Fraunhofer ISE

Support for Moroccan Solar Plan

Solar Technologies in Morocco – Industry and Value Chain Assessment

Executive Summary: Nov 30, 2012

Prepared by

Fraunhofer Institute for Solar Energy Systems ISE
Heidenhofstraße 2,
79110 Freiburg, Germany
Contact:
Dr. Thomas Schlegl
Thomas.Schlegl@ise.fraunhofer.de

Authors: Christoph Kost, Jessica Thomsen, Thomas Schlegl, Thomas Fluri, Simon Philipps, Simon Lude, Ingrid Hädrich, Dirk Weber, Werner Platzer, Harry Wirth (all Fraunhofer ISE)

Realized for: masen Moroccan Agency for Solar Energy; giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Financed by: BMZ Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung

This version includes the Executive Summary of the report which consists of 263 pages. Incomplete or misleading publication of results is forbidden. The project (PN 2003. 3505.9-011.00) was commissioned by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, Germany.

This report includes the contribution from Ernst & Young, Paris.

Contact:
Alexis Gazzo, Julien Perez, Clément Baldy
Ernst & Young
TSA 14 444, La Défense Cedex 92037, France

The contribution of Ernst & Young is not part of the Terms of Reference of the project between GIZ and Fraunhofer Institute for Solar Energy Systems ISE. Analysis and interpretations are based on the individual consultants' experiences and their evaluation of the global market situation.

Contact: Fraunhofer Institute for Solar Energy Systems ISE
Renewable Energy Innovation Policy
Heidenhofstraße 2
79110 Freiburg
Germany

Dr. Thomas Schlegl
Thomas.Schlegl@ise.fraunhofer.de

Executive Summary

1. Introduction

In 2009 the Moroccan government established the Moroccan Solar Plan (MSP), aiming at the installation large scale solar power plants with a cumulated capacity of 2,000 MW until 2020. Furthermore, it includes an integrated development strategy to strengthen the local industry participation. The newly created Moroccan agency for Solar Energy (Masen) is responsible for the implementation of the MSP as well as ensuring an adequate regulatory framework setting to achieve these objectives. The present study was realized by the Fraunhofer Institute for Solar Energy Systems ISE (Fraunhofer ISE) and Ernst&Young (E&Y) for GIZ (Gesellschaft für Internationale Zusammenarbeit) and Masen. It supports the efforts of Masen and the targets of the MSP by assessing the potential industry integration and manufacturing capabilities for Concentrated Solar Power (CSP) and Photovoltaics (PV). In this report the expression "manufacturing" is used for the production of components as well as for services during the installation of power plants. The study was carried out from May to December 2011, including direct interviews of 55 Moroccan companies and 15 international solar companies, as shown in Figure 1. The results of this study are based on a total number of approximately 100 in-depth interviews by Fraunhofer ISE, as 30 formerly interviewed companies are included in the analysis.

The considered technologies in this study are Parabolic Trough, Solar Tower and Fresnel for CSP plants and Crystalline Silicone, Thin Film as well as Concentrating PV for photovoltaic plants. Both technology fields have experienced an exponential growth in installed capacities over the last years, compare Figure 3 and Figure 7. This is due to a generally rising demand for renewable energy sources as well as improving technology efficiency, combined with falling production costs. The present study gives a detailed insight into the mentioned technologies, their differences, manufacturing processes maturity and current market situation. Furthermore, the corresponding core value chains for the different solar power plants and the international industry for each plant component are analyzed. Those analyses target to reveal the potentials for local manufacturer and to highlight the opportunities and threats each industry holds for new businesses. Based on this detailed analysis, the capabilities of the Moroccan industry itself are assessed, concerning the existing and future potentials a local solar industry could withhold for the Moroccan economy.

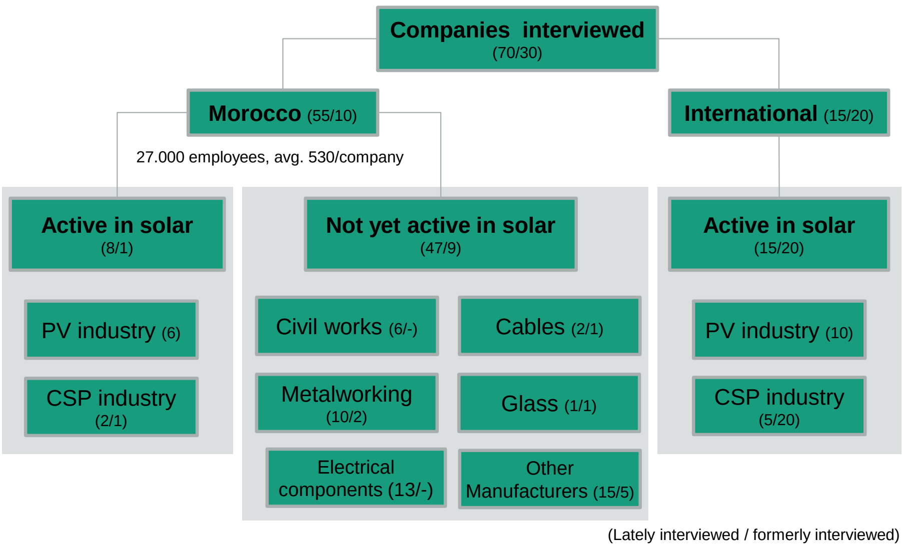


Figure 1: Moroccan and international companies interviewed during this and previous studies

2. Introduction to Concentrated Solar Power (CSP) technologies

Figure 2: Line focusing systems: Parabolic Trough collector and Linear Fresnel Collector, Point focusing systems: Solar Tower plant and Dish Stirling collector.

Global cumulative installed CSP capacity has reached 1,660 MW in 2011, showing a growth trend as shown in Figure 3. Up to now, the dominant CSP technology has been Parabolic Trough with 1592 MW, however alternative concepts such as Solar Tower and Linear Fresnel are currently gaining ground. Current installations are mainly located in Spain and the US due to a profitable combination of solar resources and lucrative feed-in-tariffs (FiT). Plant sizes vary according to local regulations and technology.

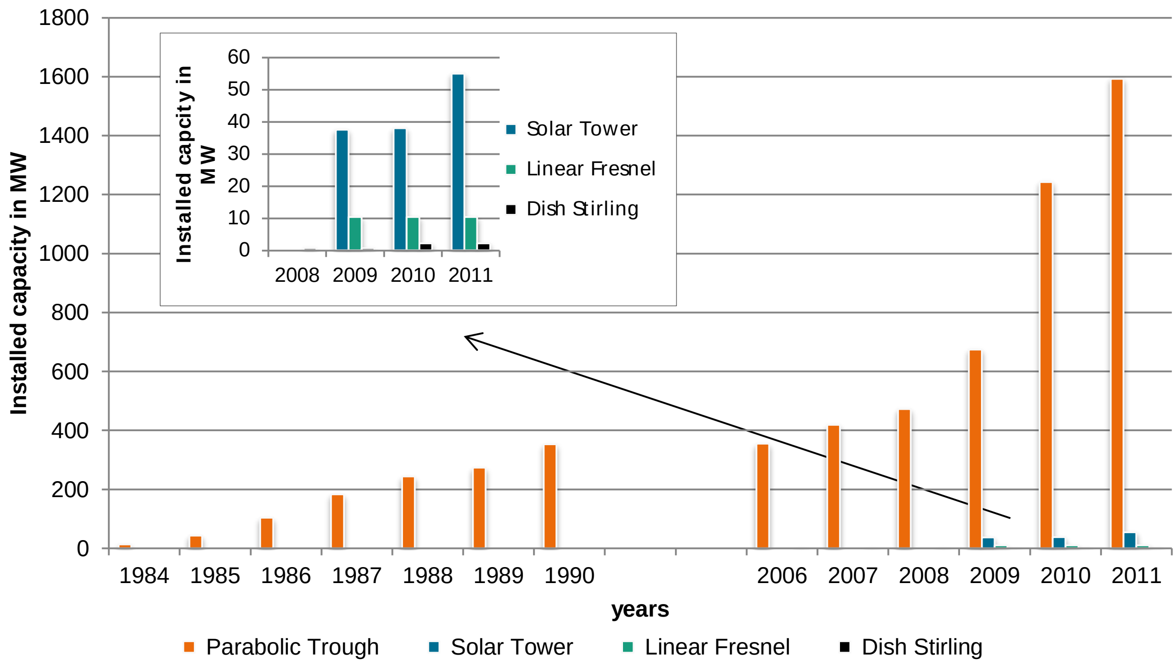


Figure 3: CSP Market development for different technologies

One of the main advantages of solar thermal power plants over many other renewable energy technologies is the ease of grid integration. Even a system without storage has a relative good stability and time constants of several minutes. Dispatchable electricity generation is possible by a CSP plant with storage integration or by using hybridization of solar power plants (see also SWOT analysis in Table1). Compared to other locations, Morocco offers good DNI resources which increase the application potential of CSP in Morocco.

Current cost analysis of the different CSP technologies, containing a detailed breakdown for different reference plants with an installed capacity of 100 MW for Parabolic Trough, 50 MW for Fresnel and 20 MW for the power tower technology, shows a specific investment of 4.784 Mio €/MW, 3.422 Mio €/MW and 10.85 Mio €/MW respectively with a strong dependence on the storage and solar field size. As Operation and maintenance (O&M) is similar to the O&M of conventional power plants,

Fraunhofer ISE

existing knowledge is transferable. Mid-term cost reduction potential of CSP plants lies in the range of 25% (by 2020) and can increase to 45% or 60% in the long-term outlook (by 2030).

Table 1: SWOT analysis of CSP technologies

Solar Thermal	Strengths	Opportunities	Threats	Weaknesses
Parabolic Through	▪ Commercially used for 25 years ▪ Large industry capacity and experiences ▪ Standardization of design ▪ Mass production of components	▪ Large amount of announced projects ▪ Scalability up to 300 MW	▪ Cost reductions not satisfactory	▪ Mirrors and receiver technologies are of high standard and cost ▪ Temperature currently limited to 400°C ▪ Costly flexible joints
Fresnel	▪ Flat mirrors, ▪ Efficient land use ▪ Similar power block like Parabolic Trough ▪ Direct steam generation ▪ (superheated soon expected)	▪ First project of 30 MW ongoing ▪ Upscaling to 300 MW	▪ Lower efficiency is not compensated by lower costs	▪ Lower optical efficiency ▪ Small industry capacity
Solar Tower	▪ Flat mirror systems ▪ High concentration ▪ High temperature potential	▪ Higher efficiencies possible by temp. up to 900-1000°C (with air as HTF) ▪ High cost reduction possible by cheap mirror production ▪ Combined cycle with HTF air	▪ Problems with storage systems ▪ Durability of receiver technologies ▪ Many competing concepts ▪ Up-scaling difficult	▪ Lower optical efficiency ▪ Little commercial experience ▪ Restricted tower height to 80 - 100m ▪ Current HTFs limit the maximum achievable temperature

The option of scalability of CSP is highly important to increase competiveness of CSP compared to other technologies. Larger plant sizes with 100 to 200 MW will lower the specific investment because the power block could be used more efficiently. Project management, balance of plant and power block cost could be cut by 20% to 25% when larger plant sizes are chosen. Expected cost reductions amount from 13% to 20%. Other cost reduction potentials are in the components' production cost as a reduction of 15% to 25% will lead to an assumed levelized cost of electricity reduction of 45% to 60%. Further actions would be an enhanced research and development, competitive market supply and further producers especially in countries with lower labor costs.

The labor impact due to the installation and operation of CSP plants will also be significantly, if local firms will be able to participate. 1,000 workers will be required during the construction phase and 49 people will be responsible for the operation of a 50 MW Parabolic Trough CSP plant with storage (layout, see Figure 4).

A CSP plant consists of main different components like mirrors, pylons, metal support structure, receiver, tubes, heat transfer fluid, concrete foundations, pumps, tracker system, pylons, cabling, power block, storage system, electrical control system and the grid connection (Figure 5 shows the core value chain for CSP plants).

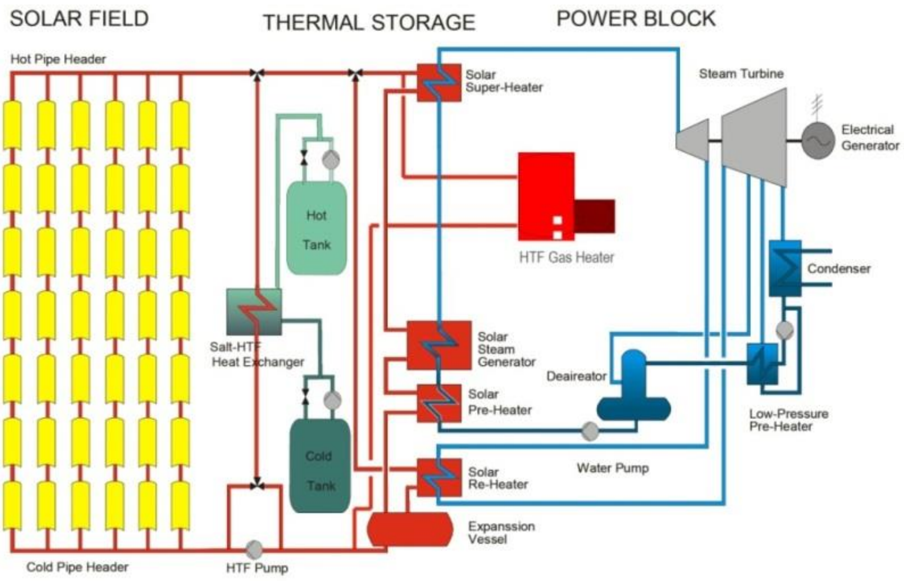


Figure 4: Schematic of a Parabolic Trough plant with integrated two-tank thermal energy storage and HTF gas heater (SolarPACES, 2006).

As displayed in Figure 5, the CSP core value chain comprises seven phases, which include:

- Project development - a suitable site is selected, the power purchase agreement is reached and a concept is made for the type and layout of the plant.
- Materials - Raw materials that are to be supplied, not only to the power plant site directly but also to the various supplying manufacturers
- Components - Pre-manufactured components and pre-assembled groups
- Engineering & Construction - EPC, which is often contracted to a specialized company.
- Operation & Maintenance – Operation including maintenance, mirror cleaning, replacement etc.
- Distribution - Distribution of the produced electricity to the end-users.
- Dismantling - Dismantling of the power plant after end of lifetime.

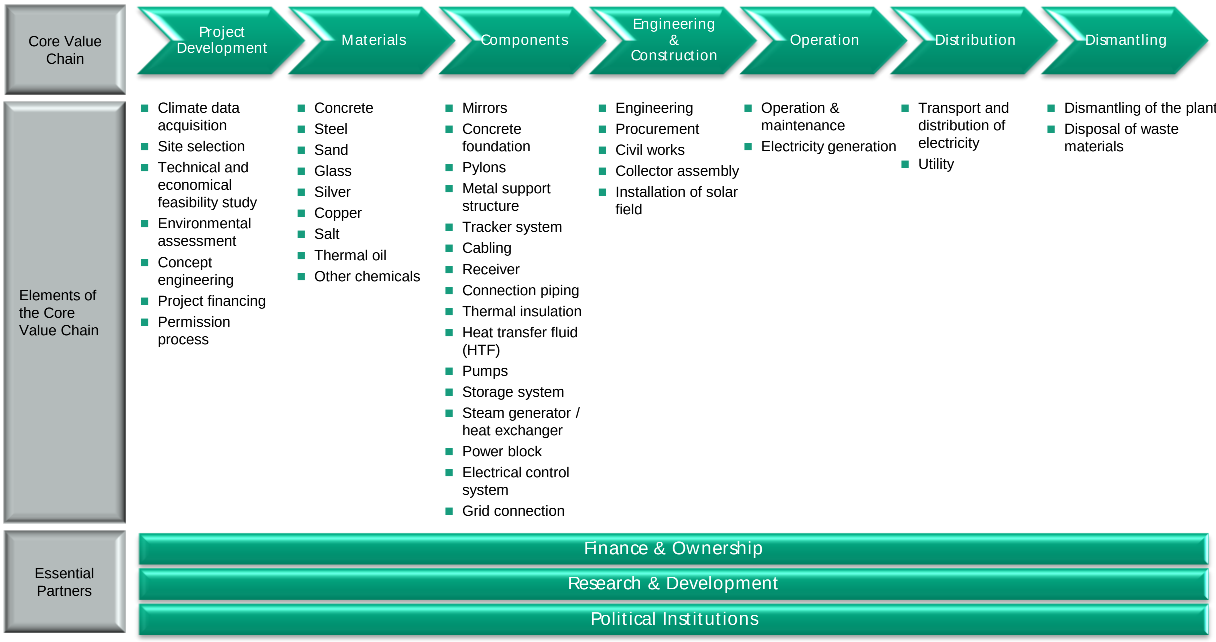


Figure 5: Core Value Chain for a CSP plant

The main raw materials used in CSP plants are:

- Glass for mirrors
- Steel for support structures and piping
- Chemicals for the heat transfer fluid HTF
- Salt for the storage
- Concrete for collector foundations, tower construction, power block etc.

Depending on costs and logistical aspects, materials are provided either by the world market or local suppliers. As can be seen, there is a large number of necessary components that require different production processes, materials and varying level of specifically trained workforce. The detailed analysis of each component regarding its functioning, manufacturing process and industry structures can be found in chapter 4. The findings are summarized in Table 2, forming the basis for the evaluation of the Moroccan industry's opportunities.

Table 2: Summary of industry structure, economics and costs, market structure and trends and key competitiveness factors of component manufacturing and services in the CSP value chain

	Industry Structure	Economics and costs
Project Development and Engineering	Small group of companies with technological know-how Intern. actors have fully integrated activities Increasing number of local developers in emerging markets (partly in cooperation with intern. players)	Activities are mainly labor-intensive engineering and permitting activities.
EPC contractors	Strong market position for construction, energy, transport and infrastructure projects.	Large infrastructure companies with high turnover
Mirrors	Few, large companies, often from the automotive sector Large factory output	Large turnover for a variety of mirror and glass products
Receivers Parabolic / Fresnel	Two large players Factories also in CSP markets Spain and US	Large investment in know-how and machines required
Receivers Solar Tower	Many players No established market	Low additional investment for industrial boiler manufacturers
Metal support structure	Steel supply can be provided locally Local and international suppliers can produce the parts	High share of costs for raw material steel respectively aluminum
	Market structure and trends	**Key competitiveness factor**
Project Development and Engineering	Strongly depending on growth/expectations of individual markets Activities world-wide	Technology know-how Access to finance
EPC contractors	Maximum of 20 companies Companies are active on the markets in Spain and the US	Existing supplier network
Mirrors	A few companies in market, increasing capacities High mirror price might decline	Bending of glass, Manufacturing of mirrors with high reflectance, Including the up-stream float glass process
Receivers Parabolic / Fresnel	Strongly depending on market growth Low competition today, but new players are about to enter the market (e.g. Italy, China)	High-tech component with specialized production and manufacturing process
Receivers Solar Tower	Young market Strong growth expected	High temperature heat exchanger manufacturing
Metal support structure	Increase on the international scale expected Subcontractors for assembling and materials	Price competition Mass production / Automation

CSP projects are often executed by an international industrial consortium that might also include entrants to the CSP market. For a single large CSP project, usually a consortium under an experienced EPC contractor is formed, that supplies the components and services for the construction of the plant. The largest players in the market are currently international company groups, which are dedicated to a variety of industry sectors. Each component was assessed regarding its technical, financial and market barriers to obtain a rating of the barrier levels for manufacturing. The rating "low" facilitates the market entrance and change of production for companies in Morocco. "Medium" and "High" states elevated requirements and problems to enter the market.

Table 3: Technical and economic barriers of manufacturing CSP components (Fraunhofer ISE, also published in Fraunhofer ISE/ISI and E&Y, 2011)

Components	Technical Barriers	Financial Barriers	Market environment	Level of barriers
Civil Work	Low technical skills required	Investment in large construction machine	Project experience from other energy projects	**Low**
Engineering and Project development	Very high skilled professionals: engineers and project managers with university degrees	Financial background for project organization	Limited market of experienced CSP engineers	**Medium**
Assembly	Logistic and management skills necessary Lean manufacturing, automation	Assembly-building for each site, training of work force	Collector assembly has to be located close to site	**Low**
Receiver	Highly specialized coating process with high accuracy Technology-intensive procedural step of sputtering	High specific investment for this manufacturing process	Low market opportunities to sell this product to other industries and sectors	**High**
Float glass production (for flat and curved mirrors)	Float glass process is the state-of-the-art technology, but large quantities and highly energy intensive, complex manufacturing line, high skilled workforce to run a line	Very capital intensive	Large demand is required to build production lines	**High**
Mirror **Flat (Float glass)**	Complex manufacturing line High skilled workforce to run a line	Capital intensive	High quality flat mirrors Limited further markets Large demand required	**High**
Mirror **parabolic**	See flat mirrors Plus: Bending: highly automated production	See flat mirrors + bending devices	Large demand required Parab. mirrors can only be used for CSP market	**High**
Mounting structure	Structure and the assembly are usually proprietary know-how of the companies Standardization and automation reduces low skilled workers, but increases process know-how	Automation is capital intensive Cheap steel is competitive advantage	Markets with large and cheap steel transformation industries are highly competitive	**Low**
HTF	Chemical industry with large productions. However the oil is not highly specific	Very Capital intensive	Large chemical companies produce the thermal oil	**High**
Connection piping	Large and intensive industrial steel transformation processes Process know-how	Capital intensive production line	Large quantities	**Medium**
Storage system (HTF, pumps, tanks, isolation, etc.)	Civil works and construction is done locally Complex design and architecture Salt is provided by large suppliers	Not identified	Low developed market, few project developers in Spain	**Medium**
Electronic equipment	Standard cabling not difficult Many specialized electrical components, but not CSP specific equipment	Not identified	Market demand of other industries necessary	**Low**

3. Introduction to Photovoltaic technologies (PV)

Figure 6: Fixed-tilt and tracked c-Si PV plants, Thin Film PV modules and tracked CPV plant

Photovoltaic (PV) technologies are classified according to their corresponding technology. Crystalline Silicon (c-Si) refers to mono, multi and ribbon c-Si, while Thin Film (TF) technologies include Cadmium Telluride (CdTe), amorph-microcrystalline Silicon (a-Si/μc-Si), Copper Indium Gallium Selenide (CIGS) and Copper Indium Selenide (CIS). Concentrating photovoltaics (CPV) represent various technologies that concentrate the irradiation before reaching the photovoltaic cell. PV has experienced a remarkable rise in installed capacity and production in recent years, resulting in a global PV capacity of more than 65 GWp and an expected further rise in installations in the forthcoming years as illustrated in Figure 7. Concerning the different technologies, c-Si has the highest market share with 87%, followed by Thin Film technologies with 12%, compare Figure 7. The remaining 1% is occupied by CPV and other alternative concepts that have not reached large-scale marketability yet.

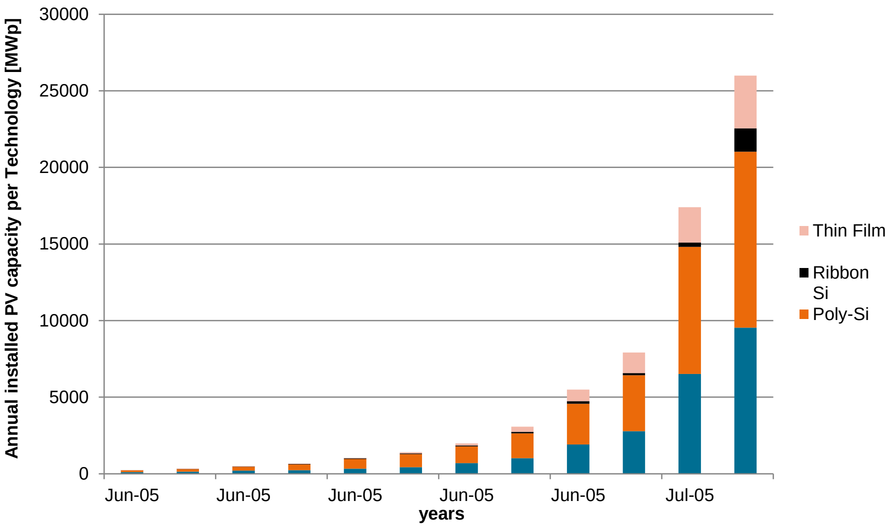


Figure 7: Cumulated PV module shipments of about 40 GWp since 1980 to 2011

The European Union is leading in installations with a cumulative installed capacity of over 29 GW (70% of total cumulative installation) (Jäger-Waldau, 2011). However, the PV market in Africa and the Middle East still remains rather small by the end of 2011. The potential for PV is huge in North Africa due to its high solar resources in the earth´s "sun belt". With the strong decrease of PV prices and under increasing fossil fuel prices, parity of PV electricity generation cost with consumer prices is expected within the next years in sunny regions, including Morocco where it is anticipated for 2013 (Breyer, 2010).

In Europe, high growth in PV installation was mainly driven by financial support schemes, the excellent scalability of PV systems due to the modular structure and a significant decrease in investment cost. A detailed analysis of module and installation costs for the mentioned technologies has been conducted, considering the steep learning curve PV has shown in the recent past. For ground mounted PV power plants, specific investments of 1.41 €/Wp with c-Si modules, 1.43 €/Wp with Thin Film modules and 2.49 Wp with CPV modules are expected in Morocco. Due to the highly automated and remote operation of PV plants, the annual operation and maintenance costs are fairly low with approximately 0.0175 €/Wp for Crystalline and Thin Film modules and 0,325 €/Wp for CPV plants. Hence, the labor impact of the PV plant operation is considerably lower than that of CSP plants. The necessary amount of workers for the module production depends significantly on the considered technology, as c-Si requires more production steps than Thin Film modules. CPV modules are currently manufactured employing less fully automated processes than the other technologies.

The PV value chain corresponding to PV power plants, shown in Figure 8, is divided into seven phases, analogous to the CSP value chain. The main components of each PV plant are the module, inverter, mounting structured, foundation, cabling, transformer and grid connection. The main materials therefore are the applicable semiconductor, solar glass, steel, aluminum, foil, concrete, copper and polymers. As for CSP, the majority of the materials are procured on a global level. The project development prepares and realizes the whole PV power plant and hence has to be present until the plant's commissioning. The materials and components are generally sourced globally, according to price, quality and country specific standards. The majority of jobs are generated within the realization and installation of the plant. The main difference between the considered PV technologies is the design, materials and production processes of the used modules. As primary component of a PV plant the module accounts for more than 40% of the investment cost. Due to the large distinctions, each module value chain is analyzed in-depth in chapter 7.3 to 7.5 of the study.

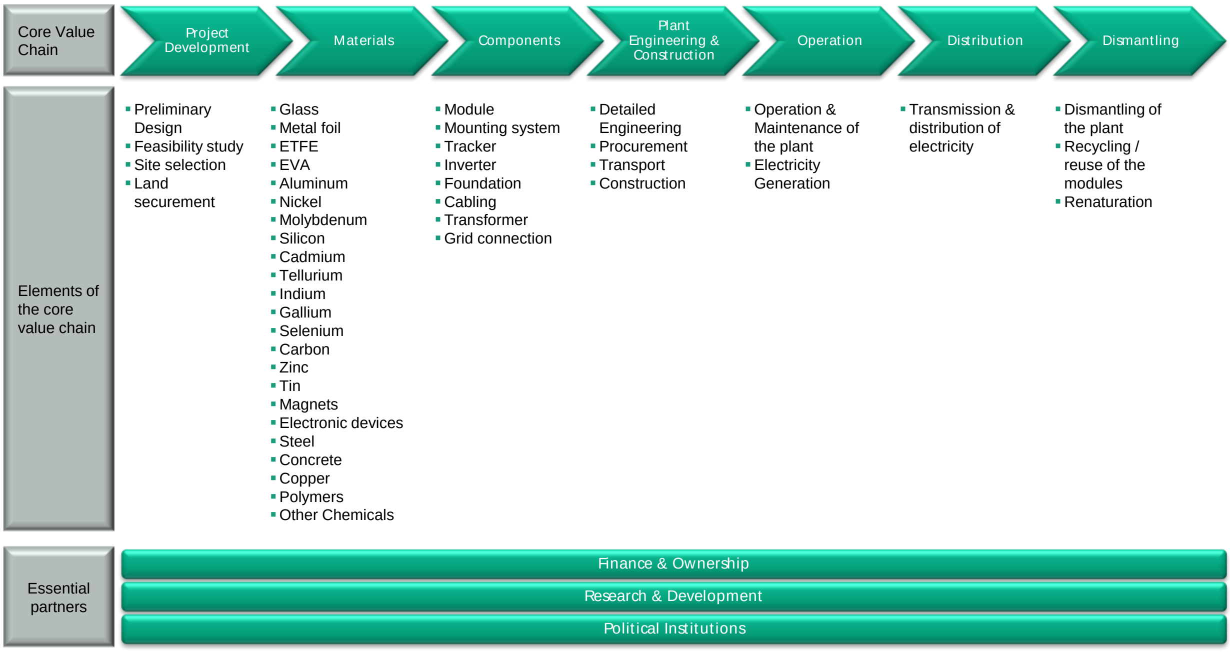


Figure 8: Core Value Chain for a photovoltaic power plant

The industrially produced c-Si-PV-module consists of a glass plate, two encapsulant foils, a backside foil, a junction box, sometimes a frame and finally the Crystalline Silicone cells, which present the most value adding item of a PV-module with approximately 70% of the total module costs. The production consists of five major steps, the silicone, ingot, wafer, cell and module. Thin film modules consist of glass plates, encapsulation foils, a junction box and thin layers of directly applied semiconductors. The production is usually integrated into one production line that covers all steps from depositing the first layer onto the glass substrate until the final test. In module-based CPV systems, the module consists of a solar cell, a receiver, primary optics and a frame. The currently most common type of CPV modules uses a Fresnel-lens to concentrate the incoming irradiation and III-V solar cells, which are produced via epitaxy. The solar cell has to be mounted on the receiver and then assembled with the primary optics, hence five manufacturing steps consisting of epitaxy, cell, receiver, primary optics and module assembly are necessary. Considering the semiconducting technology used, production of each module type requires high technology machinery, clean room facilities and availability of the respective materials such as pure silicone, materials for compound semiconductors or various rare earths.

The installation is usually realized by specialized EPC contractors or project developers. The same applies to the operation. A PV plant requires fewer workforces for the operation and maintenance than a CSP plant, as remote control and automatic operation allow, hence less on-site staff is necessary.

Considering the PV market's status quo, Table 4 summarizes the main facts of the PV industry assessment for selected components. Those factors serve as evaluation guidelines for the assessment of the Moroccan industry potentials.

Components like mounting structure, civil works, installation and electrical works are in the focus of the local interview assessment and the selection of local companies.

Table 4: Summary of the industry assessment of the PV core value chain, including a SWOT analysis for the selected components

	Industry Structure	Economics and costs
Project Development	Large group of companies with technological know-how Intern. actors have fully integrated activities of concept engin-eering; often with project development, engineering, financing.	Labor-intensive activities including the technical layout and permitting
Module	38% monocrystalline, 62% polycrystalline Large and medium size companies	Large value generation trough whole value chain
Inverter	One large player, several smaller ones Module manufacturers sometimes vertically integrate into inverters.	Competition increase Good margin in past
Mounting structure	Most companies coming from production of light alloy elements for every kind of application	Other business potentials Depend on steel and aluminum industry
Cabling	Several international players with 25.000 – 60.000 employees	Main costs caused by raw materials
	Market structure and trends	**Key competiveness factor**
Project Development	Strongly depending on developments of individual PV markets and political decisions about support for renewable energies World-wide activities	Deep knowledge and broad experience with installation of PV plants in home markets and internationally
Module	Strong market growth	Process know-how, vertical integration, good access to capital
Inverter	Strong increase in last year due to growth of PV sector, many new players	Efficiency, wide distribution, monitoring systems, long lifetime
Mounting structure	Directly connected to PV- installations Regional markets	Innovative mounting solutions and having a patent for this technology
Cabling	Both PV cables and other cables experience a continuous growth rate, however PV cables are closely linked to the PV installations	Increased durability and efficiency Adaption of national standards and norms

Table 5: Technical and economic barriers of manufacturing PV components

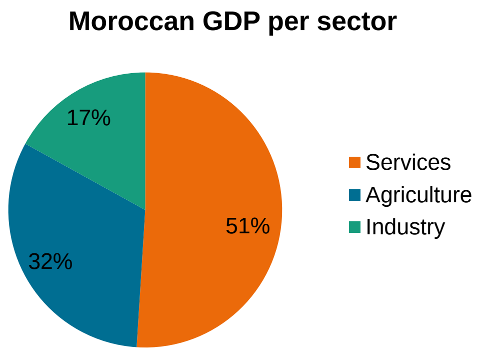
Components	Technical Barriers	Financial Barriers	Market environment	Level of barriers
Cell	High technical skills necessary Complex production line	High investment for manufacturing equipment, Energy-intensive	Large demand required, Export must be competitive on a global level	**High**
Silicon	Highly skilled professionals necessary Complex manufacturing line	Capital-intensive Energy-intensive	Large demand required to build up a production line, market shares with semi-conductor industry	**High**
Module (assembly c-Si)	Low technical skills required	Low investment cost for equipment, investment into training of workforce	Competitiveness with further integrated module manufacturers difficult to reach, has to compete with global players	**Medium**
Module (Thin Film)	Complex manufacturing line, Intensive training of workforce required	High investment into manufacturing line	Competitiveness on a global level required	**Medium**
Module (CPV)	Precise assembly Production lines individually designed for each producer, i.e. highly skilled R&D required	Medium investment for production equipment Young technology with higher investment risk	CPV has a very small market share so far, only target markets are in the sunbelt	**High**
Glass	High technical skills required	Capital-intensive Energy-intensive	Very large demand required, Glass can only be used for PV applications	**High**
Foil	Specialized process	Investment for production line	Market in MENA region is too small	**Medium**
Mounting structure	Low technical skills required	Low investment required	Markets with cheap steel, transformation industry is competitive	**Low**
Inverter	Highly skilled professionals needed for R&D and quality management	High investment cost in manufacturing equipment and quality inspection site	Large demand required to build a production line Market dominated by few global players	**High**
Cables	Low technical barriers	Low value added due to high intensity of raw materials and purchase of turn-key-production lines	Existing cable producers could integrate another product	**Medium**
Project development	Highly skilled professionals with university degrees	Low investment cost for the development, high financial risk during execution	Long-term market necessary to apply acquired competences	**Medium**
Civil Work	Standard tasks for civil works companies	Low investment necessary	Tasks will be provided by successful market players	**Low**
Electrical Works	Standard equipment, usually not PV specific	Standard projects for large company,	Tasks will be provided by successful market players	**Low**
Installation	Special training and qualification necessary	Investment into training of workforce	Long-term market required to apply acquired competences	**Low**

4. Moroccan market environment

Moroccan economy

Morocco has capitalized on its proximity to Europe and relatively low labor costs to build a diverse, open, market-oriented economy. The Moroccan economy has shown an average annual growth rate of 4% over the last five years (see Table 6). The dominant sector is the tertiary sector. However, rising expenses for processed food and fuel imports still widened the country's current account deficit. Further imported products are textiles, fossil fuels and other raw materials. Despite the fact that the majority of export is provided by a few large companies, 93% of Moroccan companies are classified as small to medium-sized businesses.

Table 6: Morocco key economic figures

<table>
<tr><td>GDP</td><td>USD 153,257 billion</td><td colspan="2" rowspan="5">
</td></tr>
<tr><td>GDP growth</td><td>4.2%</td></tr>
<tr><td>GDP per capita</td><td>USD 4,740</td></tr>
<tr><td>GDP by sector</td><td>Agriculture: 17.1%
Industry: 31.6%
Services: 51.4%</td></tr>
<tr><td>Population</td><td>31.9 million inhabitants</td></tr>
<tr><td>Exports</td><td>$14.49 billion f.o.b. (2010 est.)</td><td>Imports</td><td>$34.19 billion f.o.b. (2010 est.)</td></tr>
<tr><td>Export goods</td><td>clothing and textiles, electric components, inorganic chemicals, transistors, crude minerals, fertilizers (including phosphates), petroleum products, citrus fruits, vegetables, fish</td><td>Import goods</td><td>Crude petroleum, textile fabric, telecommunications equipment, wheat, gas and electricity, transistors, plastics.</td></tr>
<tr><td>Main export partners</td><td>Spain 19.7%, France 17.8%, India 5.8%, US 4.2%, Brazil 4.1% (2010)</td><td>Main import partners</td><td>France 16.9%, Spain 14.2%, China 7.9%, US 6.2%, Saudi Arabia 6.1%, Italy 5.9%, Germany 5.4% (2010)</td></tr>
</table>

The proportion of the working population is about one third of the total population, i.e. ten million people, and is expected to grow with more women entering the labor market. The current level of unemployment is at 9.8% on average, with a much lower rate in rural areas as nearly one half of the working population is employed in the agricultural sector. The unemployment rises with higher education and is currently reaching up to 24% for academics. Even if businesses claim that Moroccan universities do not sufficiently adjust to their needs and demands, the need for training of new employees is judged very differently by large or small and medium-sized Moroccan companies. The latter notably believe that there is a serious lack in qualified technicians, emphasized by a high emigration of qualified employees. Therefore, a trend to inflexible long-term contracts can be observed. Several R&D and training course projects, notably through Masen, are currently addressed.

In spite of a better investment climate than in most African countries, access to international credit remains expensive which is seen as a key barrier to enter the solar business. Nevertheless, the general findings show that the activities in the solar business are on a very small scale, offering much room for further industry integration. To conclude on this general overview, we underline that the procedures and time required to conduct tax payments have been improved significantly in the last year in Morocco. The free trade zone in Tangier for instance offers tax exemptions.

Moroccan solar energy market

The Moroccan energy sector relies heavily on imported fossil fuels. Since the beginning of the years 2000, the share of imported electricity (mainly from Spain, from Algeria since 2009), natural gas and hydroelectricity have significantly increased. Targets for renewable energy development are established within the National Energy Strategy. Over the last years, the legal and regulatory frameworks in favor of renewable energy development have been considerably reinforced. The objective is to increase the contribution of renewable energies in the primary energy consumption by nearly 5% in 2009 to 8% in 2012 and reach 10 to 12% in 2020 and 15 to 20% in 2030 (MEMEE, 2011b). Their share in electricity production will reach 42% in 2020. By 2020, the strategy also considers the Moroccan Solar Plan with 2000 MW of installed solar capacity in Morocco (MEMEE, 2011b).

Currently, the installed CSP capacity is around 20 MW in Morocco, which essentially consists of the solar share of the 470 MW Integrated Solar Combined Cycle (ISCC) power plant in Ain Beni Mathar. A large PV plant (i.e. over 1 MW of capacity) does not exist in Morocco, although several programs for promoting solar PV, especially for decentralized rural electrification purposes, have been implemented in the past.

5. Moroccan manufacturing potential

The results of the interviews with the Moroccan industry show that there is a considerable potential within the implementation and realization of solar power plants. Especially in the field of civil and electrical works, mounting structures and installation a considerable number of 37 companies were interviewed. For interviews only companies were selected which can in principle contribute with their competences and know-how to a part of the value chain of the solar energy technologies of PV and CSP. During the current CSP tender process, contacts between the international CSP industry and local firms have already been established, demonstrating that the participating consortia are interested in an involvement of local businesses and strongly require a local supply network for the sectors mentioned above. An active and continuous support by the Moroccan industry associations FIMME, FNTB and FENELEC can foster a fast integration of the different sectors into the value chain. However, the production of CSP or PV specific high tech components such as receiver or the complete module production would require a successful attracting of international companies which could provide the necessary technology and process know-how. Strong partnerships could help to overcome the lacking experience in the solar business. Additional potentials are likely to appear in further industry sectors that are not directly linked to solar manufacturing, e.g. financing, logistics and engineering.

The results of Morocco’s manufacturing potential are summarized in Figure 9. In Morocco there are currently only few players already active in the field of solar energy technologies. However, most of the interviewed companies were familiar with the overall targets of the MSP. A considerable part of the value chain has been evaluated with a high potential for local manufacturing, especially parts like civil and electrical works or mounting structures to which existing competences can be transferred. Also the project management requires a certain local know-how to succeed and thus offers good opportunities for local companies to enter the market together with an experienced (international) partner. Those parts with a low potential for local manufacturing also require a high amount of investment and technology transfer, making it more risky and more complicated to enter the market. Moreover, an international partner would be required and even then, the conducted interviews showed rather high barriers for such a business.

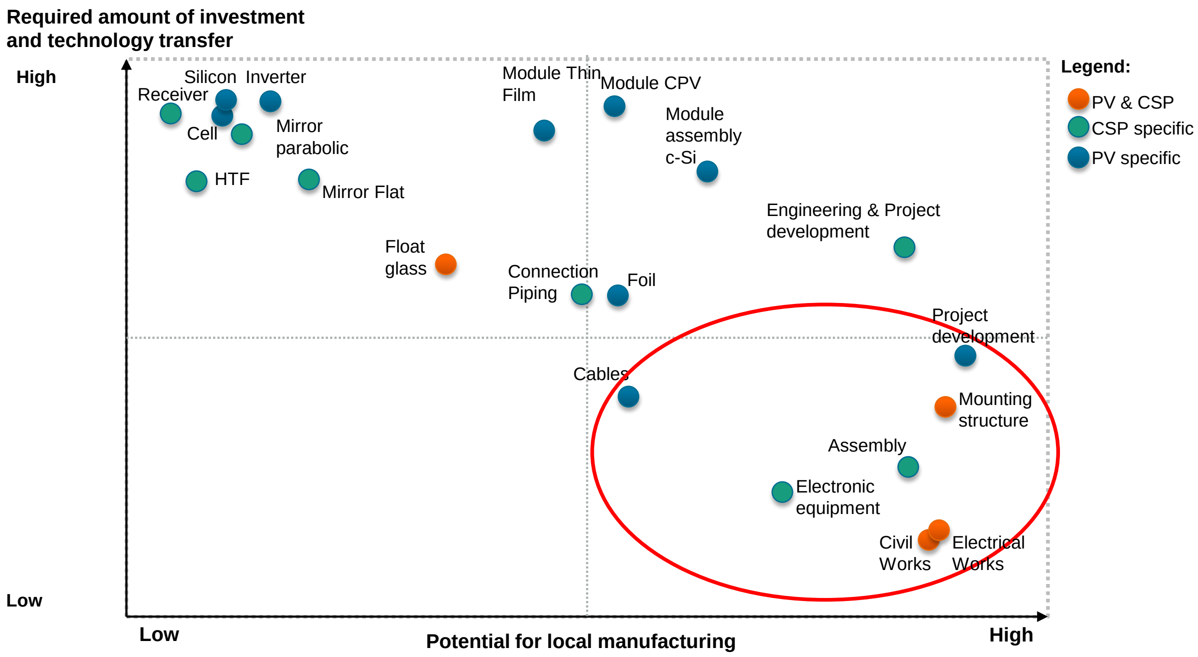


Figure 9: Mapping of local Moroccan manufacturing potential of each component

Civil Works

The share of civil works is much higher for a solar power plant than for a conventional power plant due to the fact that land preparation and ground works cover larger land areas. The treatment of one or more square kilometers requires the movement of large amounts of ground materials with large machines (shovel dredgers, flatbed trucks). Many companies in Morocco are specialized in other application of large infrastructure such as public buildings, highways, harbors and other large industry installations. Also the construction of conventional power plants (for ONE) always needs subcontracted infrastructure companies. These companies, which mainly have national projects and low international activities, are potential candidates for the installations and civil works of a large solar power plant. They currently show a very high interest in solar projects and their reference projects are comparable in size and complexity (excavation works, streets, harbor, etc.) implying an easily localizable area. The necessary equipment and machines are available in every kind.

Metalworking

Within the metalworking industry, four important branches have to be integrated for a production of mounting structures for CSP or PV: The steel producing industry, metal construction, fabrication of tubes and profiles as well as galvanization. Currently, the metalworking industry is active in the energy sector by supplying thermal power plants and providing pylons for transmission lines. Competences of energy technologies as well as quality standards have been obtained during these projects. Moroccan metal working companies are also active in wind power projects. Experience in the solar sector of Moroccan metal working companies however is very limited. The mounting structures for the smaller off-grid systems installed in the rural electrification program were all imported. Also the support structures of the solar field at Ain Beni Mathar were supplied from Spain. Thus a knowledge transfer would be necessary in order to exploit the identified potentials. Already, some companies have been contacted by the Spanish CSP industry promising future co-operations that could facilitate the localization. This also highlights the sincere interest in the solar industry and possible benefits of an early integration of local subcontractors.

Glass and Mirrors

Up to now, the glass industry in Morocco uses imported glass from international suppliers. The local manufacturing processes of the existing glass industry are mainly focused on glass bending for the automotive sector. The coating and bending of mirrors remains an area with very low potential for local manufacturing as intensive R&D, experience and specialized machines are necessary. In general, flat mirrors require less complex processes since bending and mirror coating are not coupled or not necessary. Furthermore, high energy prices, small local demand, high investment cost and the lack of know-how are the main barriers to an entrance into the glass production itself. Potential could only be created in a later market development, when the Moroccan Solar Plan creates a constant stable market. Then, companies could start to investigate the potential to build up production sites.

Cables and Electrical Works

Electrical works in the solar field (PV and CSP) including installation of cabling, inverters, transformers and grid connection can be realized by a couple of companies. Those companies generally have gained experience in working for ONE, ensuring their capability to meet required standards and quality as well as to conduct larger electrical projects such as a substation. Cables can be purchased from one of three large Moroccan cable manufacturers. Moroccan companies play an important role in the national and also international cable market with subsidiaries of international players as well as large Moroccan manufacturers. Currently the solar market is not supplied by the companies from Moroccan production facilities although some of the international players offer PV cables in its portfolio. Producing PV cables in Morocco appears to be feasible in terms of process know-how, assuming some knowledge transfer from the international mother company.

Electrical components

The Moroccan electrical and electronic sector counts more than 320 enterprises, employs over 65,000 people and covers a broad range of activities and products. For example equipment and installation of conventional power plants regarding substations, low tension transformers; cables in all voltage levels; urban and street lightning; monitoring systems; retail of electronic equipment; voltage regulators; rural electrification; assembly of electrical cabinets, control or distribution panels or semiconductor solutions. As can be seen from this list of activities, the Moroccan electric and electronic industry has a very diverse portfolio. For those applications all components are assembled, installed and commissioned by the Moroccan companies. The raw materials and components are purchased from international suppliers and imported to Morocco. Concerning the solar industry, many companies gained experience in the installation of small PV systems within the rural electrification program (PERG) that ended 2007.

CSP specific components

Regarding the specific CSP components, the analysis of the local companies could be based only on a few companies that have (similar) capabilities to the requirements of CSP components and services like mirrors, receivers, tubes, trackers, storage system, power block and engineering. Thus, a local manufacturing would have to be built on a knowledge transfer from abroad, possibly by attracting international companies with co-operations or joint ventures with Moroccan firms. Those are possible and often likely manners of gaining new know-how and obtaining support when entering a new market. The first CSP project in Ain Beni Mathar has increased the knowledge about CSP technologies in Moroccan companies. Construction related services and installations at this location have been first experiences for local companies. Moreover, one Moroccan company has already started activities to act as a project developer for CSP.

However, the international requirements for CSP plants concerning pumps and pipes seem to exceed the locally present capabilities. Thus, for a successful integration international partners would be necessary. Moreover, at the moment the majority of Moroccan companies import those products as Moroccan production capacities are not sufficient for current market demand. Concerning the operation and maintenance of the CSP plants, the experience from Ain Beni Mathar will be important and enhance the local know-how, making it available for further projects.

PV specific components

The three companies identified in the interview assessment as manufacturers or potential manufacturers of PV modules are all either local branches of international companies or manufacturers with an international partner. Their target markets are mainly off-grid installations in several African countries. They use readily available turn-key production lines for c-Si modules; similar turn-key lines are also available for Thin Film technologies. The turn-key production lines offer an interesting opportunity to enter the market for emerging companies which do not have much experience in the PV sector.

Regarding further components like inverters and trackers, companies could not be found which are planning to enter the solar market. There are companies active in the aircraft or automotive industry with potential for the solar sector due to their experience in electronic devices and inverters for off-grid applications. However, the PV inverter requires a special know-how and the market is dominated by four European companies. Thus, with an already high level of barriers to a local production, the inverter should rather be targeted in the long-term once there is a stable Moroccan solar market and experience in the production of other components as well as the operation of the power plants.

Within the conducted industry assessment, nine companies were identified in the area of project development for PV power plant and installation of PV modules. Half of those companies were small, local businesses, the other half were branches or partners of large international enterprises with employees varying from 3 to 300.The majority of the companies are dedicated to the distribution and installation of small PV systems. Having gained experience by the rural electrification program, they now want to proceed to larger, grid connected applications. Concerning the operation and maintenance of a PV power plant, the identified companies in the project development and installation field are considered capable of taking on the responsibility for O&M.

The main problems to attract an international partner or successfully launch a Moroccan company in the business are the lack of local suppliers as well as the need for global competitiveness regarding quality and cost. Especially with decreasing prices and increasing competition in the PV module market, entrance for inexperienced businesses faces large hurdles. Furthermore, there is no local PV market concerning installations besides the MSP, yet for grid connected installations, which significantly limits sale options. Moreover, the companies lack a clear view on preferred technologies and thus cannot rely on the tenders to plan investments and future business activities. To conclude the assessment on PV specific components it can be said that there is a positive vision on the local manufacturing of mounting structures, the project development and O&M. Module manufacturing is seen as feasible, but current international market events impose high risks on the investment.

Potential development of the Moroccan manufacturing share

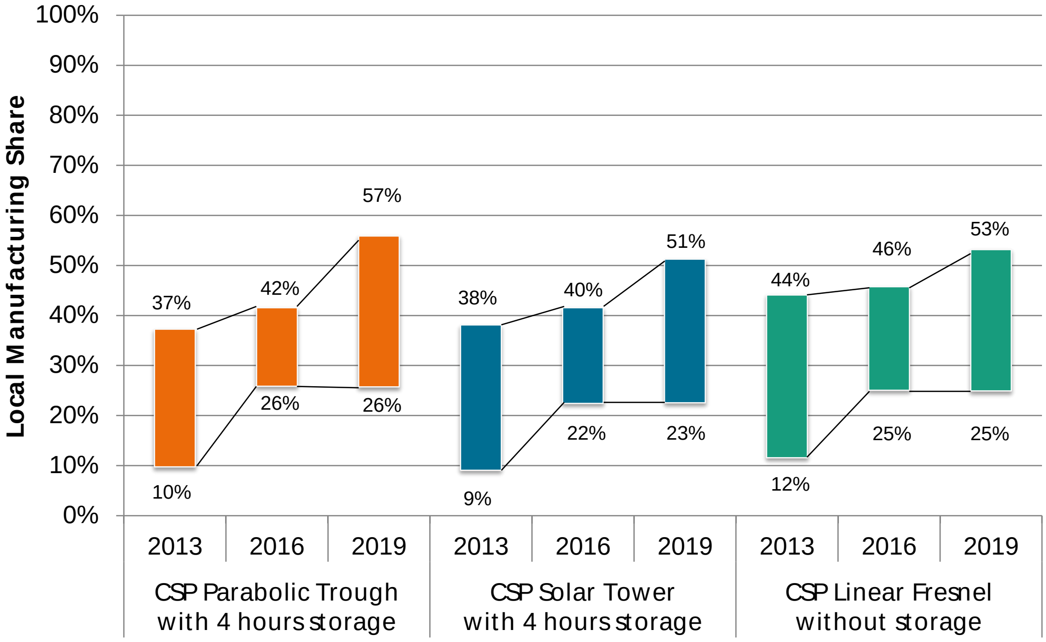
Considering the local potentials for the different components and services described above, a scenario analysis has been conducted to assess the potential local manufacturing share for a CSP or PV power plant in 2013 and the possible development until 2019. This was done considering the current foreseen market development and cost structures as given in Table 7.

For each technology, a high and a low case scenario were analyzed, where the low case considers the local potential that can be tapped easily and the high case requiring a high effort and large investments into new production facilities. The further assumptions for the scenarios are explained in detail in chapter 8 of the present study.

Table 7: Assumed annual tender volume in Morocco in accordance with the MSP

year of tender	CSP [MW]	PV [MW]
2013	100	50
2014	100	50
2015	200	75
2016	200	75
2017	200	100
2018	300	100
2019	300	125
2020 and later	unknown	unknown

As a result, the potential range of the local manufacturing share can be seen in Figure 10 and Figure 11. The local value creation is calculated for a 100 MW power plant with 4 hours of storage for both Parabolic Trough and Solar Tower technologies. The Fresnel technology does not include storage since the technology does not offer storage options today. The bars show the range of the potential between the minimum potential local share and the maximum potential local share calculated for the high scenario. The actual achievable value will lie within the range of the bars and depend on the cost development of each component as well as investment decisions and economic and regulatory framework in Morocco.

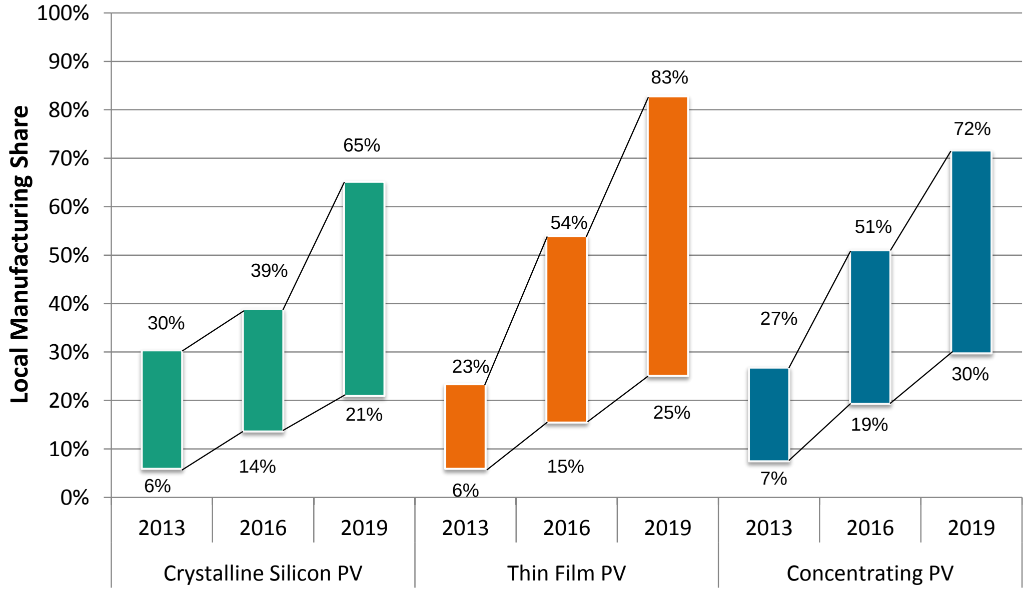


	2013	2016	2019	2013	2016	2019	2013	2016	2019
Total Capex in Mio €	478	429	402	590	526	490	342	315	299
Min local Capex in Mio €	46.65	110.97	103.25	53.52	118.07	110.55	39.55	78.90	74.61
Max local Capex in Mio €	178.24	178.43	224.36	224.79	211.02	251.33	150.98	144.01	159.22

Figure 10: Development of the potential local manufacturing share for CSP power plants in Morocco

Figure 10 shows the results of the different scenarios for the considered CSP technologies. One of the main results is that the minimum potential increases between the years 2013 and 2016 rapidly (e.g. Parabolic Trough from 10% to 25%), whereas after 2016 until 2019 the maximum potential raises more with the prerequisite that the market is stable in the long term (e.g. Parabolic Trough from 42% to 56%). In 2019, Solar Tower see potential local manufacturing share of 51% and Fresnel technology 53%.

For all CSP technologies there is a constant growth expected. With the rise in the expected demand (from 100 MW to 300 MW per year, the local share will increase. For the non-specific CSP components the market entrance of local companies is expected at earlier stages whereas, for the CSP specific ones the local share is expected to rise after 2018. All three technologies are expected to have a maximum local share between 50-55% by 2020. Figure 11 shows the results of the scenario evaluation for PV. As for CSP, the minimum and maximum potential local manufacturing share for each technology is displayed, indicating the local manufacturing share.



	c-Si 2013	c-Si 2016	c-Si 2019	TF 2013	TF 2016	TF 2019	CPV 2013	CPV 2016	CPV 2019
Total Capex in €/W	1.32	1.14	1.00	1.39	1.21	1.07	2.08	1.77	1.54
Min local Capex in €/Wp	0.08	0.16	0.21	0.08	0.19	0.27	0.15	0.34	0.46
Max local Capex in €/Wp	0.40	0.44	0.65	0.32	0.65	0.88	0.56	0.90	1.11

Figure 11: Development of the potential local manufacturing share for PV plants in Morocco

It can be seen that the development of the minimum local share (e.g. c-Si PV: 2013: 6%, 2016: 14%, 2019: 21%) is quite similar for all technologies as the BOS-components and supporting services resemble strongly. For these components, a continuous growth of local manufacturing can be identified which is caused by steady learning effects and knowledge acquisition. Interestingly, the minimum potential is the highest for c-Si but c-Si has the lowest maximum potential. This is explained by the fact that there is no local silicon and cell production assumed which would significantly increase the local share. The gap of the maximum achievable values of the different technologies in 2019 is due to the assumed local module production for TF (total: 83%) compared to the local module assembly of c-Si (total: 65%) and CPV (total: 72%). The minimum values range from 21% (c-Si) to 25% (TF) and 30% (CPV) in 2019. Investing into a full value chain integration for c-Si seems unlikely as it requires a large financial investment and production capacities in the GW range to become competitive in the global market. Therefore, only a local module assembly is assumed, using imported cells. Theoretically, with the correspondent finances, a cell production would be feasible, increasing the local share of the module significantly. Installing a local TF production is feasible using readily available turn-key line but requires that the manufacturing reaches global competitiveness or is completely sold on the Moroccan market.

For all PV technologies, there is a constant growth of local industry participation expected. Especially BOS components and services hold promising opportunities for local companies also in the short term. Investing into a local module production would result in a steep increase of the local manufacturing share but also holds a considerable economic risk for the investor. The same applies to a local inverter production which would furthermore require an international partner to ensure the necessary technology transfer. Thus, the long-term achievable values range between 20 and 82%, depending on the technology and investment decisions.

Summary

Regarding the overall advantages for each solar technology in terms of development of production capabilities and construction of solar power plants, Table 8 concludes the findings of the technology specific assessment. To sum up, each technology could give benefit to the Moroccan Solar Plan. A further definition of the main targets of the MSP would not only allow to focus the necessary efforts but also to establish a stable, long-term local market. Additional potentials are likely to appear in further industry sectors that are not directly linked to solar manufacturing, e.g. financing, logistics and engineering.

Table 8: Aspects of solar technologies in terms of local production capacities and industry integration for the implementation of solar power plants

CSP	Local production capacities	Implementation of solar power plants
CSP Parabolic Trough	▪ Foundations, trough structure and assembling feasible, first contacts ▪ Important components are not available from local manufacturers (Mirrors, receiver etc.) ▪ High local content in solar field proven in Egypt (60%)	▪ Large share of civil and electrical works ▪ O&M experience from conventional power plants transferable ▪ Proven technology with many suppliers ▪ First experience in Ain Beni Mathar ▪ Storage integration possible
CSP Solar Tower	▪ Potential for local production similar to Parabolic Trough ▪ Mirrors and mounting systems easier to produce than for Parabolic Trough	▪ Large share of civil and electrical works ▪ Additional tower construction ▪ Risk due to precision, new concepts, steam as HTF and difficult to clean ▪ Storage integration possible
CSP Fresnel	▪ Potential for local production similar to Parabolic Trough ▪ Mirrors and mounting systems easier to produce than for Parabolic Trough	▪ Solar field construction simplified ▪ Less assembly works due to prefabrication ▪ Young market offers first mover advantage ▪ Operation risk with HTF (steam,>400°C) ▪ Process heat possible
PV	**Local production capacities**	**Implementation of solar power plants**
PV Crystalline Silicon	▪ Mounting structure and cables feasible ▪ Unlikely to develop whole value chain, module assembly feasible ▪ Turn-key production lines are offered by various suppliers ▪ Large scale production necessary due to high competition on the world market	▪ Easy and fast installation and operation ▪ Proven technology with many suppliers ▪ Less BOS due to higher efficiency compared to Thin Film
PV Thin Film	▪ Mounting structure and cables feasible ▪ Complete module manufacturing in one process line ▪ Turn-key production for module lines are offered by various suppliers ▪ Large scale production necessary due to high competition on the world market	▪ Easy and fast installation and operation ▪ Proven technology ▪ Good temperature coefficient
CPV Concentrating Photovoltaics	▪ Mounting structure and cables feasible ▪ Relatively young market offers market entry with smaller production capacities ▪ International player with production know-how for CPV modules necessary ▪ Solar cells from several suppliers	▪ Potential technology pioneer role with CPV in MENA region ▪ Significantly higher energy yields than for flat plate PV can be expected. ▪ Risk due to precision, dust and difficult to clean

6. Key opportunities and obstacles for the Moroccan Solar Plan

The interviews not only allowed identifying the manufacturing potential, but also revealed several issues of concern and lead to a number of recommendations and actions concerning the policy and legislation, the solar projects and the necessary industry know-how. These topics are illustrated in Figure 12, ranging from a required long-term solar strategy, an improved regulatory framework, smaller projects, and an industry specialization to necessary training and cooperative research. Moreover, one should learn from the achievements of the rural electrification program and other successful industry sectors as well as attract and integrate international companies with the respective know-how. All topics are explained briefly in this section, followed by a concluding action plan.

To increase the attractiveness of the Moroccan solar sector to local and international companies, certain adjustments and improvements concerning the regulatory and political framework should be considered. The solar strategy should be defined more clearly in terms of technology choices, plant sizes, but also regarding the long term vision of Moroccan's energy and electricity supply. A more detailed definition as well as a longer outlook of the governmental objectives would considerably enhance the investment security and thus reduce the financing risk for local companies as well as international investors when investing in new production capabilities. Moreover, positive industrial experience from past projects such as the rural electrification program should be applied to the Moroccan Solar Plan in order to involve the industry. This refers for example to the dialogue between the institutions and industry about necessary technical specifications and standards of the electrical parts that increased the transparency of the whole process and even allowed companies to enter new business areas. A specialization of the Moroccan solar sector with an economic strategy, combined with enlarged research and development facilities, could significantly improve Morocco's competitive advantage within the solar sector. This should be supported by a dedicated training program of technicians and other qualified employees.

The Moroccan Solar Plan includes an important energy transformation and offers a tremendous economic potential to the whole country. Morocco will be the first MENA country implementing large-scale CSP and PV power plants contributing a considerable proportion of 14% solar electricity to the consumers by 2020. Furthermore, it could provide insights into the installation of solar power plants in desert areas as well as matters of grid stabilization while balancing generation and demand. This means that Morocco will gain a first mover advantage in the MENA region as several large solar power plants will be realized and local industry know-how will be created at the same time.

Morocco can prove the feasibility of implementing renewable energy technologies to other countries and hence function as a "solar model". Furthermore, it has to be considered that the Moroccan Solar Plan comprises a total investment of roughly 9,000 Mio US$ which will certainly encourage a local industry development as well as increase Morocco's attractiveness to investors. Handling of an economic investment program for future energy technologies of such a large extent will demonstrate the capabilities of Morocco and enlarge its future opportunities as manufacturing and production site. Such a development scenario also can affect other industry sectors. Therefore the further implementation of the Moroccan Solar Plan should realize all the opportunities that have been identified for the industry in this study. Hence policies should reflect the objectives of the plan and develop a clearly defined long-term strategy that supports and ensures the success of the program.

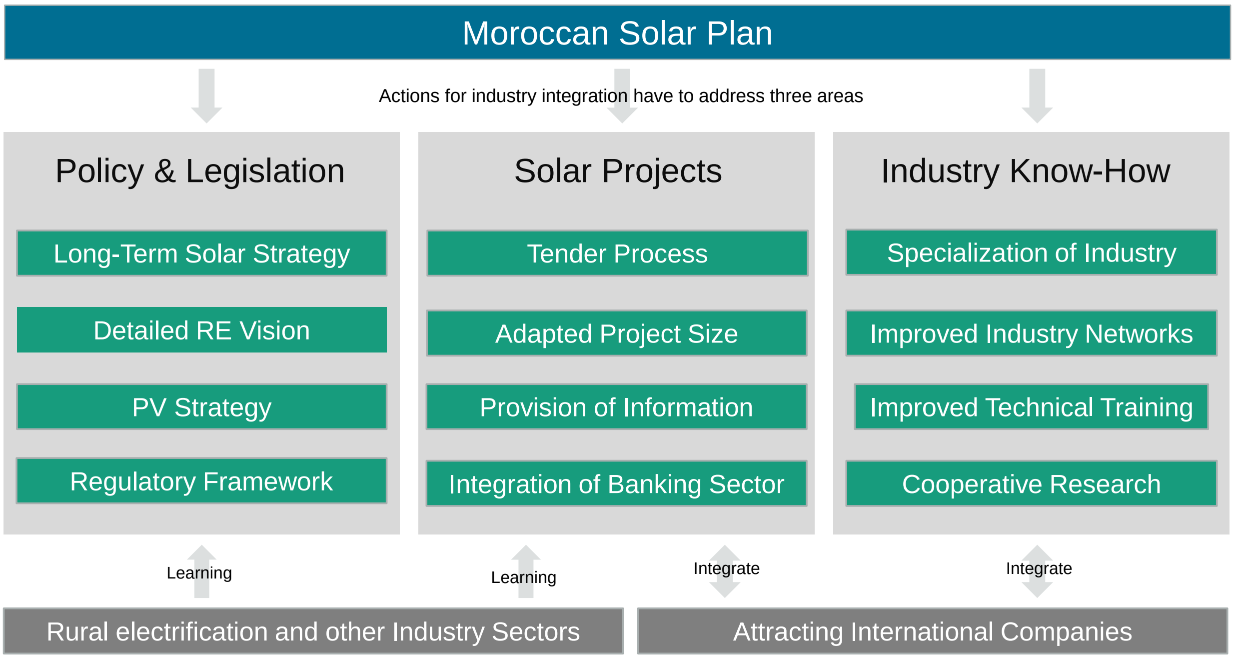


Figure 12: Recommendations concerning policy issues, the solar projects and industry know-how for the Moroccan Solar Plan

Long-term solar and PV strategy

To build up an adequate product portfolio and to invest in new manufacturing processes, the mid to long-term market for solar technologies has to be defined. This means establishing a detailed long-term energy strategy that goes beyond 2020 and sets explicit, technology-specific targets enabling involved stakeholders to see a stable, developing market as well as estimating its size. Furthermore, smaller PV applications like rooftop installations are not allowed to feed into the grid according to the current legislation. Enabling it would further increase the potential for solar technologies by including the small-scale, domestic PV market. As grid parity is expected to be reached in the forthcoming years the market potential is expected to increase accordingly. Tapping the roof-top market would provide an easier market access to Moroccan companies due to the small scale of the applications and demand from domestic customers. Both will allow Moroccan companies to rapidly and easily acquire know-how without facing very high investment costs or the challenge to directly install several MW. Therefore, a common strategy of both markets (large-scale and small-scale) is highly recommended.

Regulatory framework for RES

The regulatory and technical framework for all renewable energies requires further detailing and definitions. Since no experience with the authorization process exists, best practices from countries with large RE markets should be considered as best practices and adapted to local conditions. Furthermore, the experience from the first CSP tender should be taken into account to reevaluate the administration process. The grid access to different tension levels could be facilitated to create an opportunity for smaller grid-connected PV plants of 10 kW to 1 MW. Additionally, a dialogue between grid operators and the local industry via a technical commission could be supporting local companies by clarifying all technical specifications of equipment.

Moreover, as already mentioned, opening the market for small-scale installations of solar power plants within the current framework might significantly enhance opportunities for local companies to participate and gain knowledge in the renewable energy field.

Adapted project size

Although Masen has the obligation to realize large-scale solar power plants in Morocco, the current tender sizes, the required reference projects and the lack of experience place an insuperable obstacle to local companies who have not been active in the solar sector yet. Additional smaller projects would allow small to medium-sized businesses to gain experience without facing the financial risk of large projects and exhaustive tender requirements.

Tender process

The communication concerning the tender process and the qualification requirements should be improved to enable local companies to better assess their capabilities. Furthermore, Moroccan companies fear to be overseen by international consortia if the information on existing subcontractors is not available to them or not sufficiently communicated.

Provision of information

An existing lack of information about the technologies, including detailed process know-how, is a high barrier to enter the market for many companies. An important target will be to raise the level of available information for all interested companies and stakeholders.

Integration of banking sector

As investments in new manufacturing lines, processes and training have to be undertaken in the phase of market growth, an awareness for potential financing and funding sources has to be raised in the industry. At the same time, the banking sector should be informed about the MSP's perspective and the industry's targets to supply this new market. Additionally, the level of knowledge about solar technologies in the banking sector has to be improved to lower the perceived project risk.

Learning from the rural electrification program

The experiences gained in the PERG regarding the industry integration, bilateral dialogue with ONE, technical specifications and local supply could support the participation of different industry sectors in the Moroccan Solar Plan.

Specialization of Moroccan solar industry

For a successful market entrance, a specialization on certain solar components and niche markets would be beneficial for the Moroccan industry. Building up all competences at once is rather unlikely and would require a huge amount of investment and effort. However, this would be highly dependent on the national energy strategy and thus not be realized before a local market development is perceivable. By all means, Morocco would need to strengthen and develop its existing competitive advantages to face international competition and to develop an own solar industry. Starting own R&D would help to improve solar components according to local requirements, decrease their cost, increase their quality and would be beneficial for human capacity building. Thus, Moroccan companies could tailor their solar products and components to local environmental conditions that hold different challenges like high radiation, high temperatures and a dry, sandy desert.

Improve industry networks of involved sectors

The industry associations FENELEC, FIMME and FNBTP play an important role as information and contact platform by supporting the industry to enter the new markets. These existing networks facilitate both, the market access for new suppliers and finding business partners within the solar industry. Therefore the role of networks and associations in the RE industry should be strengthened.

Improve education for technical experts

The availability of qualified technicians for production processes with completed technical training of 2 to 3 years is limited within the industry. As no lack of engineers is reported from the industry, a bottleneck of more trained workers exists mostly for technicians. Therefore, specific education in partnerships between companies and training centers is highly recommended, e.g. in the field of maintenance for electrical and mechanical works or for manufacturing processes. Furthermore, co-operations with universities or foreign institutions should be established to offer a specific training as well as to improve the technical knowledge about solar technologies amongst students and new professionals.

Cooperative research

Very few companies hold specific R&D activities in solar technologies. As market competition and pricing pressure are quite high in 2011, local R&D competences could more easily be started jointly with international partners, e.g. research institutes or the industry. One option could be to close the gap by focusing on specific technical aspects that are important in the Moroccan Solar Plan such as specific environmental conditions and adaptation to local cultural circumstances.

Attracting international companies

As international companies might enter the Moroccan market to manufacture and assemble their products, the next analysis evaluates the impact of creating joint ventures or co-operations with international companies. The results for the different solar components are displayed in Table 9.

Table 9: Outlook on potentials of international companies for each CSP and PV component in Morocco

Component	Identified Issues
CSP mirrors (flat/parabolic)	Large international companies might get interested in the Moroccan market as large demand from new CSP projects in the region will arise (a few hundred MW installed every year).
CSP engineering	Local subsidiaries support the management and engineering of CSP projects.
CSP receivers	Only under special market conditions, receivers will be produced in Morocco.
Trackers/Drives	Supply by local manufacturers who are close to the market might be possible.
Cables	Existing companies or new market entrances could supply cables to PV or CSP projects. Special PV cables would require investment into different production process.
PV cells (c-Si)	Integrated turn-key production lines are available, but long-term market potential will be an important driver as well as secured material supply.
PV modules (c-Si)	Some activities can already be found today. Larger investments in a market with mid-term market demand might be possible.
PV modules (TF)	Turn-key production lines allow a rapid localization of the complete value chain.
Component	**Identified Issues**
CPV modules	Niche market of CPV might be a high potential to invest in Morocco as there is less installed production capacity in the world market and lower competition. Therefore a strategic investment in one country with a high DNI might be a good option.
Inverter	Expected market growth might be an option to diversify local presence in an emerging market
Grid Connection	Existing competences in fossil plants will be transferred to RE technologies.
PV Engineering	Local subsidiaries improve the capabilities to operate local projects. JV with local companies is likely to improve the business processes.

7. Action Plan

This section presents a synthetic overview of the potential for local integration for main segments of the solar PV, including both, Crystalline Silicone and Thin Film, and solar CSP value chain. The two tables below provide a ranking for most of the relevant segments of the CSP and solar PV value chain, addressing first the strengths of the local industries and second the attractiveness of the market for each segment.

Table 10 : Mapping of key opportunities – Strengths of the local industries

Sector	Segment	Experience in large scale solar projects	Output quality vs solar requirements	R&D potential	Investment requirements	Cost competitiveness potential	**Barriers for penetrating solar market**
CSP	Civil works	Limited	Medium	Low	Low	High	Low
CSP	Mounting structures	Low	Medium (variable)	Medium	Medium (variable)	High	Low
CSP	Mirrors	Low	Low	Medium	High	Low	High
CSP	Receivers	na	na	na	High	Low	High
CSP	Cables	Low	High	Medium	Low	Low	Low
CSP	Electrical components	Limited	High	Medium	Medium	Medium	Low
CSP	EPC	Low	na	na	Low	Medium	Medium
Solar PV	Silicon	na	na	na	High	Low	High
Solar PV	Cell	na	na	na	High	Low	High
Solar PV	Module	na	na	na	Medium	Medium	Medium
Solar PV	Module (CPV)	na	na	na	Medium	Low	High
Solar PV	Glass	Low	Low	Medium	High	Low	High
Solar PV	Mounting structures	Low	Medium (variable)	Medium	Low	High	Low
Solar PV	Cables	Low	Low	Medium	High	Low	Medium
Solar PV	Electrical components	Limited	Medium	Medium	Medium	Medium	Medium
Solar PV	EPC	Low	na	na	Low	Medium	Medium

Table 11 : Mapping of key opportunities - attractiveness of the market

Sector	Segment	Expected penetration on the domestic solar market	Export potential in nearby markets	Job creation potential	Partnership opportunities (JV)	**Overall attractiveness of market**
CSP	Civil works	High	Low	High	Medium	Medium
CSP	Mounting structures	High	High	High	Medium	High
CSP	Mirrors	Low	Medium	Medium	High	Medium
CSP	Receivers	na	na	Low	High	Low
CSP	Cables	Medium	Medium	Low	High	Medium
CSP	Electrical components	High	High	High	Medium	High
CSP	EPC	Medium	Medium	Low	High	Medium
Solar PV	Silicon	na	na	Low	Medium	Low
Solar PV	Cell	na	na	Low	Medium	Low
Solar PV	Module	Medium	Medium	Medium	Medium	Medium
Solar PV	Module (CPV)	Medium	Medium	Medium	High	Medium
Solar PV	Glass	Low	Medium	High	High	Medium
Solar PV	Mounting structures	High	High	High	Medium	High
Solar PV	Cables	High	Medium	Medium	Medium	Medium
Solar PV	Electrical components	Medium	Medium	High	High	High
Solar PV	EPC	High	Medium	Low	Medium	Medium

The next step is to position the various segments on a graph in order to compare their relative positioning. We have divided these segments into three groups:

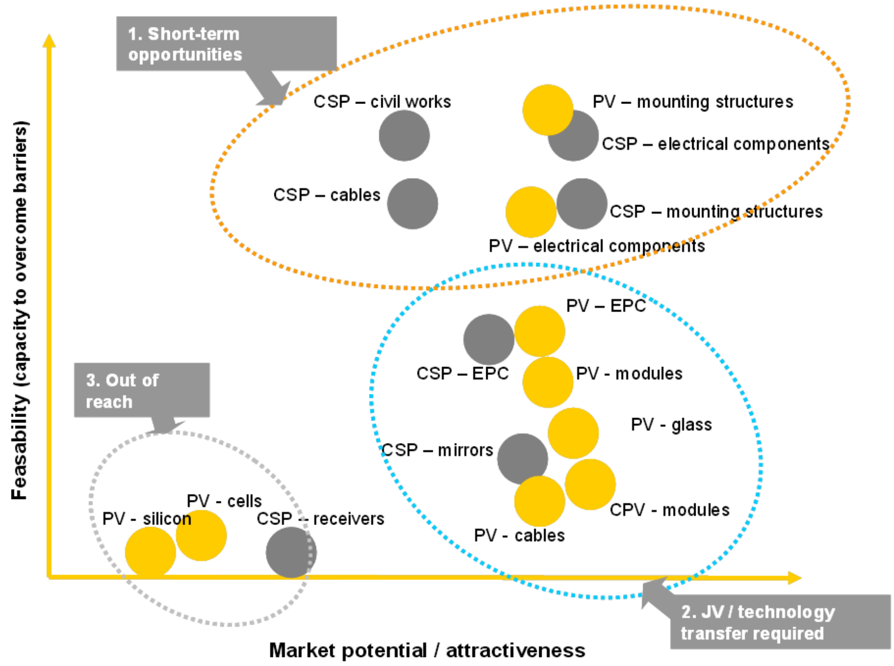


Figure 13: Market potential and attractiveness versus feasibility for PV and CSP solar technologies

- **Group 1**: There are a number of segments for which the barriers for new entrants will not be difficult to overcome by local companies. For this group of segments, solar PV and CSP constitute business development opportunities for the next years. This group includes segments which are not technology-intensive (civil-works) or not specific to solar PV or CSP (simple mounting structures, general cables). These segments also reflect areas where Morocco has developed a significant industry (cables, electrical equipment, metallic constructions) which is used to the quality standards of export markets and in particular the EU. For these segments the key actions will mostly involve training, awareness raising for entrepreneurs, and to some extent investments in order to upgrade the quality of the products.
- **Group 2**: In other cases for which the market potential is significant, the technical or investment barriers can hardly be addressed in the short term. In order to develop local manufacturing activities, segments included in this group will require financial support as strong investments are needed, training and capacity building, as well as technology transfer. This group includes several components of solar PV systems (such as PV cables for instance), CSP mirrors and joint piping as well as EPC activities which require significant expertise. One of the key actions in this case will relate to attracting foreign investment so as to benefit from joint-ventures which will provide technology transfer and capital.
- **Group 3**: In other cases both the investment to undertake as well as the global market dynamics do not play in favor of local investments, at least not in a short to medium term perspective. The segments covered here are usually highly capitalistic, sometimes energy intensive as well and require a large threshold (in terms of annual output) per year, such as production of PV cells or CSP receivers. However, this does not rule out the possibility that some potential joint-ventures could also be set up for these segments.

In addition, a number of development opportunities also lie in the service activities. Partnerships with several project developers, EPC contractors and O&M players will have to be concluded in order to allow local players to gain experience and handle large-scale solar projects.

Based on the results from the interviews and the technology assessment, a detailed action plan should now be developed to obtain a strong roadmap for the industry integration. First, a typical market growth analysis could be done for the solar potential in Morocco.

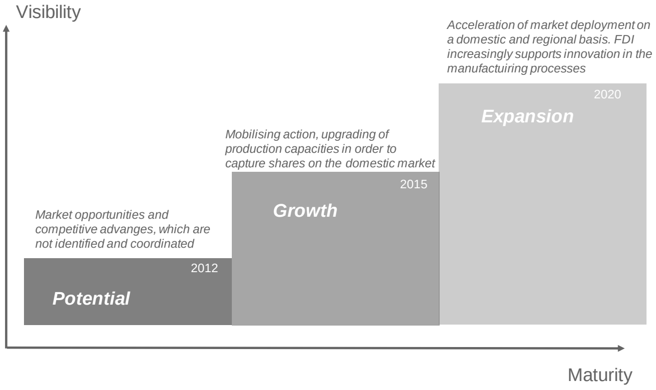


Figure 14: Market growth potential (Source: Authors)

A number of actions could be envisaged be used to shape an operational action plan, through three key items to overcome:

1. Supporting activities related to R&D and innovation and to training of workforce, in collaboration with the private sector (in a cluster approach).
2. Supporting supply-side development and industrial development by the provision of capacity building support, information on market and technology developments, as well as adequate financing mechanisms to encourage the upgrade of manufacturing processes and plants, and also to support the emergence of new companies.
3. Outreach strategy to ensure the promotion of local expertise and products, especially on export markets, and increase the visibility of Morocco for FDI providers.

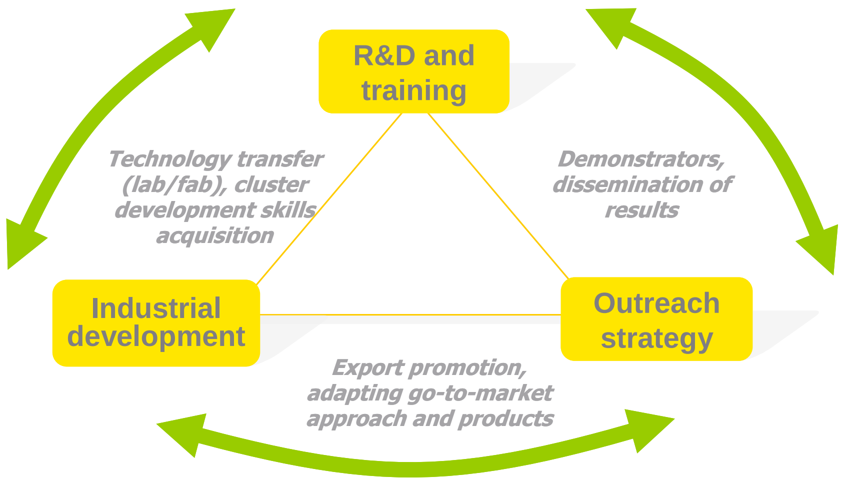


Figure 15: Barriers and challenges

These three items rely on the fact that the policy framework ensures continuous market development for solar projects. To conclude, one of the first measures to implement would be developing an ambitious national strategy, with clear objectives and means. This could be achieved for instance during workshops or specific meetings involving key partners.

8. Conclusion

The present study aims to assess the potential of the industrial value chain associated with solar technologies that are considered for deployment in the Moroccan Solar Plan by 2020. The solar technologies considered in this study are both CSP technologies (Parabolic Trough, Solar Tower, Linear Fresnel) and PV technologies (Crystalline PV, Thin Film PV, Concentrating PV). A detailed review of the latest relevant technology developments and value chain processes leads to a set of applicable requirements and the identification of manufacturing processes for solar technologies in the Moroccan market over the next ten years.

The industry analysis realized in this present report reveals a considerable amount of local manufacturing potentials for the Moroccan solar sector. There are not only a number of components that could be manufactured locally, but also a high number of companies showing interest in the MSP. Interviews conducted in Morocco during autumn 2011 show a considerable potential for local value creation within the implementation of solar power plants, especially the fields of civil works, electrical works, mounting structures and power plant installation are identified as low-hanging fruits. Tasks which require local competences, such as project management, offer good opportunities for local companies to enter the market together with an experienced partner.

Manufacturing scenarios for Morocco assess the minimum and maximum local manufacturing potential for a CSP and PV power plant constructed in 2013 and possible development pathways until 2016 and 2019. For all CSP and PV technologies a constant growth of the local manufacturing share will take place if companies start to change production processes and invest in new production capabilities for key solar components like PV modules or eventually CSP mirrors.

Recommendations were concluded and an action plan was developed to foster local industry integration, one of the Moroccan Solar Plan's main pillars. These recommendations cover the topics policy and legislation, solar projects and manufacturing know-how. The most urgent one, being the underlying base for all activities, will be the definition of the main targets of the MSP and the development of a long-term energy strategy. In such a framework, a successful market and industry growth will definitely be accelerated faster and more sustainable in the Moroccan economy.

The Moroccan Solar Plan embraces an important energy transformation and offers a tremendous economic opportunity for the whole country. Morocco will be the one of the first MENA countries implementing large-scale CSP and PV power plants, which means that Morocco can gain a first mover advantage in the MENA region as several large solar power plants will be realized and local industry know-how will be created at the same time.