A Transition Towards Localizing the Value Chain of Photovoltaic Energy in Saudi Arabia

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Research Article

Keywords: Photovoltaic Energy Localization, Value Chain Analysis of PV Energy, Saudi Arabia Renewable Energy Plan

Posted Date: February 9th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-217780/v1

Abstract

The present paper draws attention to the importance of localizing the value chain of photovoltaic solar energy in Saudi Arabia based on the country's vision for 2030 to meet the expected increase in energy demand. This paper describes various obstacles and enablers and shows the critical factors that restrain the development of the value chain of photovoltaic solar energy. In this paper, different phases of upstream and downstream activities of the photovoltaic industry value chain related to the current situation in Saudi Arabia were examined and analyzed. This paper further examines the capabilities of the local content of photovoltaic solar energy to determine the scenarios that can be adopted to enhance the photovoltaic solar energy industry. This paper analyzes the expected significant positive impact of localizing the value chain of the photovoltaic solar energy industry on the socioeconomic development, job creation, and technology transfer in Saudi Arabia. The paper concludes with recommendations to facilitate the expansion of the photovoltaic solar industry in Saudi Arabia.

1. Introduction

Solar Photovoltaic (PV) has become a worldwide maturing technology that has been targeted as a critical area for investment. Solar PV is considered to be one of the vital energy resources in the coming future, and it will have a major role in resolving energy security issues and environmental concerns. The global solar PV industry has shown rapid growth and considerable progress in the past five years. Globally, there are several companies that produce various products in the PV value chain ranging from polysilicon to a complete module where other companies depend on the supply chain for the balance of system (BOS) components from other suppliers. Crystalline silicon, which represents more than 90% of the global PV market share, is the most common source used for solar PV production (Mulvaney, 2015). It is followed by thin-film technology that is currently implemented in various market segments (Ozturka et al., 2018). However, concentrated solar PV (CPV) is an emerging technology that is shifting from the pilot scale to large commercial implementation such as utility-scale and outer space applications. Other PV technologies such as dye-sensitized cells, organic cells, and thermo-PV are still in the R&D stage.

The existing global demand for energy is mainly met by fossil fuels, which account for more than 80% of the total (Sahu, 2015). This heavy dependence on fossil fuels results in a set of global environmental challenges. Therefore, clean energy systems that have the capacity to alleviate environmental effects are urgently needed to achieve the desired sustainable development goals. Alternative energy technologies are considered to have a major role in resolving both energy security and environmental impacts. In particular, solar PV is considered to be one of the most important energy resources in the future. Production methods and technology improvements have resulted in significant cost reductions and a rapid increase in demand. During the last decade, solar PV applications have increased steadily and progressively in many parts of the world with new capacity records. At the end of 2019, the global cumulative solar photovoltaic capacity amounted to 633.7 GW, resulting in solar PV to become the largest renewable energy source after hydro and wind energy (Statista, 2020). Furthermore, it is expected that the world`s PV industry capacity could increase threefold by 2030 based on the trajectory of the market expansion and other related drivers. Indeed, there are many reasons behind the fast growth of global solar deployment, including technology development, reduced prices of modules and other related components, increasing concerns regarding environmental protection, securing the energy supply, access to modern resources, and above all strong energy policy initiative commitments (REN21, 2017).

The power sector in Saudi Arabia is assumed to be the largest in the Middle East, with an annual growth rate of 7–10 % (ECRA, 2016). However, the demand is expected to grow even further in the following years. Accordingly, the energy consumption in the country is predicted to increase threefold by 2030 based on Saudi Arabia`s vision. As a result of this high energy consumption, the export revenues from fossil fuels are expected to be significantly reduced by 25% (IRENA, 2016) unless new energy sources are introduced.

The 2030 vision involves several components including strategic objectives, specific targets, policies, goals, indicators of the oriented outcome, and achievement of various sectors. An integrated model has been developed by the Council of Economic and Development Affairs (CEDA) to translate the vision into different implementation programs. The renewable energy plans recognized that the huge potential resources are so far untapped and that the country still lacks competitive renewable energy. By 2030, the anticipated local consumption of energy is expected to triple. Accordingly, the vision has set a target of 9.5 GW of renewable energy. A major share of this ambitious target is allocated for the development of the solar energy sector. In order to achieve these goals, the vision intends to incorporate the local manufacturing of renewable energy components in the national economy. However, further steps will come after launching the King Salman Renewable Energy Initiative (KSREI). During the implementation of the vision, all plans associated with renewable energy and the legal regulatory framework will be thoroughly reviewed to allow private companies to invest in this sector. The 2030 vision encourages the participation of private companies to localize the renewable energy industry. The vision also intends to smooth the liberalization of the fossil fuels market to ensure the competitiveness of the renewable energy sector (Saudi Vision 2030, 2016). This smooth fuel liberalization started in 2018.

According to the 2030 vision, the localization of PV module manufacturing and its related components are considered a top priority by the Saudi government. Therefore, the government seeks to fully support and strengthen national companies so that they are developed regionally and globally. It is believed that the employment opportunities created by renewable energy technologies are greater than those created by current technologies based on fossil fuel facilities within the lifespan of the technology, and, in particular, solar PV creates the most jobs per unit of electricity generation (Wei M. et al, 2010). The existing unemployment rate in Saudi Arabia is 10.7 %. It is believed that local solar supply chain manufacturing could contribute to increasing the number of jobs (Solar Power Europe, 2016). The main focus of the government`s plans is to increase the development of the local industry, which will provide job opportunities and ensure sustainable economic development.

Despite the strong industrial infrastructure in Saudi Arabia, solar PV manufacturing is still in its infancy stage, there is no local solar value chain manufacturing, and all the modules and most BOS components available in the market are imported. The ambitious targets of the 2030 vision coupled with the potential demand for solar energy make the country compete to invest in local manufacturing to secure and diversify its future energy demand. The 2030 vision is expected to significantly propel the solar PV market industry in the country from now onwards. The establishment of a local solar industry value chain will also attract international solar manufacturers to establish joint ventures with local investors in the country. The following are the main objectives of this paper:

(1) Assess the competitive position and manufacturing potential of the key components of the PV value chain in Saudi Arabia. The assessment aims to analyze the current local value chain and various BOS components.

(2) Analyze the gaps and identify the local value chain manufacturing capacity. This requires analyzing the various barriers hindering the development of local manufacturing capacities in terms of training and workforce skill development.

(3) Identify the opportunities and challenges and set strategic recommendations to enable PV value chain localization in the country based on the 2030 vision.

2. National Transformation Program (Ntp) 2020

During the implementation of the 2030 vision, the government is expected to face obstacles and challenges. Accordingly, the NTP was developed to assist the government in identifying the challenges. The duration of the program was set from 2016 to 2020 during which strategic objectives were developed by the NTP to address the challenges based on specific targets and an operating model was proposed. The operating model of the NTP consists of five different phases, including the identification of challenges facing the various entities to fulfil the vision within the interim targets of 2020. Additionally, the NTP model assists in initiative development to attain the strategic objectives and develop plans for implementation. Figures (1) shows the five phases of the NTP operating model (National Transformation Plan, 2016).

Figure (1): Operating Model of the National Transformation Program

In order to allow a greater share of renewable energy technologies in the country`s total energy supply, the NTP target was to raise the contribution of renewable energy to the total energy production by 4% by 2020. The total solar capacity in the medium scenario was expected to reach 2285 MW by 2020 (National Transformation Plan, 2016). To maximize the local industrial content in the value chains and localization of expertise in the sector, the NTP targeted the local content contribution to reach 35% by 2020. To fulfil these targets, the government allocated SR 1167 million to develop human capabilities. In addition, SR 48 million was allocated to promote local private industry and to assist in developing private industry partnerships, and another SR 42.9 million was allocated to establish suitable methods to help the participating local companies in their renewable energy plans. However, a significant amount of SR 1121 million was reserved to support the desalination and power sectors in using renewable energy technologies by 2020 (National Transformation Plan, 2016).

3. Energy Policy And Strategies In Saudi Arabia

Due to the rapid growth of the energy demand in the country, the government has implemented several measures and policy initiatives, such as the establishment of the Electricity and Cogeneration Regulatory Authority (ECRA) in 2001 to regulate the electricity industry and the founding of the National Energy Efficiency Program (NEEP) in 2008 to promote the efficient use of energy, to increase the share of renewable energy sources and reduce fossil fuel energy consumption. The Saudi Energy Efficiency Centre (SEEC) was launched in 2010 to develop policies to improve energy efficiency; and King Abdullah's City for Atomic and Renewable Energy (KACARE) was established in 2010 to conduct research and development, implement renewable energy and nuclear energy policy and provide guidelines for the implementation of policies in the country.

The government has established key components of the strategic initiatives to implement the 2030 vision, including the National Renewable Energy Plan (NREP), which aims to increase the share of renewable energies by 3.45 GW and 9.5 GW in 2020 and 2023, respectively. In addition, according to the 2030 vision, the Renewable Energy Project Development Office (REPDO), affiliated with the Ministry of Energy, is planning to deliver new renewable energy projects for various stakeholders across the country, including KACARE, ECRA, the Saudi Electricity Company, etc. In July 2018, the government also introduced a net metering policy to encourage the small-scale private generation of less than 2 MW of renewable electricity for individuals' own accounts and deliver the excess energy to the national network. It is expected that this policy initiative will accelerate small-scale investments in renewable energy sources, leading to economic development. In addition, to ensure the competitiveness of renewable energy sources, in 2018, ECRA announced a new energy tariff. The new pricing policy has led to a threefold increase in energy tariffs, which undoubtedly consolidates the activity of developing renewable energies and supports sustainable development.

4. Solar Pv Industry Value Chain

The solar PV value chain includes all activities conducted by a venture or group of ventures to move a product from the initial phase of ideation to various steps of production supply to beneficiaries and end disposal after utilization (Zhang and Gallagher, 2016). The solar photovoltaic energy value chain can be subdivided into a group of upstream and downstream activities.

4.1 Solar PV industry upstream activities

The stages of the upstream solar PV value chain include all industrial steps starting from the production of polysilicon, crystalline silicon, ingot, wafer, PV cells, modules, inverters, and other BOS components (EPIA, 2011).

4.1.1 Polysilicon production

Polysilicon is the feedstock that solar wafer manufacturers start with, and manufacturers melt it into solar grade crystalline silicon (Xakalashel and Tangstad, 2011). Silicon is available across the world in the form of quartz or sand. Crystalline silicon (Si) is the most efficient and mature technology commonly used in solar PV production and accounts for more than 90% of the world PV market share (Pandey et al., 2018). Polysilicon production requires high capital investments of approximately 500–1000 million USD to build a plant and requires a long time to reach its full capacity. Silicon purification is an energy-intensive process that requires a large amount of energy. The processing of polysilicon consumes almost 85% of the total input energy needed to manufacture an entire PV module (Green Rhino Energy, 2016). According to (IEA, 2016), the energy consumption was 80 kWh/kg in 2010. Then, by using more cost-efficient production equipment, the energy consumed decreased to 55 kWh/kg in 2015, but this was still considered high. This industry requires a joint venture with one of the leading silicon manufacturing firms in the world. The silicon industry is dominated by 7 firms, namely, Hemlock, Wacker Chemie, MEMC, OCI, REC, LDK Solar, and Tokuyama, that produce approximately 90% of the total polysilicon in the world (Green Rhino Energy, 2016). Saudi Arabia is a good candidate to be a leader in this industry because the country owns the three main pillars of this industry: sand, energy, and capital. The quality of polysilicon is critical in maintaining the efficiency of the system. There is fierce competition between the electronics industry on one side and the solar industry on another side in demanding polysilicon (Michaele and Plarzer, 2015). Hence, the increased demand stimulated the investment in and expansion of the polysilicon processing capacities. During this decade, the global overproduction of polysilicon resulted in a significant price reduction (WWF, 2013).

4.1.2 Ingot/wafer production

Depending on the technology used, polysilicon is formed into ingots, and then the ingots are sliced into thin wafers. Monocrystalline wafers are made from silicon with a single crystal structure grown from a small seed crystal while polycrystalline wafers consist of small grains of monocrystalline silicon (Green Rhino Energy, 2016). Wafer production is a significant capital expenditure. It requires high-performance manufacturing equipment, and significant manufacturing experience is also needed to achieve optimal efficiency.

4.1.3 Cell manufacturing

The solar cell manufacturing process starts with wafer texturing to enhance the absorption of sunlight, and then wafers are doped by diffusion to produce p-type and n-type materials. The PV cells are fabricated in such a way to form a sandwich structure to create the p-n junction, fixed with appropriate and substantial electrical contacts and then finally coated with suitable anti-reflective material (FEMIP, 2015). Additionally, cell manufacturing requires high-performance manufacturing equipment, and significant manufacturing experience is needed; therefore, solar cell manufacturing plants are capital intensive.

4.1.4 Module manufacturing

Module manufacturing is conducted by soldering solar cells together in a string and then laminating the toughened glass placed on the front side of the soldered cells and a sheet of polymeric material at the other back side. Supporting frames are used to form a rigid structure and further facilitate mounting in the field. The capital costs for the manufacturing process are generally less than those of cell manufacturing (FEMIP, 2015). Crystalline silicon modules are the most common and widespread PV technologies with greater than 90% of the global market share (Xakalashel and Tangstad, 2011). Figures (2) illustrates the whole value chain of PV module manufacturing. Establishing a PV module production line that consists of an assembly line process will not need high capital investment costs, and it is the simplest method to start PV localization in Saudi Arabia. In the later stages, the know-how of solar cell manufacturing could be transferred and acquired, and then the industry can engage further in cell, ingot, and wafer manufacturing.

Figure (2): PV module value chain

4.1.5 Inverters

Inverters are devices used to convert the direct current (DC) generated by a solar PV module to AC power. Such devices will allow the solar system to be more compatible with most AC appliances. A variety of wide-ranging inverters, ranging from a few hundred watts to several kW, are available in today`s market; and they are considered to be the most essential component for PV grid connections. Inverter technology has already been localized in Saudi Arabia since 2015 by the Advanced Electronics Company (AEC). The production line was constructed through a partnership with Germany’s KACO new energy and has an annual production capacity of approximately 1 GW, roughly equivalent to 2000 units. AEC inverters (Shams series) cover the power range from 20 kW to 1 MW and are considered to be the first inverter to achieve the Saudi standard specifications for local content (PV Tech, 2019).

4.1.6 BOS Components

In Saudi Arabia, there is a strong base of industry infrastructure that is expected to contribute to increasing the local content of the solar industry. There are already several industries that have a commonality with the solar industry that could be primarily linked to BOS manufacturing, e.g., support structures, wiring, circuit breakers, protection relays, power transformers, batteries, glass, aluminum frames, junction boxes, etc. The manufacturing of these components for other industrial purposes is already localized in the country. Local industries might need to make special modifications to meet the requirements of the solar industry, e.g., the local manufacturer of normal glass will need to produce glass with a low iron content and a high transmission rate of solar irradiance. By the time the local companies gain increasingly more experience with improved track records, then all of the BOS components could be locally manufactured.

4.2 Localization potential of upstream activities of the solar PV value chain

The localization potential of the upstream activities of the solar PV value chain in Saudi Arabia is quite high since the 2030 vision offers significant market demand. The production of polysilicon at a competitive price has been quite hard in the last few years due to the increase in global production, which brought down the price from $470/kg in 2008 to $25/kg in 2015 (IEA, 2016). Many plants, particularly in China, exited the polysilicon market due to the price decreases (Chase, 2013). Despite the continued decrease in price, new polysilicon production plants were established in the USA (e.g., Wacker Chemie) and South Korea (OCI), and these new polysilicon plants were characterized by installing more cost-efficient production equipment (IEA, 2016). However, in Saudi Arabia, the price of energy is low, which will make polysilicon production more competitive. In addition, profits are not a major concern in Saudi Arabia, and the major driver for localizing the polysilicon industry is know-how transfer. During the starting phase of the solar value chain, including the production of polysilicon and ingots/wafers, solar cell manufacturing requires a considerably high investment in equipment and a very technically skilled labor force, and a joint venture is necessary. Therefore, localization is more likely to begin with constructing module manufacturing facilities. Table (1) shows the analysis of the localization potential of the solar PV upstream industry in Saudi Arabia.

4.3 Solar PV industry downstream activities

Downstream activities include services related to the PV industry other than manufacturing processes such as planning and design, construction, O&M, R&D, etc. Most of the downstream activities have already partially or totally existed in Saudi Arabia for decades as several entities have led and developed various projects that can easily switch to solar energy projects based on their previous experience in development, construction, and logistics operations. The major players of the downstream segment of the value chain include the following: wholesalers who work as intermediaries between PV manufacturing companies and engineering installation contractors; system developers who provide installation, monitoring, repair, and maintenance services; owners of PV facilities who sell their power production to the utility grid; and policy, consulting and financial services (EPIA, 2011). Figures (3) shows typical segments of the solar energy value chain (FEMIP, 2015).

Table (1): Localization potential of the solar PV upstream industry in Saudi Arabia

Component	Localization Potential	Enablers	Barriers
Polysilicon production	Medium (future production)	• Raw material is available across the country • Energy required is available and cheap • High financial support required exists	• Joint venture is necessary • Needs high technical experience • The quality is critical in ensuring efficiency.
Ingot/wafer manufacturing	Medium (future production)	• High financial support required exists	• Needs high technical experience • Joint venture is necessary
Cell manufacturing	Medium (future production)	• High financial support required exists	• Needs high technical experience • Joint venture is necessary
PV module	Medium (future production)	• Simplicity of establishing manufacturing facilities. • Needs financial support • Can be supported by local content	• Joint venture is necessary
Inverter	High	• Currently manufactured locally by EAC • Needs expansion	
Aluminum frame	High	• Can be produced locally by local aluminum industries.	
Supersubstrate glass	High	• Local capacity exists to supply low-iron glass. • Energy required is available and cheap	
Wiring/cabling manufacturing	High	• Have significant potential in the existing local industry.	
Junction boxes	High	• Small scale manufacturing is undertaken in the country.	
Mounting structures	High	• Have significant potential in the existing local steel and aluminum industry.	

Figure (3): Typical segments of the solar energy value chain

4.3.1 Wholesale distribution

Wholesale distribution entities function as intermediaries between manufacturers and installers or end customers by supplying the required equipment and materials from local or international manufacturers.

4.3.2 Project developers

Project developers are usually experts in the financing matters and legal issues related to projects. Therefore, project developers play an essential role in identifying projects. They are responsible for all activities concerning project development including site identification, project performance, environmental assessment, and electrical network connection studies; negotiating with local society leaders; and engagement of EPC and O&M contractors (WWF, 2013).

Policies such as tax exemptions, incentives, and stimulus funding represent key elements in creating a favorable investment climate for project developers. The 2030 vision paves the way towards the implementation of these policies. During the implementation of the Saudi 2030 vision, the government is planning to review the renewable energy legal and regulatory framework in order to create a glamorous investing environment to allow both local companies and international developers to invest in this sector. This will ultimately lead to creating a favorable investment climate in the country. There are several international developers around the globe that can participate in solar PV energy value chain projects in the country.

4.3.3 EPC contractors

Generally, Engineering, Procurement, and Construction (EPC) firms have combined strong technical know-how and experience in large-scale PV projects. EPC companies are usually leased by project developers to design, construct, and monitor projects. Most of the activities during the various phases of a project starting with construction, installation, and system integration could be completed by the local task force; however, EPC firms can supervise these activities. This will allow local companies to obtain more experience in terms of construction and other activities.

4.3.4 Operation and maintenance (O&M)

During the starting years of a PV facility, the operation and maintenance activities are usually the responsibility of the EPC contractor. It is also during this period of training that technical capacity building and know-how will be transferred from the EPC contractor to the PV project owner`s technical team to ensure an adequate and smooth transfer of skills by the end of the O&M agreement period. Thereafter, the project owner will take over all O&M activities.

4.3.5 Project owner

In the large-scale utility sector, the project owner is usually a consortium or specific entity involving various partners, including project developers and potentially local utilities.

4.3.6 Users/utility

The 2030 vision`s strategic objective is to further advance the quality of power sector services by increasing electricity coverage all over the country to 99.5 % by 2020, where the total average time of electricity outages is 120 min. In this regard, the country has a well-established infrastructure of electrical networks that link all regions together. In this case, the construction of the PV industry and the deployment of PV technology necessitate fewer transmission lines to be connected, hence resulting in lower investment costs.

4.3.7 Supporting processes

i. Education and R&D

In Saudi Arabia, there are more than thirty universities and fifty technical colleges that annually graduate many qualified engineers and technicians. As proposed earlier, starting the solar module manufacturing facility with an assembly line does not need extensive training and extremely highly trained manpower. Therefore, the workers can have short training to support the assembly production line. Then, later, their labor skills can be developed to support value chain production (polysilicon, cells, module manufacturing, inverters and the remainder of the BOS). R&D is critical throughout all phases of the value chain industry. The major portion of research funding support is committed to solar cells and modules (Chinagoabroad, 2011). R&D is assumed to be crucial in solar development; and various sectors play remarkable efforts in R&D activities, including pilot and demonstration projects. Partnerships may be formed with several universities, laboratories, and private firms worldwide, which will constitute advanced and well-established R&D units emphasizing a wide range of research activities ranging from commercial to the new emerging picking up technologies. Examples of such R&D departments are the following: NREL, Sharp, and Siemens.

ii.Financial services

Funding for PV value chain activities is expected to be offered through the government and commercial banks. The 2030 vision has allocated considerable funds during the 2020 interim plan to implement renewable energy activities. Furthermore, there are several local investors and a set of local banks that are willing to support investment in the solar industry in the country. According to the provision of financing from these sectors, there will be no need to seek project financing from international institutions. However, in order to simplify the development of local capabilities, performing the following is highly important:

(1) Reduce the administration process for both local and international firms willing to establish their production units.

(2) Some of the technology risks should be taken by the government.

(3) Provide support in scaling up the already existing manufacturing facilities to shift towards some of the value chain production. Scaling up existing facilities is expected to be cheaper than building new facilities.

iii. Consulting

Consultation and collaboration with international solar value chain manufacturing companies will provide newly developed local companies in the country with good experience through the transfer of know-how in the various components of the solar PV value chain. There is an increasing awareness of the importance of solar energy use in Saudi society. This is reflected by the establishment of a number of nongovernmental solar organizations, e.g., the Saudi Arabia Solar Industry Association (SASIA), which is devoted to helping the country achieve its vast solar potential by encouraging mutually beneficial partnerships between Saudis and global solar companies.

iv. Government supporting policy options

The PV value chain industry is facing a variety of barriers affecting investments. These include policy legislation, market technology, and upfront costs, all of which are considered institutional barriers. Therefore, it is believed that supporting schemes need to be in place to promote the value chain industry in the country. In fact, there is no particular consensus on the best policy options to adopt and implement, but there are several options with merits over each other. Feed-in Tariffs (FITs) are one of the policy options based on regulating incentives aimed at increasing renewable energy adoption. This type of policy was applied by Germany during the implementation of its electricity feed-in policy by offering an attractive electricity price to the providers. The second type of policy option is Renewable Portfolio Standards (RPSs), which is a market-based mechanism aiming to achieve cost-effective renewable energy generation. The idea of this policy is that the government grants a proportionate share of renewable energy electricity to the cumulative energy supply. The RPS policy has different names in various countries for the same set of incentives, e.g., the Renewable Obligation (RO) in the UK, the Mandatory Market Share (MMS) in China, the RPSs in the USA, and quotas, which are currently used in many countries around the globe. The third type of policy option is a tendering or Centralized Bidding Mechanism (CBM), which is generally used in the power sector to promote renewable energy applications. In this policy, renewable energy investors usually call for project bids. A CBM is indeed a market-based policy that aims to achieve the minimal costs doe projects. The fourth type of policy option is Tax Credits (TC), which is a method to reduce renewable energy costs through market compensation.

Government policies are considered a key driver of the development of the PV value chain industry. Regulatory frameworks for supporting the local PV value chain industry in Saudi Arabia are still in the development process. However, in 2018, the government approved the “Small-Scale Solar PV Systems Regulations”, which would apply to PV systems ranging in size from 1 kW to 2 MW for residential PV. This regulation system adopted a new energy exchange scheme called the net metering scheme, which is similar to a FIT scheme, but the energy balance is executed by the end of each month at different tariffs for exported (generated) and imported (consumed) energy. The adopted tariff for imported energy is 0.048 $/kWh and that for energy exported to the grid is 0.01867 $/kWh. We think the price of exported energy is not encouraging for the deployment of PV energy systems in the residential sector. In addition to the regulation system of small PV, the government has used the Centralized Bidding Mechanism (CBM), which is generally dedicated to large PV projects. The CBM has been used in PV project tenders since 2017. Additional renewable energy policies and regulatory frameworks will be issued gradually during the implementation of the 2030 vision to allow private companies to invest in different activities of the solar PV value chain.

5. Expected Benefits Of The Local Manufacturing Of The Solar Pv Value Chain

The technical and economic feasibility of the solar industry seems to be promising as prices annually decrease and production efficiency increases. The socioeconomic and environmental benefits make the technology even more attractive. The expected benefits of the local manufacturing of solar PV value chains can be summarized as follows.

5.1 Technology and Know-how transfer

The traditional know-how transfer approach focuses mainly on training in technology. However, know-how transfer comprises various elements other than technology, such as know-how on regulation and policies, finance, management, local market segment, etc.

Collaboration with international companies will provide newly developed local companies in the country with good experience through the transfer of know-how in various value chain developments. In the early stage of value chain localization in the country, the transfer of know-how is a key factor of success. Therefore, at the beginning of the value chain, upstream and downstream activities will be mainly conducted by overseas experts, and then the local workforce will gradually take over the manufacturing process. This step will result in smooth and steady localization and ensure an adequate know-how transfer to the local workforce. The proposed plans of solar PV deployment will accelerate and develop other connected industries such as inverters, electrical equipment, and other BOS components. The establishment of a local value chain industry will also attract international solar manufacturers to establish joint ventures with local investors in the country; hence, it will also contribute to know-how transfer.

5.2 Job Creation Potential

The solar PV industry is receiving growing attention because it is associated with socioeconomic benefits in terms of job creation potential besides addressing energy security and environmental protection. The employment opportunities created by renewable energy technologies are greater than those created by traditional fossil fuel-based technology throughout the lifespan of a facility. Direct and indirect employment activities in the value chain industry include R&D, education, training, manufacturing, construction, and O&M (IEA, 2015). Manufacturing and supply activities create the most job opportunities along the entire value chain, followed by construction and installation, whereas O&M activities contribute to fewer jobs. The future expansion of upstream activities is expected to be associated with an increase in local content; hence, it will also likely lead to greater job creation. NTP initiatives are targeting the creation of a significant number of jobs (145,000) in the industrial sector by 2020. The value chain and the involvement of the various stakeholders' activities are presented in Table (2). The potential jobs added annually (jobs/MW) may be estimated by depending on the statistics of the annual report of the European Commission Joint Research Centre regarding PV Industry in EU countries, as shown in table (3) (Ossenbrink et al., 2015).

Table (2): The value chain and the involved stakeholders (ECRA, 2016).

Stakeholders	Equipment Provider(s)	Developer and EPC*	Utilities	Financier(s)
Role in the value chain	• Manufacturing • Assembly • Distribution	• Project planning • Construction • Operation and Maintenance	• Support functions • Decision making • System planning • Grid connection	• Support functions • Financial services
*EPC = Engineering, Procurement and Construction.				

Table (3): Potential jobs added annually by the PV value chain (Ossenbrink, et al., 2015).

Activity	O&M	Construction	Installation	Polysilicon	Cell and module industry	Inverters	BOS	Project development	Financial services
Job/MW	0.15	3.2	9.8	0.75	9.6	1.5	1.8	0.45	0.1

6. Recommendations

As previously discussed, the localization of the value chain of the solar PV industry provides essential benefits. Therefore, it is recommended that a local manufacturing program considering the current local capacities and capabilities be immediately started. The weaknesses and expected threats are addressed as follows:

(1) As a key driver to support the local PV industry, the government should urge establishing a national strategic plan for PV value chain development that includes the following: policies, regulatory frameworks, financial support, and tax privileges. Policy experience gained by recent successful countries could be transferred and applied in such a way to accommodate the existing situation in the country.

(2) In order to develop market confidence and ensure the successful development of the solar value chain industry in the country, it is recommended that all uncertainties related to future roll-outs be removed and a standardized project package be developed to minimize administration processes that developers might face.

(3) Encourage financial institutions to provide low-interest loans and grants and to establish new investment support schemes to help national companies overcome the high initial investment costs. In addition, financial institutions should be encouraged to provide financial support to upgrade the production facilities of local content manufacturing.

(4) Foster partnerships with global leaders especially through joint ventures to develop local skills and facilitate know-how transfer and to guarantee sufficient technical support for local companies to produce high-quality products. However, the local content should be carefully increased considering the current technical capabilities, the existing capacities, and the timeframes.

(5) Ensure strong and adequate government supporting policies that have a significant role in enabling the stable development of the solar PV value chain industry.

(6) Facilitate investments by simplifying the process of registering and obtaining permissions – particularly for foreign investors.

(7) Provide technical and organizational assistance for industrial companies to improve their manufacturing processes for various related PV components to enable them to tackle the new market.

(8) Support R&D activities related to PV technologies to pave the way to intellectual property through bilateral collaboration with experienced research centers and international companies.

(9) Set a strategic plan for the education and training of engineers and technicians to provide local companies with a highly skilled workforce.

7. Conclusion

In this paper, the localization potential of the solar PV value chain in Saudi Arabia was demonstrated and analyzed. Different phases of upstream and downstream activities of the photovoltaic industry value chain related to the current situation in Saudi Arabia were examined and analyzed. Various enablers and barriers have been assessed considering the current capabilities of the local content of the photovoltaic solar energy industry. In this research, the expected benefits that can be acquired by solar PV value chain localization have also been illustrated in terms of know-how transfer, strengthening international partnerships, and job creation potential. The opportunities, challenges, and other frameworks have been identified; and recommendations have been set to enable value chain localization based on the 2030 vision. Furthermore, the socioeconomic impacts in terms of employment generation, economic development and environmental advantages acquired as a result of the adaptation of the value chain scenario have been highlighted.

Declarations

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

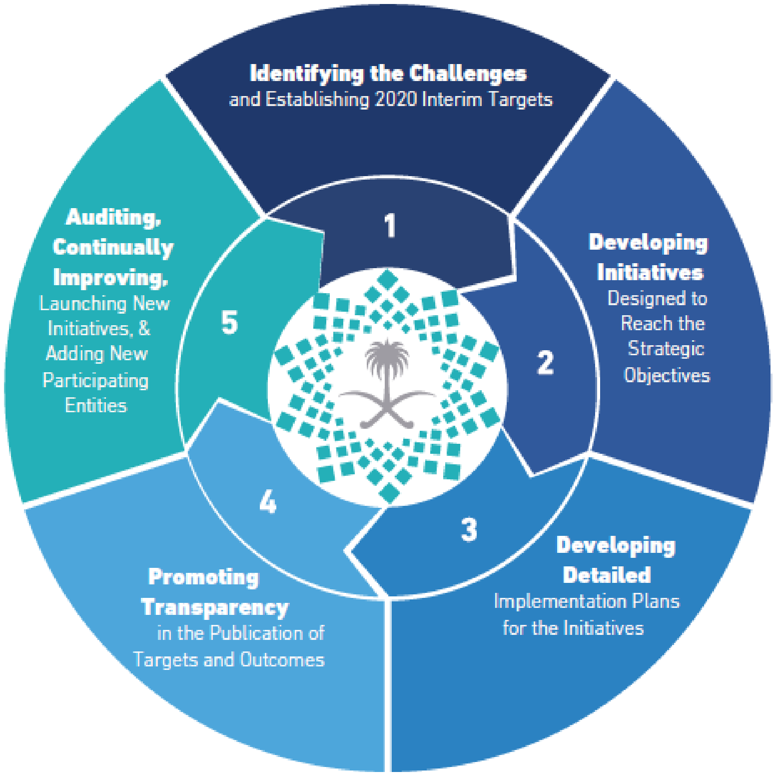

Figure 1

Operating Model of the National Transformation Program

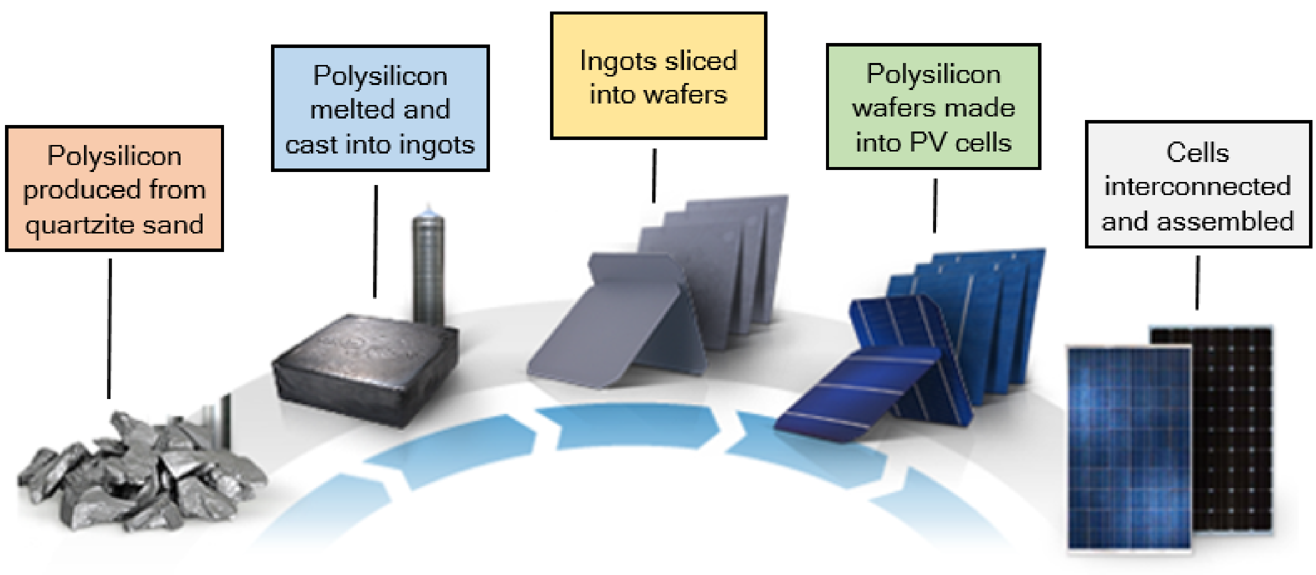

Figure 2

PV module value chain

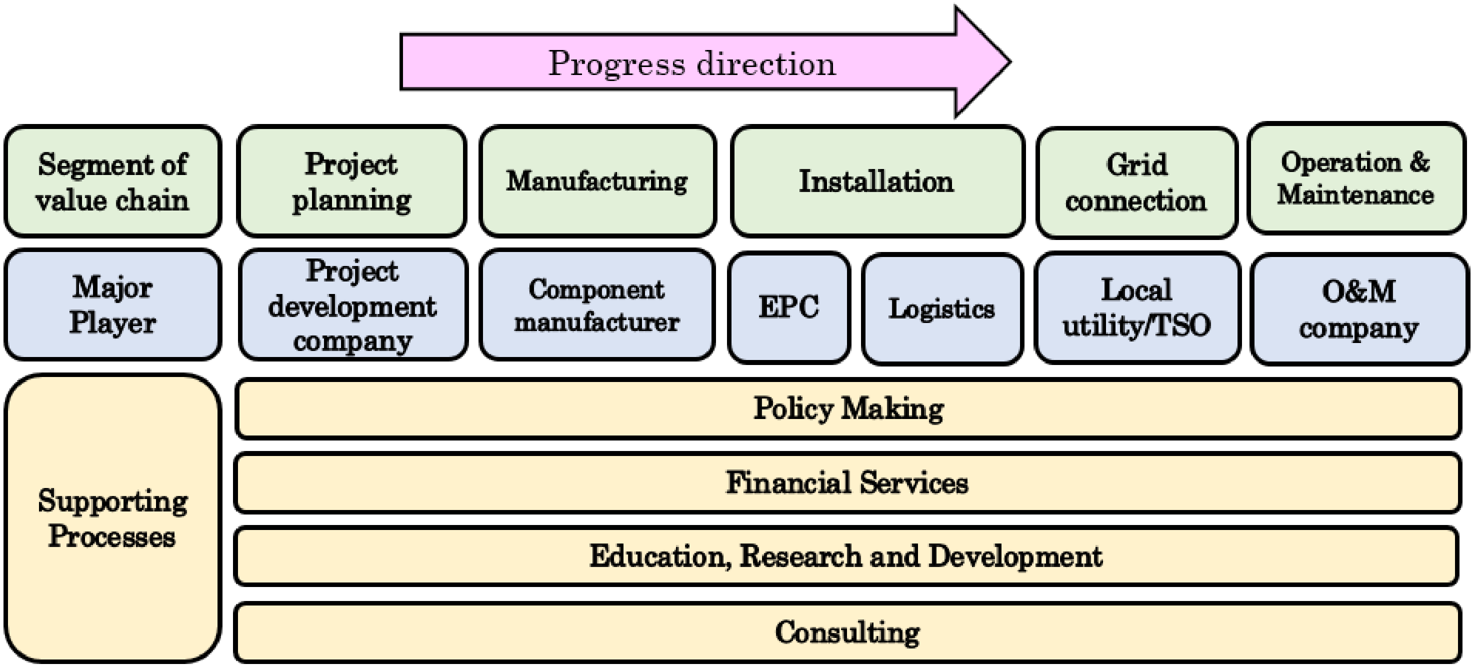

Figure 3

Typical segments of the solar energy value chain

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- GraphicalApstract.png