering the 'extremely important' scale, both the availability of solar and wind energy resources and manufacturing capacity was ranked as the top assets with 22.5% of respondents. This result is not surprising because without the availability of solar and wind energy resources, developing technology to harness the non-exist resources is not feasible. Research and development capacity and policies and incentives were ranked second with 17.5% of respondents. Ease of permitting process and workforce climate, and regulatory climate and political leadership was ranked third and fourth with 12.5% and 7.5% of respondents respectively. The ranking significantly varies with the other parameters as shown in Figure 4. These key assets are discussed in detail in the subsequent sections evidenced by the surveyed technology developers and manufacturers.

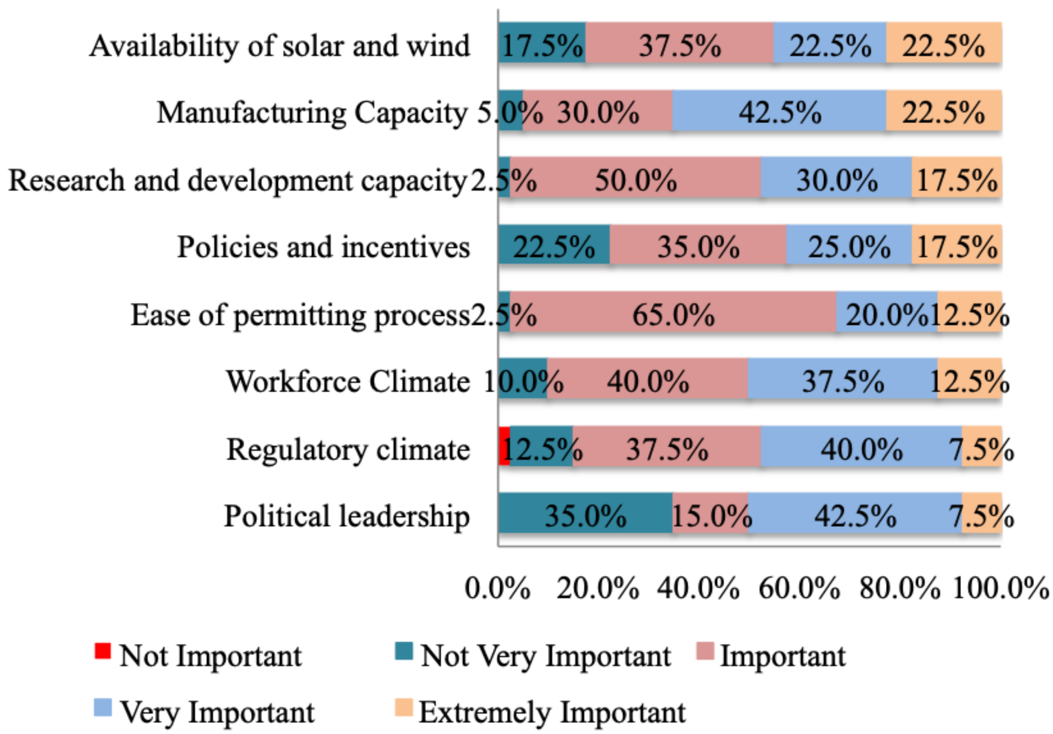

Figure 4: Assets for local manufacturing of solar and wind energy technologies

4.1. Manufacturing capacity

Ethiopia needs to make a strategic decision regarding which parts of the energy value chain to encourage. This study focused on the capacity of manufacturing of components where the raw materials and supply chain can be easily sourced locally. The research investigated the type of electrical equipment that will provide best value in relation to assembly in Ethiopia (equipment that has high volume demand, that is labour intensive (to take advantage of low local labour rates), and that is easily scalable). All components of solar and wind energy technologies such as wind towers, generators and solar panels, was considered and researched.

Developers and manufacturers were asked if they have any knowledge of these technologies and 95% confirmed that they are familiar with wind energy technologies. This was positive result and shows most of the companies and research institutions are aware of the technologies, which will be at least easier to try manufacturing all or components of the technology as shown in Figure 5. In contrast, 30% of respondents said they are familiar with solar energy technologies. This makes it difficult to imagine that these potential developers and manufacturers will have the possibility of manufacturing any solar energy technologies.

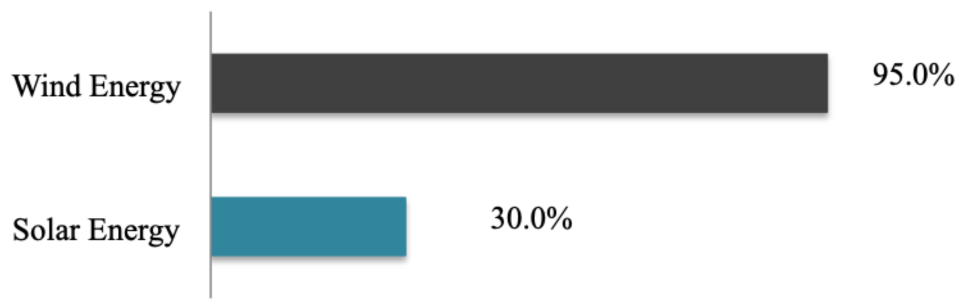

Figure 5: Knowledge of respondents on solar and wind energy technologies

Since most of the respondents indicated that they are familiar with wind energy technologies, more than 92% showed that they have the capacity of manufacturing some components of the technologies (Figure 6). However, this does not mean that they are capable of manufacturing everything but the question indicates only some components. The circumstance at the ground is completely different as indicated in Tables 4 and 5.

Table 4 shows that except electronic controllers, hydraulic systems, and anemometer most of the wind energy technologies can be manufactured locally. However, few respondents (only 2.50%)indicated that they can manufacture electrical generators, cooling unit, and wind vane which actually requires advanced machines. Nearly 65% indicated that they can manufacture tower with 40% of respondents indicated that they can manufacture high speed shaft with its mechanical brake. However, practically nearly all components of wind technologies are being im-

Figure 6: Manufacturing capacity of some components of technologies

ported, which was witnessed in the development of the two wind farms available in Ethiopia. This clearly shows that there is a huge gap in the government's side in exploiting and utilizing the potential of locally available development and manufacturing sector. One of the reasons for this is due to the monopoly of the energy sector by the government and is only tendering all the wind energy development projects to foreign developers, though there were few efforts to involve local companies in the tendering process. This has negative implications in the local capacity development and knowledge and technology transfer by which the country is not in a position to locally manufacture these technologies yet. One proposed solution for improving local manufacturing capacity is to utilize the opportunity of foreign direct investment flow for technology and knowledge transfer to local enterprises in order to improve absorptive capacities of local industries. This can be done by making the involvement of local industries mandatory during the tendering process by developing agreements that enforce foreign companies to include local companies in some of the development process.

The assessment results clearly shows that the region has sufficient asset in manufacturing of some of the wind components. Therefore, it is strongly recommended that the policy makers should support the industry to immediately start manufacturing of tower, high speed shaft with its mechanical brake, low speed shaft, and Nacelle. The experiences in the development of Adama II Wind farm shows that the transport cost for importing tower was nearly 30% of the cost of the technology. Therefore, localization of such technologies could have significant co-benefits such as reducing prices of the technology, creating local job opportunities, and avoiding the greatest challenge of importers in Ethiopia to get access to foreign currency. This will be a huge opportunity and learning curve for the stakeholders to develop strategies for locally manufacturing the rest of the components in the medium to long term.

Wind technology components	Percentage
Tower	65.0
High speed shaft with its mechanical brake	40.0
Low speed shaft	37.5
Nacelle	32.5
Gearbox	15.0
Rotor blades	15.0
Hub	7.50
Yaw mechanism	5.0
Electrical generator	2.5
Wind vane	2.5
Cooling unit	2.5
Electronic controller	0.0
Hydraulics system	0.0
Anemometer	0.0

Table 4: Manufacturing capacity of wind energy technology components

In contrast, 100% of the companies and developers indicated that they can locally manufacture a solar array mounting rack which is obvious considering the simplicity of this technology to develop. However, none of the other components of the PV system components could be locally manufactured. This stems from a combination of lack of awareness about the solar technology, lack of skilled human power, advanced manufacturing machines to process raw materials that are used as an input for the manufacturing of solar panels.

Unlike the wind energy technologies, localization of manufacturing of the components of solar technologies appears to be a distant future. The industrial asset is only capable of producing solar array mounting racks, which is already being manufactured locally. For local firms to be able to locally manufacture any of the other solar components, all stakeholders including policy makers need to create conducive business environment for the opportunity of establishing joint

Solar technology components	Percentage
Solar Array Mounting Racks	100.00
Solar Panels	0.00
Array DC Disconnect	0.00
Inverter	0.00
Battery Charge Controller	0.00
System Power Meter	0.00
Breaker Panel, AC Panel, Circuit Breaker Panel	0.00
Deep Cycle Batteries	0.00
System Power Meter	0.00

Table 5: Manufacturing capacity of solar energy technology components

ventures with foreign firms in order to develop the local capacity.

Companies and developers were given the chance to rate the quality of available manufacturing infrastructure. The infrastructure was categorized as advanced and highly advanced to mean that all infrastructures available in the companies are capable of producing products that require advanced equipment, and other modern supporting services. On the other hand, traditional and highly traditional infrastructure indicates that the company can produce very low quality products and products that need no precision manufacturing including having limited modern supporting services such as low quality energy infrastructure. According the survey results, 75% of the respondents indicated that they are neutral about the infrastructure, 15% said the infrastructure is traditional and 7.5% indicated that the infrastructure is highly traditional as indicated in Figure 7. Considering that some of the key solar and wind energy technology components require advanced manufacturing infrastructure, it is clear from this result that the available infrastructure is not up to the standards to do the job. Supporting infrastructure such as electric power supply, roads, railways, telecommunication, water etc. are not well developed in the region. Delay in connecting companies to the grid and intermittent supply of electricity is one of the major obstacles. Repeated power interruptions and power supply problem caused by institutional inefficiency, lack of competition at the service provider level, centralized power control are on the top list of the problems in infrastructure side of the development and manufacturing sectors.

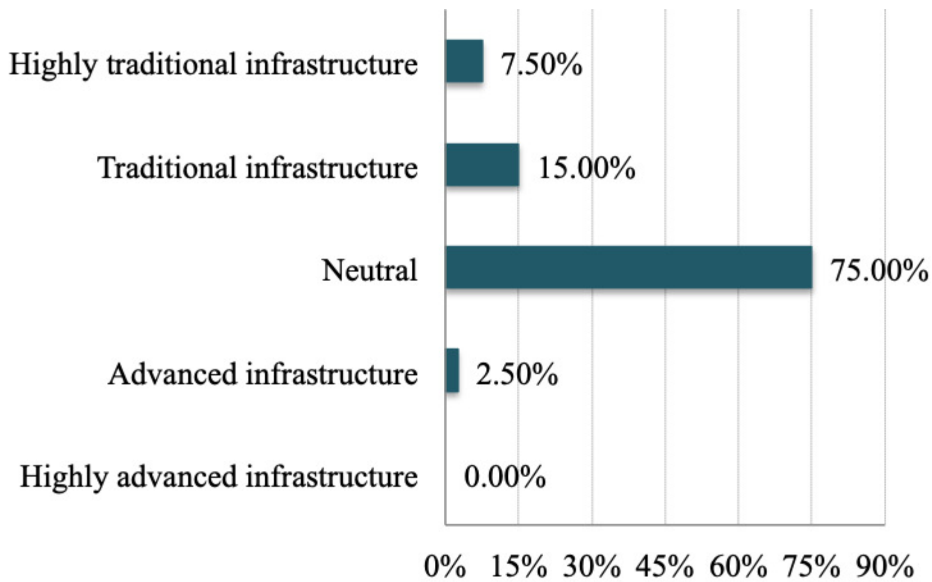

Figure 7: Quality of available manufacturing infrastructure

4.2. Availability of solar and wind energy resources

Availability of resources such as solar and wind is the foundation for the development and manufacturing of energy technologies. Without these sources, there is no need to think about energy technology innovation,diffusion and technology transfer. For this reason, more than 80% of the surveyed respondents said that the availability of resources is one of the important assets for the development and manufacturing of energy technologies.

4.3. Research and development capacity

The development, manufacturing and/or adaptation of new technologies require different sets of research capacity and technical skills. R&D supports in devising solutions for the problems to human beings through technology [24]. R&D has critical role in supporting the adaptation of technologies to local needs and in developing the capacity of local companies [25]. A study by [26] outlines research, development and innovation programme as a key strategy to facilitate manufacturing of renewable energy technologies. All these assertions by the different studies were proved during the survey with more than 97% of respondents considered research and development as one of the key assets in the development of local manufacturing capacity of developers and manufacturers as shown in Figure 4.

However, the region lacks sufficient R&D capacity that can support the local industries to develop and manufacture all components of solar and wind energy technologies. R&D covers three main activities that include basic research, applied research and experimental research, which have different level of practices in the region. Basic research requires high tech research infrastructure, huge financial resources and highly skilled manpower in order to generate new ideas and fundamental theories that may or may not create any sense and the result of basic research has long term impact. Therefore, considering the political economy of the region and the lack of skilled manpower, the practice of basic research is at its early stage and there is very little practice of this activity by most of the researchers in the R&D departments of the companies, Universities and other research institutions.

Applied research is being practiced to some extent as no new idea generation is required but the region does not consider it as a high level asset yet. As part of this activity, researchers can support the local industries in design, development and manufacturing of some of the wind and solar energy components such as tower, high speed shaft with its mechanical brake, low speed shaft, Nacelle, and solar array mounting racks. They can do modification of the existing technologies in order to adapt it to the local context. In addition, researchers can support in the design of Gearbox, Rotor blades, Hub, Yaw mechanism, Electrical generator, Wind vane, and Cooling unit but their manufacturing requires high tech machines, which is challenging in the current state of the industries. The third common research practice is experimental research and there are researchers who can conduct this type of research particularly in the higher education institutions. Considering the lack of scientific equipment, the practices are very limited and the results are not to the required standards consequently having limited support to the local industries. Considering these limited research practices, the R&D asset is considered at an early stage and its support to the local industries in the region is very limited.

4.4. Policies and incentives

Clear policies and incentives for companies and developers is also a driver for promoting and motivating developers and manufacturers to get involved in the development and manufacturing of energy technologies at a local level. Such assets have wide range of implications in creating the environment for developing local knowledge and skills including transferring the knowledge and skills by active engagement with foreign direct investment. It has been widely acknowledged that lack of proper instruments and incentives are the key barriers for active engagement in advancing knowledge and transferring technology [17] in addition to the lack of absence of comprehensive foreign direct investment policy framework with clear requirements for knowledge and technology transfer engagement. The survey conducted has proved that clear policies and incentives could promote the engagement of local developers and companies in the manufacturing of solar and wind energy technologies as more than 75% said this is one of the important assets that the country should focus on. The incentive mechanisms shall be designed and aligned to the overall policy goals in order to have the expected impact.

The National Energy Policy of Ethiopia was issued in 1994 and it has policy directions for the development of solar energy for the application of process heat and power generation and wind energy for the application of water pumping and irrigation. It is relatively old and it is inconceivable to think that this policy is sufficient at the current context considering the dramatic economic and technological changes that happened in Ethiopia and the world since this policy was issued. There are efforts to develop new policy considering the current dynamics of the energy sector but requires immediate action by the policy makers and should include necessary policy direction that support the local manufacturing industries that have the potential to be involved in the energy sector.

4.5. Ease of permitting process

Government business process is one of the key assets to facilitate and promote local developers and manufacturing industries to enter this business. However, there is very poor service delivery and weak assistance to the private investors engaged in the manufacturing sector and lengthy licensing procedures for those who want to enter this business. During the survey, developers and companies ranked ease of permitting process as one of the top assets as it is the first step to start and enter to the manufacturing sector (Figure 4). This is not surprising considering the depth and breadth of the challenges related to the permitting process that is faced by investors to enter the manufacturing sector. For example, there is limited defined and investment focused serviced land hence the land acquisition for investment is challenging for both domestic and foreign investors. Very expensive and uncertain lease or rent from private sources, limited and expensive supply, monopoly power in the land supply by city administration, unbalanced revenue from land sales, limited capacity to service land, rampant corruption and inefficient practices, lack of budget for compensation for displaced persons, lack of fair compensation, lack of standard land utilization for manufacturing are some of the problems related to the lack of conducive permitting process as indicated by the developers and companies.

4.6. Workforce climate

Skilled workforce in the engineering and technology is one of the key assets to support the development and manufacturing sectors. The World Economic Forum documented many employers in Sub-Saharan Africa could not fill job vacancies despite high unemployment rate due to skills mismatch of graduates in technical and generic skills [27]. This gap is directly related to the lack of practice-oriented competence-based curricula in engineering, access to industry-grade equipment and the lack of proper training after graduation.

A study conducted by the Royal Academy of Engineering in 2012 clearly showed that there is a chronic lack of indigenous capacity in Engineering and technology but more importantly, the study provided stark reality that the shortage was not related to the number of graduates. The problem was rather that the engineers who graduated lacked the necessary skills and experience according to the needs of the labour market [28]. These facts are in line with the current conditions in Ethiopia and the Tigray regional state as majority of respondents (95%) confirmed that finding sufficient skilled workers is being one of the key challenges despite the Ethiopian government's directive [18] enforcing the undergraduate enrollment in science and engineering to be increased from 30% to 70%. This is a stark reminder that it is not a matter of having mass graduated human power from engineering and technology but rather it is a matter of developing the skills and competencies of graduated considering the needs of the labour market.

The chronic lack of skills and competencies of graduates in the engineering and technology sector is therefore hindering the development and manufacturing capacity of the region. Several training institutions and universities have already understood these limitations in the engineering curricula and teaching facilities and several efforts are under way to improve the workforce climate of the region as this is one of the key assets for improving the capacity of the developers and manufacturers of the region and the country at large.

4.7. Regulatory climate

The national energy policy of Ethiopia developed in 2012 broadly seeks to improve the security and reliability of energy supply and be a regional hub for renewable energy, increase access to affordable and modern energy, promote efficient, cleaner, and appropriate energy technologies and conservation measures, strengthen energy sector governance and build strong energy institution, ensure environmental and social safety and sustainability of energy supply and utilization, and strengthen energy sector financing.

In order to fulfill these demands, the Ethiopian government has launched National Electrification Program (NEP 2) in 2019 laying out the country's ambition towards universal access by 2025 through a combination of grid and off-grid energy systems [29]. As part of this plan, Ethiopia is mobilizing resources for large-scale centralized grid power generation from diversified energy sources such as hydro, wind, geothermal etc. However, this centralized grid will supply electricity to around 65% of the Ethiopian population according to the plan. Smaller projects such as off-grid energy systems are also becoming more attractive because of their social and environmental accountability compared to the traditional mega projects such as hydropower [30]. This is particularly essential in the Ethiopian context considering the landscape and scattered living circumstances of the rural communities.

However, these ambitious plans will not be achieved without the involvement of the private sector. Therefore, the Ethiopian Energy Authority (EEA) is mandated to develop a regulatory framework that encourages private sector investments with proclamations enacted in 2005 and 2007. Private sector power purchase agreements (PPAs) are negotiated with the Ethiopian Electric Power. Independent power producers (IPPs) are encouraged to enter the market through the electricity. However, these new regulations are not being practically implemented except in very few circumstances. Without implementation of these regulations and constantly improving the regulatory climate according to the dynamics of the energy sector, it will be significantly challenging to achieve the ambitions of the country for universal energy access. This has been proved by the respondents as nearly 85% considered regulatory climate as one of the critical assets to improve all rounded capacity of a country in the energy sector including the ability to locally manufacture energy technologies (Figure 4).

4.8. Political leadership

Without a stable government and strong political leadership, the development of any country is uncertain. Unstable and weak political leadership has far reaching negative impact in attracting foreign direct investments and developing local and indigenous innovations and firms. Therefore, it is not surprising that political leadership is considered as one of the assets by the developers and manufacturers surveyed in this research. Therefore, the region urgently needs strong, stable and committed political leadership in order to develop the necessary policy instruments, regulatory frameworks and incentive packages discussed in different sections of this report. This will help in stimulating and encouraging investors to enter to the development and manufacturing sector particularly to the solar and energy industry.

5. Policy Instruments for Facilitating Development of the Manufacturing Sector

Global experience shows that with adequate policies aligned with the country's development objectives, Foreign Direct Investment (FDI) can provide significant economic and social benefits to the host country by transferring the necessary knowledge and technology. From a policy point of view, the Ministry of Innovation and Technology (MoIT) has a Technology Transfer and Development directorate with core process focusing on technology transfer in the nine prioritized manufacturing sectors. One of the policy directions of the directorate is to establish systems of enhancing technology transfer from FDI in Ethiopia. While the efforts being done are undeniable, much work still remains in streamlining the policy directions and harmonizing implementation efforts with different stakeholders.

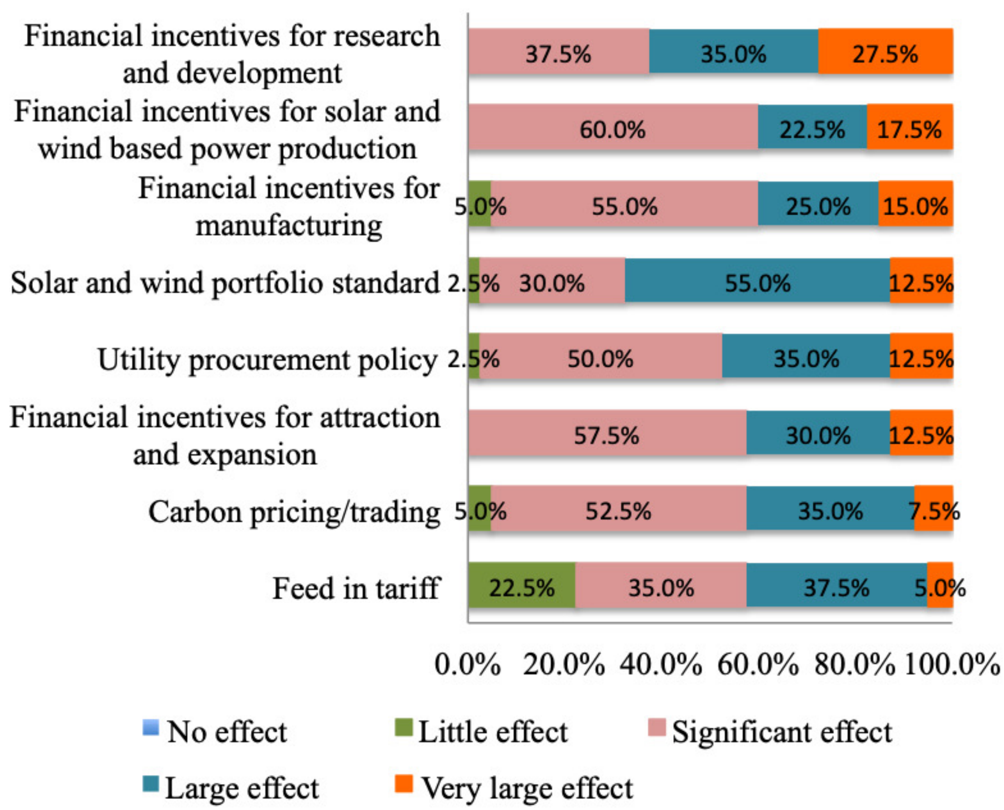

Figure 8: Policy instruments for local manufacturing of solar and wind energy technologies

Several researches indicated that the policy instruments given in Figure 8 are key for facilitating the development of the manufacturing sector. For example, a study by the International Economic Development Council in the United states [21] showed that these policy tools are critical to improve capacity of the industries involved in the energy sector. In order to understand the situation in Ethiopia, different developers and companies have been given the chance to rate the importance of these policy instruments for their businesses for developing the capacity of locally manufacturing the energy technologies. According to the survey, financial incentives for research and development was ranked as having ”very large effect” among the others with financial incentives for solar and wind based power generation ranked second with 17.5% of respondents. Incentives for manufacturing is ranked third with 15% of respondents.

Considering the ’large effect’ measuring parameter, Solar and wind portfolio standard is ranked at the top 55% of respondents, Feed in Tariff ranked second with 37.5% of respondents, Financial incentives for research and development, Utility procurement policy, carbon pricing/trading are collectively ranked third with 35% of respondents, financial incentives for attraction and expansion is ranked fourth with 30% of respondents, financial incentives for manufacturing is ranked fifth with 25% of respondents, and financial incentives for solar and wind based power production is ranked last with 22.5% of respondents. The ranking also significantly varies with the remaining parameters such as having ’significant effect’, ’little effect’ and ’no effect’. In general, more than 80% of respondents agreed that most of the policy instruments have ’significant effect’ and above for facilitating local development and manufacturing of the energy technologies with nearly 22.5% said that feed in tariff has ’little effect’.

5.1. Recommended incentive mechanisms

Defining special set of investment incentives for targeted investors is an effective strategy to promote investment in the development and manufacturing of technologies for the energy sector. The current context in the region shows that there is no incentive mechanisms implemented as there are no industries being involved in locally manufacturing of energy technologies. Therefore, considering the existing economy of the region and its ability to implement some carefully selected incentive mechanisms, the following incentive packages are recommended for improving the capacity of local developers and manufacturers and to facilitate the flow of foreign direct investment to the region to be involved in the energy sector.

5.1.1. Incentives for research and development

Financial incentives for research and development is ranked at the top with 27.5% of respondents confirmed that it has 'very large effect' for facilitating local development and manufacturing of energy technologies. This is in line with several researches that indicated research and development is critical to develop capacity for manufacturing of energy technologies. Equally, this sector 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 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.

Considering the current status of the research and development capacity of the region and its importance to stimulate and support the industrial sector, all stakeholders engaged in the energy sector shall implement the following incentive mechanisms that can easily fit to the local context.

- Establish well equipped national R&D platform to encourage joint researches
- Grants from federal and local governments, development partners etc
- Tax deductions for investments in research and development
- Performance based financial award that doesn't require repayment
- Subsidized loans for acquiring research facilities

5.1.2. Incentives for solar and wind based power generation

Incentive policy for solar and wind based power production is ranked second with having 'very large effect' in the sector with 17.5% of respondents. This has been looked into the sense of power generation where the incentives are not directly supporting the development and manufacturing sectors but for the utilities and power plant developers in order to promote the use of locally developed solar and wind energy technologies and subsequently promoting investment flows to the solar and wind industries. There are commonly practiced incentives that should be implemented by the policy makers to support developers and power generation utilities. These incentive mechanisms include but not limited to:

- Financial subsidies to solar and wind power generated with locally-made technology components
- Loans with low interest rate for developers that utilize locally manufactured solar and wind energy technology components
- Providing land at nominal prices for solar and wind based power plant developers
- Reduction of income tax for utilities who sell power generated by locally manufactured solar and wind energy technologies
- Accelerated depreciation of solar and wind energy equipment

5.1.3. Incentives for the manufacturing industries

Incentives for the manufacturing industries is rated as the third policy instruments by the respondents. While the main competitive advantage must come from creating the best business environment and providing seamless investor services, developing specific incentive packages can strategically attract the development and manufacturing investment into the region. The investment incentives specific for the manufacturing sector may include but not limited to:

- Providing free training for workers: the government can support by absorbing investors' worker-training cost by making available ready-to-start workforce. Investors don't have to spend money and time training workers. This may also include soft skill training for newcomers to ensure industrial workforce culture and industrial peace.
- Providing free worker recruitment services: the regional government can assist in worker recruitment and screening. Investors usually find it costly to recruit workers. The government through its structures can recruit and screen workers for investors in the region.
- Providing land at nominal prices for potential manufacturers particularly for those who focus on import substitutions of energy technologies
- Reduction of income tax for those who manufacture and sell local solar and wind energy technologies
- Tax deductions for labor cost involved in the local manufacturing industries

- Reduction of income tax for joint ventures involved in local manufacturing of energy technologies to encourage knowledge and technology transfer to the local firms
- Developing targeted favorable customs duties to encourage importing of few solar and wind technology components over the import of entire technology components

5.1.4. Incentives for attraction and expansion

Incentives for investment attraction and expansion of solar and wind energy technologies are proving to be an effective way to promote the development and deployment and these clean energy technologies. For example, the US federal government provides tax credits and financing mechanisms such as tax-exempt bonds, loan guarantee programs, and low-interest loans to attract the involvement of the private sector in the wind energy industry [31]. Study by [32] showed that incentives such as loan guarantees can have a huge impact in attracting private capital reducing funding requirements from the governments with [33] indicating that incentive policy instruments can play a significant role in business attraction. Therefore,in order to relieve regional government's funding for the development of solar and wind energy technologies, it is important to devise and develop such policy instruments in order to attract and expand private sector involvement in the development and manufacturing of solar and wind energy technologies.

5.2. Solar and wind portfolio standard

Renewable energy portfolio standard is one of the policy instruments that allow the trading of renewable energy certificates or emissions trading systems to tackle greenhouse gas emissions. This can help for attracting investment to the solar and wind industry as it guarantees that investors will find a market for their goods and is utilized as an incentive mechanism to compete over prices [34]. Such policy instruments have the potential to stimulate the development and manufacturing sector thereby making them competitive in the international arena. Thus, the national and regional governments should develop effective solar and wind portfolio standard considering its importance for facilitating the development and manufacturing of technologies locally.

5.3. Utility procurement policy

Well developed conducive procurement policy has huge potential in encouraging the use of locally manufactured energy technologies and equipment as indicated by [35]. Having the right policy instrument that considers the current context of the region can have significant impact for market expansion and demand for locally developed and manufactured technologies. Increased demand for locally manufactured technologies will have huge spin off effect in attracting investment to the solar and wind energy industry in the region. This is the main reason that utility procurement policy is considered as one of the key policy instruments with 50%, 35% and 12.5% of respondents saying it has significant, large and very large effect respectively in facilitating local development and manufacturing of solar and wind energy technologies. Considering its significant co-benefits of encouraging the use of locally developed technologies and attracting investments, it is critical to develop conducive procurement policy in order for the region to be self-sufficient in terms of technological development and manufacturing and energy security.

5.4. Carbon pricing/trading

Carbon pricing is being implemented in the Americas particularly in Canada with other countries implementing new carbon taxes such as in Singapore and South Africa as the first African country to consider this initiative. New initiatives are also being explored in Colombia, Mexico, the Netherlands, Senegal,Ukraine, and Vietnam according the world bank group report [36]. Carbon pricing is the most effective way of reducing emissions and encouraging the development and manufacturing of energy technologies to exploit the available renewable energy resources. However, except for a few countries, carbon pricing is not being implemented including in Ethiopia. Therefore, governments and policy makers of the country and the region in particular should focus and prioritize on the policy instruments such as carbon pricing/trading that have huge implications and consequence in stimulating the development and utilization of solar and wind energy resources and technologies.

5.5. Feed in tariff

Feed in tariff (FIT) is an energy supply policy, which is being well practiced in the developed world' particularly in the European member states to promote electricity generation from renewable energy sources [37]. FIT is considered among the effective tools to promote renewable energy development and facilitate local manufacturing [38]. This scheme allows private electricity generators to sell their surplus at a fixed price and promotes the development of the renewable energy industry. Feed-in tariff policies commonly include guaranteed access to the grid; stable and long-term purchase agreements, and payment levels based on the costs of renewable energy generation [39]. In developing countries like Ethiopia, this feed-in tariff scheme could have huge effect as it can easily attract private sectors (investors, community based power generation, household level power generation) to enter to the solar and wind energy industry. This could also promote decentralized energy systems, which is particularly important to countries like Ethiopia who have communities living in scattered circumstances where centralized energy systems are not economically feasible. The Ethiopian government has been trying to develop feed in tariff schemes but it is not yet materialized. Considering its significant co-benefits of promoting the use of renewable energy technologies and consequently being a catalyst for developing the capacity of local manufacturing and its indirect potential for energy security by promoting the use of decentralized systems, it is recommended that the policy is implemented as quickly as possible.

6. Conclusion

This paper explores the challenges and critical assets for local development and manufacturing of solar and wind energy technologies, and the necessary policy instruments that can facilitate building required capabilities to locally develop and manufacture energy technologies.

The results show that the region has very limited capability of developing and manufacturing of solar and wind energy technologies. The critical challenges for the lack of locally developing and manufacturing of technologies include lack of investment capital considered as the top challenge with nearly with 22.2% and 20.4% of the respondents for the development of solar and wind energy technologies respectively. Underdeveloped solar and wind supply chain was rated second with 16.7% and 18.8% of respondents respectively.The other key challenges showed varying degree of impact with lack of research and development capacity rated third for the solar technology and lack of skilled workforce rated third for the wind energy technology. This is a crucial indication of the different requirements of the solar and wind industry. Logistics or transportation is ranked as the lowest challenge among the other assets for both solar and wind energy technology developments.

There are internationally recognized and proved critical assets that are the foundation for a country to develop its own capacity of developing and manufacturing technologies. Some of these assets were discussed with the developers, policy makers, and manufacturers. Considering the 'extremely important' scale, both the availability of solar and wind energy resources and manufacturing capacity was ranked as the top assets with 22.5% of respondents. Research and development capacity and policies and incentives were ranked second with 17.5% of respondents.

Ease of permitting process and workforce climate, and regulatory climate and political leadership was ranked third and fourth with 12.5% and 7.5% of respondents respectively. The ranking significantly varies with the other parameters as shown in Figure 4.

In order to overcome these challenges, several policy instruments were investigated and discussed with the developers and manufacturers. According to the survey, financial incentives for research and development was ranked as having ”very large effect” among the others with 27.5% of respondents, financial incentives for solar and wind based power generation ranked second with 17.5% of respondents, and incentives for manufacturing is ranked third with 15% of respondents. However, ranking of these policy instruments by the respondents using the other parameters such as ’little effect’, ’significant effect’, and ’large effect’, significantly varies as shown in Figure 8. However, generally more than 80% of respondents agreed that all the policy instruments except feed in tariff have ’significant effect’ and above for facilitating local development and manufacturing of the energy technologies with nearly 22.5% said that feed in Tariff has ’little effect’. Therefore, a proper implementation of the internationally proven policy instruments recommended in this paper are urgently needed in the region in order to achieve one of the sustainable development goals that stipulate facilitation of the implementation of modern, affordable and sustainable energy to the society.

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