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MENA ENERGY SERIES | REPORT NO. 95144-EG

Local Manufacturing Potential for Solar Technology Components in Egypt

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Energy & Extractives

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Energy Sector Management Assistance Program

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Acronyms and Abbreviations

ABB	Asea Brown Boveri Ltd.
ABINEED	Brazilian Electrical and Electronics Industry Association
ADEREE	National Agency for the Development of Renewable Energy and Energy Efficiency (Morocco)
AGADIR	Arab Mediterranean Free Trade Agreement
AISI	American Iron and Steel Institute
ANME	Agence Nationale pour la Maîtrise de l'Énergie (Tunisia)
APEC	Asia Pacific Economic Cooperation
API	American Petroleum Institute
ASEAN	Association of Southeast Asian Nations
ASME	American Society of Mechanical Engineers
BIPV	Building integrated photovoltaic
BNDES	Brazilian Development bank
BOP	Balance of plant
BoPET	Biaxially oriented poly-ethylene terephthalate
CCGT	Combined cycle gas turbine
CDM	Clean Development Mechanism
CdS	Cadmium sulfide
CdTe	Cadmium telluride
CEEE	State Electrical Utility Rio Grande do Sul
CHEC	China Huadian Engineering Company
CIC	Climate Innovation Center
CIGS	Copper/indium/gallium di-selenide
CIS	Copper/indium sulfide
CNY	Chinese Renminbi Yuan
COP	Coefficient of performance
CoSPER	Committee for Rural Electrification Program (Morocco)
CPV	Concentrated photovoltaic
CSEM	Centre Suisse d'Electronique et Microtechnique
CSP	Concentrated solar power
DNI	Direct normal irradiation
DSG	Direct steam generation
EEHC	Egyptian Electricity Holding Company
EgyptERA	Egyptian Electricity Regulatory Agency
EIB	European Investment Bank
EN	European Standard
EPC	Engineering, procurement and construction contract; occ., the contractor
EPIA	European Photovoltaic Industry Association
ESMAP	Energy Sector Management Assistance Program
EU	European Union
EVA	Ethylene vinyl acetate
E&Y	Ernst & Young
FAO	Food and Agriculture Organization of the United Nations
FAPEMIG	Gerais State Research Foundation
FDI	Foreign direct investment
FINEP	Studies and Projects Financing Agency
FIT	Feed-in tariff
GAFTA	Greater Arab Free Trade Area
GCR	Global Competitiveness Report
GDP	Gross domestic product

GHG	Greenhouse gas(es)
GHI	Global horizontal irradiation
GNP	Gross national product
GW	Gigawatt
GWe	Gigawatt-electric
GWEC	Global Wind Energy Council
GWh	Gigawatt-hour
HTF	Heat transfer fluid
ICT	Information and communication technology
IDA	Industrial Development Authority (Egypt)
IEA	International Energy Agency
IEE CAS	Institute of Electricity Engineering of the Chinese Academy of Sciences
IFC-WB	International Finance Corporation (World Bank Group)
IPF	Investment Promotion Fund
IPP	Independent power producer
IRENA	International Renewable Energy Agency
ISCC	Integrated solar combined cycle
ISO	International Organization for Standardization
kt	kiloton
kW	Kilowatt
kWe	Kilowatt-electric
KWh	Kilowatt-hour
LCD	Liquid crystal display
LCOE	Levelized cost of energy
LED	Light-emitting diode
MAD	Moroccan Dirham
MASEN	Moroccan Agency for Solar Agency
MED	Multiple-effect distillation
MEM	Ministry of Energy and Mines (Ministere de l'Energie et des Mines) (Egypt)
MENA	Middle East and North Africa
MG-Si	Metallurgical grade silicon
MIFT	Ministry of Industry and Foreign Trade (Egypt)
Mo	Molybdenum
MoE	Ministry of Environment (Egypt)
MoEE	Ministry of Electricity and Energy (Egypt)
MoI	Ministry of Investment
MoP	Ministry of Petroleum (Egypt)
MW	Megawatt
MWe	Megawatt-electric
MWh	Megawatt-hour
MWth	Megawatt-thermal
Na	Sodium
NAMA	Nationally appropriate mitigation action
NDRC	National Development and Reform Commission (China)
NREA	New and Renewable Energy Authority (Egypt MoEE)
NREL	National Renewal Energy Laboratory (U.S. DOE)
NTF-PSI	Norwegian Trust Fund for Private Sector and Infrastructure
NTM	Nontariff measure
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturer
O&M	Operation and maintenance
ONE	Office National de l'Électricité (Morocco)
PB	Power block
PER	Plan de Energías Renovables (Spain)
PERG	Global Rural Electrification Program
PGESCo	Power Generation Engineering and Services Co. (Egypt)
PRC	People's Republic of China
PRODEEM	Program for Energy Development of States and Municipalities

PROINFA	Alternative Electrical Energy Support Program
PSH	Pumped-storage hydroelectricity
PV	Photovoltaic
PVF	Poly-vinyl fluoride
PVPS	Photovoltaic Power System Programme
RD	Royal Decree
RE	Renewable energy
REC	Renewable Energy Corp. ASA
RCREEE	Regional Centre for Renewable Energy and Energy Efficiency
ROW	Rest of the world
R&D	Research and development
SF	Solar field
SME	Small and medium enterprises
SITC	Standard International Trade Classification
Si'Tarc	Small Industries Testing and Research Centre (India)
SGS	Steam generation system
STA	Solar technology advisor
STC	Standard test conditions
SWOT	Strengths, weakness/limitations, opportunities and threats
TCO	Transparent conductive oxide
TCS	Trichlorosilane
TES	Thermal energy storage
TF	Thin film
TF-Si	Thin-film silicon
ToT	Training of trainers
UAE	United Arab Emirates
UN	United Nations
UV	Ultraviolet
US	United States of America
US$	United States dollar
WEO	World Energy Outlook

Acknowledgments

This study was undertaken by the World Bank in its initiative to support Egypt in its long term plans for development of solar energy mix in the country and a follow up of the study that assess the international competitiveness of five MENA countries—Algeria, Egypt, Jordan, Morocco, and Tunisia—to develop a local solar industry.

This study concentrates on Egypt and attempts to identify strategic challenges and provide detailed recommendations for developing a local solar industry for selected concentrated solar power (CSP) and photovoltaic (PV) components. This study focuses on Egypt's business potential from four main perspectives: production factors, demand factors, risk factors and business support factors. The purpose of the study is to identify the strengths, weaknesses, and opportunities of the industry context as well as the threats to it.

The study carries out an (i) Assessment of Egypt's existing manufacturing base, (ii) Analysis of the economic costs and benefits associated with the areas of the solar component manufacturing value chains with the greatest potential and finally; (iii) comes up with a set of Recommendations.

This study was led by Fowzia Hassan, Energy Specialist, Middle East and North Africa, World Bank, and carried out by Solar Technology Advisors, team members Jorge Servert (CEO and Team Leader) Eduardo Cerrajero (Solar energy expert), José Luis Servert (Energy policy expert) in collaboration with Accenture, team members José Ramón Alonso, Paz Nachón, and Irene Moya. The report was prepared under the direction of Jonathan Walters Director, Regional Programs and Partnerships, Middle East and North Africa and Patricia Veevers-Carter, Sector Manager, World Bank. Special thanks are due to Alicia Hertzner (Editor). National consultant from Regional Center of Renewable Energy and Energy Efficiency (RCREEE); Maged Mahmoud, Senior Renewable Energy Expert and Rana El-Guindy, Economic Research Assistant participated in the project.

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Context and Objectives

In 2012 the World Bank carried out a study to assess the international competitiveness of five MENA countries—Algeria, Egypt, Jordan, Morocco, and Tunisia—to develop a local solar industry.

In that study, Egypt appeared to have significant potential to develop several key industries. The current study delves into the Egyptian case to identify strategic challenges and provide detailed recommendations for developing a local solar industry for selected concentrated solar power (CSP) and photovoltaic (PV) components.

This study focuses on Egypt's business potential from four main perspectives: production factors, demand factors, risk factors and business support factors. The purpose of the study is to identify the strengths, weaknesses, and opportunities of the industry context as well as the threats to it.[1]

Based on a bottom-up approach, this study involved three main analytical phases:

1. Assessment of Egypt's existing manufacturing base
2. Analysis of the economic costs and benefits associated with the areas of the solar component manufacturing value chains with the greatest potential
3. Recommendations,

A large solar photovoltaic (PV) park to produce up to 200 MWs is foreseen to be built in Kom-Ombo, Egypt.

1. The study is based on what Egypt could do based on its historical trajectory and business context. The study focuses on the country's potential and conditions that facilitate and enable the development of an industry. However, the study does not consider the specific challenges that Egypt is facing at this moment, which transcend the solar sector.

Two missions were carried out in Egypt during the study:

1. The first phase comprised a series of interviews with key relevant players in the sector in Egypt, including, among others, policy makers, private companies in different sectors, academic institutions, and associations.[2]
2. The second phase was a workshop with key stakeholders to present preliminary results, validate assumptions, and gather their suggestions and recommendations.[3]

These two missions in Egypt were key to identify strategic challenges, to gather main stakeholders' opinion, to focus the analysis and to start the dissemination.

This study presents an assessment of:

- International solar component manufacturing value chains and the outlook for their robustness
- Egypt's existing manufacturing base and its potential to participate or dominate the international solar component manufacturing value chain
- Update on the existing and potential applications of solar technology, solar components, and/or solar energy in residential, commercial, governmental, and industrial sectors
- Estimation of potential economic costs and benefits—including job creation—that could result from enlarging solar component manufacturing in Egypt
- Recommendations for a road map for the development of solar industry in Egypt.

2. Carried out during a mission in Egypt in April 2013.
3. Workshop carried out in May 2013.

The final objective is to make recommendations by which Egypt could enhance its competitiveness in the solar sector. The choice of recommendations within the entire solar sector or value chain should focus on the ones that would be most promising to pursue.

In this vein, actions to enhance the local manufacturing potential of solar energy components in Egypt are proposed taking into account the link with the Kom Ombo project and the leverage that can be obtained through its development.

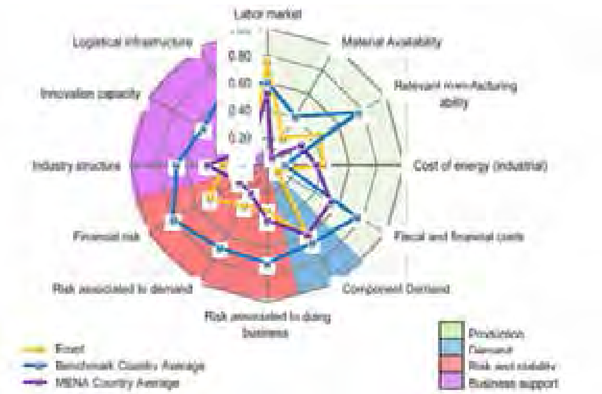
CHAPTER 1:
Executive Summary

1.1 Rationale

In 2012 the World Bank carried out a study to assess the international competitiveness of five MENA countries—Algeria, Egypt, Jordan, Morocco, and Tunisia—to develop a local solar industry. Egypt appeared to have significant potential to develop several key industries.

The analysis revealed that Egypt's key strengths for solar industrial development are production factors. These strengths are (1) low cost of labor and low cost of energy for industrial consumers; (2) availability of material for solar industries, particularly glass, steel, and stainless steel; and (3) strong manufacturing capability. Due to Egypt's planned deployment of solar energy up to 2020, its competitiveness associated with demand factors also is strong.[4]

Figure 1 | Competitiveness Parameters in Egypt Compared to Benchmark and MENA Averages



World Bank 2012a.

4. Intermediate objective of the Egyptian solar plan, as communicated by the Ministry of Electricity and Energy, is 1,100 MW for CSP and 200 MW for PV.

The rationale behind Egypt's ability to develop a solar component industry is that:

- There are reasons to create a stable pipeline of solar projects in Egypt.
- Egypt has a solid industrial and technical background.
- Basic materials and industries already exist.
- Production factors have some competitive advantages.

1.2 Project Pipeline and Demand

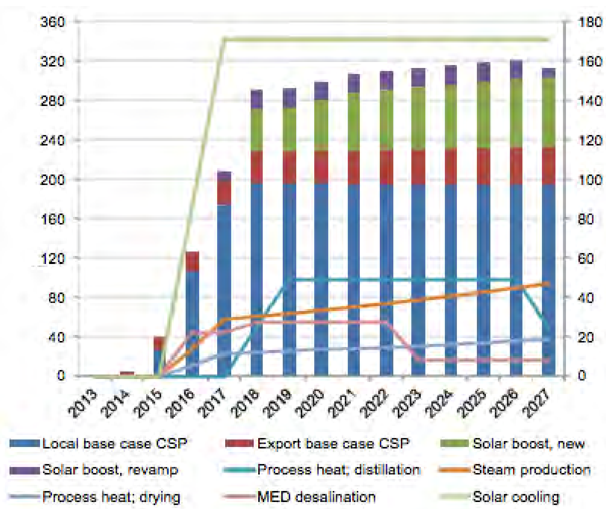
A stable, visible, and credible pipeline of solar projects is a key element to create a sustainable solar component industry. Having such a pipeline is a lesson learned from leading countries in the solar component industry and a message received from the different stakeholders.

On the demand side, Egypt has some clear drivers to become a market for solar components:

- Egypt possesses land, a solar resource, and wind speeds that make suitable the development of renewable energies (RE) including wind, solar, and biomass. For solar energy development specifically, Egypt's maximum annual global horizontal irradiation (GHI) and direct normal irradiation (DNI) are equal to 6.6 kWh/m2/day and 8.2 kWh/m2/day, respectively. These numbers are the highest in the MENA Region, and Egypt is one of the areas with the best resource globally (U.S. DOE NREL n.d.).

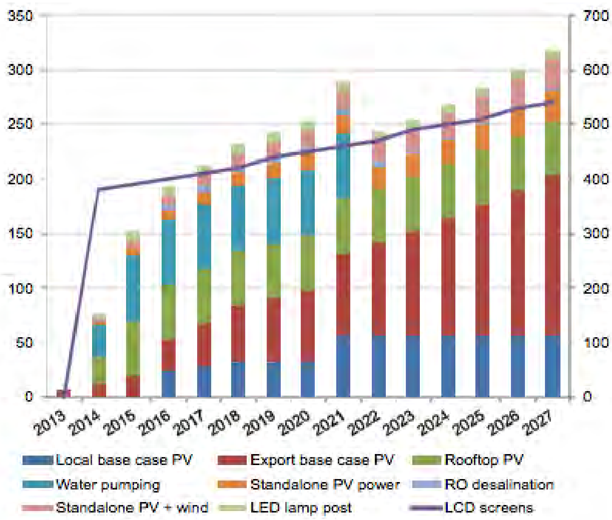
- In late 2012 the government announced new, more ambitious targets for the 2027 Plan to increase total installed power by 2,800 MW of CSP and 700 MW of PV.[5]
- Currently, a shortage exists in the capacity to supply the demand for both thermal and electrical energy.
- The cost of solar-related technologies is reducing this gap with conventional solutions.
- Once enough experience is gained in its national market, Egypt could export components to other markets.

Figure 2 | Forecasted Demand for CSP Applications, Either Electric (Bars) or Thermal (Lines), 2013–27



Although alternative applications can be significant, the main demand for CSP components is expected to come from large-scale solar power plants, especially local developments.

Figure 3 | Forecasted Demand for PV Applications, Either Electric (Bars) or Area (Lines), 2013-27

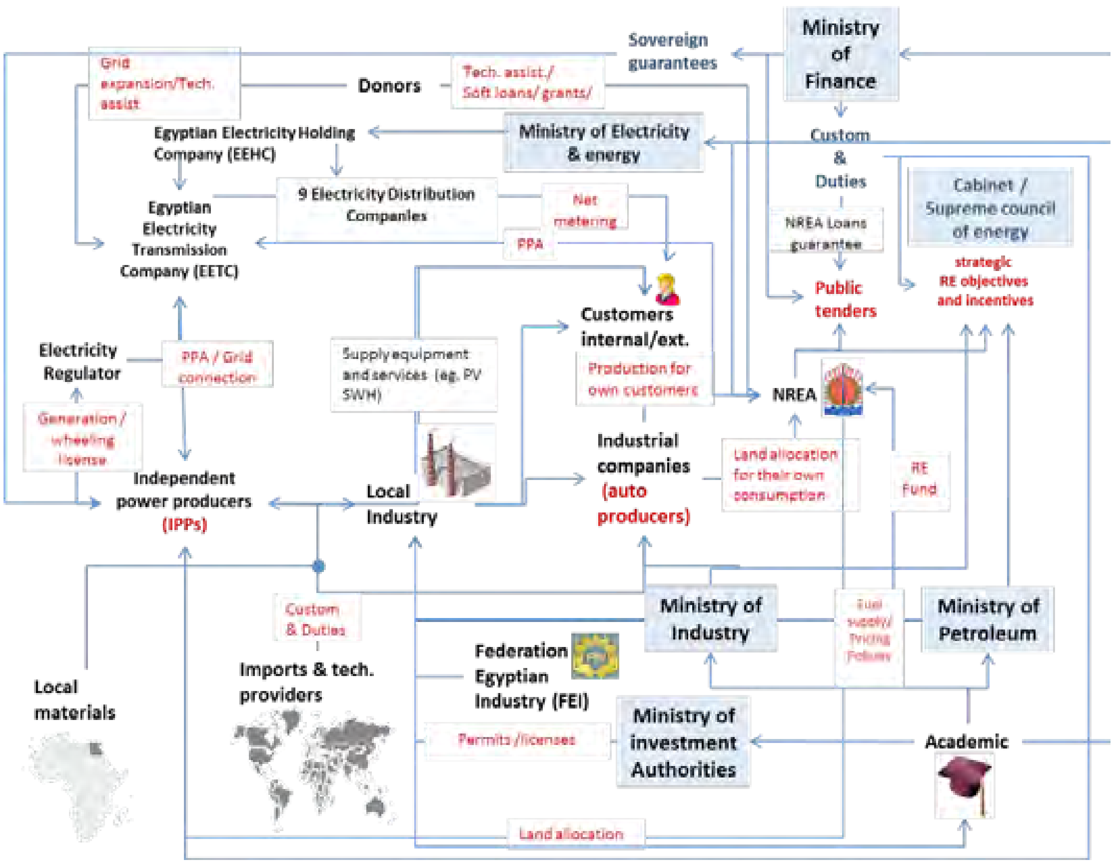


Exports and alternative applications are expected to play a major role in PV components demand. Local developments, on the other hand, might become more important if the Egyptian PV target increases.

Recent reports have highlighted that Egypt's solar development program still lacks a targeted vision and incentive system, as well as a specialized agency with skills and experience, to make the plan a reality (AfDB 2012). Nevertheless, the solar sector in Egypt already has a significant number of active players (Figure 4).

5. www.nrea.gov.eg.

Figure 4 | Map of Stakeholders Involved in Egypt's Solar Energy Sector



1.3 Industrial and Technical Background

Unlike other African economies, Egypt has a low dependency on agricultural production. The reason is its diverse industrial sector, which is dominated by the steel industry, automotive, construction, and consumer goods.

In 2012, 37.4 percent of GDP was due to the industrial sector, almost 5.0 percent more than in Morocco and 8.0 percent more than in Tunisia.

At the same time, Egypt has a developed service sector. Although it is not the focus of this study, the service sector is worth mentioning because of the country's important trajectory in plant engineering, developed largely through the Power Generation Engineering and Services Company (PGESCo) and construction services, through companies such Orascom. The presence of such companies is a singularity in the Region and may help Egypt become a Regional supplier of services in the solar industry, as well as a manufacturer of selected solar component industries.

Despite having little local capacity in the solar sector to date (20 MW Kuraymat plant), Egypt has the potential to develop local manufacturing for different components in the solar value chain, due partly to the availability of materials and related industries.

1.4 Existing Industrial Sector

Egypt's industrial sector has the following capabilities linked to solar component manufacturing necessities:

- Base steel manufacturing: over 8 million t/year[6]
- Float glass manufacturing: over 400 kt/year[7]
- Electric and power electronics: global sector leaders[8] operate in the country
- Pumps and metal fabrication: several local and international companies operate in the country.

These capabilities could help Egypt's industrial sector to overcome the entry barriers and take advantage of the key factors described above for some of the CSP and PV industries. The highly skilled workforce required for several of these industries could be obtained through capacity building programs such as partnerships with technology providers and specialized training courses.

Assembly industries, such as automotive, have proven their feasibility in Egypt, and some solar components could do the same.

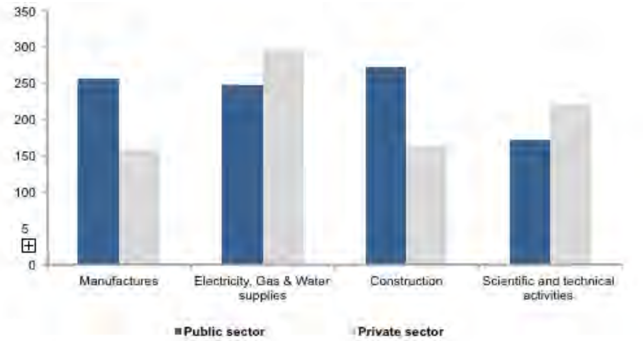
1.5 Production Factors

1.5.1 LABOR

In the Region, Egypt is competitive in labor cost—a significant advantage and opportunity (Figure 5)

6. Ezz Steel Rebars: 5.8; Suez Steel: 2.5.
7. Saint Gobain: 250; Sphinx Glass: 200.
8. ABB, Elsewedy, Schneider, Siemens.

Figure 5 | Egyptian Employee Wage Average by Industry, 2009 (US$/mo)



Source: Egypt, CAPMAS 2010.

The key barriers identified in the labor market are:

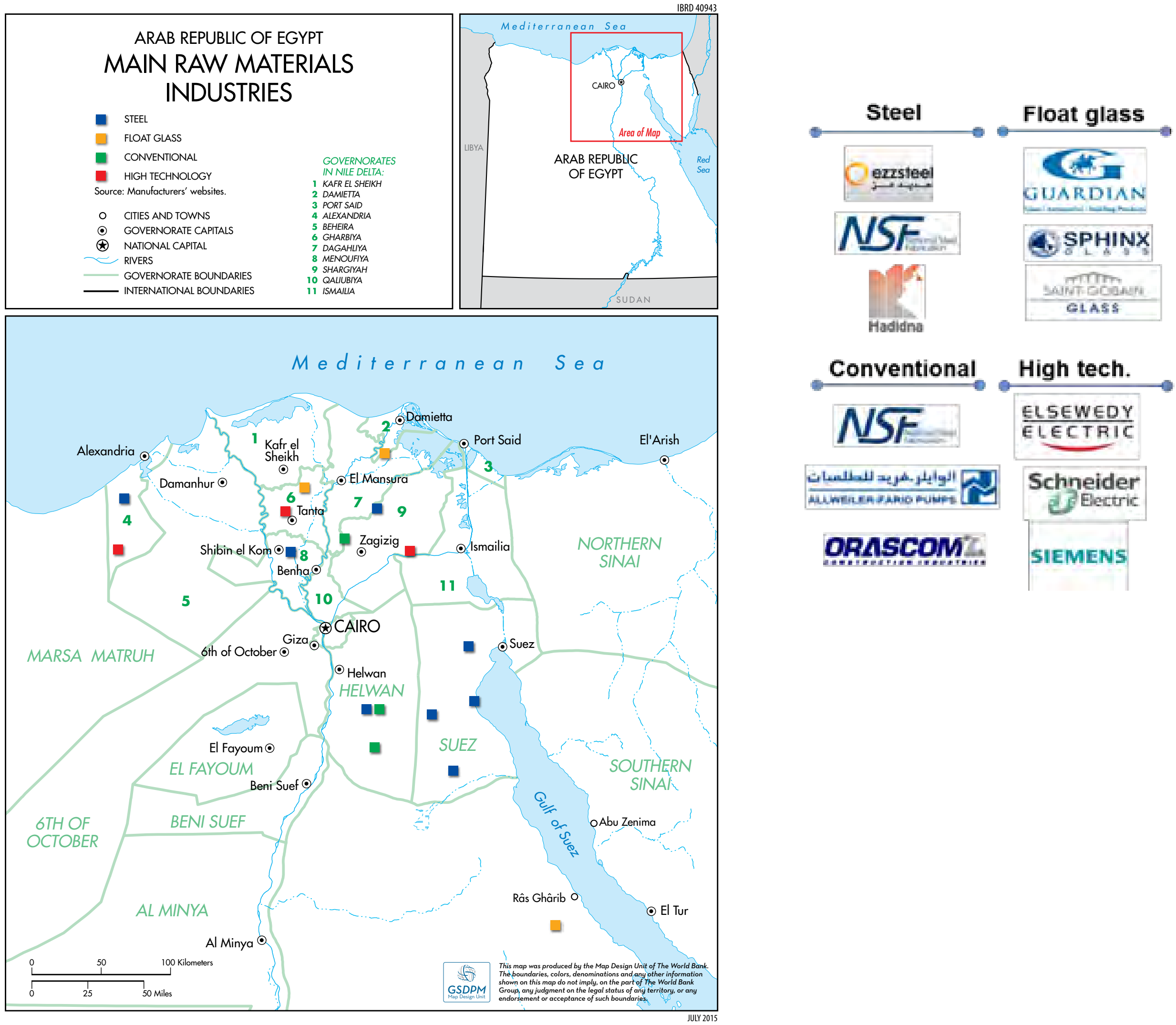
- Lack of technical knowledge of solar-energy-related component design and manufacturing
- Upstream: Lack of preparation for solar projects development; downstream: lack of qualification for downstream operation and maintenance (O&M), which would be required for a pipeline of projects)
- Absence of specialized centers to train and develop specific skills
- Low productivity.

However, the labor market situation is seen more as an opportunity for Egypt rather than as an insoluble barrier, since Egypt already has a solid base of qualified professionals. Cairo University, for example, is ranked as one of the top 500 universities globally [5].

Steel and float glass manufacturing facilities exist in Egypt with enough capacity to supply the solar component industry.

Regarding float glass, however, some additional investments would be required to fulfill CSP and PV market needs. Egypt's current float glass production has an iron content that would not immediately comply with CSP or PV requirements.

Figure 6 | Main Raw Material Industries in Egypt



Source: Manufacturers' websites. Re-created by World Bank Cartography, July 2015.

In the past, electricity subsidies in Egypt have kept electricity prices artificially low. Although it brings with it other risks,[9] at first sight, the subsidies appear to be a competitive advantage to private industrial investors, particularly for energy-intensive industries. However, seeing subsidies as competitively advantageous is changing in Egypt because energy costs are increasing for industrial consumers.

In the past year, industrial consumers have experienced tariff hikes. For the most energy-intensive industries, these hikes have been accompanied by a 50 percent hike in the price of electricity consumed during a defined 4-hour peak period (EgyptERA n.d.). Along the same lines, a plan by the Egyptian electricity regulator to put in place a series of barriers to high-energy-consumption companies could hamper the future development of energy-intensive industries in the country.

9 From the country's point of view, subsidies to energy consumption introduce tensions in the system, because they veil the true price signal to electricity consumers and may lead to adverse economic and environmental impacts. The sustainability of these artificially low costs therefore can be perceived as an investor risk.

1.5.2 FINANCIAL COSTS

For the last 5 years, Egypt's interest rate has remained above 10 percent (World Bank 2008-2011), reaching 16 percent in 2012 for small/medium companies.[10] This high interest level makes it difficult for small/medium companies to invest due to the high pay-back required.

1.6 Status of Global Solar Component Value Chain

To assess the value chains that could be developed in Egypt, this study analyzed the current global solar component value chains. The goal is to obtain an overview on their robustness and attractiveness to a potential investor.

The following factors have been taken into account:

TABLE 1 | CRITERIA USED FOR THE QUALITATIVE ASSESSMENT

	Technological maturity	Number of competitors	Upstream bottlenecks	Geographicdispersion	Demand-to-offer ratio	Robustness
	Newcomer	Oligopoly	Shortage	Few	Shrinking	Weak
+	Demo	Several	Alternatives	Several	Stable	Medium
+ +	Established	Many	Unlikely	Many	Growing	Strong

TABLE 2 | QUALITATIVE ASSESSMENT OF MANUFACTURING VALUE CHAINS FOR CSP

		Technological Maturity	Number of Competitors	Upstream Bottlenecks	Geographical Dispersion	Demand-to-Offer Ratio	Robustness
CSP	Condenser	++	++	++	++	++	++
	Electrical Generators	++	+	++	+	++	+
	Heat Exchanger	++	++	++	++	++	++
	HTF Pumps	++	+	++	+	++	+
	HTF Oil	+	?	+	?	++	?
	Mirror	+	+	++	+	++	+
	Pumps	++	++	++	++	++	++
	Receiver	+	?	+	?	+	?
	Solar Salt	+	?	?	?	++	?
	Steam Turbine	++	?	++	+	++	?
	Storage Tank	++	++	++	++	++	++
	Structure & Tracker	+	++	++	++	++	++

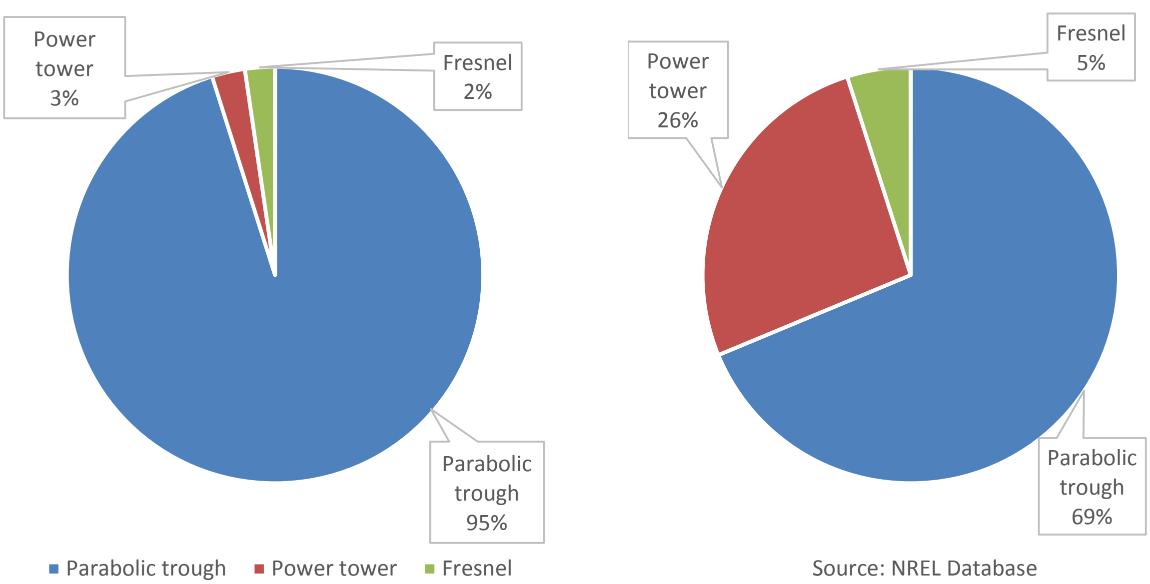
2. As detailed by several stakeholders during the mission carried out in Cairo in April 2013.

TABLE 3 | QUALITATIVE ASSESSMENT OF MANUFACTURING VALUE CHAINS FOR PV

		Technological Maturity	Number of Competitors	Upstream Bottlenecks	Geographical Dispersion	Demand-to-Offer Ratio	Robustness
PV	Cells	++	+	?	++	?	?
	Ingots/Wafers	++	+	?	++	?	?
	c-Si Modules	++	++	?	++	?	?
	Polysilicon	++	+	++	+	?	?
	Solar Glass	+	+	++	++	+	+
	TF Materials	+	+	+	+	++	+
	TF Modules	+	++	+	++	++	?
	Inverters	++	++	++	++	++	++
	Structures	++	++	++	++	++	++

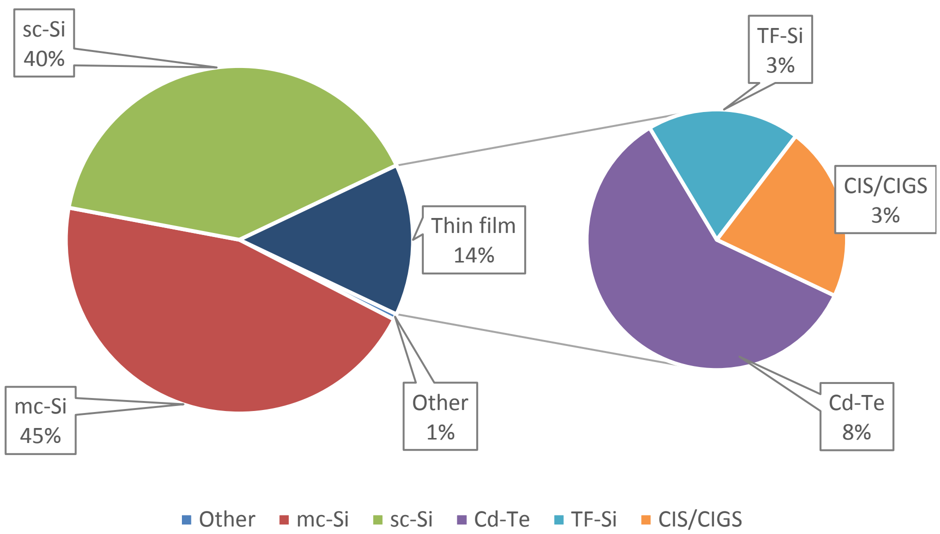
The market share of the different technologies (current and in construction) provides a lead on the tendency and markets.

Figure 7 | Market Share of the Different CSP Technological Approaches, Both Operating (left) and under Construction (right), 2012 (%)



Source: Authors based on U.S. DOE NREL 2013b.

Figure 8 | Market Share of the Different PV Technological Approaches, 2011 (%)



Source: Authors based on Fraunhofer ISE 2012.

1.7 Solar Industries That Have a Potential to Be Developed in Egypt

In an earlier stage of this project (World Bank 2012a), Egypt's and some other countries' competitiveness for developing local solar industries was assessed. A series of metrics regarding production factors, demand factors, risk and stability factors, and business support factors were used in an aggregation and weighting model to provide an "attractiveness index" for each country and industry studied. These indexes enable comparing how likely it would be for an investor to choose Egypt as the preferred destination to invest in a solar component manufacturing industry. The results of this report are summarized in Tables 4–7.

TABLE 4 | NORMALIZED ATTRACTIVENESS INDEX FOR CSP COMPONENT INDUSTRIES (I)

	Condenser	Electrical Generator	Heat Exchanger	HTF Pumps	HTF Thermal Oil	Mirror
Egypt	0.5	0.5	0.5	0.5	0.5	0.5
Chile	0.6	0.7	0.5	0.6	0.6	0.6
China	0.9	0.7	1.0	0.8	0.7	0.9
Germany	0.9	0.9	0.8	0.9	0.9	0.9
India	0.7	0.7	0.7	0.7	0.7	0.7
Japan	0.9	0.9	0.9	0.9	0.9	0.8
South Africa	0.7	0.9	0.6	0.8	0.9	0.7
Spain	0.8	0.8	0.7	0.8	0.8	0.8
United States	1.0	1.0	1.0	1.0	1.0	1.0
Average BENCHMARK	0.8	0.8	0.8	0.8	0.8	0.8

TABLE 5 | NORMALIZED ATTRACTIVENESS INDEX FOR CSP COMPONENT INDUSTRIES (II)

	Pumps	Receiver	Solar Salt	Steam Turbine	Storage Tanks	Structure & Tracker
Egypt	0.5	0.5	0.4	0.5	0.5	0.7
Chile	0.6	0.6	0.9	0.7	0.5	0.5
China	0.9	0.8	1.0	0.7	1.0	1.0
Germany	0.8	0.9	0.5	0.9	0.8	0.8
India	0.7	0.7	0.4	0.7	0.7	0.9
Japan	0.9	0.9	0.4	0.9	0.9	0.9
South Africa	0.7	0.7	0.4	0.9	0.7	0.8
Spain	0.8	0.8	0.5	0.8	0.7	0.7
United States	1.0	1.0	0.5	1.0	1.0	0.9
Average BENCHMARK	0.8	0.8	0.6	0.8	0.8	0.8

TABLE 6 | NORMALIZED ATTRACTIVENESS INDEX FOR CRYSTALLINE PV COMPONENT INDUSTRIES

	Cells	Ingots/Wafers	Modules c-Si	Polysilicon
EGYPT	0.5	0.5	0.5	0.5
Chile	0.6	0.7	0.5	0.7
China	0.8	0.7	1.0	0.7
Germany	1.0	1.0	0.9	0.9
India	0.7	0.7	0.7	0.7
Japan	0.9	0.9	0.9	0.9
South Africa	0.7	0.9	0.6	0.9
Spain	0.8	0.8	0.7	0.7
United States	1.0	1.0	1.0	1.0
Average BENCHMARK	0.8	0.8	0.8	0.8

TABLE 7 | NORMALIZED ATTRACTIVENESS INDEX FOR THIN FILM AND COMMON PV COMPONENT INDUSTRIES

	Solar Glass	TF Materials	TF Modules	Inverter	Support Structure
Egypt	0.5	0.5	0.5	0.6	0.7
Chile	0.7	0.6	0.5	0.5	0.5
China	0.7	0.9	1.0	1.0	1.0
Germany	0.9	1.0	0.9	0.7	0.9
India	0.7	0.6	0.7	0.8	0.9
Japan	0.9	0.9	0.9	0.9	0.9
South Africa	0.9	0.7	0.6	0.6	0.7
Spain	0.7	0.7	0.7	0.6	0.7
United States	1.0	0.9	1.0	0.9	0.9
Average BENCHMARK	0.8	0.8	0.8	0.8	0.8

A set of "benchmark countries" was used as a reference in the analysis. The results show that Egypt has an attractiveness index closer to the average of benchmark countries for the industries of structure and tracker (CSP) and inverter and support structure (PV).

Based on these results and the analysis of the circumstances of the different solar industries in the world, the following solar industries have been selected due to their attractiveness in Egypt.

Figure 9 | Solar Components Considered in This Study

A. CSP
- Condenser
- Heat exchangers
- HTF pump
- Mirror
- Pumps
- Storage tanks
- Structure and tracker

B. PV
- Inverter
- Solar glass
- Support structure.

A. CSP Technologies	
Condensers	
Barriers to Entry	*Key Factors*
• **Guarantees of turbine manufacturer.** The design of the condenser is linked to that of the turbine, partly conditioning the condenser's design and performance. Thus, turbine manufacturers might subcontract the condenser manufacture and include it in their own scope of supply.	• **Stainless steel market.** Availability, quality, and price of stainless steel condition the final price of the condenser.
• **Technical barrier.** Complex design to achieve performance. Condenser design must comply with more constraints than conventional heat exchangers, such as a limited pressure drop in the shell side, a complex heat transfer in phase-change and vacuum conditions.	• **High-precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
• **Highly skilled workforce required.** Stainless steel welding and heavy duty machinery handling require specific training	
Heat Exchangers	
Barriers to Entry	*Key Factors*
• **Highly skilled workforce required.** Steel welding and heavy duty machinery handling require specific training.	• **Steel market.** Availability, quality, and price of steel condition the final price of the condenser.
	• **High-precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
	• **Adapt existing industries.** Light duty heat exchangers or other metal fabrication industries likely exist in Egypt. Diversifying their production toward the solar sector would reduce initial investment cost and would profit from skilled workforce.

A. CSP Technologies	
HTF Pump	
Barriers to Entry	*Key Factors*
• **Highly skilled workforce required.** Carbon, stainless steel and bronze casting, machining and welding, and heavy duty machinery handling require specific training.	• **High-precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
	• **Motor and power electronics.** Availability, quality, and price of motors condition the final price of the HTF pumps. Variable frequency drive controllers for some or all of the pumps frequently are included within a solar plant.
Mirror	
Barriers to Entry	*Key Factors*
• **Technical barrier: Complex manufacturing line.** State-of-the-art parabolic shaping achieves accuracy above 99 percent (measured as reflected light that would reach the focus) thanks to optimized design and high manufacturing quality.	• **Energy.** Availability and price of thermal energy condition the final price of the mirror.
• **Highly skilled workforce required.** Glass processing, chemical reagents, and heavy duty machinery handling require specific training. The product itself is fragile.	• **Transport.** Transportation of float glass can raise the final costs by 15 perhaps (Glass Global 2012). It is common practice to avoid road transportation of glass more than 600 km (Glass for Europe 2012).
• **Capital-intensive unless integrated in existing float glass.** Transportation of float glass can raise the final costs by 15 percent (Glass Global 2012). Glass for solar applications is a minor fraction of overall float glass market. Typical float glass factory produces 200,000 t/year and must maintain at least 70 percent utilization rate to be profitable (Glass for Europe 2012).	• **Adapt existing industries.** For an existing float glass factory, diversifying production toward the solar sector would reduce initial investment cost and profit from skilled workforce and developed logistics.

A. CSP Technologies	
Pumps	
Barriers to Entry	*Key Factors*
• **Technical barrier: complex design for molten salt pumps.** State-of-the-art molten salt pumps prevent the problems associated with the high melting point of solar salt thanks to optimized design and high manufacturing quality.	• **High-precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
• **Highly skilled workforce required.** Carbon and stainless steel casting, machining and welding, and heavy duty machinery handling require specific training.	
Storage Tanks	
Barriers to Entry	*Key Factors*
• **Technical barrier.** Complex design of molten salt tanks, steam drum, and deaerator. State-of-the-art molten salt hot tank design prevents damage to the foundations while avoiding the problems associated with the high melting point of solar salt thanks to optimized design and high manufacturing quality. Steam drum and deaerator design must comply with more constraints than conventional storage tanks, such as a complex mass transfer in phase-change conditions.	• **Manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.

A. CSP Technologies	
Structure and Tracker	
Barriers to Entry	*Key Factors*
• **Hot-dip galvanizing of large structures (>12 m) can be a bottleneck.** Torque-tube-based collector designs require the galvanizing of a 12-m long piece (torque tube), and galvanizing baths with the required dimensions are not frequent (Galvanizers Association 2012).	• **Carbon steel market.** Availability, quality, and price of carbon steel condition the final price of the structure.
• **Technical barrier.** Complex design to achieve stiffness. State-of-the-art collector design achieves accuracy near 75 percent (measured as reflected light that would reach the focus) thanks to optimized design and high manufacturing quality. This barrier can be overcome through partnerships or license acquisition.	• **Transport.** Normal packing ratios can be reached for transportation of collector structures based on torque box or space frame concepts. For torque tubes, packing ratio is lower due to their shape, so transport costs can be higher.
• **Technical barrier.** Complex design of hydraulic circuit and components. State-of-the-art tracker design achieves a half-acceptance angle better than 0.1º thanks to optimized design and high manufacturing quality. This barrier can be overcome through partnerships or license acquisition.	• **Galvanizing.** Availability, quality, and cost of nearby galvanizing facilities condition the final price of the structure.
	• **Adapt existing industries.** For an existing steel structure factory such as transmission tower factories, diversifying production toward the solar sector would reduce initial investment cost and profit from skilled workforce and developed logistics.

B. PV TECHNOLOGIES	
TF Solar Glass	
Barriers to Entry	*Key Factors*
• **High overall investment for manufacturing process due to scale.** High investment increases the exposure in case a competitor develops a more efficient manufacturing process, or an alternative product for the same application enters the market.	• **Vertical integration or association with existing float glass line.** Integrated companies achieve competitive costs while ensuring raw materials supply and quality. A coupled manufacturing line would reduce initial investment cost and profit from skilled workforce, as well as avoid intermediate handling costs.
• **Solar glass is usually <1 percent of total float glass.** Alternative demand (building, automotive) must exist to achieve at least 70 percent capacity factor.	• **For CIS/CIGS: Stable sodium (Na) composition, integration of molybdenum (Mo) coating.** Vertical integration would enable addressing both issues.
	• **For CdTe and TF-Si: Integration of TCO deposition to access alternative markets (liquid crystalline displays, or LCDs).** A coupled manufacturing line would reduce initial investment cost, profit from skilled workforce, and avoid intermediate handling costs.
	• **Transport.** Transportation of float glass can raise the final costs by 15 percent (Glass Global 2012). It is common practice to avoid road transportation of glass products more than 600 km (Glass for Europe 2012).
	• **Energy.** Availability and price of thermal energy condition the final price of solar glass.
	• **Alternative markets: Crystalline modules.** General requirements for solar glass also apply to glass covers for crystalline modules, so additional sales could be obtained for c-Si Modules manufacturers.

B. PV TECHNOLOGIES	
Inverter	
Barriers to Entry	*Key Factors*
• **Technical barrier: Complex design to achieve performance.** State-of-the-art inverter design achieves efficiency above 98 percent (SMA Solar Technology 2012) thanks to optimized design and high manufacturing quality.	• **Distinguishing features, quality control.** Strong competitors exist in the market. To gain market share, higher quality, pre- and/or post-sales services should be offered.
• **Most inverter manufacturers are large power electronics companies that diversified into the solar market.** Diversified companies are less sensitive to oscillations in PV market.	• **Maximum power point tracking and anti-islanding protection.** These features are specific to solar inverters, and mandatory in cases in which Institute of Electrical and Electronics Engineers (IEEE) 1547 standard applies.
Support Structure	
Barriers to Entry	*Key Factors*
• **Technical barrier: Complex design to achieve reliability and low maintenance for tracker.** State-of-the-art tracker design achieves an average replacement ratio near 2 percent/year thanks to optimized design and high manufacturing quality.	• **Carbon steel market.** Availability, quality, and price of carbon steel condition the final price of the support structure.
	• **Transport.** Normal packing ratios can be reached for transportation of support structures, but the cost can be significant in the final price.
	• **Galvanizing.** Availability, quality, and cost of nearby galvanizing facilities condition the final price of the support structures.
	• **Adapt existing industries.** For an existing steel structure factory such as transmission tower factories, diversifying production toward the solar sector would reduce initial investment cost and would profit from skilled workforce and developed logistics.

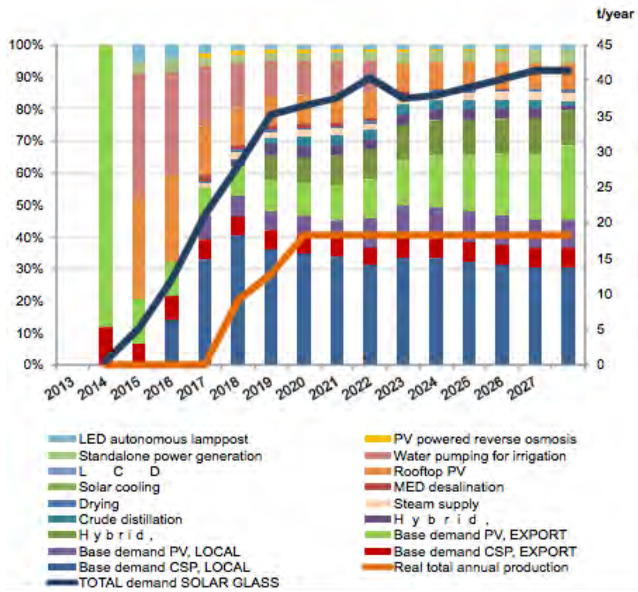
1.8 Market Volume

The market volume for the various solar industries has been estimated by aggregating the forecasted demand for:

- Large-scale solar power plants both CSP and PV both in Egypt and abroad (base demand)
- Other applications of solar energy in Egypt:
  - Power generation: Solar boost (for new facilities as well as for revamping existing ones)
  - Process heat (CSP):
    - High-temperature distillation
    - Steam production
    - Drying
    - Multiple-effect distillation (MED) desalinization
    - Cooling
  - Rooftop integrated PV
  - Solar glass in LCD screens
  - Water pumping for irrigation
  - Standalone power generation (PV)
  - Reverse Osmosis desalinization (PV)
  - Inverters for small wind power
  - Light-emitting diode (LED) lampposts for street lighting (PV).

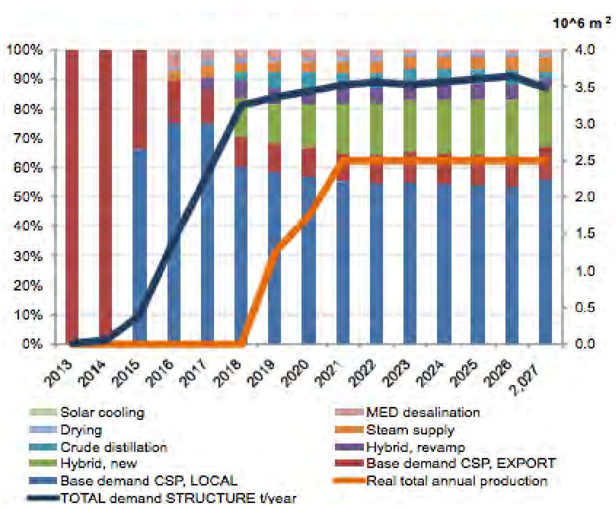
Hypotheses on share and penetration of each technology to cover total demand of each need have been made, leading to forecasted demand for each component (Figure 10 to Figure 16).

Figure 10 | Forecasted Demand and Annual Proposed Production for CSP and PV Structure, 2013–27



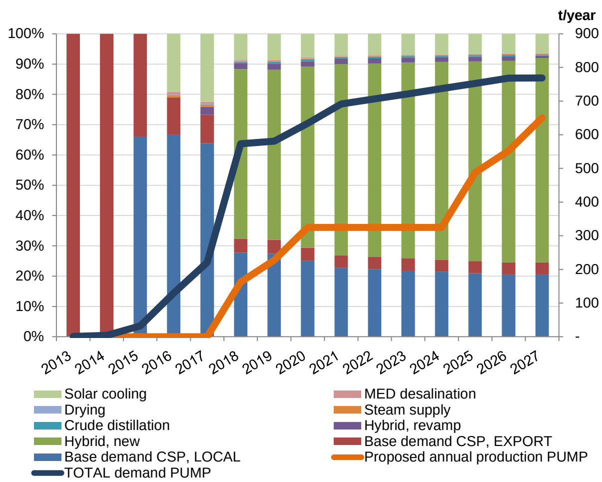
The combination of PV and CSP structures is expected to be demanded mainly by large-scale solar power plants (base demand). Alternative applications could garner up to 30 percent of the total market volume.

Figure 11 | Forecasted Demand and Annual Proposed Production for CSP Mirror, 2013-27



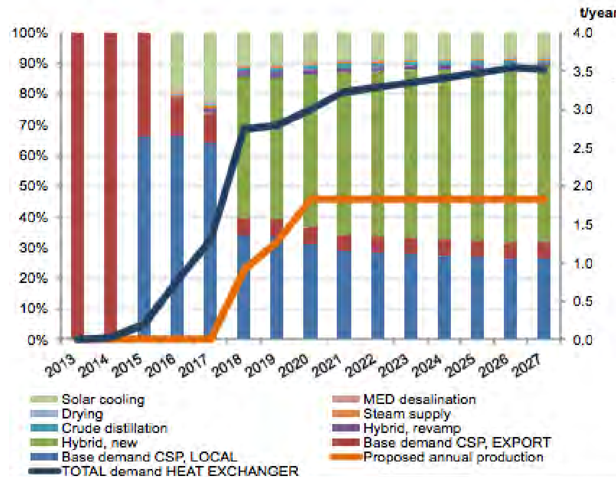
Mirrors will be demanded mainly by large-scale solar power plants (base demand), especially local developments. However, alternative applications could garner up to 30 percent of the total market volume.

Figure 12 | Forecasted Demand and Annual Proposed Production for CSP Pumps, 2013–27



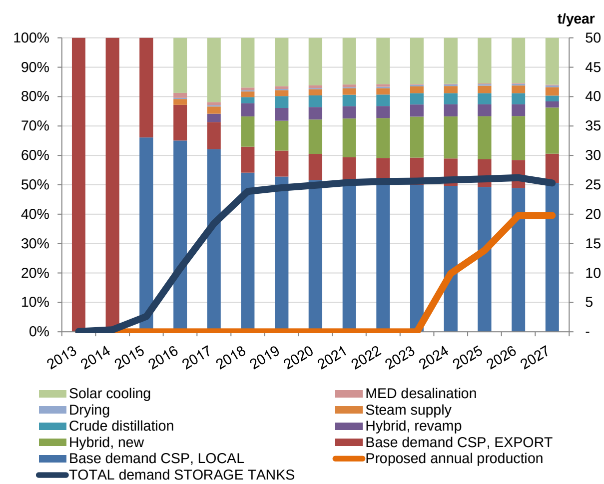
Large-scale solar power plants (base demand), especially local developments, can suffice for the development of the first CSP pumps factory. However, the second factory shall be justified only if the alternative demand from new hybrid power plants is present.

Figure 13 | Forecasted Demand and Annual Proposed Production for CSP Heat Exchangers, 2013–27



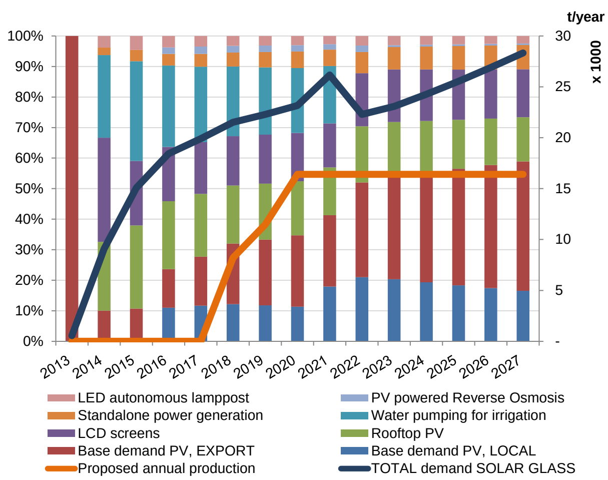
Large-scale solar power plants (base demand), especially local developments, can suffice for the development of the first CSP heat exchangers factory. Although the alternative demand from new hybrid power plants is significant, it has not been considered enough for the development of a second factory.

Figure 14 | Forecasted Demand and Annual Proposed Production for CSP Storage Tanks, 2013–27



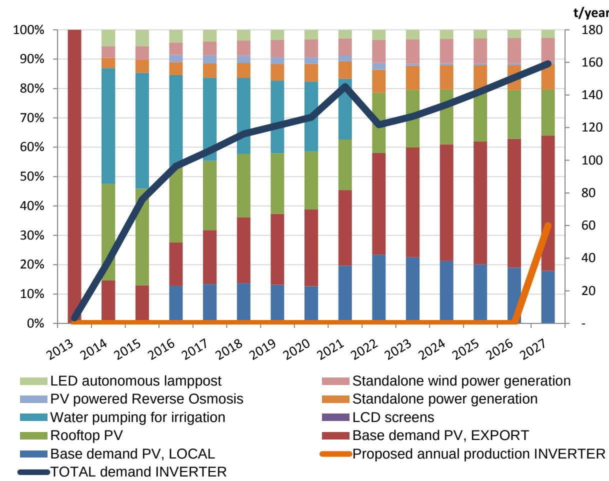
Storage tanks will be demanded mainly by large-scale solar power plants (base demand), especially local developments. However, alternative applications can garner up to 40 percent of the total market volume.

Figure 15 | Forecasted Demand and Annual Proposed Production for PV Solar Glass, 2013–27



Solar glass will be demanded mainly by large-scale solar power plants (base demand), especially for exports. However, alternative applications can garner up to 40 percent of the total market volume.

Figure 16 | Forecasted Demand and Annual Proposed Production for PV Inverter, 2013–27



Inverters will be demanded mainly by large-scale solar power plants (base demand), especially for exports. However, alternative applications can garner up to 30 percent of the total market volume.

1.9 Aggregated Economic Costs and Benefits Associated with an Enlarged Solar Sector in Egypt

The development of the solar sector in Egypt will contribute to:

- Labor creation
- GDP increase
- Upstream impacts: materials and energy consumption.

Besides lowering the cost of the solar plants to be built, a developed solar sector will increase the country's energy security and contribute to Regional renewable energy development.

Egypt has the opportunity to enlarge its solar component manufacturing base, which, according to the assumptions in this study, would create up to 3,000 jobs, most of them in installation activities.

Growing solar component manufactures also would increase GDP by over 300 million US$/year, and no shortages of materials supply are expected. Energy, on the other hand, might pose a problem, because some of the proposed industries are energy intensive and depend strongly on heavy-duty, continuous production to achieve profitability.

1.9.1 LABOR CREATION

Direct high- and medium-qualification jobs will be created in the component manufacturing industries, construction of large power plants (CSP or PV),[11] and installation of small[12] or domestic plants. The impacts are shown in Figure 17 and Figure 18.

Figure 17 | Labor Creation in the PV Solar Sector, 2013-27

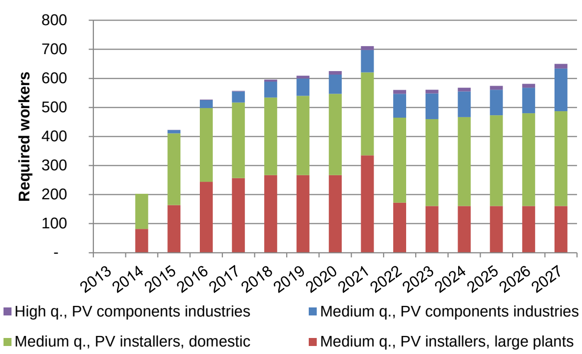
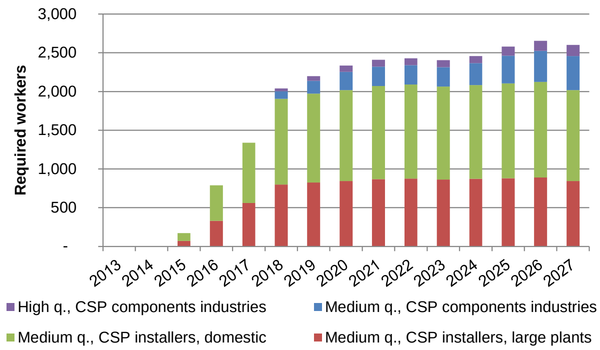


Figure 18 | Labor Creation in the CSP Solar Sector, 2013-27



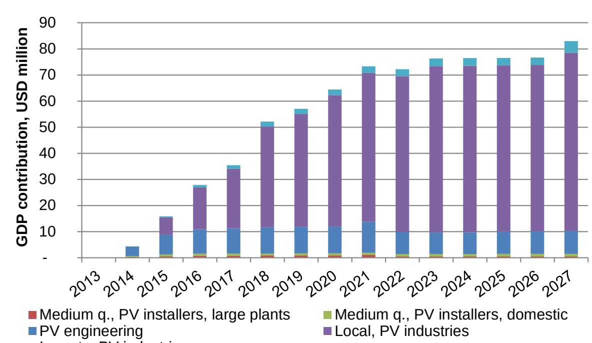
1.9.2 GDP INCREASE

The following sources of GDP have been aggregated:

- Wages of workers in installation activities, in both large and small plants
- Local share[13] of component manufacturing industries revenue, including:
  - Wages of local workers
  - Expenditure in energy, both electric and thermal
  - Material costs from local suppliers
  - Profit

Engineering services provided by local companies for the solar plants in the country.

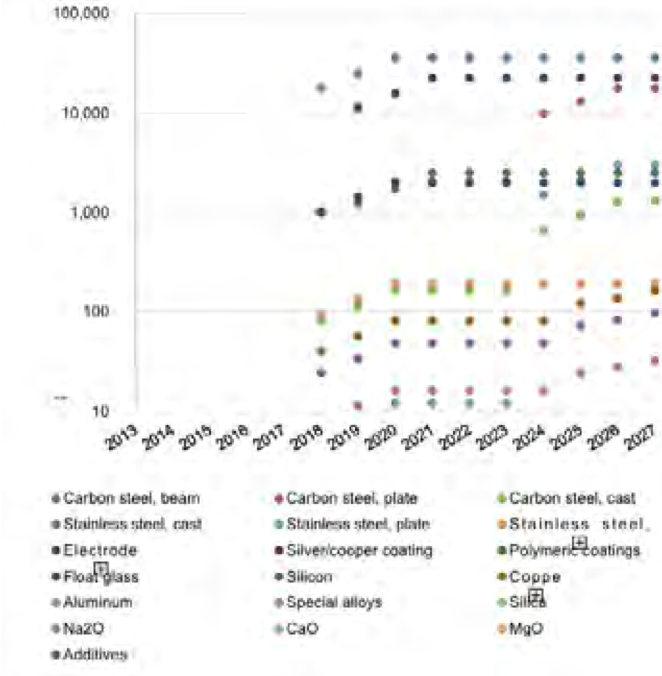
Figure 19 | Contribution to GDP from the Solar PV Sector, 2013–27



11. An average labor demand of 33 person-month/MW has been taken into account.
12. An average labor demand of 45 person-month/MW has been taken into account.

13. The imported share is shown in Figure 19 and Figure 20 for comparison.

Figure 20 | Contribution to GDP from Solar CSP Sector, 2013–27



The main long-term contribution to Egypt's GDP from both PV and CSP would be the local share of component manufacturing industries revenue.

1.9.3 UPSTREAM IMPACTS

MATERIALS REQUIREMENTS

A variety of materials is expected to be consumed by the component manufacturing industries. These materials and the estimated amounts required for PV and CSP industries through 2027 appear in Figure 20 and Figure 21, respectively.

Figure 21 | Material Requirements for PV Industries, 2013–27 (metric tons)

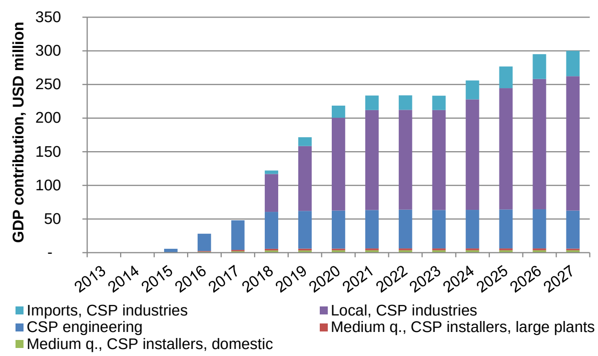
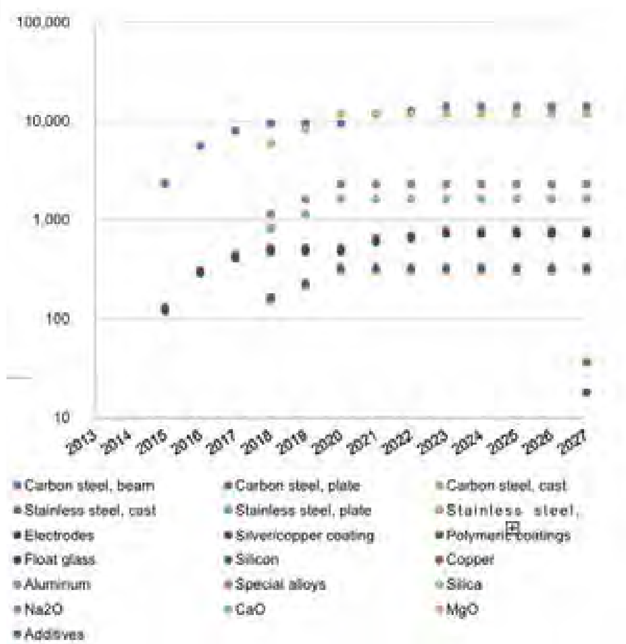


Figure 22 | Material Requirements for CSP Industries, 2013–27 (metric tons)



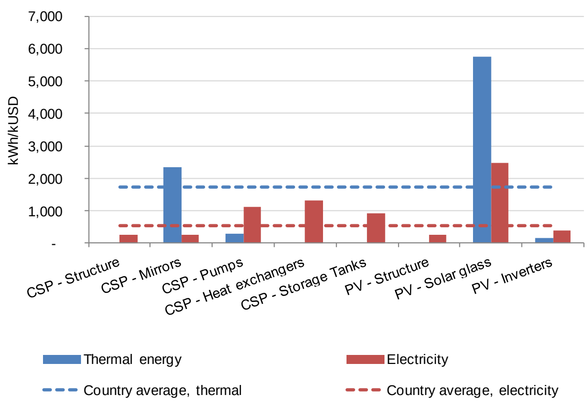
Egypt's expected consumption of local supplies is below 1 percent of its production capacity (Chapter 2.2), so no quantitative shortages are expected in the short term. The quality of the materials, on the other hand, could be troublesome, for example, in extra-clear float glass for mirrors or silicon wafers for inverters.

2.1.3.2 ENERGY REQUIREMENTS

Egypt has expressed its intention to discourage the installation of new energy-intensive industries. As a reference, to determine the relative energetic intensity of the component manufacturing industries, this study estimates the actual average energy consumption of the Egyptian industrial sector in energy consumption per unit of GDP (MWh/US$ mil).

Figure 23 shows that inverters and structures have a lower specific energy consumption of both thermal and electric than the country averages. Solar glass, on the other hand, is above the averages for both.

Figure 23 | Energy Intensity of Solar Component Manufacturing Industries



Source: Authors based on Egypt EEHC 2012.

1.10 Recommendations for the Development of Solar Industries in Egypt

Egypt has a good background for developing solar component industries. However, the following issues have been identified as relevant for the sustainable development of solar industries in Egypt:

- Visibility of the pipeline
- Capital availability
- Qualified labor
- Technology transfer
- Clustering
- Materials supply
- Exports
- Certification and accreditation.

To create the necessary momentum, leading countries have combined public support with private initiatives:

- China: Five-year plans (focusing support) combined with strong private industry
- Europe: Feed-in tariff to create a pipeline of projects, support to R&D combined with industry development and clustering
- U.S.: Tax credits and loan guarantees to create a pipeline of projects, support to R&D combined with industry development
- MNA Region, Morocco: Created a dedicated agency (MASEN).

To focus the actions, it would be advisable for Egypt to identify a champion that can catalyze a cluster to develop the solar component industry. Taking into account the stakeholders' opinions and the experience gathered in leading countries, Egypt's private sector should lead the initiative. However, initial support from the public sector or multilateral organizations may be needed to catalyze the process.

TABLE 8 | ISSUE DEFINITION AND OBJECTIVES

Issue	Stakeholders involved	Definition	Objective
Visibility of pipeline	Policy makers	Private sector has little visibility of the developing pipeline, so it does not perceive demand (both public and private) and does not react.	Give visibility of pipeline to private sector, so that it perceives demand and can react appropriately.
Capital availability	Financial institutions, policy makers, private sector	Capital market is difficult to access (in both equity and loans) and expensive (two-digit zone).	Ensure enough capital is available to develop sector competitively, with appropriate payback periods.
Qualified labor requirements	Policy makers, private sector	Training is required to ensure that international quality standards are met, including for skilled engineers and managers for the manufacturing process and specific training for installation and maintenance.	Develop training programs to ensure that all necessary capabilities are in place to develop sector.
Technology transfer	Academia, private sector	Local industry is lacking some of the know-how required by manufacturing processes and solar market.	Identify know-how requirements, and acquire know-how over shortest time.
Clustering	Policy makers, private sector	Company dispersion leads to lost opportunities in synergies and economies of scale.	Define, design, and develop clustering opportunities to maximize synergies in sector and encourage new entrants.
Materials supply	Private sector	Increase in demand of local materials caused by development of solar component industry could impact material supply and price.	Monitor this phenomenon and give visibility to upstream actors in sector so they can be prepared in quality and quantity.
Exports	Policy makers, private sector	Egyptian exports could be affected by internal customs duties, destination customs duties, or other requirements imposed by destination countries.	Identify key export markets and develop future agreements to minimize this risk.
Certification and accreditation	Policy makers, private sector	Adoption of international quality standards is necessary for exports and internal market.	Design and facilitate development of Egyptian standards, encouraging communication between national and international laboratories.

TABLE 9 | ACTION PLAN AND TIMELINE

Time	Immediate actions (1 year) 2013–2014	Medium Term actions (3 years) 2014–2017	Long Term actions (3 years) 2017–2020
1. Visibility of the pipeline	• **Carry out** an **analysis of possible mechanisms** to develop the pipeline • **Select** and **put in place the mechanism** of choice • **Develop** a credible **action plan** • **Make permit** and **license** processes **more agile**	• **Implement technical and environmental regulation** to facilitate pipeline development • **Analyze effectiveness of the mechanisms** and measures implemented • **Inform society of the milestones** being achieved	• **Review mechanisms** and/or introduce new ones • **Focus on external pipeline development**
2. Capital availability	• **Identify and disseminate possible international and national sources of financing** for solar industries • Put interested **industrial parties in touch with financial institutions** and other sources of finance • **Assist** industrial project developers in the **development of business plans**	• **Develop an investment fund** to drive the sector • **Develop local bank capabilities** and knowledge on these sectors • **Elaborate case studies and success stories** based on international examples, to disseminate nationally • **Participate in the development of a** regional Clean Innovation Center	• **Review financing rates, participation on the part of local banks**, etc. to evaluate next steps • **Create new mechanisms**, eg. Multi-currency swaps, partial guarantees, to continue driving finance to solar industries
3. Qualified labor requirements	• **Perform a detailed analysis** of required **capabilities and gaps** • **Kick off a "training the trainers" technical capability development** program • **Kick off a management program** focused on the solar industry	• **Develop national, regional and international collaboration programs** with universities and academic institutions • **Increase** the breadth and depth of **training programs** according to market development	• **Perform a review of required capabilities and gaps** to identify missing capabilities • **Put in place** any required **programs to meet these gaps** • **Develop programs** to transform Egypt into a **capability trainer in the region**
4. Technology transfer	• **Identify technological gaps in the local industry** required for solar industry development • **Coordinate a local platform of interested industrial players and academics** in order to generate interest and establish the most effective ways of bridging the gaps	• **Coordinate activities to bridge technological gaps** with the solar industry cluster being developed • **Support the cluster** to generate the matches between interested industries • **Put together and disseminate success stories**	• **Perform a review of technological knowledge and gaps** to see how many are left to bridge • **Develop new mechanisms** to close the gaps
5. Clustering	• **Identify interested industrial partners and a champion** to lead the cluster • **Create cluster** with **virtual infrastructure** • **Catalyze the creation** of the cluster	• **Support the cluster and disseminate** information about it • **Prepare for the existence of a physical cluster**, including infrastructure, etc.	• **Create new clusters** based on the original cluster
6. Materials supply	• **Engage with local upstream materials partners from the start**, to give them visibility on sector requirements for both quality and quantity • **Engage with international upstream materials partners** for materials not available in Egypt	• **Analyse and consider new mechanisms for improving material flow** to the industry	• **Review** whether material supply to the industry is an issue • If applicable, **put in place additional policies or mechanisms** to help flow • Analyze further opportunities for Egypt to export materials in the region
7. Exports	• **Identify preliminary list of potential markets** for Egyptian solar components • **Identify existing or potential barriers** for said exports	• **Analyze possible mechanisms that could be applied** • **Apply said mechanisms** and, in parallel, **develop bilateral or multilateral agreements** with other countries	• **Review success of export policy** and identify new actions if program has not been successful • **Review preliminary list of potential markets** to expand to others
8. Certification and accreditation	• **Analyse existing Egyptian technical standards** applicable to the industry for **availability and quality** • **Develop a list of requirements and identify actors** who can assist in developing said standards	• **Assist in the development of standards** • **Encourage collaboration** between different parties • **Disseminate results** nationally and internationally	• **Develop accreditation activities** • **Continue encouraging collaboration** to stay on top of new technological developments

1.11 Synergistic Actions to Build on Kom Ombo CSP Project

The Kom Ombo CSP project, as well as the newly announced large-scale PV projects, can be the starting points for the solar component industry in Egypt.

To fully profit from the positive effect that these projects may bring, this study suggests areas of required technical assistance (TA) activities to enhance the local potential to manufacture solar energy components. The World Bank could support these TA activities under the preparation of the Kom Ombo CSP project. Suggestions to increase the proportion of local components in the project and to facilitate Kom Ombo's project implementation (from engineering through to operation) follow.

These TA actions cover preparatory actions and support actions and are oriented toward local capacity development and enabling the necessary structures.

A virtual cluster for the private sector and an interministerial committee for the public sector would be great supports to effectively implement capacity development. A strong coordination between both would further strengthen local ownership.

The preparatory actions focus on identifying the gaps and opportunities jointly with the involved stakeholders. Examples are to:

- Identify the gaps in local manufacturing industry required to be filled to develop solar industries.
- Identify possible international and national sources of financing for solar
- Identify and disseminate success stories
- Identify industrial partners interested in clustering and a champion to lead the cluster
- Analyze existing Egyptian technical standards applicable to the industry for availability and quality.

The following actions are proposed to be taken by the national government in collaboration with the stakeholders. The purposes are to develop the capacity of both government and stakeholders to empower the solar cluster, to support its first activities, and to enable the basic structures. The actions are:

- In collaboration with public stakeholders, prepare a plan to develop the cluster, including the identification of the cluster champion
- In collaboration with Egypt's New and Renewable Energy Authority (NREA) and the Ministry of Industry, identify the mechanisms to develop a sustainable pipeline of projects in Egypt and their effect (cost and benefits), and prepare a communication strategy for both Kom Ombo and the plan.
- Disseminate among the local industry the possible business opportunities associated to Kom Ombo project
- Workshop on Kom Ombo project with the participation of national and international players.
- Promote contact among interested industrial parties and financial institutions or other sources of finance through workshops and dissemination activities
- In collaboration with the solar cluster, prepare workshops to exchange ideas, develop capacity, and create a network of solar industries
- Identify promising solar component projects and support the initial stages
- Identify pilot energy supply projects that could lead to solar component industry development, and support the initial stages
- Prepare and initiate a "training of trainers" (ToT) technical capability development program
- Support the development of national, Regional, and international collaboration programs among R&D centers, universities, and academic institutions
- Disseminate success stories
- Catalyze the development of technical standards and certifying bodies.

This holistic institutional capacity development program, first, will ensure the sustainability of the Kom Ombo project. Second, the program will enable the growth of Egypt's solar expertise, solar industries, and other key economic sectors supporting solar projects.

PART A | Summary Assessment of International Solar Component Manufacturing Value Chains and Outlook for Their Robustness

CHAPTER 2:

Solar Component Manufacturing Value Chains

2.1 Introduction

The following summary assessment analyzes the value chains related to the manufacturing of components for Concentrated Solar Power (CSP), described in Chapter 1.2, and Photovoltaic (PV) in Chapter 1.3; and the outlook and status of the manufacturing value chains in Chapter 1.4.

The status of the different solar applications is analyzed, and the result is the background used to analyze Egypt's potential with, and using, an international holistic approach. Technology (maturity), market, and risks are assessed to identify value chain robustness.

Solar energy can be used to heat a medium to increase its internal energy to either produce electricity or heat for a process, or to produce electricity though the photovoltaic effect.

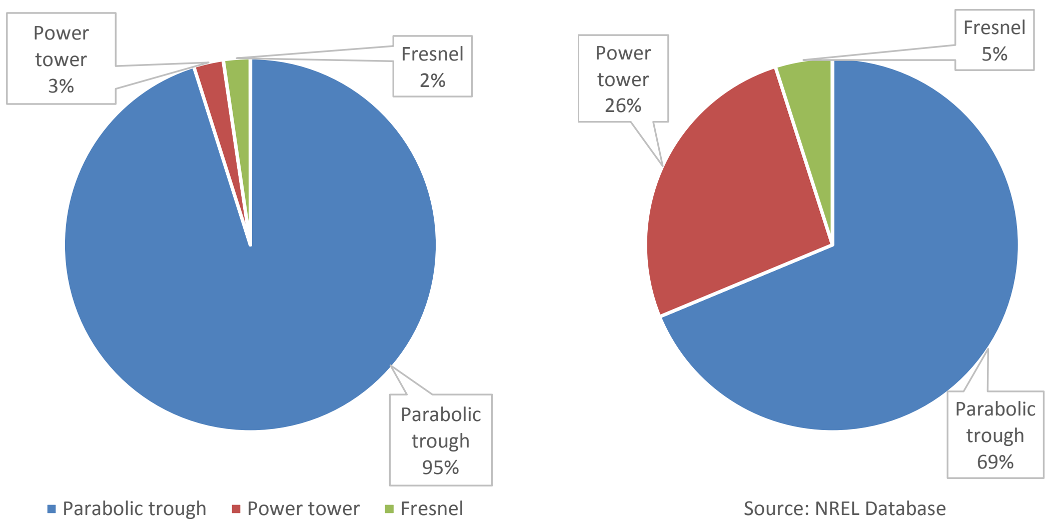
The present assessment focuses on the applications that use concentrated solar irradiation to produce either heat or photovoltaic effect.

In the thermal process, Concentrated Solar Power (CSP) technologies use mainly reflection and, in some cases, refraction to concentrate the sunlight energy, which is transformed into thermal energy at medium (up to 300ºC) or high temperature. This thermal energy can be used to produce electricity through a thermodynamic cycle or as process heat. CSP electrical plants can be divided into three main subsystems:

a. Solar Field, which collects solar energy and converts it to heat
b. Power block, which converts the heat energy to electricity; and sometimes, between them
c. Thermal Energy Storage (TES) system.

Four alternative technological approaches (Parabolic Trough, Power Tower, Linear Fresnel, and Parabolic Dish Systems) can be described (Figure 24). The component industries included in Chapter 1.2 have been chosen for this study because they have a major share in the overall investment cost of CSP projects.

Figure 24 | Market Share of the Different CSP Technological Approaches, Both Operating (left) and under Construction (right), 2012

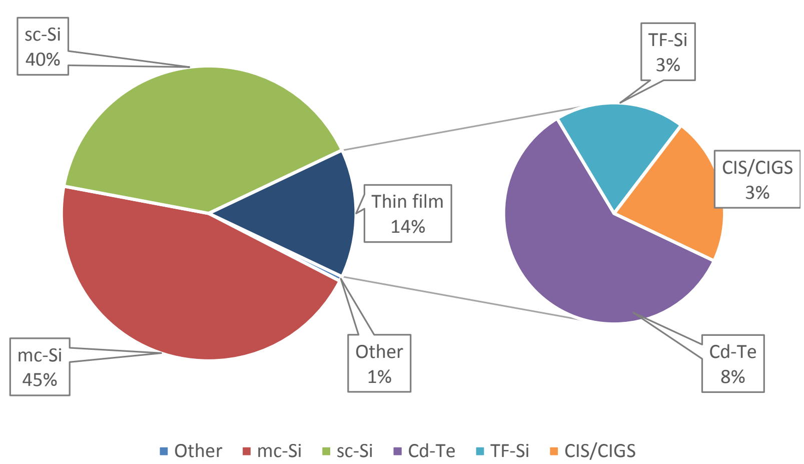


Source: Authors based on U.S. DOE, NREL 2013b.

The basic building block of a PV system is the PV cell. This cell is a semiconductor device that converts solar energy into direct-current (DC) electricity due to the photovoltaic effect. PV cells are interconnected to form a PV module, typically in the range of 50-200 Watts (W). The PV modules combined with a set of additional application-dependent components (such as support structure, inverters, batteries) form a PV system.

R&D and industrialization have led to a portfolio of available PV technology options at different levels of maturity. Commercial PV modules may be divided into 2 broad categories: wafer-based crystalline silicon (c-Si) and thin films (TF). Chapter 1.3 describes the component industries selected for PV systems. For their market share, see Figure 25.

Figure 25 | Market Share of the Different PV Technological Approaches, 2011



Source: Authors based on Fraunhofer ISE 2012.

For each solar component industry, the international value chain has been assessed, and an outlook of its robustness is presented.

2.2 Concentrated Solar Power (CSP) Value Chain

Strictly speaking, "Concentrated Solar Power" also could apply to Low- and High-Concentration Photovoltaic systems. However, the term is more commonly used to describe technologies that use the thermal energy from solar radiation to generate electricity. These systems can be divided in three main subsystems:

- A **Solar Field (**SF), in which mirrors (or, in some new developments, lenses) are used to concentrate (focus) the sunlight energy and convert it into high temperature thermal energy (internal energy). This heat is transferred using a heat transfer fluid (HTF), which can be synthetic oil (the most widely used), molten salt, steam, air, or other fluids. The point focus systems enable higher concentration ratios and, therefore, higher temperatures and efficiencies; but they also require highly precise, two-axis tracking systems. On the other hand, linear focus systems are less demanding, but less efficient as well. Either way, as for any concentrating solar technology, only the beam (direct) component of the solar irradiation is used, because the diffuse portion does not follow the same optical path so will not reach the focus.

TABLE 10 | CSP SOLAR FIELDS

	Point focus	Linear focus
Single focus	Power Tower systems	
Multiple focus	Dish/Engine systems	Parabolic Trough systems Linear Fresnel systems

Note: Multi-tower Solar Fields are at a demonstration stage (a 5 MWe plant started operation in 2009).

- A **Power Block** (PB), in which the heat contained in the HTF is used to generate electricity. The most common approach is to produce high pressure steam, which is then channeled through a conventional steam turbine and generator in a Rankine cycle. The Dish/Engine systems, however, use a Stirling engine.
- A **Thermal Energy Storage** (TES) system, in which excess energy from the SF is stored for further use in the PB. The state of the art in this field is to use molten salts stored in two tanks (one "cold" and one "hot"), and a reversible heat exchanger. However, other approaches exist such as steam storage, direct use of molten salt as HTF, and experimental prototypes.

To sum up, actual CSP plants utilize four alternative technological approaches: Parabolic Trough Systems, Linear Fresnel Systems, Power Tower Systems, and Dish/Engine Systems.

2.2.1 PARABOLIC TROUGH SYSTEMS

Today, the Parabolic Trough is considered a commercially mature technology, with thousands of megawatts already installed in commercial power plants, mainly in the US and Spain. In 2102, the Parabolic Trough approximated 95 percent of total CSP installed capacity (Figure 24).

The Parabolic Trough (as well as the Linear Fresnel) is a two-dimensional concentrating system in which the incoming direct solar radiation is concentrated on a focal line by one-axis-tracking, parabola-shaped mirrors. The mirrors are able to concentrate the solar radiation flux 30–80 times, heating the HTF to 393 ºC. (A different approach, using molten salts as HTF, can reach up to 530 ºC, but it is not yet commercially proven.) The typical unit size of these plants ranges from 30–80 MWe (megawatt-electric). Therefore, they are well suited for central generation with a Rankine steam turbine/generator cycle for dispatchable markets.

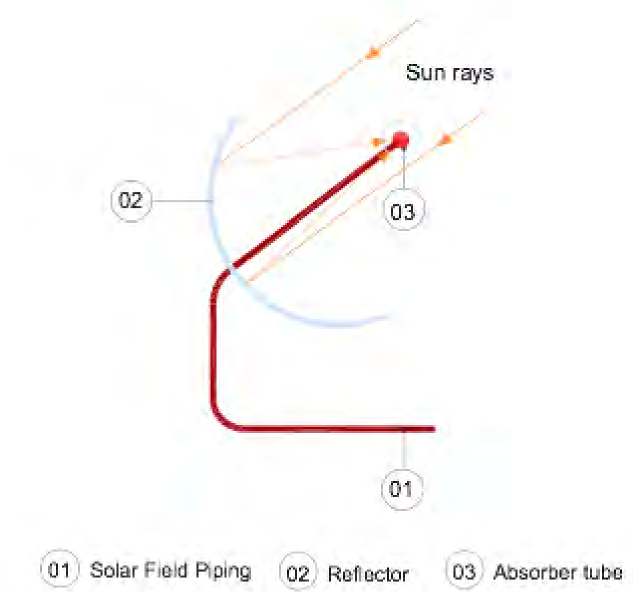
Figure 26 | Parabolic Trough Collectors Installed at Plataforma Solar de Almería, Spain

Source: Photo courtesy of PSA-CIEMAT.

A Parabolic Trough Solar Field comprises a variable number of identical "solar loops" connected in parallel. Each loop can raise the temperature of a certain amount of HTF from the "cold" to the "high" operation temperature (typically, from 300 to 400 ºC). The loops contain from 4 to 8 independently moving subunits called "collectors." The main components of a Parabolic Trough collector are:

- **HTF thermal oil:** A synthetic oil is used as heat transfer fluid in all commercial Parabolic Trough CSP plants in operation. The most common oil used is a eutectic mixture of biphenyl and diphenyl oxide. Other fluids (such as silicone-based fluids) are under development and testing.
- **Mirror:** Reflects the direct solar radiation incident on it and concentrates the radiation onto the Receiver placed in the focal line of the Parabolic Trough collector. The mirrors are made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness and parabolic shape.
- **Receiver** or absorber tube: Consists of two concentric tubes. The inner tube is made of stainless steel with a high-absorptivity, low-emissivity coating, and channels the flow of the HTF. The outer tube is made of low-iron, highly transparent glass with an antireflective coating. The vacuum is made in the annular space. This configuration reduces heat losses, thus increasing overall collector performance.
- **Structure and tracker:** Solar tracking system changes the position of the collector following the apparent position of the sun during the day, thus enabling concentrating the solar radiation onto the Receiver. System consists of a hydraulic drive unit that rotates the collector around its axis, and a local control that governs it. The structure, in turn, must keep the shape and relative position of the elements, transmitting the driving force from the tracker, and avoiding deformations caused by their own weight or other external forces such as the wind.

Figure 27 | Schematic of a Parabolic Trough Collector

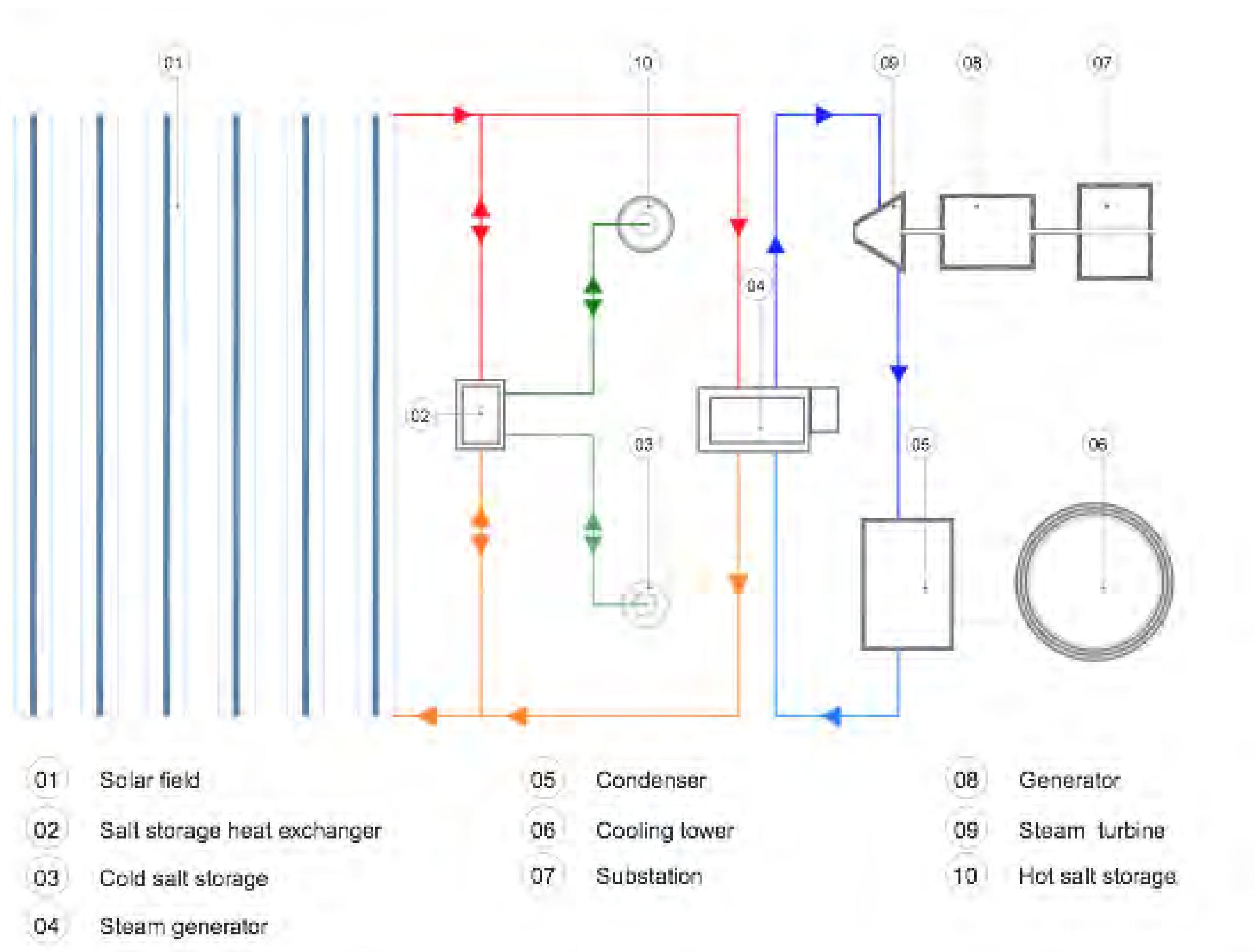


The Power Block of a Parabolic Trough CSP plant resembles a conventional Rankine-cycle power plant. The main difference is that, instead of combustion or a nuclear process, the heat used to generate superheated steam is collected in the Solar Field and transferred using a heat transfer fluid. The main components of the Power Block are:

- **Condenser:** Although the condenser also is a heat exchanger, its design is more complex. In addition, it affects the overall performance of the plant more than the other heat exchangers in the plant because it modifies the discharge pressure of the turbine. Given the condenser's importance, the turbine manufacturer could try to limit the possible suppliers to give a performance guarantee, or even include the condenser in its own scope of supply.
- **Electrical generator:** Within the generator, the rotary movement from the turbine is transmitted to a series of coils inside a magnetic field, thus producing electricity due to electromagnetic induction. The design and manufacturing of a generator require special materials and alloys and a highly specialized workforce, available in only a limited number of companies around the world. Carbon steel, stainless steel, and special alloys are required for their manufacture, as well as copper and aluminum in smaller amounts.
- **Heat exchanger:** Two different sets of heat exchangers are required in the Power Block. First, HTF-water heat exchangers (usually referred to as SGS, or Steam Generation System) are required to generate the high-pressure and high-temperature steam that will drive the turbine. Second, water-water heat exchangers are used to recover the heat from turbine bleeds, to preheat the condensate or feed water, thus increasing the Rankine cycle efficiency. If a TES system is included, a reversible, molten salt-HTF heat exchanger also is necessary. Carbon steel and stainless steel are required for their manufacture, as well as copper and aluminum in smaller amounts.
- **HTF pumps:** The materials commonly used in joints for the range of temperatures and pressures required for this application are not compatible with the chemical composition of the HTF oil. Thus, specific designs and materials, mostly derived from the petrochemical industry, are necessary.
- **Pumps:** Several sets of pumps are required within a Parabolic Trough CSP plant: feed water pumps, cooling water pumps, condensate pumps, and other minor pumps for dosing, sewage, raw water, and water treatment purposes. If a TES system is included, molten salt pumps also are necessary. Carbon steel and stainless steel are required for their manufacture, as well as copper, aluminum, and other materials in smaller amounts.
- **Steam turbine:** The expansion of the steam inside the turbine will cause the motion of the rotor blades, and this movement will be transmitted to the electrical generator to produce electricity. The design and manufacturing of a turbine requires special materials and alloys and a highly specialized workforce, available in only a limited number of companies around the world. Carbon steel, stainless steel and special alloys are required for their manufacture.

- **Storage tanks:** A large number of tanks and pressure vessels are required in a Parabolic Trough CSP plant. They include raw and treated water storage tanks, the deaerator, the steam drum, and the condensate tank for the Rankine cycle, the HTF storage, expansion and ullage vessels, and other minor tanks for sewage, water treatment intermediate steps, and others. If a TES system is included, molten salt "hot" and "cold" storage tanks also are necessary. Carbon steel and stainless steel are required for their manufacture.

Figure 28 | General Schematics of a Parabolic Trough CSP Plant with Thermal Energy Storage



The state of the art in the field of Thermal Energy Storage (TES) is to use molten salts. The most common mixture used for this purpose is referred to as "solar salt," and is composed by sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3). As described above, this salt is stored in two tanks (one "cold" and one "hot"), and a reversible heat exchanger is used to move energy from the Solar Field and to the Power Block.

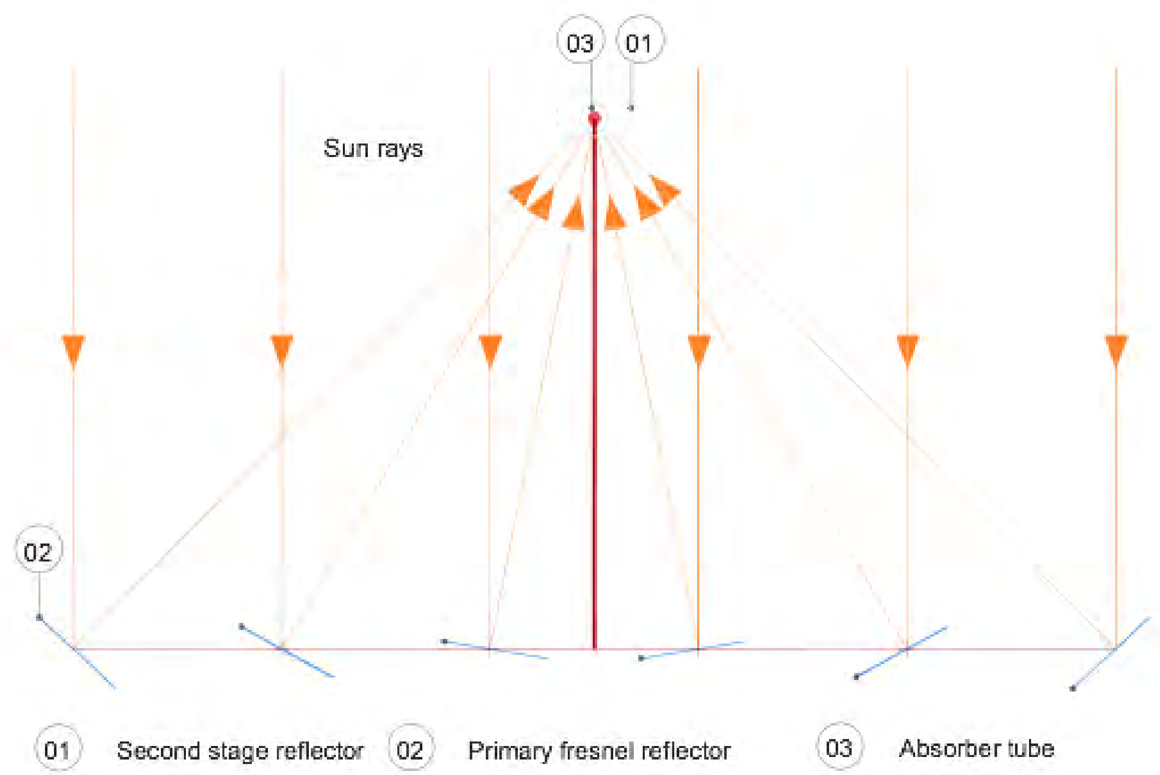
Other necessary elements include piping, insulation, and either flexible piping or rotating joints to connect adjacent collectors, as well as electric switchgear and water treatment equipment. However, these elements are either not specific to CSP technology; or, in the case of flexible piping or rotating joints, comprise a minor fraction of the investment costs and are a highly specialized component, and thus have been omitted from this report.

2.2.2 LINEAR FRESNEL SYSTEM

Linear Fresnel Systems are conceptually simple. They use inexpensive compact optics (flat mirrors), which can produce saturated steam at 150 ºC –360 ºC with less than 1 ha/MW land use. Linear Fresnel systems account for 2 percent of total CSP installed capacity (Figure 24). However, this amount is expected to increase in the near future because this system's share in the pipeline is higher than 2 percent.

The Linear Fresnel system uses flat or slightly curved mirrors to direct sunlight to a fixed absorber tube positioned above the mirrors, sometimes with a secondary reflector to improve efficiency. With flat mirrors that are close to the ground, Linear Fresnel collectors are cheaper to produce and less vulnerable to wind damage. On the other hand, their efficiency is lower due to a lower concentration ratio, and their intraday energy outflow variation is higher than in Parabolic Trough.

Figure 29 | Schematic of a Linear Fresnel Collector



A Linear Fresnel Solar Field comprises a variable number of identical "solar loops," connected in parallel. Each loop can raise the enthalpy of a certain amount of HTF. Most commercial applications use water as HTF in a Direct Steam Generation (DSG) configuration (U.S. DOE NREL 2013a). However, instead of raising the temperature, they increase the vapor fraction of the fluid. The main components of a linear Fresnel loop are:

- **Mirrors:** Reflect the direct solar radiation incident on them and concentrate it onto the Receiver placed in the focal line of the linear Fresnel loop. The mirrors are made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness. They are similar to the mirrors for Parabolic Trough, differing in size and shape. Alternatively, aluminum foils are being tested by some leading companies (3M).
- **Receiver** or absorber tube: Made of stainless steel with a high-absorptivity and low-emissivity coating, it channels the flow of the HTF. The tube is placed inside a secondary reflector with a flat cover made of low-iron, highly transparent glass with an antireflective coating. This configuration reduces heat losses and increases the half-acceptance angle,[14] thus increasing overall performance.
- **Structure and tracker:** Solar tracking system changes the position of the mirrors following the apparent position of the sun during the day, thus enabling concentrating the solar radiation onto the Receiver. The system consists of several drives that rotate the mirrors, and a local control that governs it. The structure, in turn, must keep the shape and relative position of the elements, transmitting the driving force from the tracker, and avoiding deformations caused by their own weight or other external forces such as the wind.

14. "Half-acceptance angle" is the angle of the maximum cone of light that will reflect onto the focus; the term is used to characterize nonideal optic systems.

The Power Block of a Linear Fresnel CSP plant resembles a conventional Rankine-cycle power plant. The main difference is that, instead of a combustion or nuclear process, the heat used to generate superheated steam is collected in the Solar Field and transferred using a heat transfer fluid. The main components of the Power Block are:

- **Condenser:** It is analogous to the equipment described for Parabolic Trough plants.
- **Electrical generator:** It is analogous to the equipment described for Parabolic Trough plants.
- **Heat exchanger:** Because most commercial Linear Fresnel applications use water as HTF in a Direct Steam Generation (DSG) configuration, the need for heat exchangers is largely reduced when compared to a Parabolic Trough plant. The Solar Field will act as SGS, or Steam Generation System, generating the high-pressure and high-temperature steam that will drive the Turbine. On the other hand, water-water heat exchangers are still necessary to recover the heat from turbine bleeds to preheat the condensate or feed water, thus increasing the Rankine cycle efficiency. Carbon steel and stainless steel are required for their manufacture, as well as copper and aluminum in smaller amounts.
- **Pumps:** Several sets of pumps are required within a Linear Fresnel CSP plant: feed water pumps, cooling water pumps, condensate pumps, and other minor pumps for dosing, sewage, raw water, and water treatment purposes. Carbon steel and stainless steel are required for their manufacture, as well as copper, aluminum and other materials in smaller amounts.
- **Steam turbine:** It is analogous to the equipment described for Parabolic Trough plants.
- **Storage tanks:** A large number of tanks and pressure vessels are required in a Linear Fresnel CSP plant. They include raw and treated water storage tanks, the deaerator, the steam drum, and condensate tank for the Rankine cycle and other minor tanks for sewage and water treatment intermediate steps. Depending on the DSG configuration, additional steam drums might be required for the Solar Field. Carbon steel and stainless steel are required for their manufacture.

The state of the art in the field of Thermal Energy Storage (TES) is to use molten salts. However, the use of water (phase change) in Linear Fresnel plants makes it difficult to use actual molten salts. Short-term energy storage using steam is the usual approach in these plants, if any (U.S. DOE NREL 2013a).

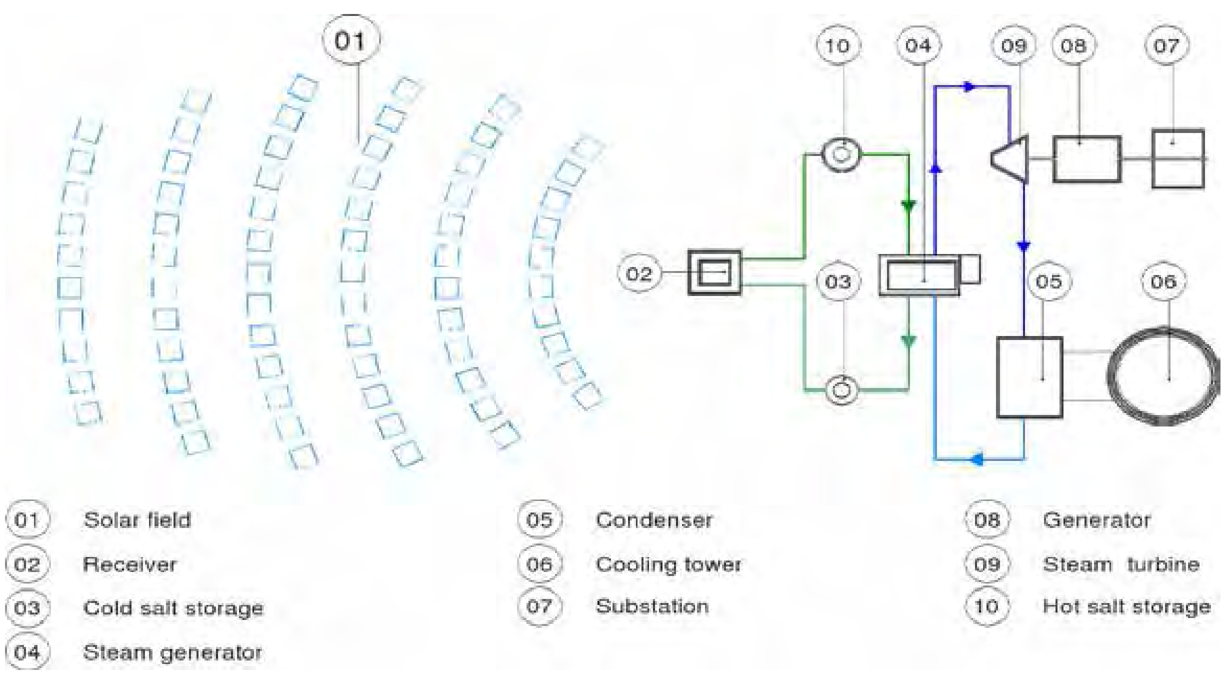
Other elements also are necessary, such as piping, insulation, electric switchgear, and water treatment equipment. However, these elements are either not specific to CSP technology or comprise a minor fraction of the investment costs, and thus have been omitted from this report.

2.2.3 POWER TOWER SYSTEM

The Power Tower systems, also known as Central Receiver systems, have more complex optics than the systems above because they are a 3-D concentration concept. A single solar receiver is mounted on top of a tower, and sunlight is concentrated by means of a large paraboloid that is discretized in a field of heliostats. Multi-tower systems also are under development. Power Tower systems make up 3 percent of total CSP installed capacity (Figure 24). However, this number is expected to increase in the near future because their actual share in the pipeline is higher.

Concentration factors for this technology range between 200 and 1,000. Plant unit sizes could range between 10 and 200 MW and therefore are suitable for dispatchable markets. Integration in advanced thermodynamic cycles also is feasible.

Figure 30 | Functional Scheme of a Power Tower System, Using Molten Salt as HTF, with TES



Although less mature than the Parabolic Trough technology, after a proof-of-concept stage, the power tower is taking its first steps into the market with three commercial plants in operation in southern Spain: PS10 and PS20 (11 and 20 MWe, using saturated steam as heat transfer fluid) and Gemasolar (17 MWe, using molten salts as HTF). Sierra SunTower, a 5-MWe plant in Lancaster, California (US), started operation in 2009 using a multi-tower Solar Field.

To date, more than 10 different experimental power tower plants have been tested worldwide, generally small demonstration systems between 0.5 and 10 MWe. Most of them operated in the 1980s.

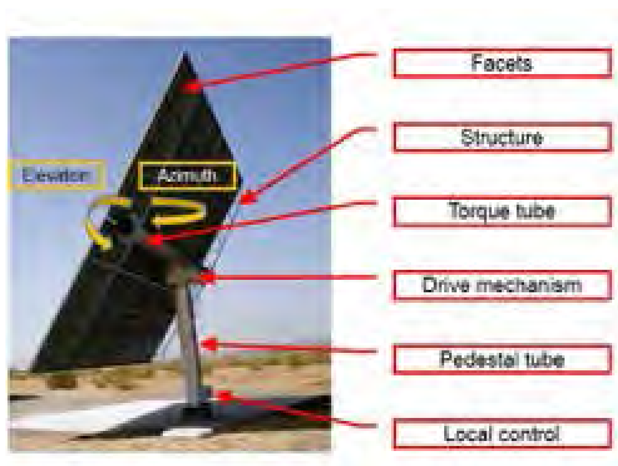
A wide variety of heat transfer fluids such as saturated steam, superheated steam, molten salts, atmospheric air, or pressurized air can be used. Temperatures vary between 200 ºC and 1,000 ºC.

Falling particle receiver and beam-down receiver are other promising technologies but are further from the market.

A power tower Solar Field comprises a variable number of identical heliostats, which reflect the sunlight toward the receiver. The heat transfer fluid temperature will reach 250 to 700 ºC, depending on whether the HTF used is air, steam, molten salt, or other. The main components of a power tower Solar Field are:

- **Mirrors:** Reflecting the direct solar radiation incident on them and concentrating it onto the Receiver, they sometimes are referred to as "facets." The mirrors are made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness. They are almost identical to the mirrors for Parabolic Trough, differing only in size and shape. Although small heliostats can be made of flat glass, a slight curvature is necessary[15] for larger sizes.
- **Receiver**[16]: Collects the radiation reflected by the heliostats and transfers it to the HTF in the form of heat. It is the real core of a power tower system. It is the most technically complex component because it has to absorb the incident radiation under very demanding concentrated solar flux conditions and with minimum heat loss. Receivers can be classified either by their configuration, as flat or cavity systems; or by their technology, as tube, volumetric, panel/film and direct absorption systems. Super Alloys or ceramics are the usual material for receivers.
- **Structure and Tracker:** The solar tracking system changes the position of the mirrors on the heliostats, following the apparent position of the sun during the day and allowing concentrating the solar radiation onto the Receiver. Each heliostat performs a two-axis tracking with a drive that rotates the mirrors, and a local control that governs it. The structure, in turn, must keep the shape and relative position of the elements, transmitting the driving force from the tracker, and avoiding deformations caused by their own weight or other external forces such as the wind.

Figure 31 | Main Components of a Heliostat



Source: Photo courtesy of PSA-CIEMAT.

15. Due to nonideal optics, as the sun is not a point focus.

16. The receiver has been included in the Solar Field to keep an analogous structure for all CSP technologies, although in Power Tower systems, it is physically within the power block.

The Power Block of a Power Tower CSP plant resembles that of a Rankine-cycle power plant. The main difference is that, instead of a combustion or nuclear process, the heat used to generate superheated steam is collected in the Solar Field and transferred using a heat transfer fluid. The main components of the Power Block are:

- **Condenser:** It is analogous to the equipment described for Parabolic Trough plants.
- **Electrical generator**: It is analogous to the equipment described for Parabolic Trough plants.
- **Heat exchanger:** Two different sets of heat exchangers are required in the Power Block. First, HTF-water heat exchangers (usually referred to as SGS, or Steam Generation System) are required to generate the high-pressure and high-temperature steam that will drive the Turbine. This set will not be necessary if steam is used as HTF. Second, water-water heat exchangers are used to recover the heat from turbine bleeds to preheat the condensate or feed water, thus increasing the Rankine cycle efficiency. If a molten salt TES system is included, a reversible, molten salt-HTF heat exchanger also is necessary, unless the very molten salt is used as HTF. Carbon steel and stainless steel are required for their manufacture, as well as copper and aluminum in smaller amounts.
- **Pumps:** It is analogous to the equipment described for Parabolic Trough plants.
- **Steam turbine:** It is analogous to the equipment described for Parabolic Trough plants.
- **Storage tanks:** It is analogous to the equipment described for Parabolic Trough plants.

The state of the art in the field of Thermal Energy Storage (TES) is to use molten salts. The most common mixture used for this purpose, "Solar salt" is composed of sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3). As described above, this salt is stored in two tanks (one "cold" and one "hot"), and a reversible heat exchanger is used to move energy from the Solar Field and to the Power Block. This heat exchanger is not necessary if the molten salt is used directly as HTF.

Other elements also are necessary, such as piping, insulation, electric switchgear, and water treatment equipment. However, these elements are either not specific to CSP technology or comprise a minor fraction of the investment costs, and thus have been omitted from this report.

2.2.4 DISH/ENGINE SYSTEM

These systems are small modular units with autonomous generation of electricity. In other words, each Dish/Engine set has its own Solar Field and Power Block, except for the power regulation switchgear.

These systems are parabolic three-dimensional concentrators (thus requiring 2-axes tracking) with high concentration ratios (600–4,000), and a Stirling engine or Brayton mini-turbine located at the focal point, using hydrogen, helium, or air as working fluid. Current Dish/ Engine systems range from 3 kWe (Infinia) to 25 kWe (Tessera Solar). Their market niche is both in distributed/on-grid and remote/off-grid power applications.

Because the design of Dish/Engine systems is modular, they can compete with PV to serve the same applications. Typically, stand-alone PV systems are being used for rural electrification or electricity supply in remote water pumping stations. Power capacity in these kinds of applications normally ranges from a few tenths to several hundred kilowatts.

However, besides the higher investment costs for Dish/Engine compared to photovoltaic systems, other concerns need further technical development, for instance, engine reliability.

Two decades ago, Dish/Engine Stirling systems, with concentration factors of more than 3,000 suns and operating temperatures of 750 ºC, already had demonstrated their high conversion efficiency at annual efficiencies of 23 percent and 29 percent peak (Stine and Diver 1994). However, Dish/Engine systems have not yet surpassed the pilot project plant operation phase.

Figure 32 | Main Components of a Dish/ Engine System

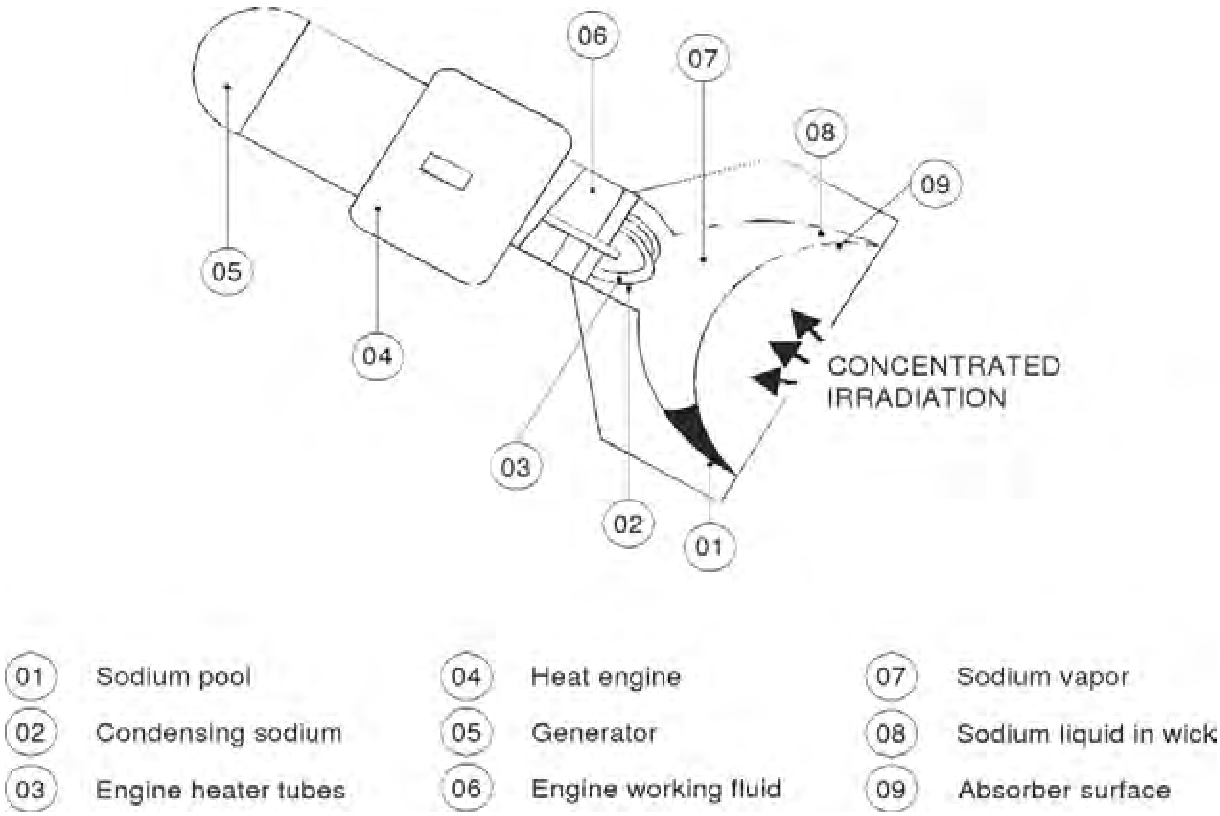
Source: Photo courtesy of PSA-CIEMAT.

A Dish/Engine Solar Field comprises a variable number, from one to dozens, of reflective elements or "facets" in the shape of a paraboloid or "dish." Each dish can rise the temperature of a certain amount of working fluid from the "cold" to the "high" operation temperature (up to 850 ºC). The main components of a Dish/Engine solar collector are:

- **Mirrors:** Reflect the direct solar radiation incident on them and concentrate it onto the Receiver placed in the focal point of the dish. The mirrors can be made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness and parabolic shape. They are similar to the mirrors for Parabolic Trough, differing in size and shape. Although small facets can be made of flat glass, a slight curvature is necessary[17] for larger sizes. A different approach can use a reflective layer coating a flexible film, which is given the parabolic shape through vacuum.
- **Receiver:** Dish/Engine receivers can be smaller versions of those used in Power Tower systems. However, simpler versions exist adapting the heater tubes of a Stirling engine, although it is hard to integrate multiple cylinder engines (Adkins and others 1999). On the other hand, liquid-sodium, heat-pipe solar receivers solve this issue by vaporizing liquid sodium on the absorber surface, which condenses on the engine's heater tubes. This system enables the receivers to reach more uniform temperatures, although complexity and cost are higher as well.
- **Structure and Tracker:** The solar tracking system changes the position of the collector following the apparent position of the sun during the day, thus allowing concentrating the solar radiation onto the Receiver. Each collector performs a two-axes tracking with a drive that rotates both the dish and the Receiver, and a local control that governs it. The structure, in turn, must keep the shape and relative position of the elements, transmitting the driving force from the tracker, and avoiding deformations caused by their own weight or other external forces such as the wind. The high precision required, together with the weight of the set receiver plus engine, and the necessity to prevent the "arm" holding the receiver from blocking too much light make this a demanding task.

17. Due to nonideal optics because the sun is not a point focus.

Figure 33 | Schematic Showing the Operation of a Heat-Pipe Solar Receiver



Source: Adkins and others 1999.

The Power Block of a Dish/Engine CSP collector is a compact set comprising the Receiver described above plus either a Stirling engine, or a Brayton turbine and a compressor. The main components of the Power Block are:

- **Electrical generator:** Induction generators are used on Stirling engines tied to an electric utility grid. They are off-the-shelf items and can provide single or three-phase power with high efficiency. For turbines, a different approach might be advisable. The high-speed output of the turbine can be converted to high frequency alternate current in a high-speed alternator, converted to direct current by a rectifier, and then converted to 50 Hz or 60 Hz power by an inverter.
- **Heat exchanger:** No heat exchanger is necessary per se because the heat transfer takes place at the engine heater tubes.
- **Turbine** or engine: Design and manufacturing of a turbine and compressor for a Brayton cycle requires special materials and alloys and a highly specialized workforce. These are available to only a limited number of companies around the world. In this case, however, the small size of the equipment required increases the range of possible manufacturers. Stirling engines are less demanding, and the main expected issue (the high precision required in the piston fabrication) is probably solvable if the country has motor vehicle industries. Carbon steel, stainless steel, and special alloys are required for its manufacture.

Dish/Engine systems have not been conceived with Thermal Energy Storage as a guiding principle, although experimental approaches using thermochemical energy storage have been made (García Iglesias 2012).

Other elements also are necessary, such as wiring, insulation, and electric switchgear. However, these elements are either not specific to CSP technology or comprise a minor fraction of the investment costs, and thus have been omitted from this report.

2.3 Photovoltaic (PV) Value Chain

This group of technologies converts solar energy directly into electricity using the photovoltaic effect. When solar radiation reaches a semiconductor, the electrons present in the valence band absorb energy and, being excited, jump to the conduction band and become free. These highly excited, nonthermal electrons diffuse, and some reach a junction in which they are accelerated into a different material by a built-in potential (Galvani potential). This acceleration generates an electromotive force, thus some of the light energy is converted into electric energy. Unlike CSP, solar PV can use all radiation (direct and diffuse) that reaches the system.

The basic building block of a PV system is the PV cell, which is a semiconductor layer that converts solar energy into direct-current electricity. PV cells are interconnected to form a PV module, typically 50-200 Watts (W). The PV modules combined with a set of additional application-dependent system components (such as inverters, batteries, electrical components, and mounting systems), form a PV system. PV systems are highly modular, that is, modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW).

R&D and industrialization have led to a portfolio of available PV technology options at different levels of maturity. Commercial PV modules may be divided into two broad categories: waferbased crystalline silicon (cSi) and thin films.

An overview of the main PV technologies follows:

- Crystalline silicon (cSi) modules
  - Single-crystalline silicon (scSi)
  - Multi-crystalline silicon (mcSi)
- Thin Film (TF) modules:
  - Amorphous (aSi) and Micromorph (μcSi) silicon
  - Cadmium-Telluride (CdTe)
  - Copper/Indium Sulfide (CIS) and Copper/Indium/Gallium di-Selenide (CIGS).

Although thin films are relatively new to the PV industry, they are reaching noticeable market share. Their rise has been slowed in recent years due to a decrease in silicon prices, but they have kept a stable market share despite the PV market growth (Fraunhofer ISE 2012).

Conversion efficiency, defined as the ratio between the produced electrical power and the amount of incident solar energy per second, is one of the main performance indicators of PV cells and modules. Table 11 lists the current efficiencies of different PV commercial modules.[18]

TABLE 11 | CONVERSION EFFICIENCIES OF DIFFERENT PV COMMERCIAL MODULES (%)

Crystalline silicon (c-Si)		Thin film (TF)		
sc-Si	mc-Si	a-Si/ Qc-Si	CdTe	CIS/ CIGS
14-20	13-15	6-9	9-11	10-12

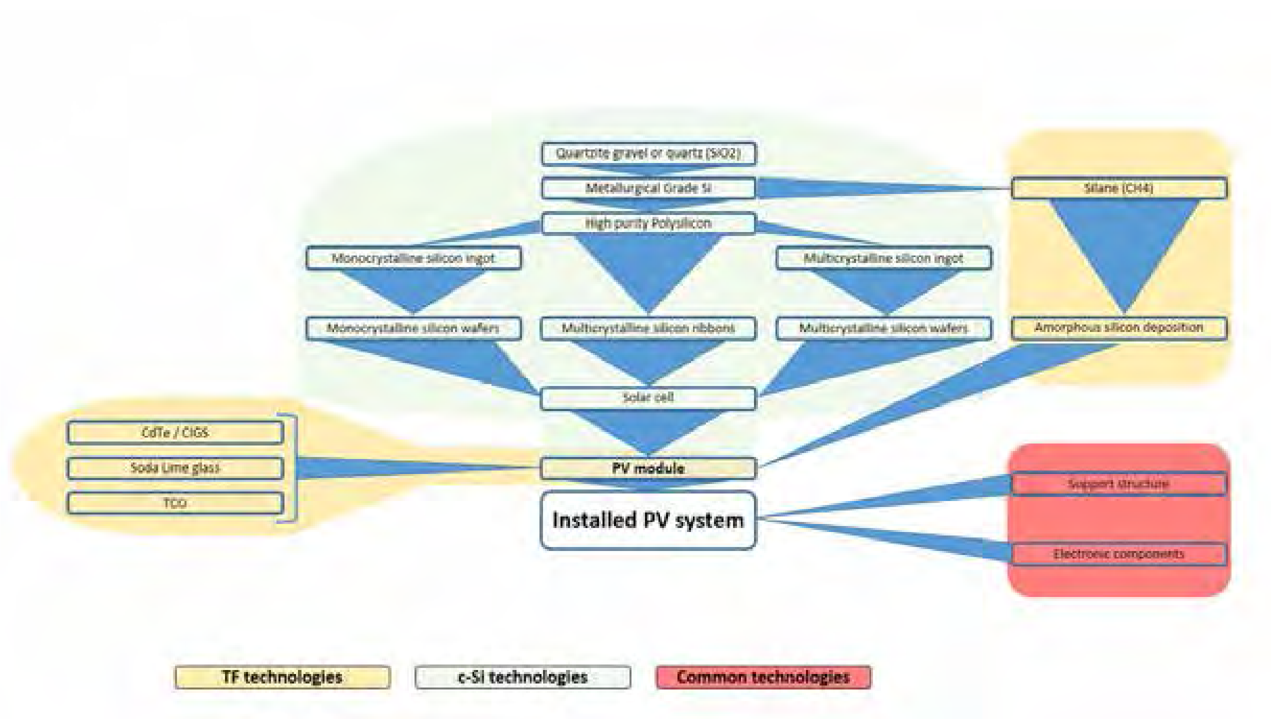
Source: Frankl and Nowak 2010.

18. This is the range of optimum values. When selecting a technology influence of angle, temperature, and diffuse direct irradiation share must be compared. A one-year simulation of the system is recommended.

The large variety of PV applications enables a range of different technologies to be present in the market, with a direct correlation between cost and efficiency. Note that the lower cost (per watt) to manufacture some of the module technologies, namely, thin films, is partially offset by the higher area-related system costs (support structure, required land, and wiring, due to their lower conversion efficiencies).

Chips for electronic devices share many of the resources and manufacturing processes with PV elements, especially if silicon-based. However, the purity level required for solar cells is "five nines" (99.999 percent Si), whereas electronicgrade silicon must be "nine nines."

Figure 34 | PV Solar Energy Value Chain



2.3.1 CRYSTALLINE SILICON TECHNOLOGIES

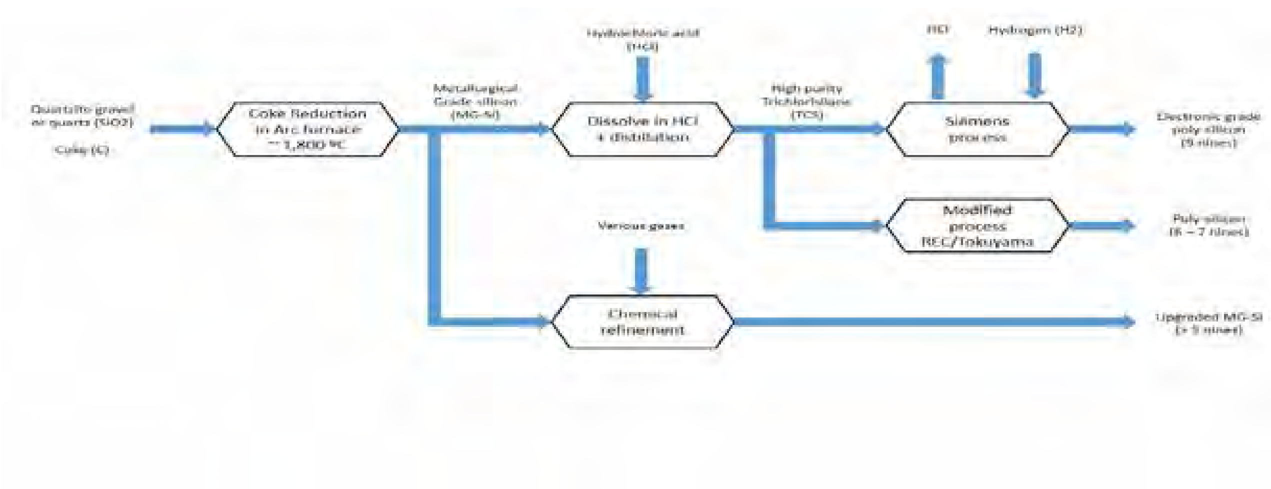
2.3.1.1 POLYSILICON

In the first step to make solar cells, the **raw materials**—silicon dioxide of either quartzite[19] gravel (the purest silica) or crushed quartz—are first placed in an electric arc furnace, to which a carbon arc is applied to release the oxygen. This simple process yields commercial brown Metallurgical Grade silicon (MG-Si) of 97 percent purity or better, useful in many industries but in not the solar cell industry.

MG-Si is **purified** by converting it to a silicon compound that can be more easily purified by distillation than in its original state, and then converting that silicon compound back into pure silicon. Trichlorosilane (TCS, $HSiCl_3$) is the silicon compound most commonly used as the intermediate, although silicon tetrachloride ($SiCl_4$) and silane (SiH_4) also are used. As an example, in the **Siemens process** (Schweickert 1957), high-purity silicon rods are exposed to trichlorosilane at 900 to 1,150 ºC. Electronic-grade purity silicon can be obtained; however, to do so, requires an expensive reactor as well as a great amount of energy.

In 2006 **REC** (Renewable Energy Corporation ASA) announced **construction of a plant based on fluidized** bed technology using silane. This process operates at lower temperature and does not generate by-products. Furthermore, unlike the Siemens Process, which is a batch process, this process uses fluid bed technology which can be run continuously. The purity is lower but is still enough for solar applications. Other similar processes exist with different advantages and drawbacks. Examples are the Vapor-to-Liquid Tokuyama deposition; or even totally different chemical refinement processes starting with MG-Si that blow different gases through the silicon melt to remove the impurities.

Figure 35 | Polysilicon Manufacturing Value Chain



19. Quartzite, not to be confused with the mineral quartz, is a metamorphic rock formed from quartz-rich sandstone that has undergone metamorphism.

2.3.1.2 INGOTS/WAFERS

Solar-grade purified polysilicon can be cast into square ingots and undergo the wafering process to directly produce mc-Si cells. For sc-Si cells manufacturing, the atomic structure of the silicon must be dealt with first.

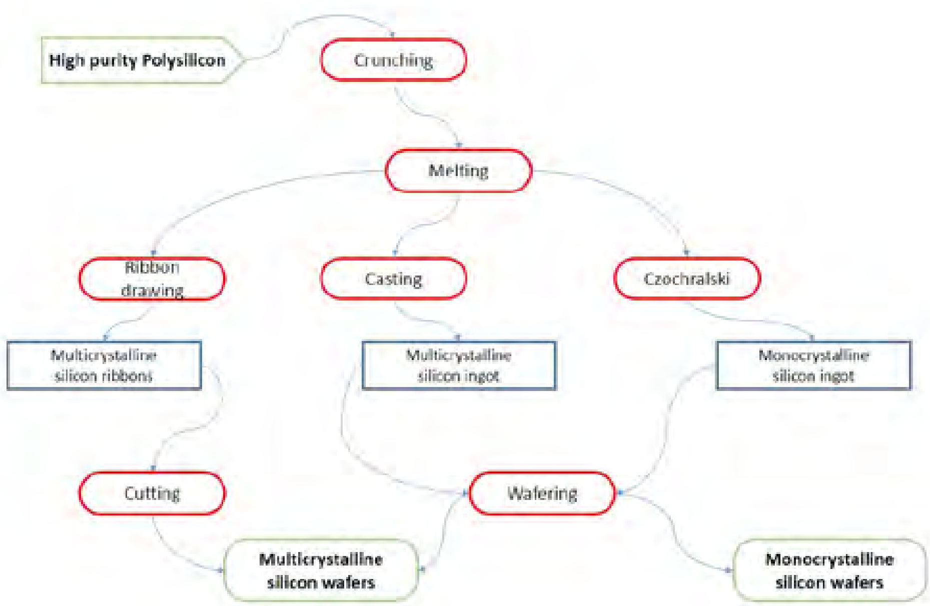
In the more widely used (Bullock and Grambs 1981) **Czochralski method,** the pure polysilicon is melted again. Then a silicon seed single-crystal is put into a Czochralski growth apparatus, where it is dipped in a crucible of molten silicon. The seed crystal rotates as it is withdrawn, forming a cylindrical "ingot" or "boule" of very pure silicon with a singular crystal orientation.

The **wafering** process starts from the ingot, either single-crystal or poly-silicon. Wafers are sliced with a multi-wire saw. A **diamond saw** produces cuts that are as wide as the wafer—0.5 millimeter thick. About one-half of the silicon is lost[20] from the ingot to the finished circular wafer—more if a single-crystal wafer is then cut to be rectangular or hexagonal.

The wafers are then **polished** to remove saw marks; state-of-the-art manufacturing processes try to optimize light absorption by surface micromachining of the polished wafer.

Doping the wafers is required for cell manufacturing.[21] However, certain doping techniques must be undergone during ingot manufacturing. For crystalline silicon, some dopants can be added in the crucible during the Czochralski process. The **doping of polycrystalline silicon** does have an effect on the resistivity, mobility, and free-carrier concentration. Nevertheless, these properties strongly depend on the polycrystalline grain size, which is a physical parameter that the material scientist can manipulate. Through the methods of crystallization to form polycrystalline silicon, an engineer can control the size of the polycrystalline grains, thus varying the physical properties of the material.

Figure 36 | Ingot/Wafer Manufacturing Value Chain



20. Silicon waste from the sawing process can be recycled into polysilicon, but a greater part of the energy is not recovered.

21. Doping means the introduction of impurities into the semiconductor crystal to deliberately change its conductivity due to deficiency or excess of electrons." Wikipedia, http://www.halbleiter.org/en/waferfabrication/doping/.

2.3.1.3 C-SI CELLS

Single-crystal wafer cells tend to be expensive, and because they are cut from cylindrical ingots, do not completely cover a square solar cell module without a substantial waste of refined silicon. On the other hand, multicrystalline silicon or polycrystalline silicon (mc-Si or poly-Si) is made from cast square ingots, large blocks of molten silicon carefully cooled and solidified. These cells are less expensive to produce than single-crystal silicon cells but also are less efficient.

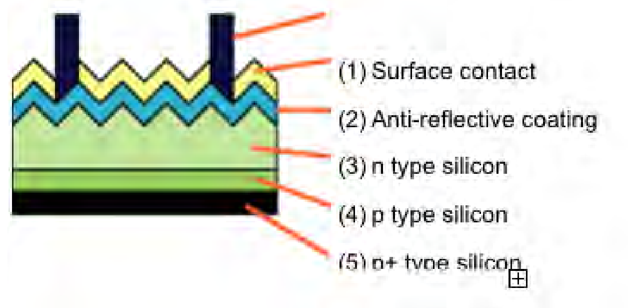
The single-crystal wafers usually are lightly p-type doped. To make a solar cell from the wafer, a surface diffusion of n-type dopants (boron and/or phosphorus) is performed on the front side of the wafer. This forms a p–n junction a few hundred nanometers below the surface.

One of the key processes in silicon surface micromachining is the selective **etching** of a sacrificial layer to release silicon microstructures. Improving the surface texturing is one of the factors required to increase the solar cell short-circuit current, and hence the solar cell conversion efficiency due to the enhanced absorption properties of the silicon surface (Xiao and Xu 2011).

Because pure silicon is shiny, it can reflect up to 35 percent of the sunlight. To reduce the amount of sunlight lost, an **anti-reflective coating** is put on the silicon wafer. The most common coatings used to be titanium dioxide and silicon oxide. However, silicon nitride is gradually replacing them as the anti-reflection coating because of its surface passivation qualities. Actual commercial solar cell manufacturers use silicon nitride because it prevents carrier recombination at the surface of the solar cell.

The wafer then has a full area **metal contact** made on the back surface. The rear contact also is formed by screen-printing a metal paste, typically aluminum. The paste is then fired at several hundred degrees Celsius to form metal electrodes in ohmic contact with the silicon. A grid-like metal contact made up of fine "fingers" and larger "bus bars" are screen-printed onto the front surface using a silver paste. After the metal contacts are made, the solar cells are given connections such as flat wires or metal ribbons and **encapsulated**, that is, sealed into silicone rubber or ethylene vinyl acetate (EVA).

Figure 37 | c-Si Cell Structure



2.3.1.4 C-SI MODULES

The encapsulated solar cells are interconnected and placed into an aluminum frame that has a BoPET (Biaxially oriented Poly-Ethylene Terephthalate) or PVF (Poly-Vinyl Fluoride) back sheet and a glass or plastic cover. Front and rear connections are channeled through the junction box.

2.3.2 THIN-FILM TECHNOLOGIES

2.3.2.1 TF MODULES

Three main types of thin-film modules can be described: thin-film silicon[22] (TF-Si), cadmium telluride (CdTe), and copper-indium-(gallium) amphid films (CIS/CIGS).

Unlike crystalline modules, the manufacturing process of thin-film modules is a single process that cannot be split. Two different manufacturing approaches can be considered:

22. Three different technologies lie within this term: amorphous silicon (a-Si), micromorph silicon (mc-Si), and tandem thin films (a-Si + mc-Si). The third is the most advanced development.

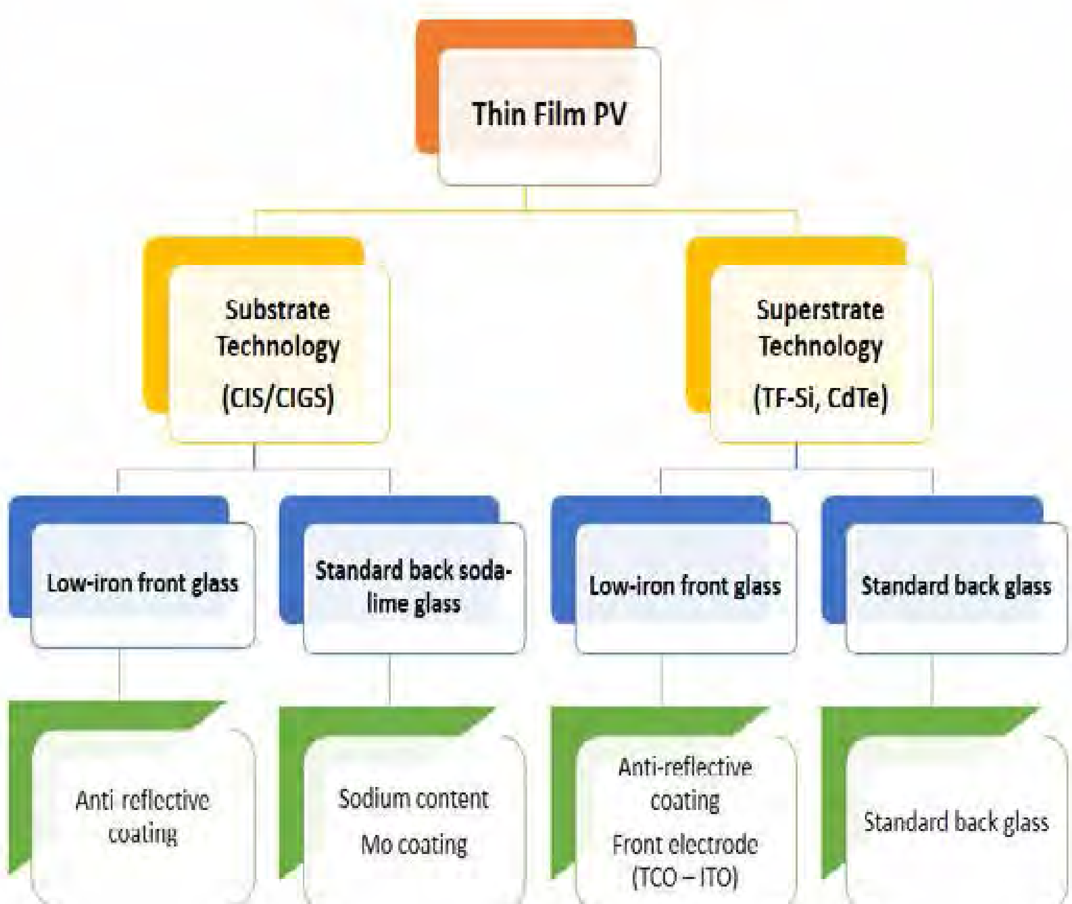
- **"Superstrate" approach:** For CdTe and TF-Si modules, the manufacturing process starts on the front glass superstrate.
- **"Substrate" approach:** For CIS/CIGS modules, the manufacturing process starts on the rear soda lime glass substrate.

CIS/CIGS and, in some recent developments, TF-Si can be manufactured on a transparent conductive organic film instead of on glass by means of low-temperature deposition techniques. The resulting flexible modules are especially useful for building-integrated applications (BIPV).

2.3.2.2 SOLAR GLASS

Solar glass can be defined depending on the final use (Figure 38).

Figure 38 | Types of Solar Glass



General requirements can be defined for any of the following applications:

- Tight tolerances in overall dimensions, warp
- Surface quality, smoothness and planarity to avoid coating problems
- Edge shape and quality required for assembly
- Durability and small loss of properties with aging
- Reliability and repeatability.

2.3.2.3 TF MATERIALS

The main materials required for TF modules are:

- **Transparent conductive oxides** (TCO): Tin and/or zinc oxides, with dopants such as cadmium or aluminum. Indium tin oxide (ITO, or tin-doped indium oxide) yields a better performance, but its cost also is higher.
- **Molybdenum:** Mined as a principal ore, and also is recovered as a byproduct of copper and tungsten mining.
- **Cadmium sulfide** (CdS): Occurs in nature as rare minerals, but is more prevalent as an impurity substituent in similarly structured zinc ores, which are the major economic sources of cadmium.
- **Cadmium telluride** (CdTe): Does not occur in nature and is obtained from its base elements, cadmium and tellurium. Cadmium occurs as a minor component in most zinc ores and therefore is a byproduct of zinc production. The principal source of tellurium is from anode sludge produced during the electrolytic refining of blister copper.
- **Cadmium chloride** ($CdCl_2$): Does not occur in nature. Anhydrous cadmium chloride can be prepared by the action of anhydrous chlorine or hydrogen chloride gas on heated cadmium metal.
- **Copper sulfide** (CuS): Copper sulfides describe a family of chemical compounds and minerals with the formula Cu_xS_y, both minerals and synthetic.
- **Selenium** precursors: Selenium is found impurely in metal sulfide ores, in which it partially replaces the sulfur.
- **Indium** precursors: Zinc ores are the primary source of indium, in which it is found in compound form.
- **Gallium** precursors: Do not occur in nature, but as the gallium (III) compounds in trace amounts in bauxite and zinc ores.

2.3.3 COMMON TECHNOLOGIES

2.3.3.1 SUPPORT STRUCTURE

The structure must keep the shape and relative position of the modules, avoiding deformations caused by their own weight or other external forces such as the wind; and transmit the driving force from the tracker, if included. Welded, hot-dip galvanized carbon steel frames are the usual choice, although aluminum structures can be used in building-integrated applications for which weight is an issue.

2.3.3.2 INVERTER

An electrical power converter changes direct current to alternating current. Solid-state inverters have no moving parts. They are used in a wide range of applications from small switching power supplies in computers to large electric utility high-voltage direct current applications that transport bulk power.

Grid-tied inverters are designed to inject electricity into the electric power distribution system. Such inverters must synchronize[23] with the frequency of the grid, and include safety features such as anti-islanding protection.

The manufacturing of the inverter is similar to any electronic device based on semiconductor technologies.

23. During the stakeholder interviews performed by the consultant group during the mission in Cairo, one stakeholder mentioned that European standard inverters could be troublesome when connected to the Egyptian grid and require reprogramming to comply with frequency tolerances.

2.4 Current Status of Manufacturing Value Chains

To assess the current status of the solar components value chains, five qualitative parameters have been considered:

- Technological maturity: Accumulated track record versus expectation of paradigmatic changes
- Number of competitors
- Upstream bottlenecks, either recent, current, or expected
- Geographic dispersion of manufacturing facilities
- coolDemand-to-offer ratio.

The robustness of the value chain is constrained by the lowest value obtained in the parameters. Under this definition of robustness, the most robust component value chain would be one in which the technology is sufficiently mature and established to enable its commercial development; in which production takes place in different countries rather than being limited to just 1 or 2 countries; in which there are enough competitors present to provide healthy competition but not so many as to lead to over-competition; in which the upstream value chain is well structured and unlikely to lead to bottlenecks; and in which the demand-to-offer ratio is stable or growing, rather than shrinking and troubled by overproduction.

The detailed criteria used for the assessment are presented in Table 12.

These criteria have been applied to each of the solar component manufacturing industries considered in this report. Results are shown in Table 13 and Table 14 for CSP and PV, respectively.

TABLE 12 | CRITERIA USED FOR THE QUALITATIVE ASSESSMENT

	Technological maturity	Number of competitors	Upstream bottlenecks	Geographic dispersion	Demand-to-offer ratio	Robustness
	Newcomer	Oligopoly	Shortage	Few	Shrinking	Weak
+	Demo	Several	Alternatives	Several	Stable	Medium
+ +	Established	Many	Unlikely	Many	Growing	Strong

TABLE 13 | QUALITATIVE ASSESSMENT OF MANUFACTURING VALUE CHAINS-CSP

		Technological Maturity	Number of Competitors	Upstream Bottlenecks	Geographical Dispersion	Demand-to-Offer Ratio	Robustness
CSP	Condenser	++	++	++	++	++	++
	Electrical Generators	++	+	++	+	++	+
	Heat Exchanger	++	++	++	++	++	++
	HTF Pumps	++	+	++	+	++	+
	HTF Oil	+	?	+	?	++	?
	Mirror	+	+	++	+	++	+
	Pumps	++	++	++	++	++	++
	Receiver	+	?	+	?	+	?
	Solar Salt	+	?	?	?	++	?
	Steam Turbine	++	?	++	+	++	?
	Storage Tank	++	++	++	++	++	++
	Structure & Tracker	+	++	++	++	++	++

TABLE 14 | QUALITATIVE ASSESSMENT OF MANUFACTURING VALUE CHAINS-PV

		Technological Maturity	Number of Competitors	Upstream Bottlenecks	Geographical Dispersion	Demand-to-Offer Ratio	Robustness
PV	Cells	++	+	?	++	?	?
	Ingots/Wafers	++	+	?	++	?	?
	c-Si Modules	++	++	?	++	?	?
	Polysilicon	++	+	++	+	?	?
	Solar Glass	+	+	++	++	+	+
	TF Materials	+	+	+	+	++	+
	TF Modules	+	++	+	++	++	?
	Inverters	++	++	++	++	++	++
	Structures	++	++	++	++	++	++

The following solar industries have been found to lack robustness:

- The **HTF oil** industry is dominated by a small number of competitors (large chemical companies such as Dow Chemical and Solutia) that focus their manufacturing facilities in a few countries.
- The Receiver industry is in a similar situation, being in hands of a few companies (Schott, Siemens-Solel) with scarce manufacturing facilities (some Chinese companies are entering the market). The manufacturing capacity grew rapidly, and the market has slowed. However, these trends can change if new CSP markets (for example, in MENA, South America, or China) start developing.
- The **Solar Salt** industry also is dominated by two main companies (SQM and Haifa) with manufacturing restricted to their respective countries. An additional drawback is that because solar salt is a mining product, it is not possible to change the manufacturing location in the medium or long term. This restriction could cause an upstream bottleneck if problems with production, transportation, or any other issues occur.
- The design and manufacturing of a **Steam Turbine** requires special materials and alloys and a highly specialized workforce, available to a limited number of companies globally.
- The **Cells, Ingots/Wafers,** and **c-Si Modules** industries suffer from similar problems. They have been constrained in the recent past by upstream bottlenecks due to silicon shortages. The industrial sector overcompensated this issue. Now the ratio Demand/Offer is shrinking, and there is overcapacity in the sector. Competitors are ready to cover actual and future demand without delay or incurring new investments.
- The **Polysilicon** industry also is suffering from the overcapacity in the c-Si sector.

At the international level, the remaining component industries can, in different degrees and based on differing strengths and weaknesses, be considered robust. The following chapter will evaluate Egypt's manufacturing base and potential competitiveness to participate in solar component manufacturing value chains. By cross-checking Egypt's assets with component industries' needs, this report will suggest a set of component industries to be developed in Egypt.

PART B | Detailed Assessment of Egypt's Existing Manufacturing Base and Its Potential to Participate or Dominate the Solar Component Manufacturing Value Chains

CHAPTER 3:

Egypt's Manufacturing Base and Potential to Participate in Solar Component Manufacturing Value Chains

3.1 Country Context

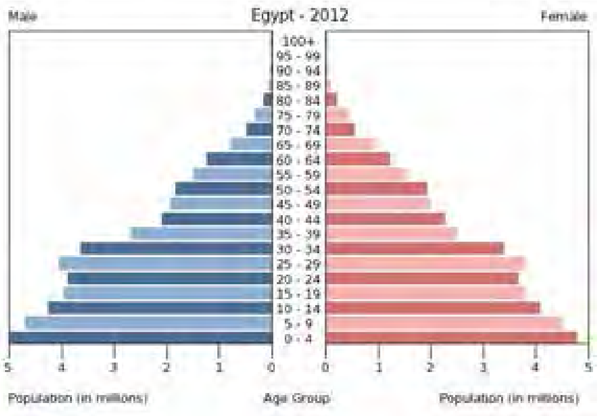
3.1.1 GEOGRAPHIC LOCATION

Egypt is located in Northern Africa. It borders the Mediterranean Sea between Libya and the Gaza Strip, and the Red Sea north of Sudan; and includes the Asian Sinai Peninsula. This location permits Egypt to have control of the Sinai Peninsula and Suez Canal and dominance over Nile basin issues.

3.1.2 POPULATION AND ECONOMY

Egypt is the third most populated country in Africa with more than 85 million people (U.S. CIA 2012) concentrated in 3 main areas: Cairo; Alexandria; and the Nile, the Nile Delta, and the Suez Canal. Egypt has a young population, with a median age of 24.6 years and 88.8 percent under 55 years old (U.S. CIA 2012). Men make up 50.6 percent of the population, and women 49.4 percent (U.S. CIA 2012).

Figure 39 | Egypt's Population Pyramid, 2012

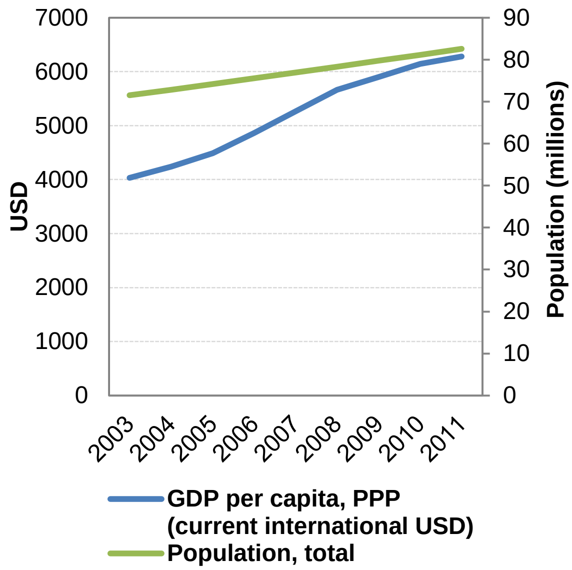


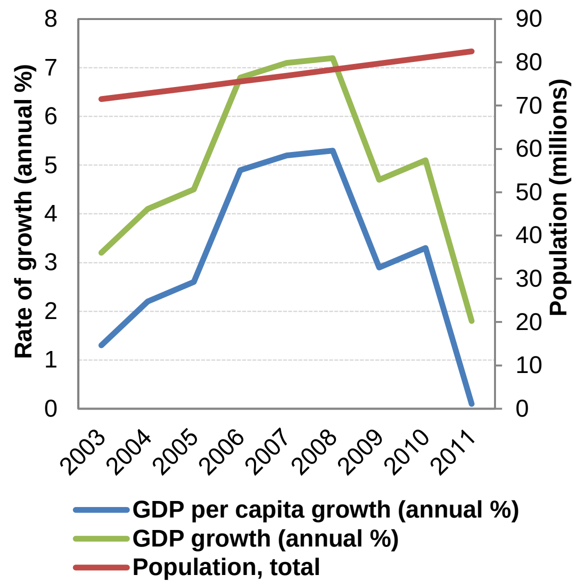
Source: U.S. CIA 2012.

With a GDP of US$229.5 billion, Egypt is the third largest economy in North Africa and the Middle East, after Saudi Arabia and the United Arab Emirates (World Bank 2012b). The Egyptian economy is diversified. About half of its GDP (47 percent) corresponds to the service sector, which includes the public sector, tourism, and the Suez Canal. Tourism is highly dependent on political developments in the area, which have had a negative impact since 2011. On the other hand, Egypt also has a large industrial sector, which contributes 37.4 percent of GDP and attracts foreign direct investment (FDI) (U.S. CIA 2012).

The constant and significant growth of the Egyptian population has been an obstacle to increasing GDP per capita. However, the good performance of the Egyptian economy over the fiscal years 2006-07 and 2007-08, during which growth exceeded 7 percent, led to significant increases in GDP per capita. However, due to the international financial crisis and to the country's political context, the rate of growth, while still positive, slowed to 1.8 percent in fiscal year 2010-11.

Figure 40 | Evolution of GDP (left) and Rate per Capita (right) in Egypt, 2003-11



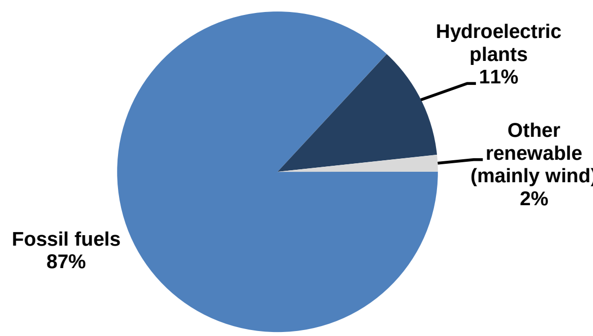


3.1.3 ELECTRICAL SECTOR

In 2009 Egypt had an electrification rate of approximately 99.6 percent (World Bank 2011). Although this is one of the highest rates in Africa, with 100 percent access to electricity in urban areas and 99.3 percent in rural areas, approximately 300,000 people in Egypt still lack access to electricity.

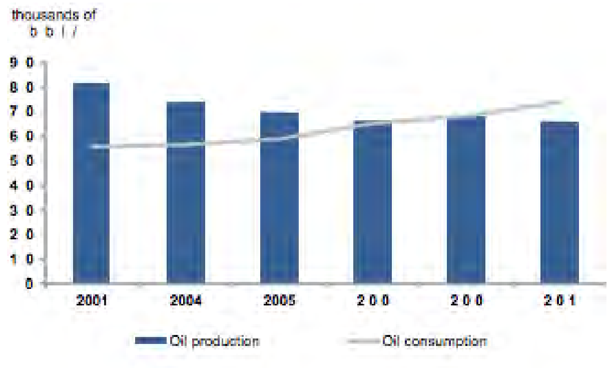
Egypt is the largest oil producer on the continent that is not member of the OPEC (Organization of Petroleum Exporting Countries). It also is the second largest natural gas producer in Africa after Algeria. In 2010 Egypt's electricity generation reached 137 billion kWh (U.S. EIA 2010). Nearly 90 percent of its electricity derived from traditional fossil fuels, with the remainder coming mainly from hydropower (Figure 41).

Figure 41 | Egyptian Electricity Generating Capacity Sources (%)



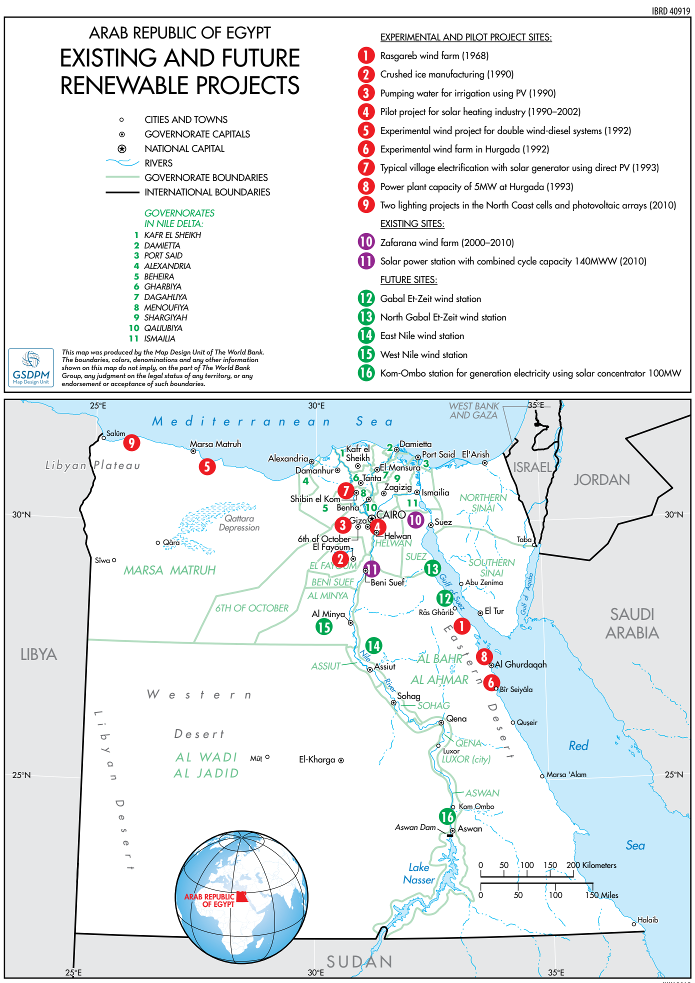
Despite being a production leader, Egypt's oil consumption is increasing much faster than its production. Domestic oil consumption has grown by over 30 percent during the last decade, leading to an increase in Egypt's imports of both crude oil and refined petroleum products. Egypt meets 95 percent (U.S. DOE NREA 2011) of its overall oil needs through production, importing the rest from third countries.

Figure 42 | Total Oil Production and Consumption in Egypt, 2001-10



Source: U.S. EIA 2010.

Figure 43 | Existing and Future Renewable Projects in Egypt



Source: Based on Egypt NREA 2011. Re-created by World Bank Cartography, July 2015.

Determined to diversify the energy mix and to improve the efficiency of electricity production, the Egyptian government is planning to invest in its power sector over the next decade. Under existing plans, Egypt hopes to produce 20 percent of its electricity from renewable energy by 2020, while also developing a nuclear power industry (U.S. EIA 2010).

3.1.4 CURRENT SITUATION

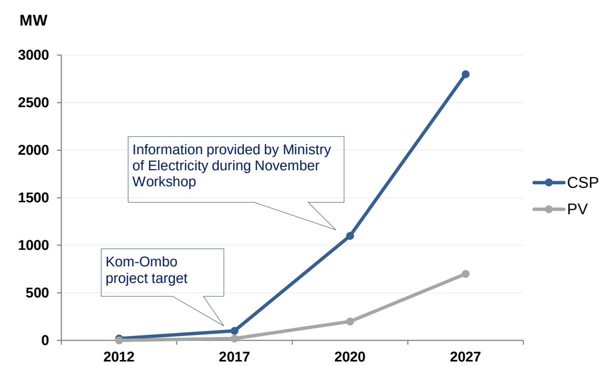
Egypt's economy is facing tough hurdles characterized by the growing budget deficit—which has grown by 59 percent in the last 5 years from 6.8 percent of GDP in 2008 to 10.8 percent of GDP in 2012—combined with the national currency devaluation, the drop in tourism and the reduction in foreign investment.

3.1.4.1 STRUCTURE OF THE SOLAR ENERGY SECTOR

Egypt possesses land, solar resource, and wind speeds that make suitable the development of renewable energies (REs) including wind, solar, and biomass. For solar energy development specifically, Egypt's maximum annual global horizontal irradiation (GHI) and direct normal irradiation (DNI) are equal to 6.6 kWh/m^2/day and 8.2 kWh/m^2/day, respectively. These rates are the highest in the MENA Region. In fact, Egypt is one of the areas with the best resource globally (U.S. DOE NREL n.d.). However, REs in Egypt are still a new market, with 550 MW of wind installed capacity and 20 MW[24] of solar thermal installed capacity (Egypt NREA 2011).

Egypt aims to increase the share of RE to 20 percent of the energy mix by 2020, which will include 12 percent through wind energy, 5.8 percent through hydro, and 2.2 percent through solar (Egypt NREA 2012). While the solar target was conservative until last year, in late 2012 the government announced the new, more ambitious targets of the 2027 Plan—2,800 MW of CSP and 700 MW of PV—as well as indicative intermediate targets for both technologies by 2020.

Figure 44 | Solar Energy Egyptian Target, 2012-27

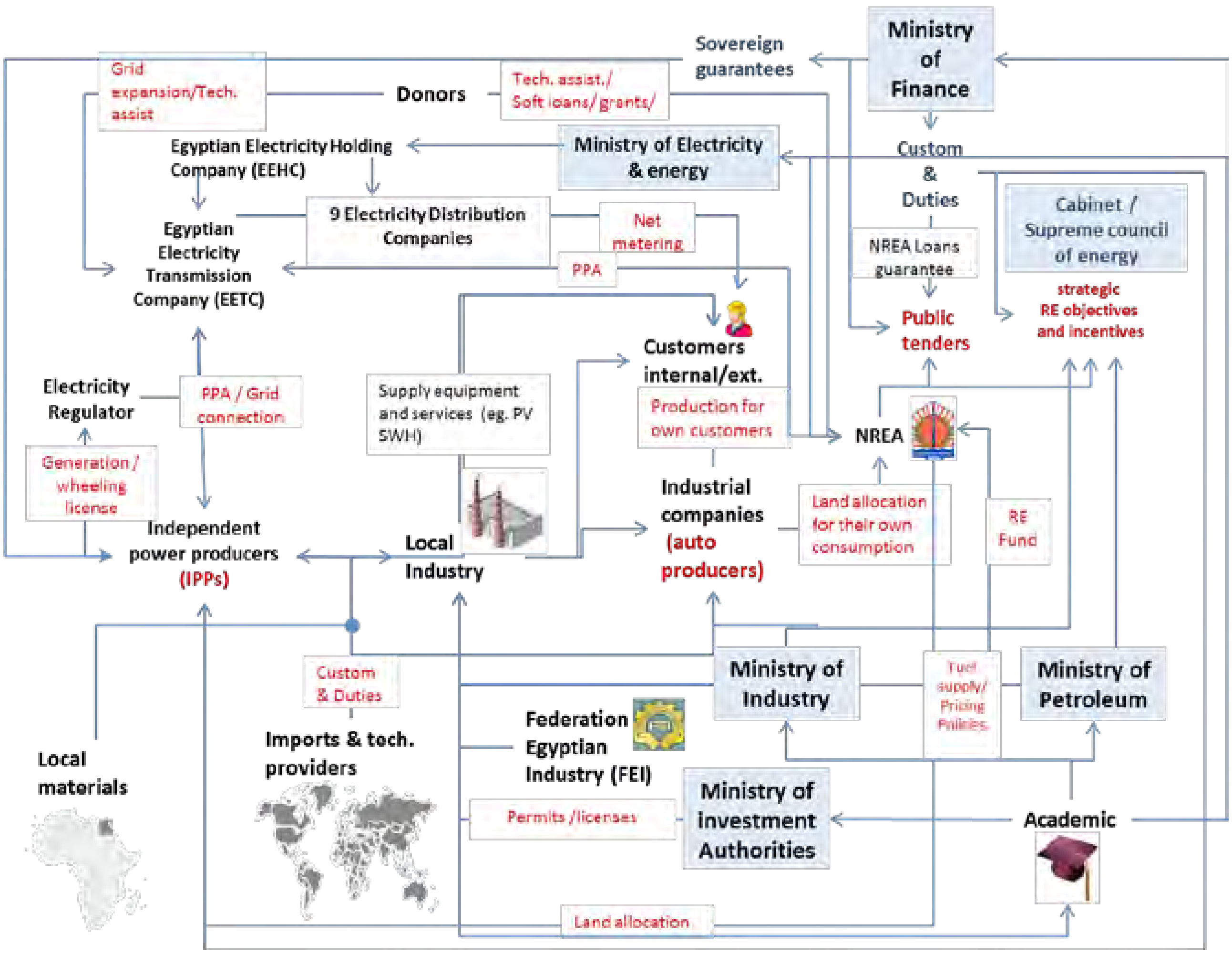


Source: Egypt NREA 2012.

Recent reports have highlighted that Egypt's solar development program still lacks a targeted vision and incentive system, as well as a specialized agency with the skills and experience to make the plan a reality (AfDB 2012). Nonetheless, Egypt's solar sector already has a significant number of active players (Figure 45).

24. As part of Kuraymat integrated solar combined cycle power plant.

Figure 45 | Map of Stakeholders Involved in the Solar Energy Sector



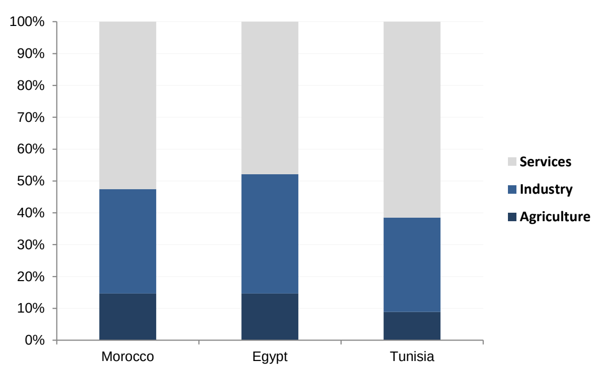
Of these actors, the policy makers play particularly key roles:

- The Ministry of Electricity and Energy (MoEE) is responsible for electricity generation, transmission, and distribution. It also recommends the pricing of electricity to the cabinet for the pricing of petroleum products to be recommended by the Ministry of Petroleum (MOP).
- The New and Renewable Energy Authority (NREA) falls under the umbrella of the MoEE. NREA is a specialized energy agency that has developed solar energy projects in the past, including the hybrid plant, Kuraymat, which has capacity for 20 MW solar and 120 MW natural gas.

3.2 Egyptian Industrial Sector

Unlike other African economies, Egypt has a low dependency on agricultural production. It has a diverse industrial sector dominated by the steel industry, automobile, construction, and consumer goods (Figure 46).

Figure 46 | GDP Composition by Sector (%)



Source: U.S. CIA 2012.

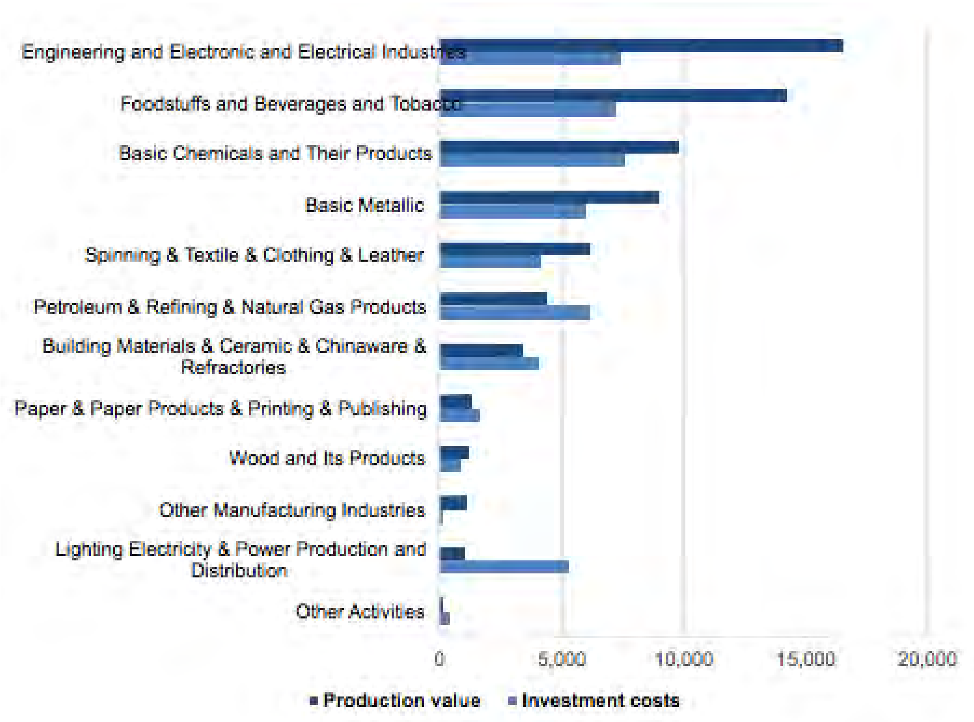
In 2012, 37.4 percent of Egypt's GDP was due to the industrial sector, almost 5 percent more than in Morocco and 8 percent more than in Tunisia.

At the same time, Egypt has a developed service sector. This sector, although it is not the focus of this study, is worth mentioning because of the country's important trajectory in plant engineering. The latter has been developed largely through companies including PGESCo and EPS, and construction services through companies including Orascom. The presence of such companies is a singularity in the Middle East and North Africa (MENA) Region so may help Egypt become a Regional supplier of services in the solar industry as well as a manufacturer of selected solar component industries.

Figure 46 shows the key sectors of industrial activity in Egypt, whose total production value totaled US$4,278,000 in 2009 (Egypt IDA 2009).

Industrial sector production values in Egypt vary widely by activity (Figure 46). The total production values of the engineering and electronic and electrical industries double the investment costs. In contrast, production values for the electricity and power production and distribution industry are approximately five times less than the investment costs of the same industry (Egypt IDA 2009).

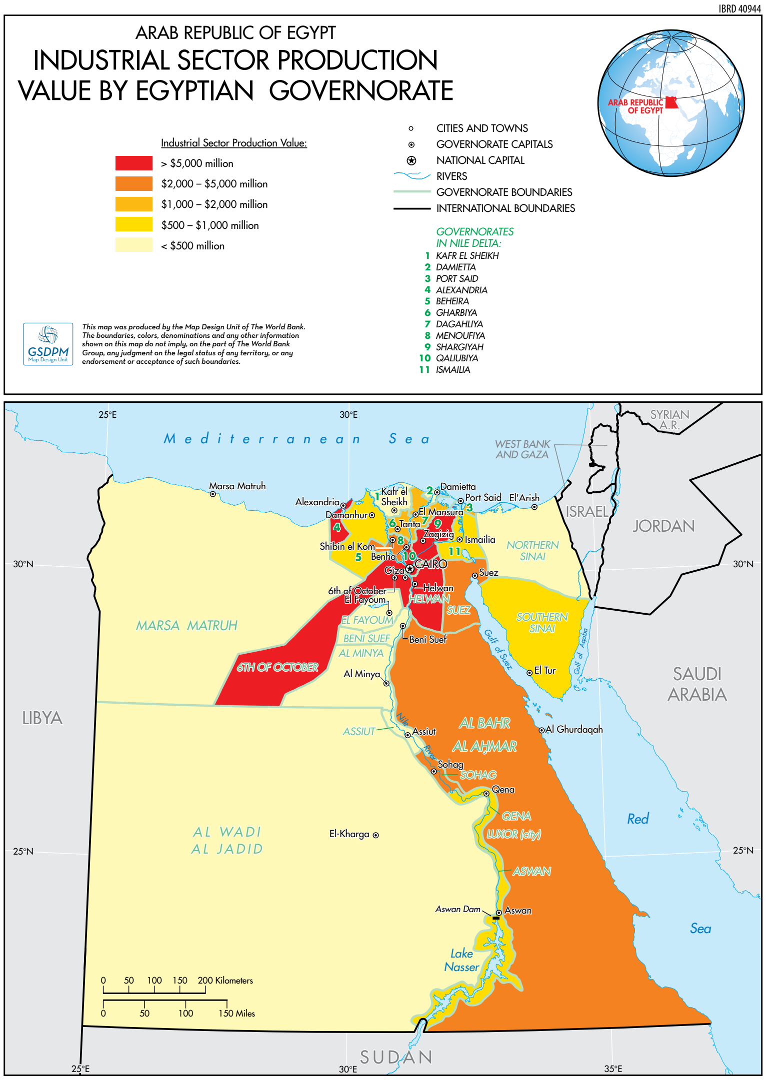
Figure 47 | Production Value and Investment Costs According Activities



Source: Egypt IDA 2009.

Geographically, in 2009, only 5 governorates—Cairo, Alexandria, Giza, Qalyubia, and Al Shariquia—contributed more than 68 percent of the total production value for the industrial sector (Figure 48).

Figure 48 | Industrial Sector Production Value by Egyptian Governorate (US$)



Source: Egypt IDA 2009. Re-created by World Bank Cartography, July 2015.

3.2.1 IMPORTS AND EXPORTS

A diversified industrial sector and strategic location that controls the Sinai Peninsula and Suez Canal has enabled Egypt to become a major North African economic power.

Egypt's economy depends on petrochemical exports to European nations, which are a major source of its foreign income. Since 2007, petroleum exports have increased by 17.5 percent per year, reaching US$30.8 billion in 2011. However, total imports increased by 21.7 percent each year, reaching US$59.3 billion in 2011, resulting in a trade deficit of US$28.5 billion (UN Comtrade n.d.). Figure 49 shows this shift in the trade balance.

Egypt's main exported commodities are petroleum products, petroleum oils (other than crude), petroleum gases and other gaseous hydrocarbons and petroleum oils, and oils obtained from bituminous minerals. Its top export partners are India, Italy, and Saudi Arabia.

Figure 49 | Egypt's Total Imports, Exports, and Trade Balances, 1997-2011 (US$ bil)

Source: UN Comtrade n.d.

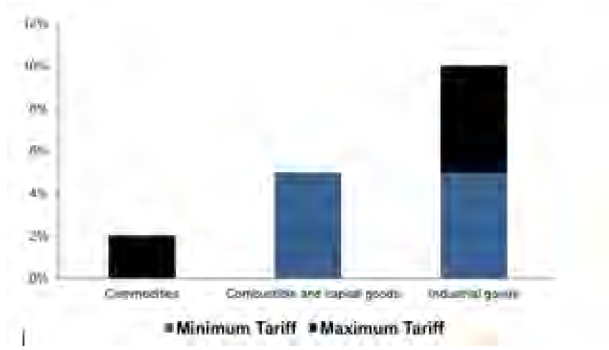
Egypt has little local capacity in the solar sector to date (20 MW Kuraymat plant). However, due partly to the availability of materials and related industries, Egypt has the potential to develop local manufacturing for different components in the solar value chain. In this context, the following industries are detailed below: steel, float glass, high technology and inverters, heat exchangers, pumps, storage tanks, and condensers.

3.2.2 MATERIAL FOR SOLAR COMPONENT: STEEL

Egypt has the largest steel industry in Africa and Middle East. The country produces locally three main types of steel: carbon steel, stainless steel, and special steel. After several years of strong demand growth, steel consumption in Egypt has decreased, leaving the potential supply higher than demand. Due to this situation in the steel market, and to protect the local economy, Egypt had reduced its import tariffs for most industrial products in 2004.

Nevertheless, in 2012 the Ministry of Industry and Foreign Trade announced that protective tariffs of 6.8 percent would be applied temporarily on imported steel rebars (Ahramonline 2012).

Figure 50 | Egyptian Import Tariffs, 2010 (%)



Source: AFI 2010.

The market leader in Egypt is Ezz Steel.

TABLE 15 | EXAMPLES OF RELEVANT STEEL MANUFACTURERS IN EGYPT (MT)

Main Companies in Egypt	Factories	Products	Production Capacities
Ezz Steel Rebars (ESR)	4 factories: Alexandria, Sadat City, Suez, 10th of Ramadan city	Rebar Wire Flat	5.8 million tons per year
Suez Steel	3 factories; Attaka (Suez)	Billets Rebars Wire rod in coils Spooled bars Cut and bend Other	2.5 million tons per year
National Steel Fabrication	1 factory 6th of October factory	Steel structure Steel collector elements (Solar energy applications) Plate works	120,000 tons annually (total combined production Egypt and Algeria)

Source: Manufacturers' websites.

3.2.3 MATERIAL FOR SOLAR COMPONENT: FLOAT GLASS

Egypt is one of the glass industry pioneers in the MENA Region and in the rest of Africa. Egypt has an experienced labor force in the glass industry. It also has several mines producing high purity silica sand used for different industries including glass production.

Egypt's three main float glass companies—Saint-Gobain, Sphinx, and Guardian— have production facilities (Table 16).

3.2.4 MATERIAL FOR SOLAR COMPONENT: CABLING, HIGH TECHNOLOGY AND INVERTERS

In the high technology domain, Elsewedy Electric is the leading integrated cables and electrical products manufacturer in the Middle East and Africa.

TABLE 16 | EXAMPLES OF RELEVANT FLOAT GLASS MANUFACTURERS IN EGYPT

Company	Factories	Products	Production Capacities
Egyptian Glass Company (EGC) -Guardian	One in El Sharkia	InGlass Interior Glass SunGuard Architectural Glass ClimaGuard Residential Glass EcoGuard Energy Glass Technical Glass	
Sphinx Glass	One factory in Sadat City (Menofia)	Clear Float Glass Tinted float glass Pyrolytic Reflective Glass PPG products	Annual capacity of 200,000 tons
Saint-Gobain	One factory in Ain El Sokhna Total area: 750,000 square meters	Clear glass Tinted glass Reflective glass	Capacity of production of 900 tons/day.

Source: Manufacturers' websites.

TABLE 17 | EXAMPLES OF RELEVANT HIGH TECHNOLOGY COMPONENTS MANUFACTURERS IN EGYPT

Company	Factories	Products	Production capacities
Elsewedy Electric	More than 23 factories around the World	Wires and cables Electrical products Energy measurement Telecom	
ABB	Head office in Cairo	Solar inverters Solar Power Solutions Solar Thermal Systems	
Siemens	Branch office in Alexandria	Smart Grid Transformers Energy automation	
Schneider	5 manufacturing facilities in 10th of Ramadan City, 100,000 sq m	Motor and motion control photovoltaic power compensation and filtering power monitoring and control power protection and control	

Source: Manufacturers' websites.

3.2.5 MATERIAL FOR SOLAR COMPONENT: HEAT EXCHANGERS, PUMPS, STORAGE TANKS, AND CONDENSER

Egypt has a developed conventional pumps market. Total import value of all segments of water pumps rose by 7 percent in 2010, reaching US$100 million, which was still less than the value in 2008, when it reached US$142 million (BCI 2011).

However, it is important to note here that, despite synergies, pump manufacturing for the conventional industry differs from pump manufacturing for solar industries.

TABLE 18 | EXAMPLES OF RELEVANT PUMPS MANUFACTURERS IN EGYPT

Company	Factories	Products	Production Capacities
Egyptian Arab Pumps	1 factory, Cairo	Vacuum pumps Loura Daoud pumps Water pumps	
Allweiler-Farid Pumps	6 branches distributed geographically to cover the whole area of Egypt	Power plants Irrigation systems Oil, gas, and mining	280 employees

Source: Manufacturers' websites.

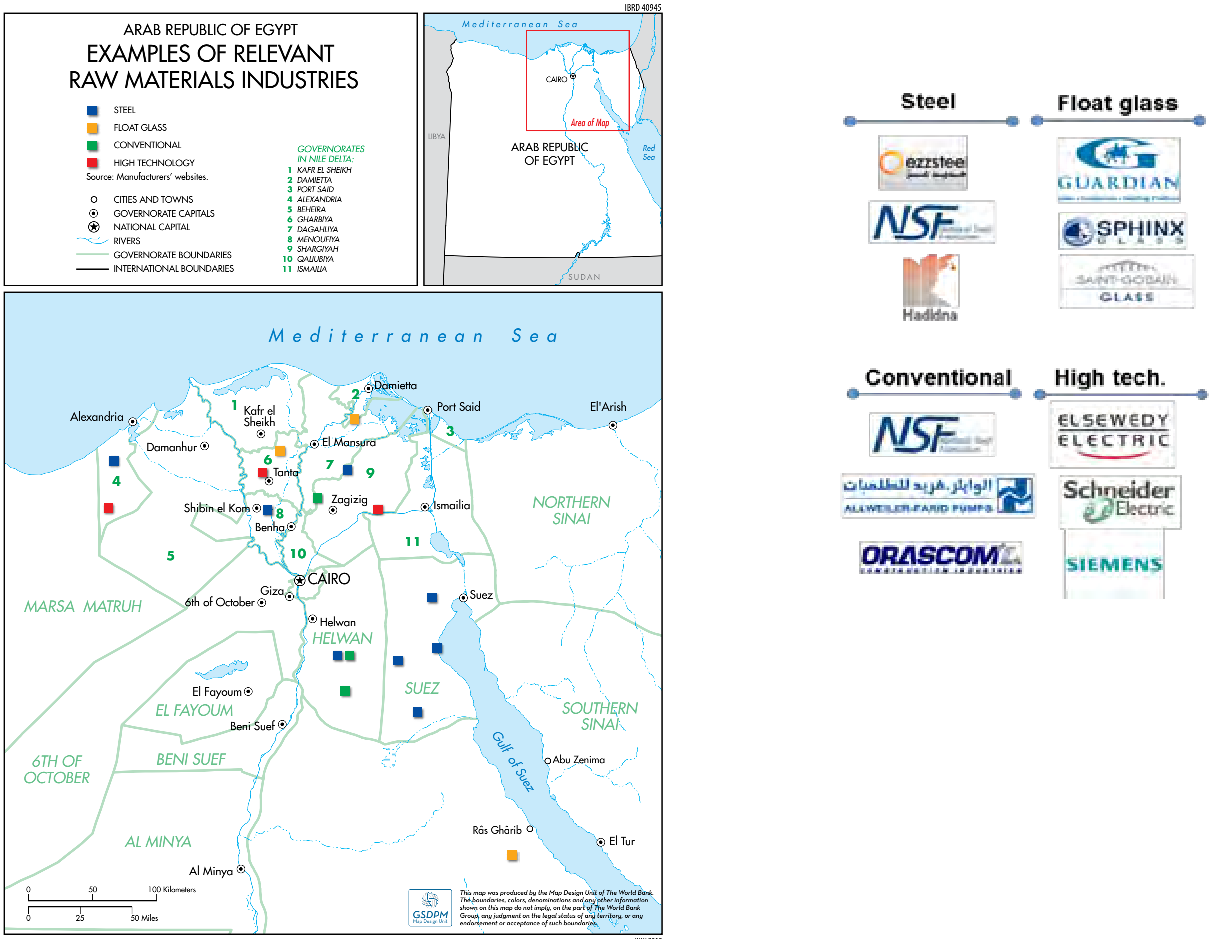
Pressure vessels, storage tanks, piping work, and heat exchangers are being manufactured by Ferrometalco and other companies with experience in local manufacturing of steel such as the Orascom Group and the Egyptian Iron and Steel Co.

TABLE 19 | EXAMPLES OF RELEVANT CONVENTIONAL MATERIAL MANUFACTURERS IN EGYPT

Company	Factories	Products	Production capacities
DSD Ferrometalco	Belbeis, total area of 320,000 sq m	Pressure vessels Storage tanks Piping work Heat exchangers	50,000 tons/year
Egyptian Iron and Steel Company (HADISOLB)	Heliopolis Workshop, 20,000 square meters	Manufacture spare parts as requested Steel structures Manufacturing	447,392 tons produced in 2012
Orascom Group	Five in Egypt:	Power plants Petrochemicals Industrial	

Source: Manufacturers' websites.

Figure 51 | Examples of Relevant Raw Material Industries in Egypt



Source: Manufacturer's website. Re-created by World Bank Cartography, July 2015.

3.3 Egypt's Manufacturing Competitiveness

3.3.1 INTRODUCTION

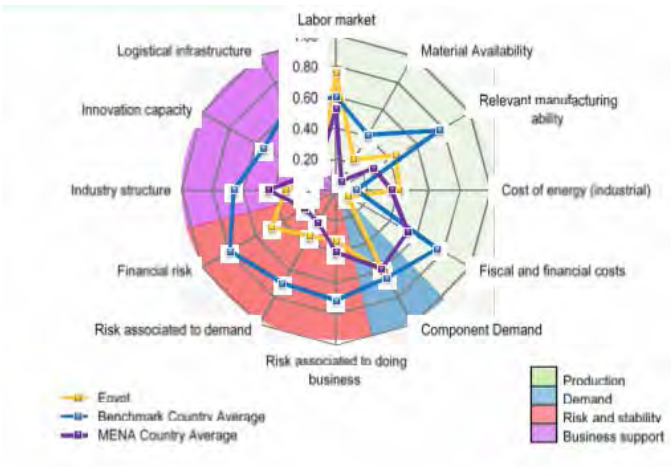
The previous stage of this analysis is the "Competitiveness Assessment of MENA Countries to Develop a Local Solar Industry" (World Bank 2012a). The assessment made a benchmark analysis to identify the potential to develop different solar component industries in the different MENA countries.

Egypt's existing competitiveness for the solar component manufacturing value chain was analyzed according to 12 competitiveness parameters organized within 4 main competitiveness categories: production factors, demand factors, risk and stability factors, and business support factors.

The analysis showed that Egypt's key strengths from the point of view of solar industrial development are in production factors. The reasons are due particularly to the low cost of labor and energy for industrial consumers; the availability of materials for solar industries, particularly glass, steel, and stainless steel; and the country's high manufacturing ability. Due to Egypt's planned deployment of solar energy up to 2020,[25] its competitiveness associated with demand factors also is strong.

25. The intermediate objectives of the Egyptian solar plan, as communicated by the Ministry of Electricity and Energy, are 1,100 MW for CSP and 200 MW for PV.

Figure 52 | Competitiveness Parameters in Egypt Compared to Benchmark and MENA Averages



Source: World Bank 2012a.

Data gathered during the mission carried out in Cairo in April 2013 have been combined with desk review and bibliographic research to dive deeply into Egypt's potential. The mission focused on four key types of stakeholders: policy makers, private companies in key sectors, institutions, academia, and associations. The results of the meetings have been kept confidential and have been aggregated to show relevant aspects.

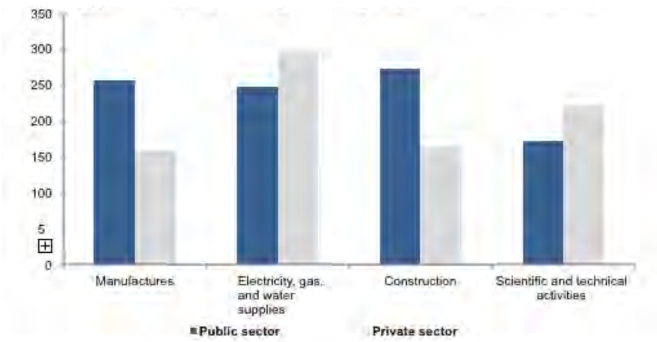
3.3.2 PRODUCTION FACTORS

3.3.2.1 PRODUCTION FACTORS – LABOR MARKET

Main barriers	Main opportunities
• Lack of technical knowledge on solar energy related component design and manufacturing • Upstream, lack of preparation for solar projects development and, downstream, lack of qualification for downstream, operation and maintenance • Absence of specialized centers to train and develop specific skills	• Promote specialized training on the domain • Complement the already good basic knowledge of engineers and technicians • Profit from past experience from similar cases (automotive industry) in Egypt. • Competitive labor wage • Training trough technology transfer and cooperation with technology providers

In the MENA Region, Egypt is competitive in terms of labor cost—a significant advantage and opportunity (Figure 53).

Figure 53 | Egyptian Employee Wage Average by Industry, 2009 (US$)



Source: Egypt CAPMAS 2010.

The key barriers identified in the labor market are:

- Lack of technical knowledge of solar-energy-related component design and manufacturing.
- Upstream: Lack of preparation for solar projects development; downstream: lack of qualification for downstream operation and maintenance (O&M). Qualification would make possible a pipeline of projects.
- Absence of specialized centers to train and develop specific skills.
- Low productivity.

However, since Egypt already has a solid base of qualified professionals, the labor market situation is seen more as an opportunity for Egypt than an unsolvable barrier. For example, Cairo University is ranked as 1 of the world's 500 best universities (Center for World-Class Universities of Shanghai Jiao Tong University 2012). It ranks above many relevant Australian, Canadian, and European universities.

All stakeholders interviewed during the mission, including policy makers, industry representatives, associations, and institutions, stated that capacity can be built upon existing foundations through new trainings and specialization. It would be valuable to extend this training also to installers and other technical (nonengineering) positions.

Egypt also can become a knowledge exporter to address the challenge of unemployment, which increased by 3.5 percent in 2011. Implementing this strength is particularly important for youth, whose average unemployment lasts almost 3 years (34 months) (WEF 2012).

3.3.2.2 PRODUCTION FACTORS – MATERIAL AVAILABILITY

Main barriers	Main opportunities
• Local manufacture is oriented to system integration based on imported materials.	• Solar component materials (steel, glass, high technology, conventional materials) are manufactured locally so could be adapted easily to this new market.

To date, Egypt's local manufacturing for the solar industry has focused on assembling imported components. However, during the mission in Cairo, local sector experts expressed their confidence in the local availability of almost all primary materials and components required to manufacture solar components, including steel and float glass.

For float glass, additional investments would be required to fulfill CSP and PV market needs. Current Egyptian float glass production in Egypt manufactures glass with an iron content that would not be immediately compliant with CSP or PV requirements.

Moreover, should demand for a particular material (such as steel for CSP or PV structures) suddenly shoot up due to the development of a solar component industry, current local availability might not be enough to meet the full additional demand. In such a case, some materials would have to be imported while local capacities were being developed.

3.3.2.3 PRODUCTION FACTORS – RELEVANT MANUFACTURING ABILITY

Main barriers	Main opportunities
• Lack of experience in manufacturing solar components. Lack of specific testing or certifying facilities.	• Automotive industry has developed properly in the past.

During the Cairo mission, different stakeholders brought up Egypt's promising automotive industry as an example of a successful industrial sector and a possible opportunity to replicate. This sector is of particular interest because of its synergies with the solar CSP industry. At the same time, Egypt already has a series of important industries for the development of different solar components from the value chain. The lack of quantification of the country's own potential was cited as a common concern by different stakeholders during the mission. Egypt already has begun demonstrating its ability in solar projects with the development of the Kuraymat Integrated Solar Combined Cycle Power Plant.

3.3.2.4 PRODUCTION FACTORS – ENERGY (INDUSTRIAL PERSPECTIVE)

Main barriers	Main opportunities
• Electricity subsidies have kept prices artificially low, but prices are increasing. • Future trend is oriented to penalize high-energy-consumption companies.	• Potential opportunities exist for renewable energies, which may incentivize the component industry. • Existing capacity may not be enough to cover increasing demand.

In the past, electricity subsidies in Egypt have kept electricity prices artificially low. Although they bring other risks,[26] at first sight, subsidies appear to be a competitive advantage to private industrial investors, particularly for energy-intensive industries. However, this picture is changing because energy costs are increasing for industrial consumers.

Industrial consumers have experienced tariff hikes in the last year. In the case of the most energy-intensive industries, the tariff hikes were accompanied by a 50 percent hike in the price of electricity consumed during a defined 4-hour peak period (EgyptERA n.d.). Along the same lines, a plan by the Egyptian electricity regulator to put in place a series of barriers to high-energy-consumption companies may hamper the future development of energy-intensive industries.

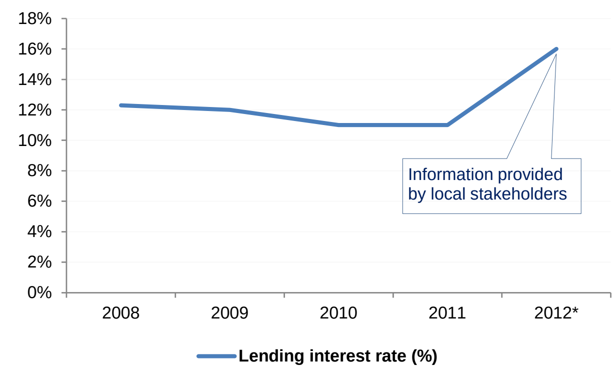
3.3.2.5 PRODUCTION FACTORS – FINANCIAL COSTS

Main barriers	Main opportunities
• High interest rate. • Difficult access to financing. • Fluctuating inflation rate.	• Federation of Egyptian industries has a fund for industrial projects.

26. From the point of view of the country, subsidies to energy consumption introduce tensions in the system, because they veil the true price signal to electricity consumers and may lead to adverse economic and environmental impacts. In other words, the sustainability of these artificially low costs can be perceived as an investor risk.

In the last 5 years, the Egyptian interest rate has remained above 10 percent (Figure 54), reaching 16 percent in 2012 for small/medium companies.[27] This interest level makes it difficult for small/medium companies to invest due to the high pay-back.

Figure 54 | Lending Interest Rate in Egypt (%)



Source: World Bank 2008-11.

3.3.3 DEMAND FACTORS

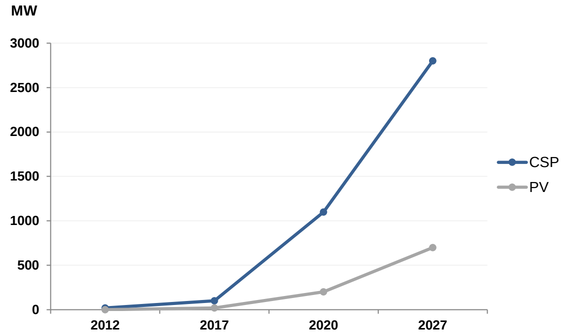
3.3.3.1 DEMAND FACTORS – COMPONENT DEMAND

Main barriers	Main opportunities
• The Egyptian Solar Plan provides a target, but no clear mechanisms guaranteeing demand.	• Different mechanisms and instruments being considered to stimulate demand. • Business alternative off-grid-> for remote areas. • Companies start to prioritize energy security over price.

27. As detailed by several stakeholders during the mission in Cairo in April 2013.

It is positive that Egypt already has targets in place until 2027, and intermediate targets until 2020, showing the government's engagement with solar energy development in the country

Figure 55 | Egyptian Solar Energy Target, 2012-27 (MW)



Source: Egypt NREA 2012.

Due to the limited electricity supply capacity, a market for off-grid solar energy may emerge, not only for remote areas but also as back-up systems to face possible supply cuts.

These opportunities notwithstanding, there is no visibility into the pipeline to meet this target. This lack of visibility and lack of a clear mechanism in place to incentivize the projects were seen by all stakeholders as the clearest barriers to fulfilling demand.

Policy makers are already considering different alternatives that could stimulate demand for renewable energy (RE). Alternatives include both price-based and quantity-based instruments. Examples are Build Own and Operate (BOO), project bidding, the establishment of a feed-in tariff or premium, the implementation of quotas/Green Certificates, or the development of a tender mechanism (Table 20). However, these mechanisms to guarantee demand and give visibility to the pipeline are not in place yet. Some of the ideas that are being considered, such as net metering, require local capabilities (certified installers) to be deployed before they can be applied on a large scale.

In the meetings with local industry experts during the Cairo mission, the predominant opinion was that (a) current market conditions are substantially more risk-adverse than in the past. Therefore, (b) a higher degree of certainty of future demand (for 4-5 years, at least) is required for the industry to invest.

TABLE 20 | INCENTIVE MECHANISMS FOR RENEWABLE ENERGY

Price-based instruments	
Feed-in tariffs/premiums	• Used in most EU Member States. • Normally guaranteed for 10-20 years.
Fiscal incentives	• Main incentive mechanism in the US, in the form of tax credits.
Quantity-based instruments	
Quota obligations/ Green Certificates	• Used in a small number of EU Member States, and as a complementary incentive mechanism in the US.
Tendering	• Used in multiple countries, including Brazil, Mexico, Morocco, Peru, and South Africa. Most often differentiated by technology.

3.3.4 RISK AND STABILITY FACTORS

3.3.4.1 RISK AND STABILITY FACTORS – RISK ASSOCIATED WITH DOING BUSINESS

Main barriers	Main opportunities
• Lack of promotion of foreign investment	• Government support to exports to Africa. • Promote international partners or technology providers.

If Egypt is able to develop local solar component industries, there is an opportunity for the country to become a main exporter to African countries. In this sense, there is already some government support for such exports, which could represent an opportunity for the solar industry. One example of this support is that Egypt assumes half of transport costs to African countries for all industries.[28]

On the other hand, multiple stakeholders during the mission in Cairo brought up the current lack of promotion of foreign investment in Egypt. FDI will have to be encouraged to attract international partners and technology providers and to more rapidly develop solar energy.

3.3.4.2 RISK AND STABILITY FACTORS – FINANCIAL RISK

Main barriers	Main opportunities
• Difficulty in accessing credit, particularly for small/medium companies. • Current shortage of international currency.	• Financing alternatives to traditional banks, for small/ medium companies. • Opportunity to develop partnerships with banks instead of loans.

28. As detailed during the mission to Cairo in April 2013.

Due to current market conditions, access to credit is tighter now than in the past. As mentioned by several stakeholders during the mission to Cairo, tighter credit has resulted in high interest rates of up to 16 percent for small and medium industrial enterprises. Difficulty in accessing international currency also is proving a challenge because it makes importing materials and components for different industries harder.

In terms of opportunities, it is worth highlighting that the industrial sector is showing creativity. Some industrial players are exploring the possibility of developing new relationships with banks as partners in projects rather than simply as lenders. There is at least one alternative to traditional bank: the Federation of Egyptian Industries (FEI), an association that offers soft loans with low administrative fees and a one-year grace period.

3.3.5 BUSINESS FACTORS

3.3.5.1 BUSINESS FACTORS – INDUSTRY STRUCTURE

Main barriers	Main opportunities
• Lack of collaboration among different stakeholders.	• Promote stakeholder integration/ collaboration/coordination, for example, with clusters. • Stimulate synergies among stakeholders. Initiatives already have started.

The most common barrier highlighted by stakeholders during the mission in Cairo was the lack of collaboration among different themselves, specifically among policy makers, industrial players, and research centers.

In this sense, the opportunities lie in identifying and stimulating the synergies among the different stakeholders to design a plan to achieve common goals.

3.3.5.2 BUSINESS FACTORS – INNOVATION CAPACITY

Main barriers	Main opportunities
• Lack of relationship and alignment between the industry and research center/academic resources. • R&D not a priority for companies.	• Promote innovation to develop solar technologies adapted to the local conditions regarding maintenance, grid, temperature, and demand needs. • Link innovation with industrial and commercial opportunities. • Sponsor the development of solar energy departments at all major national universities. • Promote university agreements with International universities and R&D centers specialized in solar. • Launch local laboratories to certify products.

The common view presented by stakeholders during the mission was that Egyptian companies are not prioritizing R&D. The result is that, to solve problems when they arise, the stakeholders and the companies often must look for the support of foreign technicians. This situation could be improved by strengthening the relationship and alignment between the industry and research center/academic resources, which is the other common barrier cited.

One opportunity specifically to improve R&D for the solar sector is to develop a technical innovation center specialized in solar energy or to set up collaborations with technology providers. This center could support the development of the solar energy industry in Egypt. Specifically, it (a) could target technology adaptations to meet grid, temperature, and other requirements that are specific to the Region. Having these adaptations then (b) could strengthen Egypt's position as an exporter of solar components to the Region when compared to other global manufacturers. Another role of this center would be (c) to function as the link between innovation and commercial or industrial opportunities to ensure that the needs and interests of industrial players are aligned with the work being done at the academic or institute level.

It also would be of interest to promote university agreements with international universities specialized in solar energy and solar industry components. Departments could put in place collaborations with international universities and invite international experts and faculty members to become part of the panels.

Finally, there is the opportunity to launch local laboratories to certify local products manufactured in the country to ensure that they meet international requirements and facilitate exports.

CHAPTER 4:

Potential Value Chains in Which Egypt's Manufacturing Sector Could Participate

4.1 Attractiveness of Egypt as a Country

The previous report (World Bank 2012a) assessed, among other countries, Egypt's competitiveness to develop local solar industries. A series of metrics regarding production factors, demand factors, risk and stability factors and business support factors were used in an aggregation and weighting model to give an "Attractiveness" index for each country and industry studied. These indices would enable comparing, on a quantitative basis, how likely it would be for an international investor to choose Egypt as the preferred destination to invest in a solar component manufacturing industry. The report's results are summarized in Tables 21-24.

TABLE 21 | NORMALIZED ATTRACTIVENESS INDEX FOR CSP COMPONENT INDUSTRIES (I)

	Condenser	Electrical Generator	Heat Exchanger	HTF Pumps	HTF Thermal Oil	Mirror
Egypt	0.5	0.5	0.5	0.5		0.5
Chile	0.6	0.7	0.5	0.6	0.6	0.6
China	0.9	0.7	1.0	0.8	0.7	0.9
Germany	0.9	0.9	0.8	0.9	0.9	0.9
India	0.7	0.7	0.7	0.7	0.7	0.7
Japan	0.9	0.9	0.9	0.9	0.9	0.8
South Africa	0.7	0.9	0.6	0.8	0.9	0.7
Spain	0.8	0.8	0.7	0.8	0.8	0.8
United States	1.0	1.0	1.0	1.0	1.0	1.0
Average BENCHMARK	0.8	0.8	0.8	0.8	0.8	0.8

TABLE 22 | NORMALIZED ATTRACTIVENESS INDEX FOR CSP COMPONENT INDUSTRIES (II)

	Pumps	Receiver	Solar Salt	Steam Turbine	Storage Tanks	Structure & Tracker
Egypt	0.5	0.5	0.4	0.5	0.5	0.7
Chile	0.6	0.6	0.9	0.7	0.5	0.5
China	0.9	0.8	1.0	0.7	1.0	1.0
Germany	0.8	0.9	0.5	0.9	0.8	0.8
India	0.7	0.7	0.4	0.7	0.7	0.9
Japan	0.9	0.9	0.4	0.9	0.9	0.9
South Africa	0.7	0.7	0.4	0.9	0.7	0.8
Spain	0.8	0.8	0.5	0.8	0.7	0.7
United States	1.0	1.0	0.5	1.0	1.0	0.9
Average BENCHMARK	0.8	0.8	0.6	0.8	0.8	0.8

TABLE 23 | NORMALIZED ATTRACTIVENESS INDEX FOR CRYSTALLINE PV COMPONENT INDUSTRIES

	Cells	Ingots/Wafers	Modules c-Si	Polysilicon
EGYPT	0.5	0.5	0.5	0.5
Chile	0.6	0.7	0.5	0.7
China	0.8	0.7	1.0	0.7
Germany	1.0	1.0	0.9	0.9
India	0.7	0.7	0.7	0.7
Japan	0.9	0.9	0.9	0.9
South Africa	0.7	0.9	0.6	0.9
Spain	0.8	0.8	0.7	0.7
United States	1.0	1.0	1.0	1.0
Average BENCHMARK	0.8	0.8	0.8	0.8

TABLE 24 | NORMALIZED ATTRACTIVENESS INDEX FOR THIN FILM AND COMMON PV COMPONENT INDUSTRIES

	Solar Glass	TF Materials	TF Modules	Inverter	Support Structure
Egypt	0.5	0.5	0.5	0.6	0.7
Chile	0.7	0.6	0.5	0.5	0.5
China	0.7	0.9	1.0	1.0	1.0
Germany	0.9	1.0	0.9	0.7	0.9
India	0.7	0.6	0.7	0.8	0.9
Japan	0.9	0.9	0.9	0.9	0.9
South Africa	0.9	0.7	0.6	0.6	0.7
Spain	0.7	0.7	0.7	0.6	0.7
United States	1.0	0.9	1.0	0.9	0.9
Average BENCHMARK	0.8	0.8	0.8	0.8	0.8

A set of "benchmark countries" was used as a reference in the analysis. The results show that Egypt has an Attractiveness index closer to the average of benchmark countries for the industries of Structure and Tracker (CSP) and Inverter and Support Structure (PV).

4.2 Entry Barriers and Key Factors in the Value Chains

A paradigmatic manufacturing facility was outlined for each of the industries shown above, regarding average annual capacity, investment and operating costs breakdown, and material and energetic requirements. Perceived entry barriers were identified and have been updated to reflect actual market conditions.

TABLE 25 | BARRIERS TO ENTRY AND KEY FACTORS FOR CSP COMPONENT INDUSTRIES

CSP TECHNOLOGIES	
Condenser	
Barriers to Entry	*Key Factors*
• **Guarantees of turbine manufacturer.** The design of the Condenser is linked to that of the turbine, partly conditioning its design and performance. Due to this, turbine manufacturers could subcontract the condenser manufacture and include it into their own scope of supply.	• **Stainless steel market.** Availability, quality, and price of stainless steel condition the final price of the Condenser.
• **Technical barrier: Complex design to achieve performance.** Condenser design must comply with more constraints than conventional heat exchangers, such as a limited pressure drop in the shell side or a complex heat transfer in phase-change and vacuum conditions.	• **High precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
• **Highly skilled workforce required.** Stainless steel welding and heavy duty machinery handling require specific formation.	
Electrical Generator	
Barriers to Entry	*Key Factors*
• **Technical barrier.** Complex design to achieve performance. State-of-the-art generators achieve a mechanical-to-electrical power conversion factor above 99 percent thanks to optimized design and high manufacturing quality.	• **Copper market.** Availability, quality, and price of copper condition the final price of electrical generator.
• **Fluctuations in copper market.** During 2003-12, the average world price of copper oscillated between 2,000 and 10,000 US$/t with frequent variations of up to 310 percent/month (Riley 2012).	• **Power electronics.** Generator output must comply with specifications from the grid operator such as frequency, synchronism, power factor, answer to power dips.
• **Highly skilled workforce required.** Heavy duty machinery handling requires specific formation.	

CSP TECHNOLOGIES	
Heat Exchangers	
Barriers to Entry	*Key Factors*
• **Highly skilled workforce required.** Steel welding and heavy duty machinery handling require specific formation.	• **Steel market.** Availability, quality, and price of steel condition the final price of the heat exchangers.
	• **High-precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
	• **Adapt existing industries.** It is likely that light-duty heat exchangers or other metal fabrication industries exist in the country. Diversifying their production toward the solar sector would reduce initial investment cost and would profit from skilled workforce.
HTF Pump	
Barriers to Entry	*Key Factors*
• **Highly skilled workforce required.** Carbon, stainless steel and bronze casting, machining and welding, and heavy duty machinery handling require specific formation.	• **High-precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
	• **Motor and power electronics.** Availability, quality, and price of motors condition the final price of the HTF pumps. It is common to include variable frequency drive controllers for some or all of the pumps within a solar plant.

CSP TECHNOLOGIES	
HTF Thermal Oil	
Barriers to Entry	*Key Factors*
• **Byproduct in chemical industry (phenol) with large productions (40-600 kt/year).** Diphenyl oxide occurs in small quantities in phenol manufacturing processes as a mixture of different compounds that require further purifying.	• **Adapt existing industries.** Diphenyl oxide recovery would reduce the waste in an existing phenol plant. Biphenyl can be isolated from crude oil or natural gas, or synthesized in a process analogous to that of phenol and with similar raw materials. Diversifying their production toward the solar sector would reduce initial investment cost and would profit from skilled workforce.
• **Market dominated by a small number of competitors.** Since it is associated with a commodity manufacturing process, only large chemical companies are currently offering this product.	
• **Low market opportunities to sell this product to other industries and sectors.** HTF oils currently used for solar applications have a clear niche; however, in other temperature ranges, competing heat transfer fluids exist.	
Mirror	
Barriers to Entry	*Key Factors*
• **Technical barrier.** Complex manufacturing line. State-of-the-art parabolic shaping achieves accuracy above 99 percent (measured as reflected light that would reach the focus) thanks to optimized design and high manufacturing quality.	• **Energy.** Availability and price of thermal energy condition the final price of the mirror.
• **Highly skilled workforce required.** Glass processing, chemical reagents, and heavy duty machinery handling require specific training. The product itself is fragile.	• **Transport.** Transportation of float glass can raise the final costs by 15 percent (Glass Global 2012). It is a common practice to avoid road transportation of glass longer than 600 km (Glass for Europe 2012).
• **Capital-intensive unless integrated in existing float glass.** Transportation of float glass can raise the final costs by 15 percent (Glass Global 2012). Glass for solar applications is a minor fraction of the overall float glass market. A typical float glass factory produces 200,000 t/year and must maintain at least 70 percent utilization rate to be profitable (Glass for Europe 2012).	• **Adapt existing industries.** For an existing float glass factory, diversifying production toward the solar sector would reduce initial investment cost and would profit from skilled workforce and developed logistics.

CSP TECHNOLOGIES	
Pumps	
Barriers to Entry	*Key Factors*
• **Technical barrier.** Complex design for molten salt pumps. State-of-the-art molten salt pumps prevent the problems associated with the high melting point of the solar salt thanks to optimized design and high manufacturing quality.	• **High-precision manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.
• **Highly skilled workforce required.** Carbon, stainless steel and bronze casting, machining and welding, and heavy duty machinery handling require specific formation.	
Receiver	
Barriers to Entry	*Key Factors*
• **Technical barrier.** Highly specialized coating process with high accuracy. Spraying the absorptive coating on the inner stainless steel tube of the receiver requires specialized machinery and a thorough tuning to achieve repeatable and high performance and avoid the waste of costly materials.	• **Transport.** It is a common practice to avoid road transportation of glass products for longer than 600 km (Glass for Europe 2012). Special packaging is required to prevent breakage of the glass cover during transportation and storage.
• **Technical barrier: Vacuum-tight glass to metal welding process and materials.** State-of-the-art glass-metal joints withstand the high vacuum level of the annular space between the glass and the stainless steel tubes, as well as the thermal stress and fatigue of daily heating and cooling cycles, thanks to optimized design, material selection expertise, and high manufacturing quality.	
• **High specific investment for manufacturing process.** The high investment necessary increases the exposure in case a competitor develops a more efficient manufacturing process or an alternative product enters the market.	
• **Low market opportunities to sell this product to other industries and sectors.** Receivers currently used for CSP applications have a clear niche; however, in other temperature ranges, competing products exist.	
• **Highly skilled workforce required.** Stainless steel and glass welding and heavy duty machinery handling require specific formation. The product itself is fragile.	

CSP TECHNOLOGIES	
Solar Salt	
Barriers to Entry	*Key Factors*
• **A mineral vein must exist within the territory.** Synthetic salt can be manufactured through chemical processes; however, current suppliers obtain it as part of a diversified mining industry.	• **Purity of the vein, valorization of byproducts.** Nitrates show high solubility, so dissolution in hot water and additional recrystallization is a possible way of obtaining them. Impurities with a similar solubility might contaminate the final product. Insoluble salts containing sodium, potassium, or nitrate will reduce overall production. On the other hand, other impurities such as lithium salts, rare earths, or noble metals could prove valuable.
Steam Turbine	
Barriers to Entry	*Key Factors*
• **Technical barrier: Complex design to achieve performance.** State-of-the-art turbines for solar applications allow for a Rankine cycle thermal efficiency of nearly 40 percent despite the relatively low maximum temperatures, thanks to optimized design and high manufacturing quality.	• **Long-term service agreements and performance guarantee.** A long-term service agreement is frequently included within the scope of supply of the turbine, granting the customer technical assistance and original spare parts supply. The manufacturer will give a performance guarantee on the turbine and therefore will suffer economic penalties if the rated values are not reached.
• **Highly skilled workforce required.** Carbon and stainless steel casting, machining and welding, and heavy duty machinery handling require specific formation.	
• **High specific investment for manufacturing process.** High investment required increases exposure in case a competitor develops a more efficient manufacturing process, or an alternative product enters the market.	
Storage Tanks	
Barriers to Entry	*Key Factors*
• **Technical barrier.** Complex design of molten salt tanks, steam drum, and deaerator. State-of-the-art molten salt hot tank design prevents damage to the foundations. Concurrently, it avoids the problems associated with the high melting point of the solar salt thanks to optimized design and high manufacturing quality. Steam drum and deaerator design must comply with more constraints than conventional storage tanks, such as a complex mass transfer in phase-change conditions.	• **Manufacturing under international standards.** Welder certification, quality control, and compliance with international manufacturing standards are necessary to obtain compatibility with other equipment, safety, and performance in operation.

CSP TECHNOLOGIES	
Structure and Tracker	
Barriers to Entry	*Key Factors*
• **Hot-dip galvanizing of large structures (>12 m) can be a bottleneck.** Torque tube-based collector designs require the galvanizing of a 12 m long piece (the torque tube itself), and galvanizing baths with the required dimensions are not frequent (Galvanizers Association 2012).	• **Carbon steel market.** Availability, quality, and price of carbon steel condition the final price of the structure.
• **Technical barrier.** Complex design to achieve stiffness. State-of-the-art collector design achieves an accuracy of nearly 75 percent (measured as reflected light that would reach the focus) thanks to optimized design and high manufacturing quality. This barrier can be overcome through partnerships or license acquisition.	• **Transport.** Normal packing ratios can be reached for transportation of collector structures based on torque box or space frame concepts. For torque tubes, the packing ratio is lower due to their shape so the transport costs can be higher.
• **Technical barrier.** Complex design of hydraulic circuit and components. State-of-the-art tracker design achieves a half-acceptance angle better than 0.1º thanks to optimized design and high manufacturing quality. This barrier can be overcome through partnerships or license acquisition.	• **Galvanizing.** Availability, quality, and cost of nearby galvanizing facilities condition the final price of the structure.
	• **Adapt existing industries.** For existing steel structure factories such as transmission tower factories, diversifying production toward the solar sector would reduce initial investment cost and would profit from skilled workforce and developed logistics.

TABLE 26 | BARRIERS TO ENTRY AND KEY FACTORS FOR PV COMPONENT INDUSTRIES

PV TECHNOLOGIES	
c-Si Cells	
Barriers to Entry	*Key Factors*
• **Technical barrier: Highly specialized surface treatment (etching).** Multiple materials and processes exist for etching (wet, dry) as well as for the previous coating and patterning processes, leading to a surface reflectiveness below 5 percent.	• **Vertical integration to achieve competitive costs.** Integrated companies achieve competitive costs while ensuring raw materials supply and quality.
• **High specific investment for manufacturing process.** High investment increases exposure in case a competitor develops a more efficient manufacturing process, or an alternative product enters the market.	
• **Overcapacity in the sector, downward pricing pressure, vertical integration in most cells manufacturing companies.** Several silicon-related industries have been constrained in the recent past by upstream bottlenecks due to silicon shortages. The industrial sector over-compensated this issue. Now the ratio demand/offer is shrinking, and there is overcapacity in the sector. Competitors are ready to cover actual and future demand without delay and not incur new investments. Vertical integration can be a competitive advantage.	
• **Highly skilled workforce required.** Clean atmosphere working, reactive chemicals handling, and specialized machinery require specific formation.	
c-Si Ingots/Wafers	
Barriers to Entry	*Key Factors*
• **High specific investment for manufacturing process.** High investment increases exposure in case a competitor develops a more efficient manufacturing process or an alternative product enters the market.	• **Alternative market (electronics) requires higher purity than solar; additional purification process required.** To access this market, a flexible process could be installed; or the higher purity wafers may be used for high performance cells and modules.
• **Overcapacity in the sector, downward pricing pressure, vertical integration in 75 percent of wafer manufacturing companies.** Several silicon-related industries have been constrained in the recent past by upstream bottlenecks due to silicon shortages. Now the ratio demand/offer is shrinking, and there is overcapacity in the sector. Competitors are ready to cover actual and future demand without delay and not incur new investments. Vertical integration can be a competitive advantage.	• **Vertical integration to achieve competitive costs.** Integrated companies achieve competitive costs while ensuring raw materials supply and quality.
• **Global demand in 2011 covered above 90 percent with already installed capacity of the 5 top suppliers.** Newcomers have the burden of fixed costs on their products so they could be less competitive.	

PV TECHNOLOGIES	
c-Si Modules	
Barriers to Entry	*Key Factors*
• **Overcapacity in the sector, downward pricing pressure, vertical integration in most module manufacturing companies.** Several silicon-related industries have been constrained in the recent past by upstream bottlenecks due to silicon shortages. Now the ratio demand/offer is shrinking, and there is overcapacity in the sector. Competitors are ready to cover actual and future demand without delay and not incur new investments. Vertical integration can be a competitive advantage.	• **Distinguishing features, quality control.** With overcapacity in the sector, prices are already low. To gain market share, higher quality, pre- and/or post-sales services should be offered.
	• **Vertical integration to achieve competitive costs.** Integrated companies achieve competitive costs while ensuring raw materials supply and quality.
c-Si Polysilicon	
Barriers to Entry	*Key Factors*
• **Technical barrier.** Highly specialized deposition process with high purity. Metallurgical Grade silicon (MG-Si) is purified by converting it to a silicon compound that can be more easily purified than in its original state, and then converting that silicon compound back into pure silicon. Several processes yield solar-grade silicon; electronic-grade production is less flexible.	• **Alternative market (electronics) requires higher purity than solar.** Capability to reach purity (Siemens, others in development). To access this market, a flexible process could be installed, or the higher purity wafers could be used for high-performance cells and modules.
• **High specific investment for manufacturing process.** This increases the exposure in case a competitor develops a more efficient manufacturing process, or an alternative product enters the market.	
• **Overcapacity in the sector, downward pricing pressure.** Several silicon-related industries have been constrained in the recent past by upstream bottlenecks due to silicon shortages. Now the ratio demand/offer is shrinking, and there is overcapacity in the sector. Competitors are ready to cover actual and future demand without delay and not incur new investments. Vertical integration can be a competitive advantage.	
• **Global demand in 2011 could have been covered with already installed capacity of the 6 top suppliers.** Newcomers have the burden of fixed costs on their product so they might be less competitive.	

PV TECHNOLOGIES	
Thin Film (TF) Materials	
Barriers to Entry	*Key Factors*
• **Raw material supply depends on existing zinc and copper industries.** Importing is probably uneconomic due to the low concentration in ores, which would lead to high unit transportation costs.	• **Vertical integration or association with zinc and copper industries.** TF materials recovery would reduce the waste in an existing zinc and/or copper plant. Diversifying their production toward the solar sector would reduce initial investment cost and profit from skilled workforce.
	• **Transport.** Low concentration in ores probably makes unit transportation costs uneconomic.
	• **Purity of final product.** Presence of impurities would reduce the performance of the TF Module.
	• **Valorization of byproducts.** Traces of precious metals might, if recovered, improve the business model.
	• **TCO: Alternative markets (LCD displays and others).** Transparent conductive oxides have an alternative market in liquid crystalline displays manufacturing, with similar requirements.
TF Modules	
Barriers to Entry	*Key Factors*
• **High specific investment for manufacturing process.** High investment increases exposure in case a competitor develops a more efficient manufacturing process, or an alternative product enters the market.	• **Vertical integration or association with existing solar glass line.** Integrated companies achieve competitive costs while ensuring raw materials supply and quality. A coupled manufacturing line would reduce initial investment cost and profit from skilled workforce, as well as avoid intermediate handling costs.
• **Technical barrier: Highly specialized deposition processes with high purity and thickness control.** Several physical and/or chemical processes are available. Each allows for different levels of control on thickness, surface properties, and speed; and is more or less suited for combinations of layer and substrate.	• **R&D to improve performance.** Module efficiency is lower in thin films than in crystalline products; R&D efforts might reduce or even reverse this situation.

PV TECHNOLOGIES	
• **Overcapacity in the silicon sector has led to prices below thin films, with higher performance.** This higher price may slow the penetration of thin films in the PV market, except for niche markets.	• **Niche market: Weight-constrained applications.** Thin films are lighter than crystalline modules, both in kg/m2 and in kg/kW. Wherever weight is an issue (such as mobile applications or nonreinforced rooftops), thin films can be chosen.
	• **Niche market: Flexible substrates.** Certain thin films can be deposited on organic flexible substrates. This quality enables their installation on curved surfaces and integration in waterproofing covers.
TF Solar Glass	
Barriers to Entry	*Key Factors*
• **High overall investment for manufacturing process due to scale.** This high investment increases the exposure in case a competitor develops a more efficient manufacturing process, or an alternative product enters the market.	• **Vertical integration or association with existing float glass line.** Integrated companies achieve competitive costs while ensuring raw materials supply and quality. A coupled manufacturing line would reduce initial investment cost and profit from skilled workforce, as well as avoid intermediate handling costs.
• **Solar glass is usually < 1 percent of total float glass.** Alternative demand (building, automotive) must exist to achieve, at least, 70 percent capitalization factor.	• **For CIS/CIGS: Stable Na composition, integration of Mo coating.** Vertical integration would allow addressing both issues.
	• **For CdTe and TF-Si: Integration of TCO deposition to access alternative markets (LCD displays and others).** A coupled manufacturing line would reduce initial investment cost and profit from skilled workforce, as well as avoid intermediate handling costs.
	• **Transport.** Transportation of float glass can raise the final costs by 15 percent (Glass Global 2012). It is a common practice to avoid road transportation of glass products longer than 600 km (Glass for Europe 2012).
	• **Energy.** Availability and price of thermal energy condition the final price of the solar glass.

PV TECHNOLOGIES	
	• **Alternative markets: Crystalline modules.** General requirements for solar glass also apply to glass covers for crystalline modules, so additional sales might be obtained for c-Si modules manufacturers.
Inverter	
Barriers to Entry	*Key Factors*
• **Technical barrier: Complex design to achieve performance.** State-of-the-art inverter design achieves efficiency above 98 percent (SMA Solar Technology 2012) thanks to optimized design and high manufacturing quality.	• **Distinguishing features, quality control.** Strong competitors exist in the market; to gain market share, higher quality, pre- and/or post-sales services should be offered.
• **Most inverter manufacturers are large power electronics companies that diversified into the solar market.** Diversified companies are less sensitive to oscillations in PV market.	• **Maximum power point tracking and anti-islanding protection.** These features are specific for solar inverters, and mandatory in cases in which Institute of Electrical and Electronics Engineers (IEEE) 1546657 standard applies.
Support Structure	
Barriers to Entry	*Key Factors*
• **Technical barrier: Complex design to achieve reliability and low maintenance for tracker.** State-of-the-art tracker design achieves an average replacement ratio near 2 percent/year thanks to optimized design and high manufacturing quality.	• **Carbon steel market.** Availability, quality, and price of carbon steel condition the final price of the support structure.
	• **Transport.** Normal packing ratios can be reached for transportation of support structures, but the cost can be significant in the final price.
	• **Galvanizing.** Availability, quality, and cost of nearby galvanizing facilities condition the final price of the support structures.
	• **Adapt existing industries.** For an existing steel structure factory such as transmission tower factories, diversifying production toward the solar sector would reduce initial investment cost and profit from skilled workforce and developed logistics.

Egypt's industrial sector has the following capabilities linked to solar component manufacturing necessities:

- Base steel manufacturing: Over 8 million t/year .[29]
- Float glass manufacturing: Over 400 kt/year.[30]
- Electric and power electronics: Global sector leaders[31] operate in the country.
- Pumps and metal fabrication: Several local and international companies operate in the country.

These capabilities might help Egypt's industrial sector to overcome the entry barriers and take advantage of the key factors described for some of the CSP and PV industries. The highly skilled workforce required for several of these industries might be obtained through capacity building programs such as partnerships with technology providers or specialized training courses.

4.3 Industries Suggested

Considering the above-mentioned information, the following industries are suggested for development in Egypt:

- CSP:
  - Condenser
  - Heat exchangers
  - HTF pump
  - Mirror
  - Pumps
  - Storage tanks
  - Structure and tracker
- PV:
  - Inverter
  - Solar glass
  - Support structure.

29. Ezz Steel Rebars: 5.8; Suez Steel: 2.5.
30. Saint Gobain: 250; Sphinx Glass: 200.
31. ABB, Elsewedy, Schneider, Siemens.

From an industrial point of view, certain component manufacturing lines can be considered as a single development:

- Condenser and heat exchangers: **Heat transfer equipment**
- Pumps and HTF pumps: **Pumping equipment**
- Structure and tracker (CSP) and support structure (PV): **Structures.**

4.4 Insight of the Suggested Value Chains: CSP Industries

4.4.1 HEAT TRANSFER EQUIPMENT

4.4.1.1 PRODUCTION PROCESS AND FACTORS

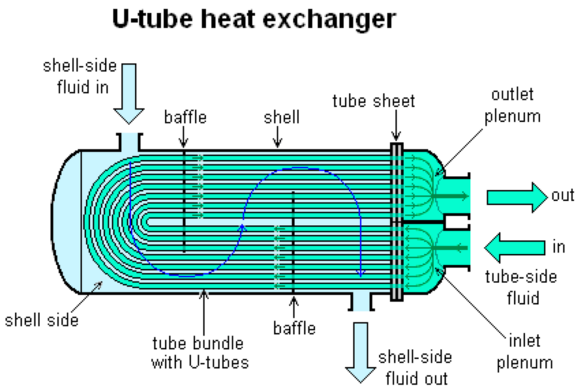
Several different sets of heat transfer equipment are required in the Power Block. First, HTF-water heat exchangers (usually referred to as the SGS, or Steam Generation System) are required to generate the high-pressure and temperature steam that will drive the turbine. Second, water-water heat exchangers are used to recover the heat from turbine bleeds to preheat the condensate or feed water, thus increasing the Rankine cycle efficiency. Third, a condenser liquefies the exhaust line of the turbine, requiring a more complex design and affecting the overall performance of the plant. If a TES system is included, a reversible, molten salt-HTF heat exchanger also is necessary. Carbon steel and stainless steel are required for their manufacture, as well as copper and aluminum in smaller amounts.

High temperature and pressure heat exchangers usually are shell-and-tube type. These exchangers comprise the following elements:

- **Tubes:** Heat exchanger tubes often are manufactured to industry standard diameters.
- **Tube sheet:** Tube sheets are constructed from a round, flattened sheet of metal. Holes for the tube ends then are drilled for the tube ends in a pattern relative to each other.

- **Shell:** The shell is constructed either from pipe or rolled plate metal.
- **Head:** Heads typically are fabricated or cast.
- **Baffles:** Baffles usually are stamped/punched, or machine drilled depending on size and application.

Figure 56 | Schematic of a U-Tube Heat Exchanger



Source: Public domain.

4.4.1.2 MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of heat transfer equipment for CSP projects:

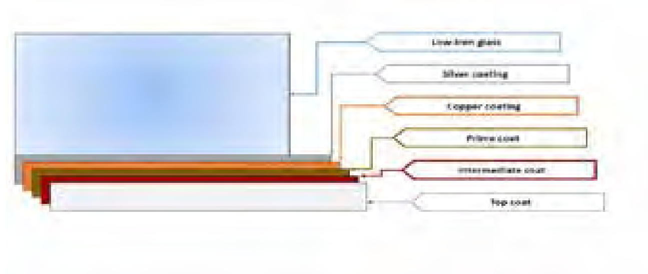
- **Aalborg CSP:** Danish company Aalborg CSP A/S has references of over 250 MWe installed since 2008 and over 75 MWe expected for 2013 and 2014.
- **Alfa Laval:** Alfa Laval AB is a Swedish company producer of specialized products and solutions used to heat, cool, separate, and transport different products.
- **Foster Wheeler:** Foster Wheeler AG is a global conglomerate focused on engineering, procurement, and construction (EPC) for power facilities.
- **GEA:** GEA Group Aktiengesellschaft focuses on process technology and components for demanding production processes in various end markets.
- **HAMON group**: Hamon & Cíe International is an engineering and contracting company (EPC) based in Belgium.

4.4.2 MIRROR

4.4.2.1 PRODUCTION PROCESS AND FACTORS

Mirrors are used to reflect the direct solar radiation incident on them and concentrate it onto the receiver placed in the focal line of the Parabolic Trough collector. The mirrors are made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness and parabolic shape. Additional layers protect the silver coating against corrosion and erosion.

Figure 57 | Schematic of a CSP Mirror Structure



4.4.2.2 MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of Mirrors for CSP projects:

- **AGC Solar:** AGC Group, with the Asahi Glass Company at its core, is a global business group. Its main industries are flat glass, automotive glass, display glass, electronics and energy, and chemicals.
- **Flabeg:** FLABEG Holding GmbH is a German technology leader in the field of glass finishing. It is among the leading global manufacturers of low-glare mirrors and cover plates for the automotive industry, as well as solar and high-tech glass applications.
- **Guardian:** Guardian Industries Corp. is a diversified global manufacturing company with leading positions in float glass, fabricated glass products, fiberglass insulation, and other building materials for commercial, residential, and automotive markets.

- **Rioglass:** Created in 1991 in Spain, Rioglass has become a significant player in the European automotive glass market. The solar division was created in 2007.
- **Saint Gobain:** Saint-Gobain S.A. is a French multinational corporation that produces a variety of construction and high-performance materials. The solar energy division, Saint-Gobain Solar Power, designs and manufactures mirrors for CSP.
- **Duro Felguera:** Duro Felguera, S.A. is an international company founded in Spain that specializes in turnkey projects for the industrial and power generation sector, as well as equipment manufacturing.
- **IMASA:** IMASA Ingeniería y Proyectos, S.A., with its headquarters in Oviedo (Spain), is dedicated to the implementation of projects and the maintenance and erection of industrial plants.

4.4.3 STORAGE TANKS

4.4.3.1 PRODUCTION PROCESS AND FACTORS

A large number of tanks and pressure vessels are required in a CSP plant. They include raw and treated water storage tanks; the deaerator, steam drum, and condensate tank for the Rankine cycle; and the HTF storage, expansion, and ullage vessels and other minor tanks for sewage and water treatment intermediate steps. If a TES system is included, molten salt "hot" and "cold" storage tanks also are necessary. Carbon steel and stainless steel are required for their manufacture.

Most of these tanks are small enough to be manufactured in a workshop and transported, but others such as molten salt tanks must be erected onsite. Both the hot tank and the cold tank will be manufactured from steel plates (stainless steel for the hot tank and carbon steel for the cold tank), laminated, and curved.

4.4.3.2 MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of storage tanks for CSP projects:

- **Aitesa:** Aitesa S.L. is a Spanish company with over 25 years of experience in design and manufacturing of heat transfer equipment over a wide range of pressures, temperatures, and fluids.
- **Caldwell Tanks:** Caldwell Tanks designs, fabricates, and builds tanks for the water, wastewater, grain, coal, and energy industries.

4.4.4 STRUCTURES

4.4.4.1 PRODUCTION PROCESS AND FACTORS

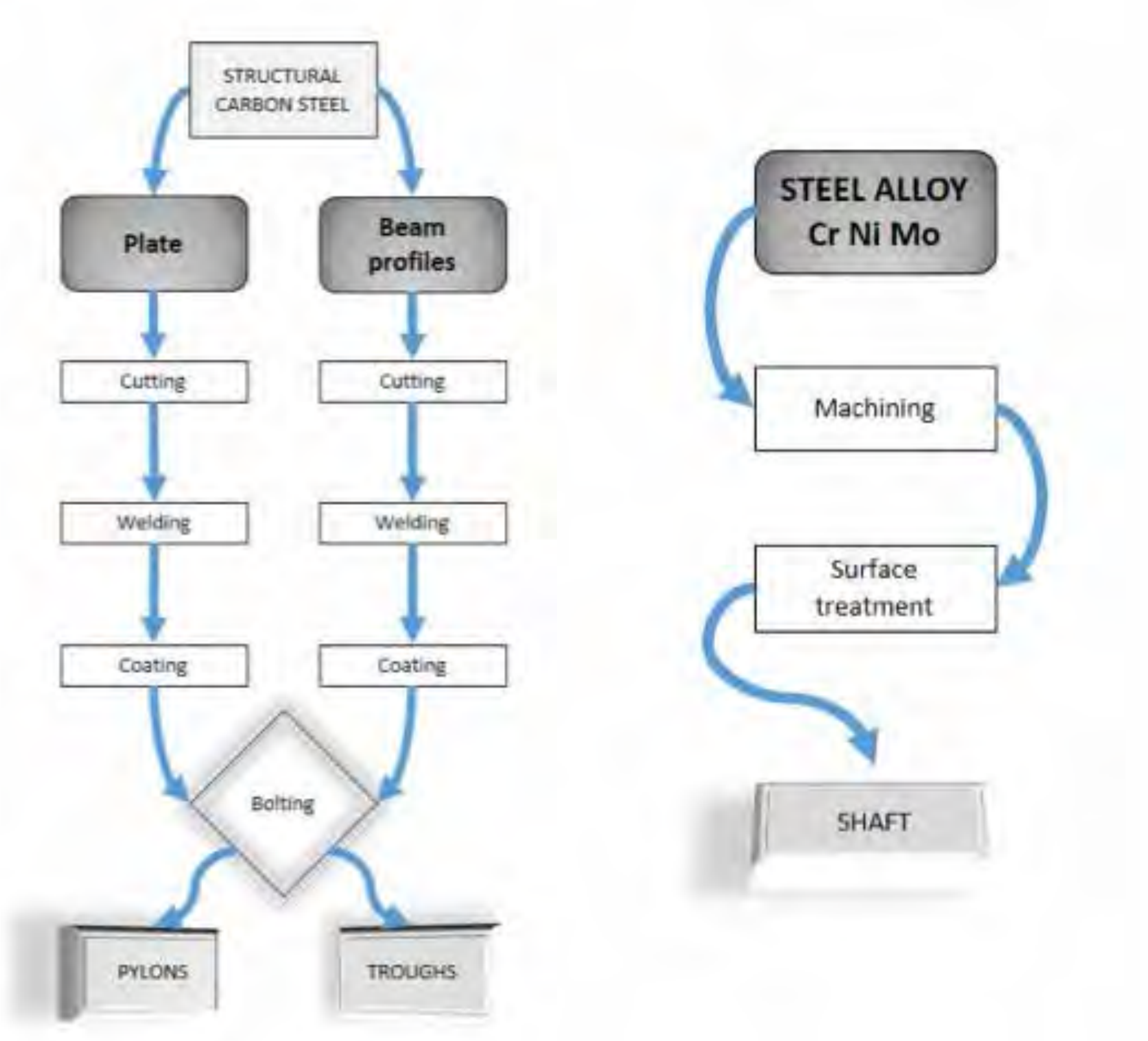
The CSP tracking system changes the position of the parabolic collector (or the heliostats, in solar tower plants) following the apparent position of the sun during the day, thus allowing it to concentrate the solar radiation onto the receiver. The system consists of a hydraulic (or electric, in solar tower plants) drive unit that rotates the optical element around its axis, and a local control that governs it. PV tracking systems follow a similar principle (with the PV module assuming the role of the receiver), but tolerances are less restrictive in manufacturing and assembly, because no optical elements are included.

The structure for both technologies must keep the shape and relative position of the elements, transmitting the driving force from the tracker and avoiding deformations caused by their own weight or other external forces such as the wind.

Galvanized structural carbon steel is the usual material for the structures. Commercial beam profiles are cut, welded, and hot-dip galvanized; the same happens for plates. On-site assembly is done by bolting the different pieces together.

Rack- or crown-and-pinion electric drives are the most commonly used to move the heliostats and PV systems. For parabolic collectors, a hydraulic drive is used due to the heavy loads that must be handled. The shaft manufacturing can be a technical challenge due to the tight tolerances required.

Figure 58 | Schematic of CSP Structure and Tracker Manufacturing



4.4.4.2 MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of structures or some of their key elements for CSP or PV projects:

- **Albiasa:** Albiasa Gestión Industrial, S.L. is a Spanish group that has developed capital assets engineering, especially in the iron and steel industry. Albiasa Gestión entered the RE field through the company ALBIASA SOLAR, SL in 2004.
- **Asturfeito:** Asturfeito S.A. is a Spanish company specialized in structure and equipment manufacturing. Its subsidiary Asturmatic focuses in hydraulic, pneumatic, and electric equipment and control systems.
- **Gossamer:** Gossamer Innovations is a structure design company based in the US. Its designs are manufactured through a network of local workshops and suppliers, and have been used in approximately 200 MWe installed capacity.
- **Ideas en Metal:** Ideas en Metal S.A. is a Spanish company specialized in the design and manufacture of space frames, storage systems, and other metal products that are made mainly from sheet and pipe and manufactured in series.
- **MADE:** Made Torres is part of the Invertaresa Group and was established in 1940. It is now an industrial company of reference both nationally and internationally, and is one of the leaders in the manufacture of structures for the CSP sector. Made Torres has supplied approximately 350 MWe installed capacity.
- **SBP:** Schlaich Bergermann & Partner, based in Stuttgart, is a structural engineering firm that manages the patent rights on the Parabolic Trough designed by the EuroTrough consortium,[32] one of the most installed collectors worldwide.
- **Sener:** Sener Grupo de Ingeniería, S.A. is a Spanish engineering company that has extensive experience in the development of thermosolar plants. Senerthough is one of the most installed collectors worldwide.
- **Siemens:** Siemens AG is a German multinational engineering and electronics conglomerate that has increased its solar portfolio including most CSP components such as structures and trackers, receivers, mirrors, and turbine.
- **Other:** Because the usual size of PV projects is smaller than for CSP, the market for PV structures is shared with many small and medium local companies.

32. The companies and research institutions in the EuroTrough consortium are Fichtner Solar, Flabeg Solar International, SBP and DLR (Germany); CRES (Greece); Iberdrola, Abengoa/Inabensa, and PSA-CIEMAT (Spain); and Solel (Israel).

4.5 Insight into the Suggested Value Chains: PV Industries

4.5.1 INVERTER

4.5.1.1 PRODUCTION PROCESS AND FACTORS

An electrical power converter changes direct current to alternating current. Solid-state inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power.

Grid-tied inverters are designed to inject electricity into the electric power distribution system. Such inverters must synchronize with the frequency of the grid and must include safety features such as anti-islanding protection.

The manufacturing of the inverter is similar to that of any electronic device based on semiconductor technologies. Aside from the electronics, an inverter includes a controller to implement anti-islanding and maximum power point tracking features as well as communication ports, harmonic filter, switchgear and protections, heat dissipation and a protective enclosure.

4.5.1.2 MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of Inverters for PV projects:

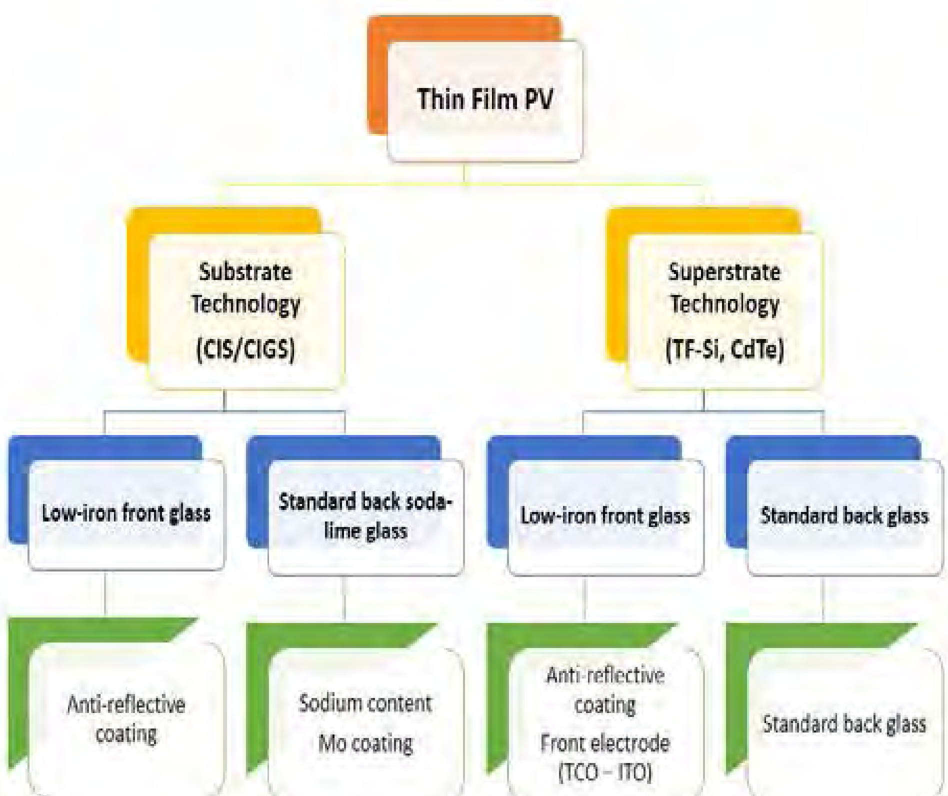
- **Danfoss:** The Danfoss Group is a global producer of components for the control of electric motors, HVAC systems, industrial automation, and elements for solar energy such as power inverters and system monitoring devices.
- **Fronius:** Fronius is an Austrian company specialized in welding equipment, battery loading regulation, and solar inverters and monitoring devices.
- **Gamesa:** Gamesa is a Spanish company manufacturing wind turbines and solar invertors.
- **GE Energy:** General Electric Company, or GE, is a multinational conglomerate. One of its divisions manufactures inverters for solar applications.
- **Ingeteam:** Engineering company specialized in power electronics design and inverter manufacturing.
- **Kaco New Energy:** Company specialized in solar inverters and monitoring devices.
- **Siemens:** Siemens AG is a German multinational engineering and electronics conglomerate that also manufactures solar inverters and monitoring devices.
- **SMA Solar Technologies:** Company specialized in solar inverters and monitoring devices.
- **Solar Max:** Company specialized in solar inverters and monitoring devices.

4.5.2 SOLAR GLASS

4.5.2.1 PRODUCTION PROCESS AND FACTORS

Solar glass can be defined depending on the final use (Figure 59).

Figure 59 | Types of Solar Glass



General requirements can be defined for any of these applications. These requirements include:

- Tight tolerances in overall dimensions, warp
- Surface quality, smoothness, and planarity to avoid coating problems
- Edge shape and quality required for assembly
- Durability and small loss of properties with aging
- Reliability and repeatability.

4.5.2.2 MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of solar glass for PV projects:

- **AGC Solar:** The AGC Group, with the Asahi Glass Company at its core, is a global business group. Its main industries are flat glass, automotive glass, display glass, electronics and energy, and chemicals.
- **Guardian:** Guardian Industries Corp. is a diversified global manufacturing company. It has leading positions in float glass, fabricated glass products, fiberglass insulation and other building materials for commercial, residential, and automotive markets.
- **Pilkington:** Pilkington is a division of Nippon Sheet Glass Co., Ltd., a Japanese company that is one of the world's largest manufacturers of glass and glazing products for the automotive, architectural, and technical glass markets.
- **Saint Gobain:** Saint-Gobain S.A. is a French multinational corporation that produces a variety of construction and high-performance materials. The solar energy division, Saint-Gobain Solar Power, designs and manufactures mirrors for CSP.
- **Schott:** Originating in Germany, Schott AG is an international technology group with more than 125 years of experience. Their products include components and systems made from specialty glasses and materials.

CHAPTER 5:

Demand Forecast

To set up an industry of the solar supply chain, a minimum demand should exist so that a threshold technical and economical production capacity can be reached. This demand can come from the country in which the industry is set up (internal demand) or from exports (external demand).

5.1 Installed Capacity

The driving force for internal demand is the growth of the installed capacity of solar power plants in the country. Therefore, a forecast up to 2027 has been made to deduce the solar component demand for Egypt.

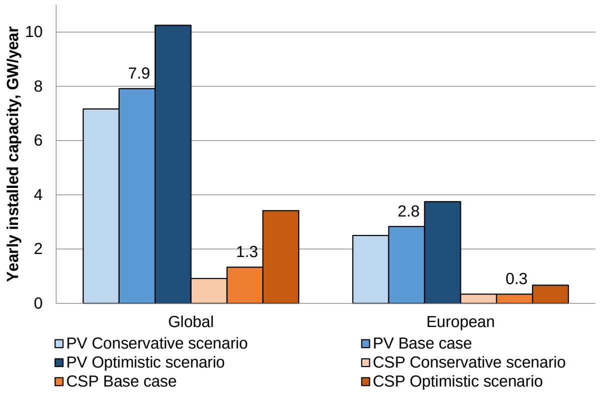
Demand for solar components is not only domestic but also can come from exports to other countries and regions. Thus, demand from four separate regions—neighboring MENA countries, the MENA Region as a whole, the European Union, and the rest of the world (ROW)—has been forecast.

The methodology to define the component demand is based on the forecast installed capacity in each of these regions, as per:

- Projections to 2020 and 2030 for Europe and the rest of the world (IEA 2010).
- Objectives and plans to 2020 and beyond for each MENA country (EIB 2010), (MEM 2012), November 11.

Global and European forecasted installed capacity includes three scenarios: conservative, moderate, and optimistic (Figure 60). Modifications were made to the projections in (IEA 2010) to include Algeria and Morocco's solar plans targets because they were disclosed after its publication. A linear hypothesis was considered to determine annual growth. In the long run, the annual installed capacity is the key number to determine whether a manufacturing industry will have a stable demand.

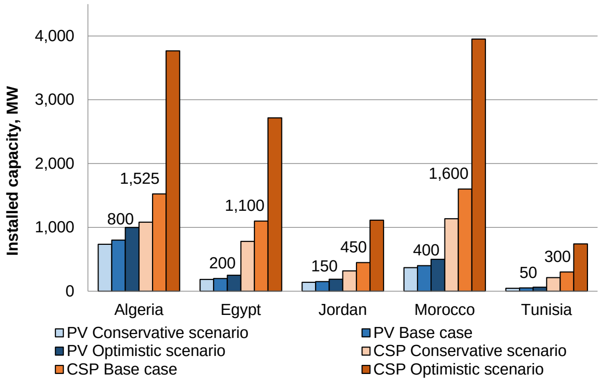
Figure 60 | Global and European CSP and PV Annual Installed Capacity in Different Scenarios, Average 2008-20



Source: Authors based on IEA 2010.

For MENA countries, the European Investment Bank (EIB), and Egypt's Ministry of Energy and Mines (MEM) and Ministry of Environment set up a similar scenario, which is called "moderate." Conservative and optimistic scenarios were built (Figure 61) following the same proportions as forecasted in *The World Energy Outlook 2010* (IEA 2010). For both PV and CSP, the moderate scenario was taken as the baseline for the present analysis.

Figure 61 | MENA CSP and PV Installed Capacity for 3 Scenarios in 2020



An initial ramp followed by a stable annual installation hypothesis was used to determine annual growth in Egypt, considering the impetus that the Kom Ombo project will give to the sector in 2015. For other regions, a linear hypothesis was considered. To evaluate the business models in Task 5, projections were continued until 2027. As explained, the annual installed capacity is the reference to determine whether a manufacturing industry will have a stable demand.

Figure 62 | CSP Annual Installed Capacity Base Case, 2013-27

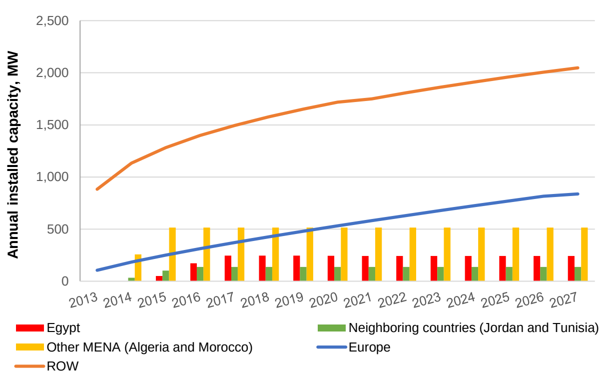
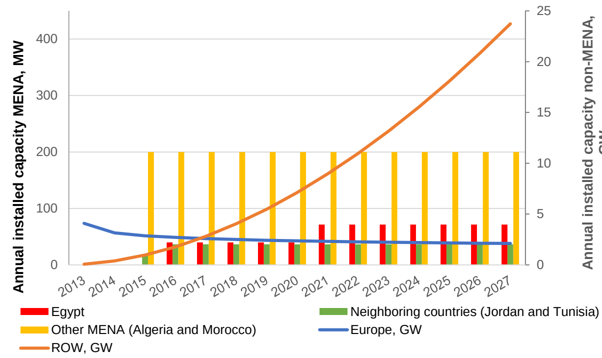


Figure 63 | PV Annual Installed Capacity Base Case, 2013-27



5.2 Market Share

The basic scenario hypothesis is that a fraction of domestic, MENA Regional, European, and ROW (rest of the world) demand could be met from Egypt, if appropriate actions were taken.

After discussion with industry leaders and taking into account the necessity of a track record to supply components in the energy business, the following hypotheses on market share growth were made:

1. Regarding the feasibility for Egypt to be competitive in the market, three main types of solar component industries are relevant:

   a. **Target** industries: Those for which Egypt is likely to be competitive in the short or medium term, if appropriate actions were taken.
   b. **Neutral** industries: Those for which Egypt could reach a certain market share in the medium or long term, but only through partnerships with technology proprietors or an extensive and expensive research and development process.
   c. **Difficult-to-reach** industries: Those with strong entry barriers, such as an oligopolistic market situation, high capital requirements, patent-protected knowledge requirements. No market share has been considered for these industries.

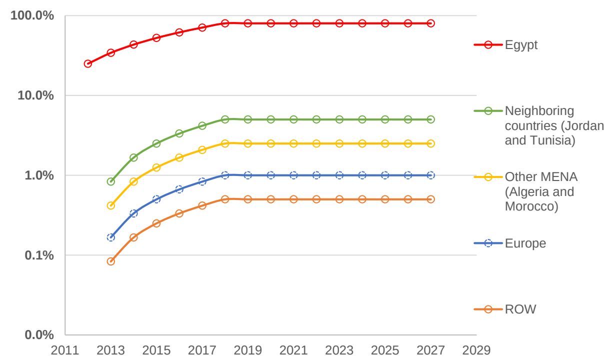
2. The hypothesis of increase in market share is the same for both CSP and PV technologies.
3. A **domestic market** share increase hypothesis for Egypt reaches 80 percent in 2018 for target industries.
4. Market share to be supplied by Egypt in **neighboring countries** (Jordan and Tunisia) has been estimated to reach a 5 percent of the demand for target industries in 2020.
5. **MENA Regional** (Algeria and Morocco) market share to be supplied by Egypt has been estimated to be a 2.5 percent of the demand for target industries in 2020.
6. A residual market share is considered for **Europe** (1.0 percent) and ROW (0.5 percent) in 2020.
7. **Actual** market share has been estimated at 25 percent for local demand. No participation in foreign markets has been considered to date.
8. A linear increase from actual to forecasted market share has been considered.

TABLE 27 | MARKET SHARE HYPOTHESES FOR EGYPT (%)

	CSP/PV Actual Market Share, Estimated	CSP/PV Market Share in 2020, Forecasted Target*
Local	25.0	80.0
Neighboring countries	0.0	5.0
Other MENA countries	0.0	2.5
Europe	0.0	1.0
ROW	0.0	0.5

Note: *Target industries are anticipated to reach their forecasted market share in 2018, and stay flat from then on.

Figure 64 | Market Share Evolution for Target Industries until 2027, Hypotheses (%)

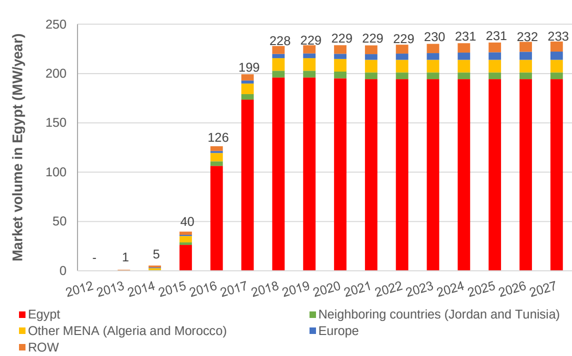


5.3 Market Volume

Combining the annual installed capacity with the expected market share, the expected market volume and, therefore, the demand to be supplied by Egypt's manufacturing sector are evaluated.

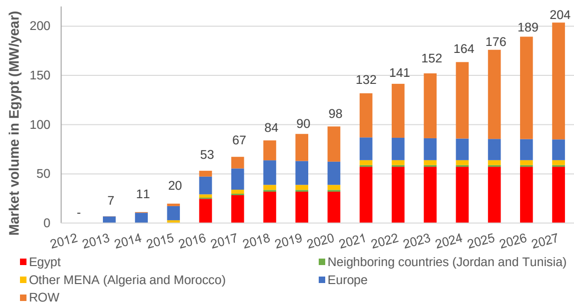
The sales structure is different for CSP and PV (Figure 65 and Figure 66). CSP demand is driven primarily by local installed capacity, whereas the PV sector is expected to rely on exports for more than 60 percent of its volume.[33]

Figure 65 | CSP Market Volume Base Case, 2012-27



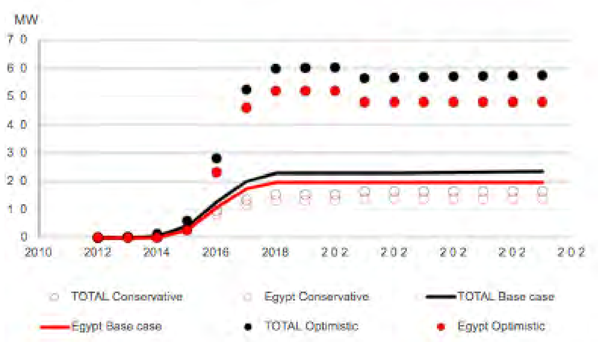
33. This conclusion, if based on the share between PV and CSP defined in the current national planning, thus is sensitive to changes in the energy matrix planning.

Figure 66 | PV Market Volume Base Case, 2012-27



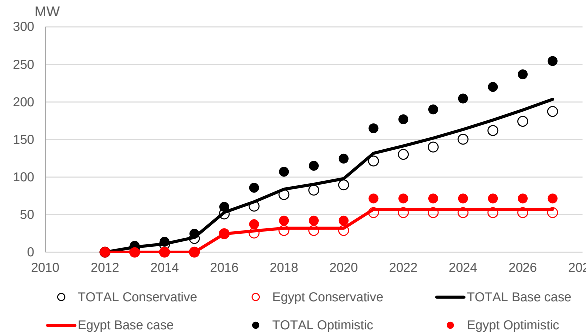
Three scenarios can be proposed that accord with the moderate, conservative, and optimistic scenarios described for the installed capacity forecast.

Figure 67 | Market Volume Sensitivity Analysis for CSP (MW)



The combination of Egypt's ambitious targets for CSP (1,100 MW in 2020 and 2,800 MW in 2027) and high market shares of local components yields a market volume strongly depending on local sales. This local dependence can pose both an advantage, because the familiarity with the local business environment is good for competitiveness, and a disadvantage, because any delay or reduction in Egypt's Solar Plan will negatively affect the success of industrial initiatives.

Figure 68 | Market Volume Sensitivity Analysis for PV (MW)



Although Egypt's targets for PV are modest (200 MW in 2020 and 700 MW in 2027), global demand can suffice as a driving force if local manufacturers succeed in foreign markets. Succeeding will require a strong commitment from local entrepreneurs to adapt their production lines to the restrictive quality levels demanded worldwide, because they will have to enter markets in which other companies are well established suppliers.

5.3.1 SALES FORECAST

The industries identified in this document for development in Egypt rely on well-known base industries (metal fabrication, steel manufacturing and glassworks), and their target market has grown every year since at least 2007, enabling us to forecast an expected sales range for each proposed technology, considering actual prices of solar components.

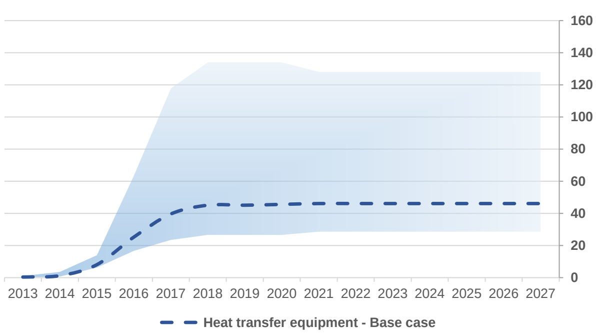
TABLE 28 | ACTUAL SALE PRICES RANGE CONSIDERED FOR COMPONENTS *(US$/KW OF INSTALLED SOLAR POWER)*

CSP	Heat transfer equipment	175-	225
	Mirrors	400-	500
	Pumping equipment	60-	70
	Storage tanks	250-	300
	Structures	600-	800
PV		200-	400
	Inverter	200-	300
	Solar glass	13-	22

5.3.1.1 CSP TECHNOLOGIES

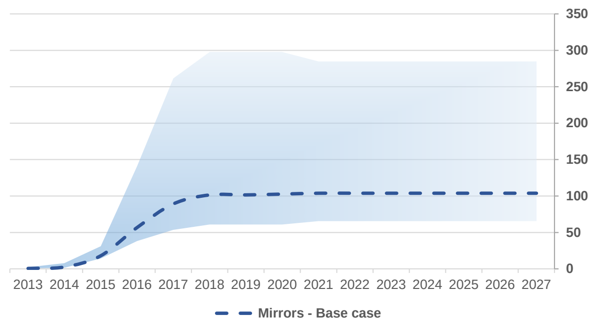
The estimated sales price of the heat transfer equipment in a CSP plant is US$175- $225/kW. This price would result in an annual market volume of US$30 million- $130 million in 2027.

Figure 69 | Sales Forecast Sensitivity Analysis for CSP Heat Transfer Equipment, 2013-27 *(US$ mil)*



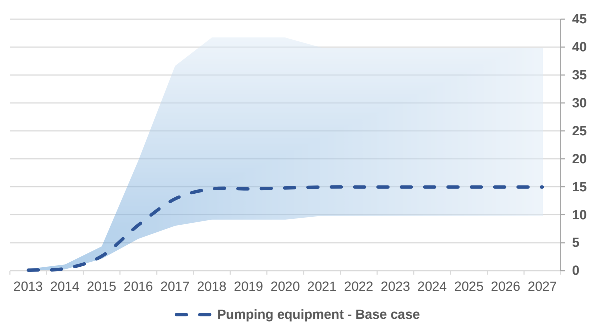
The estimated sales price of the mirrors in a CSP plant is US$400-$500/kW. This price would result in an annual market volume of US$50 million-$280 million in 2027.

Figure 70 | Sales Forecast Sensitivity Analysis for CSP Mirrors, 2013-27 *(US$ mil)*



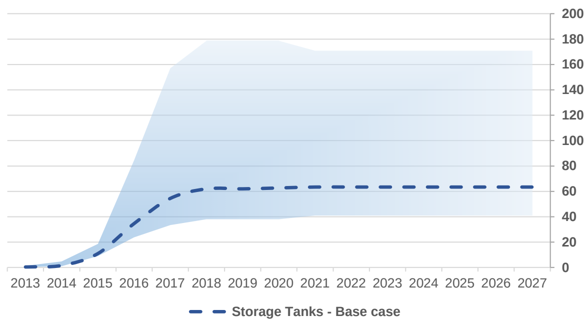
The estimated sales price of the pumping equipment in a CSP plant is US$60-$70/kWh. This price would result in an annual market volume of US$10-$40 million in 2027.

Figure 71 | Sales Forecast Sensitivity Analysis for CSP Pumping Equipment, 2013-27 *(US$ mil)*



The estimated sales price of the storage tanks in a CSP plant is US$250-300/kW. This price would result in an annual market volume of US$40 million-$170 million in 2027.

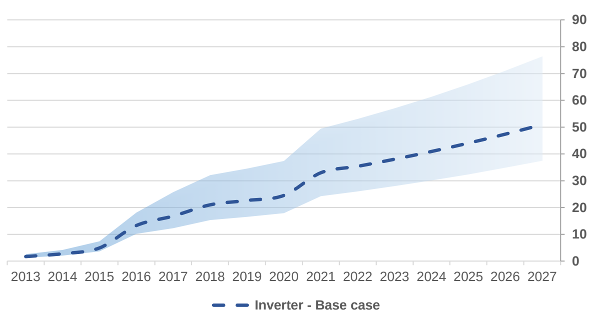
Figure 72 | Sales Forecast Sensitivity Analysis for CSP Storage Tanks, 2013-27 *(US$ mil)*



5.3.1.2 PV TECHNOLOGIES

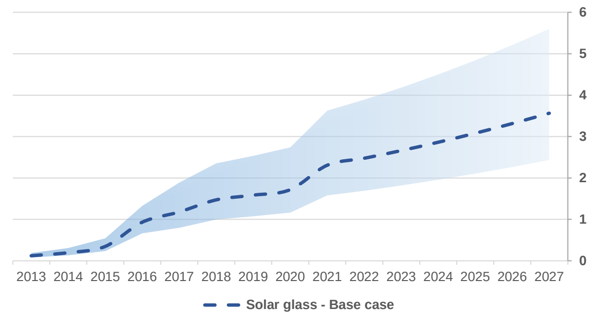
The estimated sales price of the inverters in a PV plant is US$200/kW-$300/kW. This price would result in an annual market volume of US$40 million-$75 million in 2027.

Figure 73 | Sales Forecast Sensitivity Analysis for PV Inverter, 2013-27 *(US$ mil)*



The estimated sales price of the solar glass in a PV plant is US$13kW-$22/kW. This price would result in an annual market volume of US$2 million-$6 million for 2027.

Figure 74 | Sales Forecast Sensitivity Analysis for PV Solar Glass, 2013-27 *(US$ mil)*

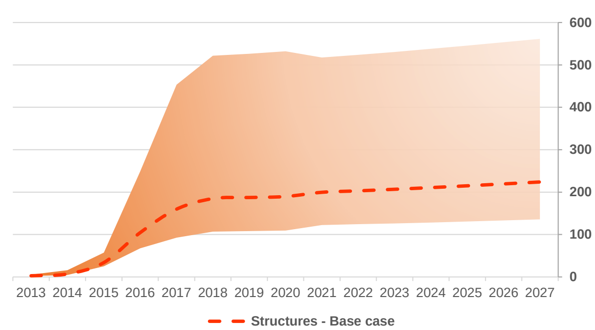


5.3.1.3 STRUCTURES

The industries of Structure and Tracker for CSP and Support Structure for PV are considered a single manufacturing industry because the techniques and materials employed are similar.

The prospective demand forecasts are combined, and the sales prices are considered proportionately. The combined demand would result in an annual market volume of US$130 million-$550 million in 2027.

Figure 75 | Sales Forecast Sensitivity Analysis for PV and CSP Structures, 2013-27 *(US$ mil)*



PART C | Existing and Potential Applications of Solar Technology, Solar Components, and/or Solar Energy in Residential, Commercial, Governmental, and Industrial Sectors

CHAPTER 6:

Existing and Potential Applications for CSP Technologies

6.1 Existing Applications

6.1.1 POWER GENERATION

"Concentrated solar power" is used to describe technologies that use the thermal energy from solar radiation to generate electricity. These systems consist of three main subsystems:

- **Solar field** (SF), in which mirrors concentrate the sunlight energy and convert it to high-temperature heat. This thermal energy is transferred using a heat transfer fluid (HTF). Point focus systems allow for higher temperatures and efficiencies, although they require two-axis tracking systems. Linear focus systems are less demanding but are less efficient as well.
- **Power block** (PB), in which the thermal energy in the HTF generates electricity by producing high-pressure steam, then channels it through a conventional steam turbine and generator in a Rankine cycle.
- **Thermal Energy Storage** (TES) system, in which excess energy from the SF is stored for later use in the PB.

These systems and their **forecasted demand** are described extensively in chapter 4.

6.1.2 PROCESS HEAT

Linear focus concentrators are well suited for process heat plants, in which a Solar Field is used to warm up either a heat transfer fluid (indirect process heat) or a process fluid from the client plant (direct heat). This concept is in use, for example, in Chile (Minera el Tesoro plant) (Abengoa 2013) and in a pilot plant in Egypt (El Nasr Pharmaceutical) (Fitchner Solar AG 2012).

"Process heat" comprises various possible system configurations that require different components, so the **forecasted demand** has been described case by case.

6.2 Potential Applications

6.2.1 POWER GENERATION

To improve the capacity factor and security of supply, hybridization of solar energy with other energy sources is possible. The approaches in use at utility scale are:

- **Alternative fuel boost:** Most CSP commercial plants have one or more auxiliary fossil-fueled burners to maintain production levels during transient situations. The existence of auxiliary burners also increases the capacity factor of the plant.

- **Full-scale hybridization:** Biomass-solar hybrid plant developed by Abantia and Comsa Emte at Les Borges Blanques (Spain) can reach its nameplate power during day, and keep up to 90 percent of this value during the night by using a biomass boiler. The plant thus achieves capacity factors comparable to those of a 100 percent biomass facility (Abantia and Comsa Emte. 2012). The advantage is that the solar energy reduces the fuel consumption of the plant.
- **Solar boost:** Coupling a Solar Field allows conventional power plants such as coal, fuel-oil, and combined cycles to work at or slightly above their rated power while reducing fuel consumption during daylight. Integrated solar combined cycle (ISCC) power plants and the Kogan Creek coal fired power station are in operation using this concept.

Kuraymat ISCC power plant has given Egypt a valuable insight into the development, construction, and operation of this type of plant. This experience may be valuable as the sector develops in the Region and could be replicated. Aside from new developments, Egypt has:

- Over **9.8 GW combined cycles**, some of which could be revamped to integrate a CSP Solar Field and become ISCC
- Nearly **900 MW gas turbines,** which could increase their outputs by including a heat recovery steam generator (HRSG) and a steam turbine, and a CSP Solar Field, thus becoming also ISCC
- Almost **13 GW "steam" power plants,** mostly fueled by heavy fuel oil and natural gas. A solar support also is feasible, either as a solar boost similar to Kogan Creek; or, if the cycle configuration cannot be adapted further, an auxiliary energy source to reduce fuel consumption.

Regarding new projects, according to the Egyptian Electricity Holding Company (EEHC), 12,400 MW thermal power projects will be implemented within the Seventh Five-Year Plan 2012-17. Of these, roughly 50 percent will be combined cycle power plants (Egypt EEHC 2012). If electricity demand keeps growing steadily a 5 percent/year, as it did from 2007-11, additional power could be necessary in the medium term (Table 29).

TABLE 29 | ELECTRICITY SOLD DURING FISCAL YEARS 2006/2007 TO 2010/2011, BY PURPOSE

	Energy Sold, by Purpose (GWh)				
	2007	2008	2009	2010	2011
Industries	34,569	37,045	37,273	38,916	40,702
Agriculture	3,789	4,209	4,617	4,834	4,927
Utilities	4,228	4,380	4,714	5,555	5,759
Public lighting	6,653	6,759	6,982	7,050	6,186
Gov. entities	5,562	5,691	5,563	5,443	5,977
Residential	36,596	40,271	43,811	47,431	51,370
Commercial	7,046	8,240	8,754	9,674	10,238
Subtotal	98,443	106,595	111,714	118,903	125,159
International connections and BOOT[7]	369	631	903	1,277	1,775
Total	98,812	107,226	112,617	120,180	126,934

Source: Egypt EEHC 2012.

Although the average capacity factor of Egyptian power plants is near 65 percent, peak demand issues have occurred during the last few years for several reasons.[34] Recurring peak demand is leading to a "fast-track program" to construct gas turbines to meet the peaks.

Egypt has a Country Strategy with targets to produce 20 percent of the electricity generated by year 2020 from renewable projects. This generation includes 7,200 MW of wind power, 1,100 MW of CSP, and 200 MW of PV (Egypt NREA 2011). Additional targets for 2027 exist (3,500 MW solar plan).

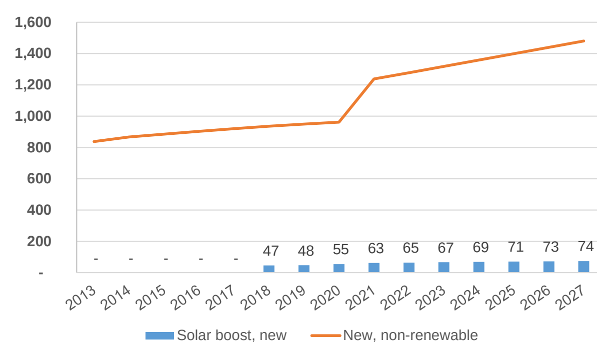
6.2.1.1 POWER GENERATION-DEMAND FORECAST

Considering the situations above, the following assumptions were made to estimate future installed capacity:

- The electricity demand will keep growing at 5 percent/year
- The Country Strategy targets will be fulfilled, reaching 20 percent renewable generation in 2020. A 30 percent renewable share in 2027 has been considered as well.
- Egypt's actual overall capacity factor is near 65 percent (Egypt EEHC 2012).
  - A typical, profitable wind farm will reach up to 35 percent capacity factor.
  - A typical, profitable Parabolic Trough CSP plant with TES will reach up to 35 percent capacity factor.
  - A typical, profitable PV plant will reach 15 percent-18 percent capacity factor.
  - A typical, profitable thermal power plant will reach up to 85 percent capacity factor.
  - Thus, increasing the renewable share probably will lower the overall capacity factor.
  - Therefore, to avoid peak demand issues, the installed capacity will need to grow more than 5 percent/year. A 6 percent annual growth has been assumed.
- The nonrenewable fraction of the installed capacity growth can be hybridized with CSP up to 10 percent of its power. Fifty percent of the newly installed plants could be located in suitable places for CSP hybridization.
- A five-year delay has been taken into account for the hybridization of new plants, considering the additional planning and engineering required.

Figure 76 shows the annual installed capacity required to include a solar boost in the new nonrenewable power plants.

Figure 76 | Installed Capacity Needed to Supply Demand Estimates, and Estimated Solar Boost of New Plants, 2013-27 *(MW)*



Revamping and improving existing plants also is feasible. The following assumptions have been made:

- Up to 10 percent of actual **combined cycles** can be adapted for solar boost. This adaptation will increase their output during sunny hours by up to 5 percent, yielding a total solar capacity of nearly 50 MW.
- Up to 10 percent of actual **gas turbines** can become ISCC. This adaptation will increase their output a 50 percent due to the steam turbine; and during sunny hours up an additional 5 percent, yielding a total solar capacity of near 30 MW.

34. Namely, delay in Abu Kir and El Sokhna projects to 2012-13, cancelling Newibaa project, and unexpected high temperatures during summer that increased electricity consumption for air conditioning (EEHC 2012).

- Up to 10 percent of actual **“steam” power plants** can be adapted for solar boost. Adaptation will increase their output during sunny hours by up to 10 percent, yielding a total solar capacity nearing 130 MW.

These changes will require extensive engineering. Furthermore, to avoid peak demand issues, the integration needs to be coordinated with the actual production schedule. A five-year delay is anticipated for the additional planning and engineering. The overall construction schedule will extend to 2027.

Figure 77 | Installed Capacity Needed to Supply Demand Estimations, and Estimated Solar Boost of Existing Plants, 2013-27 *(MW)*

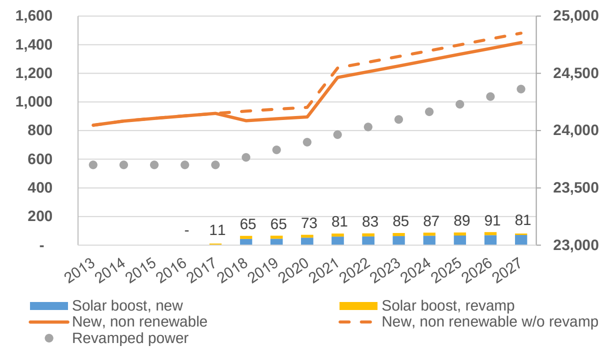


TABLE 30 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN POWER GENERATION, 2015-27 *(MW)*

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Solar boost, new	-	-	-	-	-	-	44	44	52	60	62	64	66
Solar boost, revamp	-	-	-	-	-	11	21	21	21	21	21	21	21
Total (MW)	-	-	-	-	-	11	65	65	73	81	83	85	87

Not all components for CSP power plants are required in the same amounts or proportions in this application and in utility-scale CSP power plants. The additional demand will apply to the following CSP components with the weights included beside them:

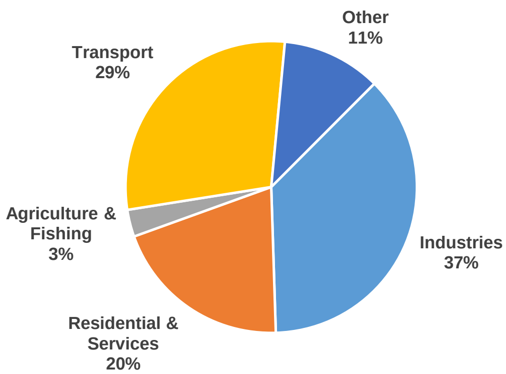
- Heat transfer equipment — 6 (new), 0.5 (revamp)
- Pumping equipment — 9 (new), 0.75 (revamp)
- HTF thermal oil — 1 (both)
- Mirror — 1 (both)
- Receiver — 1 (both)
- Storage tanks — 0.85 (both)
- Structures — 1 (both)

6.2.2 PROCESS HEAT

6.2.2.1 HIGH TEMPERATURE-DISTILLATION
Final energy consumption in Egypt in 2010 amounted over 70 Mtoe (IEA 2012). Considering the shares shown in Figure 77 and the electricity consumptions obtained from EEHC (Egypt EEHC 2012), nonelectrical energy consumption is estimated.

Additional assumptions are made for the thermal fraction of nonelectrical energy consumption, as well as for the temperature level at which that energy is demanded. Results of these estimates are shown in Table 31 and Table 32.

Figure 78 | Shares of Total Final Energy Consumption in Egypt, 2005 (%)



Source: Enerdata 2006.

TABLE 31 | ANNUAL THERMAL ENERGY CONSUMPTION ESTIMATES 2010 (GWH)-I

	Consumption Share (%)	Total Energy Consumption	Electricity Consumption	Nonelectrical Energy	Thermal Energy Fraction (%)	Thermal Energy Consumption
Industries	37	314,735	40,702	274,033	90	246,629
Residential and services	20	170,127	61,608	108,519	100	108,519
Agriculture and fishing	3	25,519	4,927	20,592	30	6,178
Transport	29	246,684	-	246,684	0	-
Other	11	93,570	17,922	75,648	50	37,824

TABLE 32 | ANNUAL THERMAL ENERGY CONSUMPTION ESTIMATES 2010 (GWH)-II

	High Temperature Fraction > 250ºc (%)	Medium Temperature Fraction 250<>120ºc (%)	Low Temperature Fraction < 120ºc (%)	High Temperature Energy Consumption	Medium Temperature Energy Consumption	Low Temperature Energy Consumption
Industries	60	30	10	147,978	73,989	24,663
Residential and services	0	50	50	-	54,259	54,259
Agriculture and fishing	0	50	50	-	3,089	3,089
Transport	0	0	0	-	-	-
Other	0	50	50	-	18,912	18,912

Within the "high temperature" fraction, two different uses are considered:

- Above 400 ºC, which usually requires direct combustion of a fuel
- Below 400 ºC, which are suitable for CSP heating.

The main industrial use that will be considered is the distillation of crude oil, which takes place at 370 ºC-390 ºC. Egypt has an installed refinery capacity of 726,000 bbl/day (U.S. EIA 2010).

6.2.2.1.1 PROCESS HEAT: DISTILLATION-DEMAND FORECAST

Given the above circumstances, the following assumptions were made to estimate future installed capacity:

- The typical thermal energy consumption for crude oil distillation is nearly 300 kWh/bbl (Metso 2012). This distillation leads to a thermal energy installed power of nearly 9 GW.
- Refineries usually will end up surrounded by auxiliary industries and petrochemical facilities, so the availability of adjacent suitable land will be low. Therefore, 5 percent of the refineries' actual thermal energy installed power[35] is proposed for substitution by CSP heating.
- These changes will require extensive engineering, and the integration needs to be coordinated with actual production schedule to avoid business interruption. A five-year delay has been taken into account for the planning and engineering, and the overall construction schedule will extend to 2027.
- No additional refining capacity installation has been taken into account.

35. A conversion factor of 2.8 is used to assimilate thermal to electrical power to determine component demand.

TABLE 33 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN PROCESS HEAT FOR DISTILLATION, 2015-27 (MW)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Thermal power	-	-	-	25	49	49	49	49	49	49	49	49	25
Electric equivalent	-	-	-	9	18	18	18	18	18	18	18	18	9

Not all components for CSP power plants are required in the same amounts or proportions in this application and in utility-scale CSP power plants. Therefore, this additional demand will apply to the following CSP components with the weights included beside them:

- Heat transfer equipment 0.50
- Pumping equipment 0.25
- HTF thermal oil 1.00
- Mirror 1.00
- Receiver 1.00
- Storage tanks 0.85
- Structures 1.00

6.2.2.2 MEDIUM TEMPERATURE-STEAM PRODUCTION

In 2010 Egypt had a medium temperature thermal energy consumption of nearly 150,000 GWh/year, of which nearly 50 percent was for industrial purposes (Table 32).

6.2.2.2.1 Process heat: Steam production-demand forecast

Given the above-mentioned circumstances, to estimate future installed capacity, the following assumptions were made:

- The medium temperature thermal energy consumption for industrial purposes was near 75,000 GWh/year in 2010. Assuming an average capacity factor of 85 percent, the thermal energy installed power would be nearly 9 GW.
- Given the diverse nature of industrial processes, 60 percent is feasible to adapt for CSP heating.
- Industrial facilities usually are grouped in industrial zones, so the availability of adjacent suitable land will be low. Therefore, 5 percent of their actual thermal energy installed power[36] is proposed for substitution by CSP heating.
- These changes will require extensive engineering, and coordinating the integration with the actual production schedule to avoid business interruption. A three-year delay has been taken into account for the planning and engineering. The overall erection schedule will extend to 2027.
- Annual thermal energy consumption growth of 5 percent has been assumed.

36. A conversion factor of 2.8 is used to assimilate thermal to electrical power in terms of component demand.

TABLE 34 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN PROCESS HEAT FOR STEAM PRODUCTION, 2015-27 *(MW)*

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Thermal power	-	14	29	30	32	33	35	37	39	41	43	45	47
Electric equivalent	-	5	10	11	11	12	13	13	14	14	15	16	17

Not all components for CSP power plants are required in the same amounts or proportions in this application and in utility-scale CSP power plants. The additional demand will apply to the following CSP components with the weights included beside them:

- Heat transfer equipment 0.25
- Pumping equipment 0.20
- HTF Thermal oil 1.00
- Mirror 1.00
- Receiver 1.00
- Storage Tanks 0.65
- Structures 1.00

6.2.2.3 LOW TEMPERATURE-DRYING FOOD OR OTHER PRODUCTS

Egypt had a low temperature thermal energy consumption of near 100,000 GWh/year in 2010, of which nearly 25 percent went for industrial purposes (Table 32).

6.2.2.3.1 Process heat: Drying demand forecast

Considering the above circumstances, the following assumptions were made to estimate future installed capacity:

- The low temperature thermal energy consumption for industrial purposes was nearly 25,000 GWh/year in 2010. Assuming an average capacity factor of 85 percent leads to a thermal energy installed power of nearly 3 GW.
- Twenty percent of the production value for companies registered in IDA (Egypt IDA 2009) is related to companies in the category, "Foodstuff and Beverages." Given the diverse nature of industrial processes, 40 percent is considered to be feasible to adapt for CSP heating.
- Industrial facilities usually are grouped in industrial zones, so the availability of adjacent suitable land will be low. However, these industries are expected to be medium to small. Therefore, 45 percent of their actual thermal energy installed power[37] is proposed for substitution by CSP heating.
- These changes will require extensive engineering and coordinating the integration with the actual production schedule to avoid business interruption. A three-year delay has been taken into account for the planning and engineering. The overall construction schedule will extend to 2027.
- Annual thermal energy consumption growth of 5 percent has been taken into account.

37. A conversion factor of 2.8 is used to assimilate thermal to electrical power in terms of component demand.

TABLE 35 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN PROCESS HEAT FOR DRYING, 2015-27 *(MW)*

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Thermal power	-	5	12	12	13	13	14	15	15	16	17	18	19
Electric equivalent	-	2	4	4	5	5	5	5	6	6	6	6	7

Not all components for CSP power plants are required in the same amounts or proportions in this application and in utility-scale CSP power plants. The additional demand will apply to the following CSP components with the weights included beside them:

- Heat transfer equipment 0.20
- Pumping equipment 0.20
- Mirror 1.00
- Storage tanks 0.35
- Structures 0.75

6.2.2.4 LOW TEMPERATURE-MED DESALINATION

Egypt has put in place plans to address water availability issues (Moawad 2004). During 2012-27, the following new desalination plants or expansion of existing plants will be carried out:

Red Sea governorate:

- 2012-17:
  North Hurgada (45,000 → 55,000 m³/day)
  South Hurgada (new 20,000 m³/day)
  Al-Qusair (new 9,000 m³/day)
  New Safaga plant (new 18,500 m³/day)
  New Marsa-Allam plant (3,000 → 6,500 m³/day)
  New city plants (10,000 → 20,000 m³/day)
  Shalateen (3,500 → 5,000 m³/day)
- 2017-22:
  North Hurgada (55,000 → 145,000 m³/day)
  South Hurgada (20,000 → 40,000 m³/day)
  Al-Qusair (9,000 → 24,000 m³/day)
  New Marsa-Allam plant (6,500 → 10,000 m³/day)
  New city plants (20,000 → 35,000 m³/day)
- 2022-27:
  New Safaga plant (18,500 → 28,500 m³/day

South Sinai governorate:

- 2012-17:
  Sharm El Sheikh (new 10,000 m³/day)
  Al Naqab (new 12,000 m³/day)
- 2017-22:
  Abo Redees (new 10,000 m³/day)
- 2022-27:
  Sharm El Sheikh (10,000 → 20,000 m³/day)
  Newaibaa (new 10,000 m³/day)
  Abo Redees (10,000 → 20,000 m³/day)

Matruh governorate:

- 2012-17:
  Al Barany (new 5,000 m³/day)
  Al Saloom (new 4,000 m³/day)
  Industrial area plant (17,000 → 50,000 m³/day)
- 2017-22:
  Al Dabaa (1,000 → 10,000 m³/day)
  Al Saloom (4,000 → 8,000 m³/day)
- 2022-27:
  Al Negaila (new 10,000 m³/day).

TABLE 36 | PLANNED INSTALLATION OR EXPANSION OF DESALINATION PLANTS UNTIL 2027 *(000S OF M^3/DAY)*

	2012-17	2017-22	2022-27
Red Sea	72.5	143.5	10
Sinai	22.0	10.0	30
Matrooh	42.0	13.0	10

Source: Osman 2011.

Reverse osmosis (RO) is a competitive option when electric grid connection is available. However, multi-effect distillation (MED) consumes less electricity and can be preferable if thermal energy is available at low cost (Osman 2011).

6.2.2.4.1 Process heat: MED desalination-demand forecast

Considering the above situations, the following assumptions were made to estimate future installed capacity:

- Multi-effect distillation requires 1.5 kWh-2.5 kWh of electricity per cubic meter of desalinated water, plus 40 kWh-100 kWh of low temperature thermal energy (Osman 2011).
- Desalination facilities usually are located beside the sea, so the availability of adjacent suitable land could be high unless environmental restrictions apply. Therefore, 70 percent of the planned desalination capacity could consider the use of MED, with a thermal energy power supply[38] of CSP heating. Forty percent of these plants found MED to be the best technological option.
- These changes will require extensive engineering, so a three-year delay has been taken into account for the planning and engineering. The plants to have been erected during those three years have been omitted from the estimate.

TABLE 37 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN PROCESS HEAT FOR MED DESALINATION, 2015-27 (MW)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Thermal power	-	22	22	27	27	27	27	27	8	8	8	8	8
Electric equivalent	-	8	8	10	10	10	10	10	3	3	3	3	3

Not all components for CSP power plants are required in the same amounts or proportions in this application and in utility-scale CSP power plants. The additional demand will apply to the following CSP components with the weights included across from them:

- Heat transfer equipment 0.20
- Pumping equipment 0.20
- Mirror 1.00
- Storage tanks 0.35
- Structures 0.75

38. A conversion factor of 2.8 is used to assimilate thermal to electrical power in terms of component demand.

6.2.2.4.2 Off-grid application: MED desalination plus Pumping

MED desalination consumes 40kW-100 kWh of low temperature thermal energy (Osman 2011) per cubic meter of desalinated water, plus 1.5kW-2.5 kWh of electricity. Considering the usual ratio for CSP of 1.5kW-2 kWh of waste heat per kWh of electricity, installing a conventional CSP power plant coupled to a MED desalination plant would result in a surplus of electricity. This surplus could be put to valuable use by installing a pumping facility to send the desalinated water to its final consumption points. The surplus also would allow for the installation of MED desalination plants off-grid in isolated locations.

To obtain a robust configuration and to avoid daily start/stop cycles, a combination of fossil fuel backup and higher than usual solar multiple and TES capacity would be required. This off-grid variant would generate the same additional demand described for the on-grid solution, plus:

- Additional heat transfer equipment +0.8
- HTF thermal oil +2/+0
- Mirrors +1
- Additional pumping equipment +2/+0
- Receivers +2/+0
- Solar salt +2
- Steam turbine +1
- Electrical generator +1
- Storage tanks +1
- Structures +2

6.2.2.5 COOLING-ABSORPTION CYCLES FOR HVAC IN LARGE BUILDINGS OR DISTRICT HEATING/COOLING

Solar-powered absorption cycles are used for air conditioning because, among other reasons, their energy source is coupled to the demand. The proliferation of air conditioning equipment in residential buildings, which is responsible for approximately 20 percent of the peak load in summer, is considered one of the main reasons for peak demand issues (Hussein 2012).

Over 6 million air conditioning devices operate in Egypt, in approximately 30 percent of the average houses. This number is likely to increase.

The overall coefficient of performance (COP) of state-of-the-art electromechanical cooling equipment is nearly 3.00. Absorption cycles show COP values between 0.55 and 1.50 (Grupo Nova Energía 2012), but they use mostly thermal energy (the electric consumption is barely noticeable). Thus, using absorption cycle is advisable when thermal energy prices are significantly lower than those of electricity.

6.2.2.5.1 Process heat: Air conditioning-demand forecast

Considering the above circumstances, the following assumptions were made to estimate future installed capacity:

- Peak load in summer 2012 reached 29.5 GW (Hussein 2012). Air conditioning equipment accounted for 20 percent of this load.
- Air conditioning demand will grow due to:
  - Population growth: Annual growth of 1.7 percent has been estimated (World Bank 2012).
  - Market growth: By 2027, 60 percent of average houses are projected to have air conditioning systems.
- The use of CSP heating allows reaching COP values near 1.2.
- The market share of CSP solar-powered absorption cycles for air conditioning will be 5 percent of the overall air conditioning market by 2027.

TABLE 38 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN PROCESS HEAT FOR RESIDENTIAL AC, 2015-27 *(MW)*

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Thermal power	-	86	171	171	171	171	171	171	171	171	171	171	171
Electric equivalent	31	61	61	61	61	61	61	61	61	61	61	61	61

Not all of the components for CSP power plants are required in the same amounts or proportions in this application and in utility-scale CSP power plants. The additional demand will apply to the following CSP components with the weights included beside them:

- Heat transfer equipment 1.00
- Mirror 1.00
- Receiver 1.00
- Storage tanks 0.01
- Structures 1.00

CHAPTER 7:

Existing and Potential Applications for PV Technologies

7.1 Existing Applications

7.1.1 POWER GENERATION

7.1.1.1 UTILITY SCALE

This technology converts solar energy directly into electricity using the photovoltaic effect. When solar radiation reaches a semiconductor, the electrons present in the valence band absorb energy and, being excited, jump to the conduction band and become free. These highly excited, nonthermal electrons diffuse, and some reach a junction at which they are accelerated into a different material by a built-in potential (Galvani potential). This technology generates an electromotive force, which converts some of the light energy into electric energy. Unlike CSP, solar PV can utilize all radiation—both direct and diffuse—that reaches the system.

The basic building block of a PV system is the PV cell, which is a semiconductor layer that converts solar energy into direct current electricity. PV cells are interconnected to form a PV module, typically up to 50-200 Watts (W). The PV modules, combined with a set of additional application-dependent system components (such as inverters, batteries, electrical components, and mounting systems), form a PV system. PV systems are highly modular, that is, modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW). These systems and their **forecasted demand** are described extensively in chapter 4.

7.1.1.2 INTEGRATED STRUCTURES

Rooftop integration of PV plants has the added benefit of locating together power generation and consumption, thus lowering distribution losses.

A typical residential building can host PV plants from 1 to few dozen kW; industrial warehouses can reach several MW.

7.1.1.2.1 Rooftop integrated PV-demand forecast

Taking into account the above circumstances, the following assumptions were made to estimate future installed capacity:

- Considering Egypt's population and an average occupation ratio of 3.75 m^2/inhabitant (on a footprint basis), the combined rooftop area has been estimated at 300 km^2.
- Solar water heaters and PV compete for the same locations. A 25 percent share of PV has been estimated.
- To improve annual output, PV plants must be oriented south, with an appropriate tilt and spacing to avoid shadows. An effective available area of 30 percent has been assumed.
- An average solar-to-electric efficiency of 12 percent has been estimated.
- Rooftop PV demand will grow due to:
  - Population growth: 1.7 percent annually has been estimated (World Bank 2012).
  - Market growth: An estimated 25 percent of all average houses will have rooftop PV systems by 2027.

TABLE 39 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN ROOFTOP PV, 2014-27 *(MW)*

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Installed power	25	50	50	50	50	50	50	50	50	50	50	50	50	50

Unlike for CSP, this additional demand will be applied evenly to all PV components.

7.1.2 COMPONENTS FOR OTHER MARKETS

7.1.2.1 SOLAR GLASS IN LCD SCREENS
Transparent conductive oxide (TCO)-coated flat glass is used in the liquid crystal display (LCD) screens industry. This industry reached worldwide sales of 203 million units in 2012 (Rapid TV News 2013), and is expected to grow by 2.8 percent/year after 2014 (IHS 2013). The average unit size was 38.6 inches (Hsieh 2012), that is, an estimated global surface of nearly 75 million m^2.

7.1.2.1.1 Solar glass in LCD screens-demand forecast
Taking into account the above circumstances, the following assumptions were made to estimate future installed capacity:

- TCO coating of solar glass is already required for PV applications, so the PV industry needs no additional modifications to supply the LCD screens market.
- Considering average efficiency of TF modules, a conversion factor of 100 W/m^2 is used to assimilate surface to electrical power in terms of component demand.
- A 0.5 percent share of the global demand for TCO-coated glass is expected to be supplied by Egyptian companies.

This additional demand will apply only to solar glass.

TABLE 40 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN LCD SCREENS, 2014-27 *(MW)*

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Surface, 10^3 m^2	380	390	400	410	420	440	450	460	470	490	500	510	530	540
Electric equivalent	38	39	40	41	42	44	45	46	47	49	50	51	53	54

7.2 Potential Applications

7.2.1 OFF-GRID

7.2.1.1 WATER PUMPING FOR IRRIGATION

In Egypt by 1997, 99.8 percent of cropland was irrigated. Smallholdings characterize Egyptian agriculture: approximately 50 percent of holdings have an area of less than 0.4 ha (1 feddan) (UN FAO 2009).

Irrigation potential is estimated at 4.4 million ha. The total area equipped for irrigation was 3.4 million ha in 2002; 85 percent of this area was in the Nile Valley and Delta. Total water withdrawal in 2000 was estimated at 68.3 km^3. This amount included 59 km^3 (86 percent) for agriculture (UN FAO 2009).

Surface water was the source for 83 percent of the irrigated area in 2000. In contrast, in the provinces of Matruh, Sinai, and New Valley, 11 percent (360,000 ha) of the area was irrigated with groundwater. The power-irrigated area in 2000 was estimated at 2.9 million ha (UN FAO 2009), or 85.8 percent of the total irrigated area.

The irrigation system for surface water is a combined gravity and water-lifting system. Downstream of the High Aswan Dam, the main canal system (first level) comprises thousands of kilometers of canals and takes its water from head regulators located upstream of the Nile barrages. Water is distributed along branches toward the distributaries, which receive water according to a rotation schedule. Water is pumped from the distributaries to irrigate fields; the typical required head is 0.5-1.5 m (UN FAO 2009).

Groundwater extraction in 2000 comprised 87 percent from the Nile Basin; 12 percent from the eastern and western deserts, that is, mainly the Nubian Sandstone aquifer; and 1 percent from shallow wells in Sinai and on the northwestern coast (UN FAO 2009). The depth of wells in the Nubian Sandston aquifer can reach up to 1,000 m. Water availability can be as low as 1 hour every 12 days (U.S. The White House 2011).

7.2.1.1.1 Water pumping for irrigation PV-demand forecast

Considering the above circumstances, the following assumptions were made to estimate future installed capacity:

- The average water consumption for agricultural uses is near 60 km^3. An 85.8 percent of this water needs to be pumped (UN FAO 2009).
- Surface water stands for 86 percent of the total and has to be pumped from the distributaries with a required head of 0.5-1.5 m. The approximate energy required for this pumping is 185 GWh/year.
- Groundwater stands for 14 percent of the total pumped water. The approximate energy required for this pumping is 3,000 GWh/year. The average depth of the wells is 100 m. Deep wells account for 12 percent of the extractions, but require over 99 percent of the groundwater pumping energy, and over 90 percent of the total pumping energy.
- The average pumping period is 10 hours/day. This creates an estimated pumping power of 900 MW.
- The market share of PV-powered pumping for irrigation purposes will be 50 percent of the overall pumping power, to be installed over the next 8 years.

TABLE 41 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN WATER PUMPING FOR IRRIGATION, 2014-27 *(MW)*

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Installed power	30	60	60	60	60	60	60	60	-	-	-	-	-	-

Unlike for CSP, this additional demand will be applied evenly to all PV components.

7.2.1.2 POWER GENERATION

As per 2009, Egypt had an electrification rate approximately of 99.6 percent (World Bank 2011). Although it is one of the highest rates in Africa, approximately 300,000 people still lack access to electricity.

Several configurations can be chosen when considering a PV plant for standalone applications. Some examples are:

- Partial PV supply with fossil backup
- Full PV supply with energy storage:
  - Batteries
  - Pumped-storage hydroelectricity (PSH).[39]

Any of the above-mentioned configurations can be coupled with small-scale wind power, increasing the primary renewable supply and benefitting from the complementary annual production cycles of both technologies. Hybrid systems improve the usage of wind and sun resources by complementing each other for higher energy production and efficiency. For example, on days with little direct sunlight such as cold and cloudy days, the wind is usually stronger, allowing the wind turbines to generate enough electricity to compensate for the lower solar energy production. On days with little wind energy production, the skies usually are clearer so enable PV panels to generate more electric power. In any case, some kind of backup or energy storage is required to ensure continuous supply throughout the day.

7.2.1.2.1 Standalone power generation PV-demand forecast

Considering the above circumstances, the following assumptions were made to estimate future installed capacity:

- The average electricity consumption for residential uses is near 600 kWh/year per capita in Egypt (Egypt EEHC 2012). This amount leads to an unsatisfied demand near 180 GWh/year.
- The peak demand of an average house ranges from 1.5 kW to 5 kW, depending on the degree of comfort demanded. The requirements are assumed to start at 1.5 kWh and reach 5 kW in 2027.
- The market share of standalone PV supply will be 60 percent of the overall off-grid requirements to be installed until 2027.

39. The plant is oversized, and the excess generation capacity is used to pump water into a high reservoir. When demand exceeds production (at night), water is released back into a low reservoir through a turbine, thus generating electricity. Reversible turbine/generator assemblies can act as both pump and turbine. The applicability of this solution depends on the availability of the high reservoir.

TABLE 42 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN STANDALONE POWER GENERATION, 2014-27 *(MW)*

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Installed power	3	7	8	10	12	14	15	17	19	21	22	24	26	27

Unlike for CSP, this additional demand will be applied evenly to all PV components.

7.2.1.3 REVERSE OSMOSIS DESALINATION-PV

Egypt has plans to increase its desalination capacity (Table 36). Reverse osmosis (RO) is a competitive option when electric grid connection is available, Multi-effect distillation (MED) (Osman 2011) has a lower electricity consumption and can be preferable if thermal energy is available at low cost. Conventional PV plants have no waste heat recovery, so only their combination with RO will be estimated.

Several configurations can be chosen when coupling a PV plant to a RO desalination facility. Some examples are:

- Grid connected:
  - Partial PV supply with grid backup
  - Full PV supply with net metering
- Off-grid:
  - Partial PV supply with fossil backup
  - Full PV supply with energy storage:
    - Batteries[40]
    - Pumped-storage hydroelectricity (PSH).

Any of the above-mentioned configurations can be coupled with small- or medium-scale wind power plants, increasing the primary renewable supply and benefitting from the complementary annual production cycles of both technologies. Hybrid systems improve the usage of wind and sun resources by complementing each other for higher energy production and efficiency. For example, on days with little direct sunlight such as cold and cloudy days, the wind is usually stronger, allowing the wind turbines to generate enough electricity to compensate for the lower solar energy production. On days with little wind energy production, the skies usually are clearer so allow PV panels to generate more electric power. In any case, some kind of backup or energy storage is required to ensure continuous supply throughout the day.

7.2.1.3.1 Reverse osmosis desalination PV-demand forecast

Considering the above circumstances, the following assumptions were made to estimate future installed capacity:

- Reverse Osmosis distillation requires 2.5 kWh to 7 kWh of electricity per cubic meter of desalinated water (Osman 2011).
- Desalination facilities usually are located beside the sea, so the availability of adjacent suitable land could be high unless environmental restrictions apply. Therefore, a 70 percent of the planned desalination capacity could consider the utilization of PV-powered RO. An estimated 60 percent of these plants find RO to be the best technological option.
- PV plants have a low capacity factor (15 percent-18 percent). To achieve a full PV supply, the ratio peak power/peak demand will be 4. Fifty percent of the installed plants will opt for full PV supply, either with net metering or energy storage.
- These changes will require extensive engineering. Therefore, a three-year delay has been estimated for the planning and engineering, and the plants to be erected during those years have been omitted from the estimate.

40. Large-capacity storage with electric batteries is not usual. Hybridization of PV with other power sources such as wind would reduce the storage necessity and might make viable this kind of solution. In this case, the batteries also would help to stabilize the power and energy flow to the desalination plant for smoother operation (U.S. DOE NREL 2005).

TABLE 43 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN PV POWERED REVERSE OSMOSIS DESALINATION, 2014-27 *(MW)*

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Installed power	-	5	6	6	6	6	6	6	2	2	2	2	2

Unlike for CSP, this additional demand will be applied evenly to all PV components.

7.2.2 COMPONENTS FOR OTHER MARKETS

7.2.2.1 INVERTERS FOR SMALL SCALE WIND POWER

Small-scale wind turbines (from a few hundred watts to 50,000 W) can share the applications for standalone power generation PV in hybrid systems, including a set of batteries. They serve the double purpose of storing energy and stabilizing the power and energy flow to the consumer (U.S. DOE NREL 2005).

The inverter manufacturing industry proposed for PV can be adapted easily to supply the inverters required for these turbines. The demand proposed for this application is analogous to the one described in Table 42 for standalone PV.

This additional demand will apply only to Inverters.

TABLE 44 | ANNUAL ADDITIONAL DEMAND DUE TO POTENTIAL APPLICATIONS IN STANDALONE POWER GENERATION, 2014-27 *(MW)*

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Installed power	3	7	8	10	12	14	15	17	19	21	22	24	26	27

PART D | Potential Economic Costs and Benefits Result from Enlarging Solar Component Manufacturing in Egypt

CHAPTER 8:

Potential Economic Costs and Benefits

8.1 Methodology

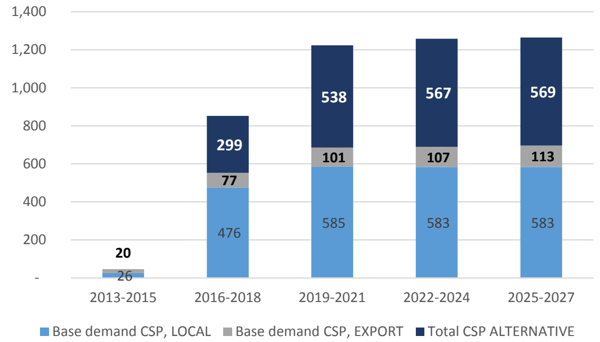
A model has been developed to estimate potential economic costs and benefits that could result from the development of key solar component manufacturing in Egypt. The estimations are projected until 2027.

The model is based on four main categories of inputs: production factors, demand factors, risk and stability factors, and business factors.

For production factors, different aspects have been analyzed for Egypt, including the labor market, material availability, manufacturing ability, energy cost, financial cost, and fiscal cost.

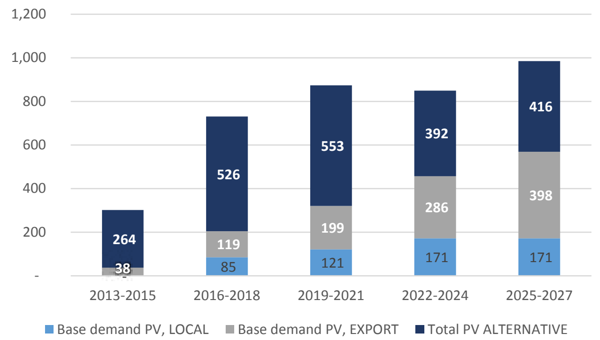
Regarding demand factors, an analysis has been conducted to forecast the demand for each component based on the estimation of local, export, and alternative applications[41] projected for 2027. Details of estimates can be found in Part C (Existing and Potential Applications of Solar Technology, Solar Component, and/or Solar Energy in Residential, Commercial, Governmental and Industrial Sectors).

Figure 79 | Potential Demand for CSP in Egypt, 2013-27 *(equivalent MW)*



Note: A conversion factor of 2.8 is used to assimilate thermal to electrical power in terms of component demand.

Figure 80 | Potential Demand for PV in Egypt, 2013-27 *(MW)*



41. Alternative applications refer to those that are not large-scale electricity generation.

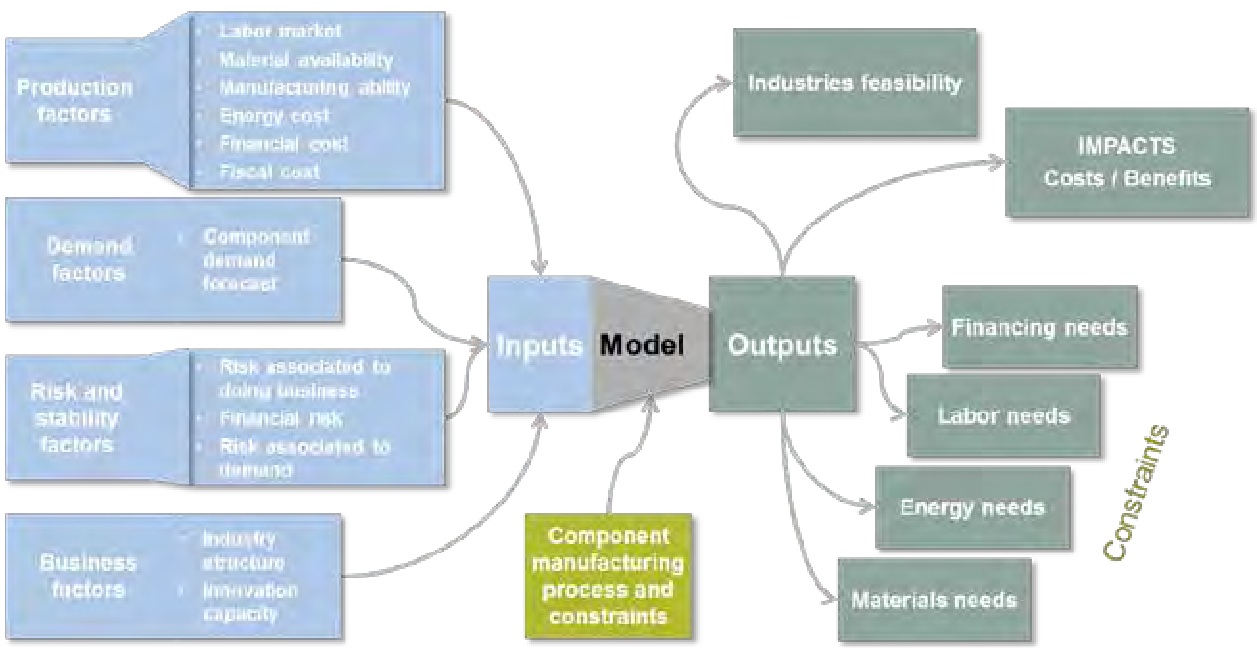
Additionally, both risk and stability factors and business factors were identified during the mission in Egypt and were estimated as part of the qualitative analysis. Some of the risks contemplated were risk associated to doing business, financial risks, and risk associated to demand. Business factors focus on Egyptian innovative capacity and the industrial structure of the country.

Apart from inputs already mentioned, constraints surrounding the manufacturing process for different components also feed into the model.

Each component has been estimated independently based on its own projected demand.

The model outputs for each component include materials, energy, labor, and financing requirements for the developments of the industry. These all have been used to determine the feasibility of the industry and cost/benefit impacts of its development in Egypt.

Figure 81 | Methodology Followed for the Model



8.2 Assumptions

Desktop analysis has been combined with stakeholders' feedback during the mission in the country in April 2013 and the Cairo workshop in June 2013.

8.2.1 ECONOMIC ASSUMPTIONS

The following economic assumptions have been made in the model:

- The assumed exchange rate is 6.9 EGP per US$.
- The model is calculated based on 2012 constant US$.
- Corporation taxes have been estimated as 20 percent, applied to profits before taxes.
- Depreciation has been calculated for the whole investment, taking a five-year lineal depreciation for each factory.
- An 8 percent financial cost has been applied to loans in US$.
- With reference to investment, an estimated 30 percent of the total investment is equity and 70 percent debt.
- Neither fiscal incentives nor subsidies have been estimated for any of the components.

TABLE 45 | ECONOMIC ASSUMPTIONS

Summary of economic assumptions	
Exchange rate	6.9 EGP/US$
Inflation	0.0
Corporation tax	20.0
Depreciation	20.0
Financial cost	8.0
Leverage	70.0
Subsidy to investment (%)	0%
Fiscal incentives	0.0

Note: Interest rates are in US$ currency.

8.2.2 LABOR WAGES ASSUMPTIONS

Labor requirements per factory have been estimated by applying labor requirements in factories of a similar size in OECD countries and extrapolating these data to the context in Egypt, assuming that labor is equally productive in both locations.

Two types of labor have been assumed: (1) medium-skilled labor, which could be found easily in the country, as confirmed with expert local stakeholders during interviews and workshop, and (2) high-skilled labor with solar energy expertise, which for at least the first years of production could be made up largely of an expatriate labor force, based on information provided by stakeholders during the information-gathering mission and workshop.

Thus, two different types of wages have been assumed. The medium-qualified labor wage was estimated based on Egyptian wages. The wage for highly qualified labor was estimated based on wages of expatriates. In both cases, social security tax has been added.

TABLE 46 | LABOR WAGE ASSUMPTIONS

	Social Security (%)	Annual wage (000 EGP)	Annual wage (US$000)
Expatriate labor wage		291	42
Local labor wage		21	3
Social security (Egypt)	20		
Average social security (OECD countries)	30		

8.2.3 ENERGY PRICES ASSUMPTIONS

Energy price assumptions consider both electric energy consumption and also thermal energy consumption. Prices were obtained by Egyptian sources and confirmed with stakeholders during the workshop.

TABLE 47 | ENERGY PRICES ASSUMPTIONS *(US$/MWH)*

Energy, thermal	42
Energy, electric	52

8.2.4 MATERIAL PRICES ASSUMPTIONS

Material requirements have been analyzed for each component, taking into account availability of each material in the country. Materials have been classified depending on whether they can be assumed to be local or import. For import materials, additional transport costs have been added.

Local prices were confirmed with stakeholders during the workshop, and import prices have been obtained from consultant sources.

TABLE 48 | MATERIAL PRICE ASSUMPTIONS

Material	Market price (EGP/kg)	Market price (US$/kg)	Source	Imports transport needs (US$/t)	Final market price (US$/kg)
Carbon steel, beam	8.0	1.2	Local	0	1.2
Carbon steel, plate	6.0	0.9	Local	0	0.9
Carbon steel, cast	8.0	1.2	Local	0	1.2
Stainless steel, cast	35.0	5.0	Import	60	5.1
Stainless steel, plate	30.0	4.3	Import	60	4.4
Stainless steel, tube	24.0	3.5	Import	60	3.5
Electrodes	19.4	2.8	Import	20	2.8
Silver/cooper coating	6,592.2	950.0	Import	20	950.0
Polymeric coatings	20.8	3.0	Import	20	3.0
Float glass	2.4	0.5	Local	0	0.5
Silicon	541.3	78.0	Import	10	78.0
Copper	75.0	10.8	Local	0	10.8
Aluminum	30.0	4.3	Local	0	4.3
Special alloys	22.6	3.3	Import	20	3.3
Silica	0.3	0.04	Local	0	0.0
Na2O	2.1	0.3	Local	0	0.3
CaO	1.0	0.1	Local	0	0.1
MgO	1.5	0.2	Local	0	0.2
Additives	1.2	0.2	Local	0	0.2

8.3 Main Economic Costs and Benefits Associated with CSP and PV: Structures

8.3.1 INTRODUCTION

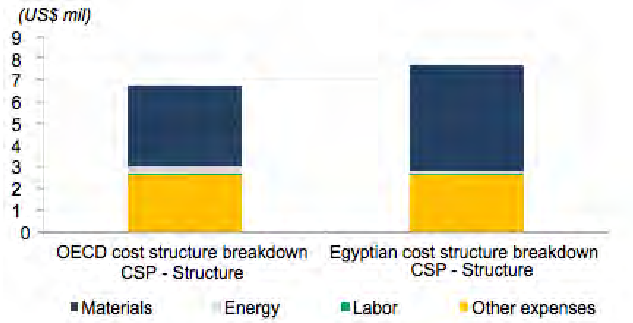
In Egypt, structures of existing industries easily could be adapted to become structures for solar energy production. For example, by using an existing steel structure factory such as a transmission tower factory, diversifying production toward the solar sector not only would reduce initial investment cost but also would profit from skilled workforce and developed logistics.

Moreover, materials requirements can be met almost completely from those available in Egypt. Except for electrodes, almost 95 percent of the materials requirements are carbon steel. Availability, quality, and price of carbon steel will condition the final price of the structure.

8.3.2 COMPETITIVENESS OF THE INDUSTRY COMPARED TO OTHER COUNTRIES

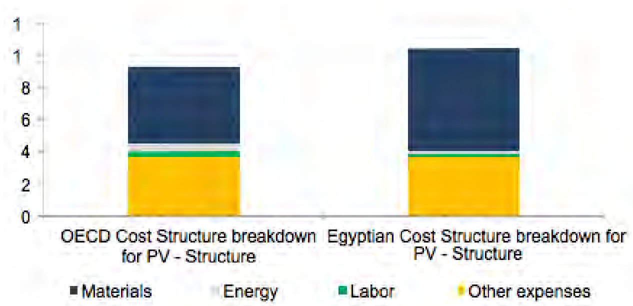
Total costs estimated for the development of Egypt's CSP structure industry have been compared with total costs for the same industry in OECD countries. Results differ by less than 15 percent, which has not been considered significant. At the moment, Egypt still poses an advantage regarding energy and labor expenses when compared to OECD countries.

Figure 82 | Cost Breakdown for CSP Structure



In addition, structures for the Egyptian PV industry have been compared to the total cost for the same industry in OECD countries. In this case, too, results differ less than 15 percent, which amount has not been considered significant. Regarding energy and labor expenses, Egypt holds the same advantages as OECD countries.

Figure 83 | Cost Breakdown for PV Structure *(US$ mil)*



In both industries, other expenses included O&M, spare parts, and general.

Since the overall estimated costs are not significantly different, the sales price in Egypt is similar to that in OECD countries.

Figure 84 | Sales Price for CSP Structure *(US$/kg)*

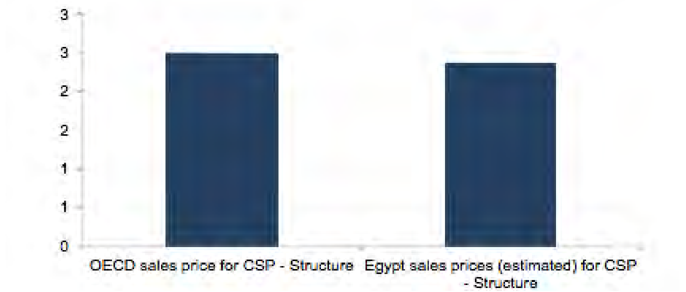
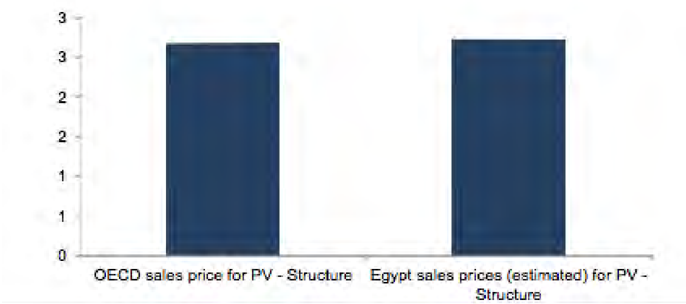


Figure 85 | Sales Price for PV Structure *(US$/kg)*



8.3.3 ANNUAL PRODUCTION AND INVESTMENT

Annual production requirements have been estimated at 45,000 tons/year. In other words, 1 plant would be needed to cover the demand from 2013 to 2027.

Figure 86 | Forecasted Demand and Annual Proposed Production for CSP and PV Structure, 2013-27

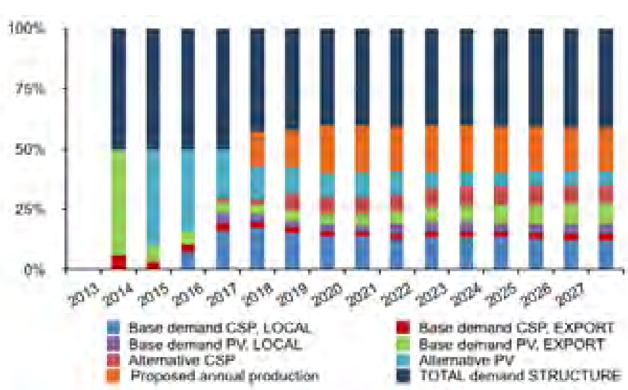


Figure 87 | Forecasted Demand and Annual Proposed Production for Structure, CSP Alternative Applications, 2013-27

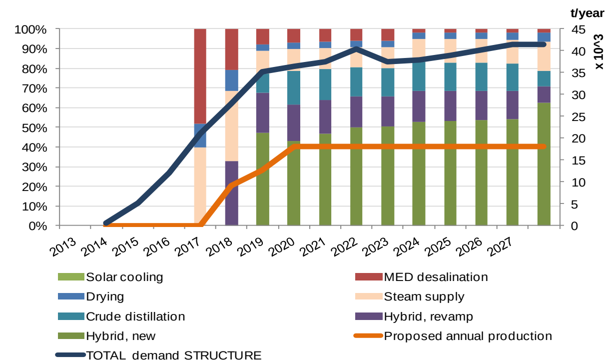
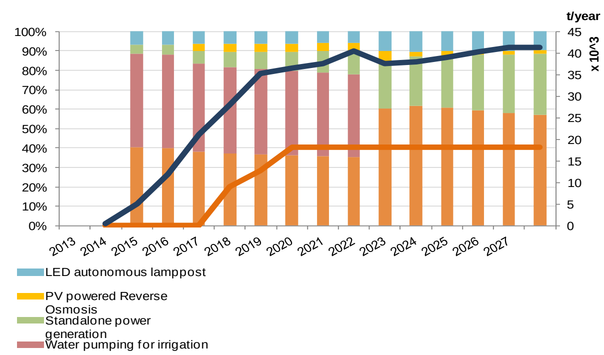
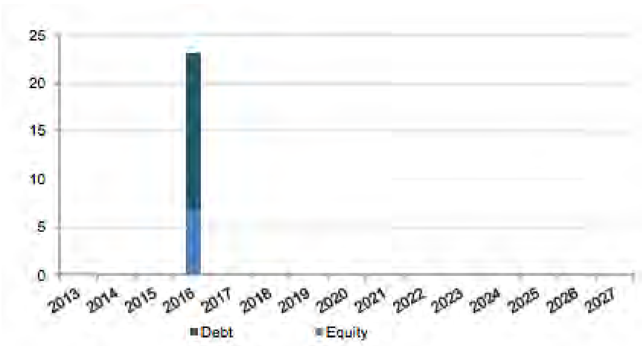


Figure 88 | Forecasted Demand and Annual Proposed Production for PV Alternative Applications, 2013-27



It has been estimated that 1 plant of this size requires an investment of approximately US$23 million. Regarding the first plant, production should be started by 2017, which means that investment would be needed 1 year earlier.

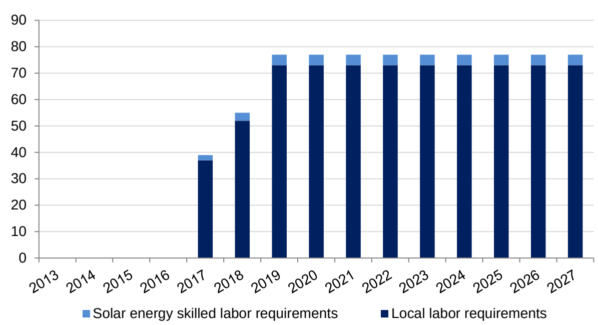
Figure 89 | Investment Requirements for CSP and PV Structure, 2013-27 *(US$)*



8.3.4 LABOR CREATION

By 2027, more than 70 jobs would be created locally. Five percent of Egypt's total labor force should have specific solar energy skills to solve the technical complexity and barriers that could appear due to the complex design of hydraulic circuits and components and also to achieve stiffness.

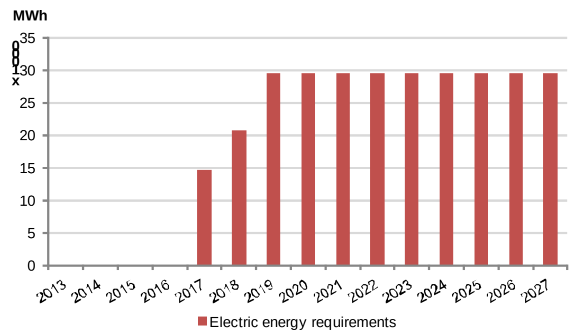
Figure 90 | Labor Requirements for CSP and PV Structures, 2013-27 *(required workers)*



8.3.5 ENERGY REQUIREMENTS

Only electric energy is required for the structure industry, mainly for welding.

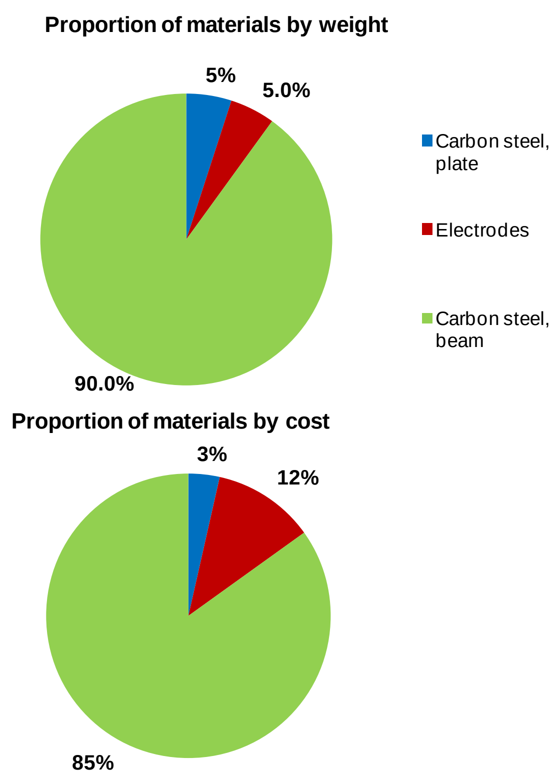
Figure 91 | Energy Requirements for CSP and PV Structures, 2013-27



8.3.6 MATERIALS REQUIREMENTS

The main material requirement is carbon steel, which is available locally. Electrodes are not available locally and will need to be imported.

Figure 92 | Description of Material Requirements for CSP and PV Structure by Weight and Cost per Plant *(%)*



8.3.7 CONCLUSION

Structures are an interesting industry for Egypt to start developing in the short term, and to continue developing as it develops solar expertise and progresses to develop other solar industries.

However, hot-dip galvanizing of large structures (>12 m) could be a bottleneck so is important to take into account for CSP. Therefore, the final price of the structure would be conditional on availability, quality, and cost of nearby galvanizing facilities and availability and price of carbon steel.

8.4 Main Economic Costs and Benefits Associated with CSP: Mirrors

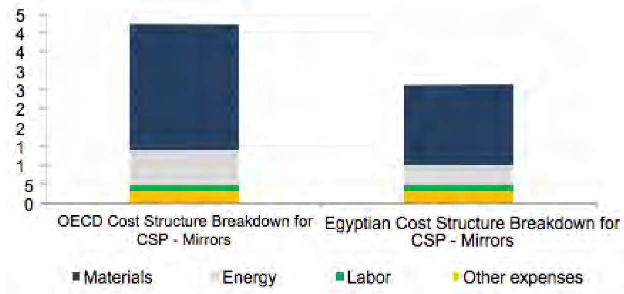
8.4.1 INTRODUCTION

CSP mirrors industries have the potential to be developed due to the existing float glass factories in the country. As part of diversifying the production strategy of the industry toward the solar sector, existing factories could find opportunities to be adapted. Advantages would be that investment needs would be reduced and the solar industry would profit from the skilled workforce and developed logistics.

8.4.2 COMPETITIVENESS OF THE INDUSTRY COMPARED TO OTHER COUNTRIES

Total costs for Egyptian CSP mirrors have been compared with total costs for the same industry in OECD countries. It is important to highlight Egypt's competitiveness in cost compared to OECD countries. Materials and energy prices could be a clear advantage to develop the industry in the country.

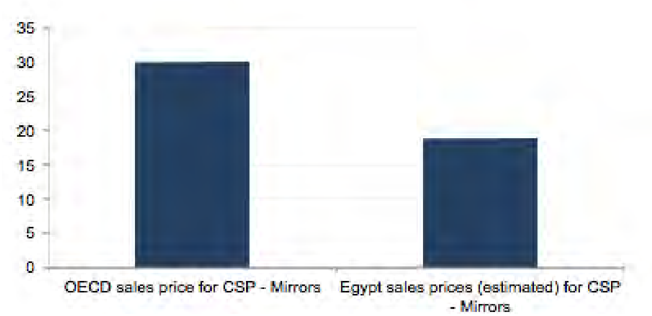
Figure 93 | Cost Structure Breakdown for CSP Mirrors *(US$ mil)*



Other expenses include O&M, spare parts, and general.

This difference in cost, mainly in materials and energy, would permit achieving a lower sales price compared to OECD countries.

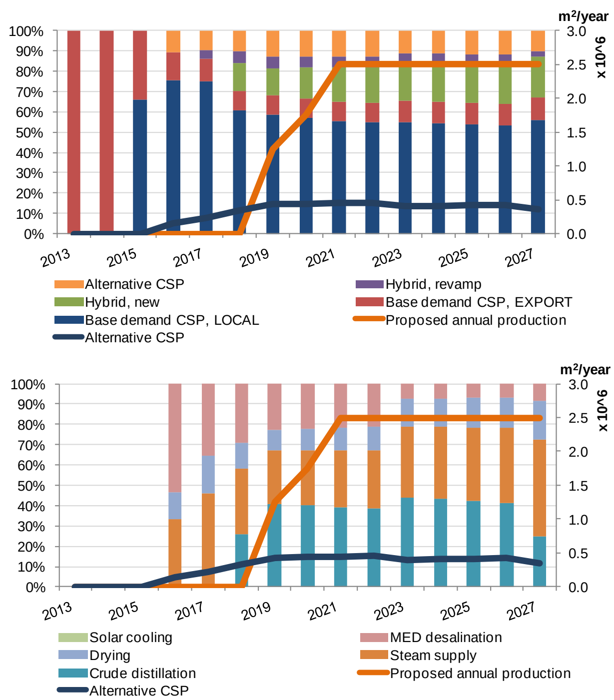
Figure 94 | Sales Price for CSP Mirrors *(US$/m²)*



8.4.3 ANNUAL PRODUCTION AND INVESTMENT

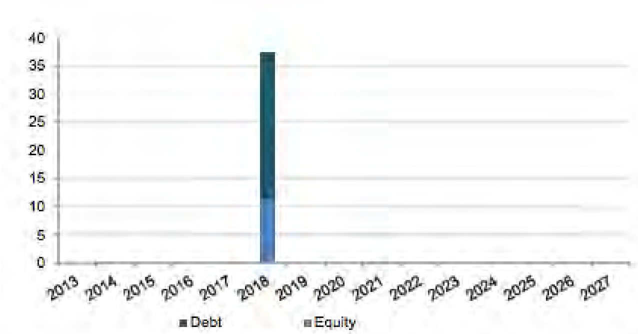
An annual production of 2.5 million square meters per year has been estimated. Under this hypothesis, only 1 plant would be needed to cover the demand from 2013 to 2027.

Figure 95 | Forecasted Demand and Annual Proposed Production for CSP Mirror, 2013-27



It has been estimated that 1 plant of this size would require an investment of approximately US$38 million. Production should start by 2019, which means that the investment would be needed by 2018.

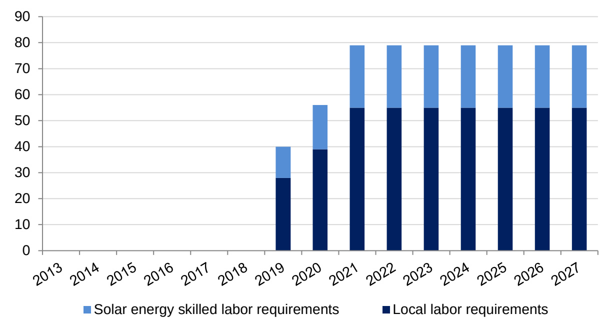
Figure 96 | Investment Requirements for CSP Mirrors, 2013-27 *(US$ mil)*



8.4.4 LABOR CREATION

By 2027, almost 80 jobs would be created. Seventy percent of them would be local owing to highly skilled workforce requirements regarding the glass processing, chemical reagents, and heavy-duty machinery handling.

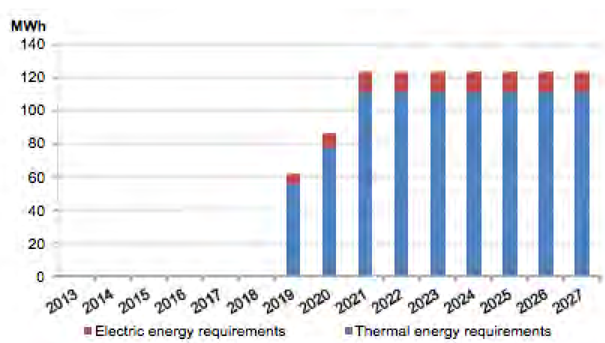
Figure 97 | Labor Requirements for CSP Mirrors, 2013-27 *(%)*



8.4.5 ENERGY REQUIREMENTS

The CSP mirror industry has electricity and, mainly, thermal energy requirements.

Figure 98 | Energy Requirements for CSP Mirrors, 2013-27

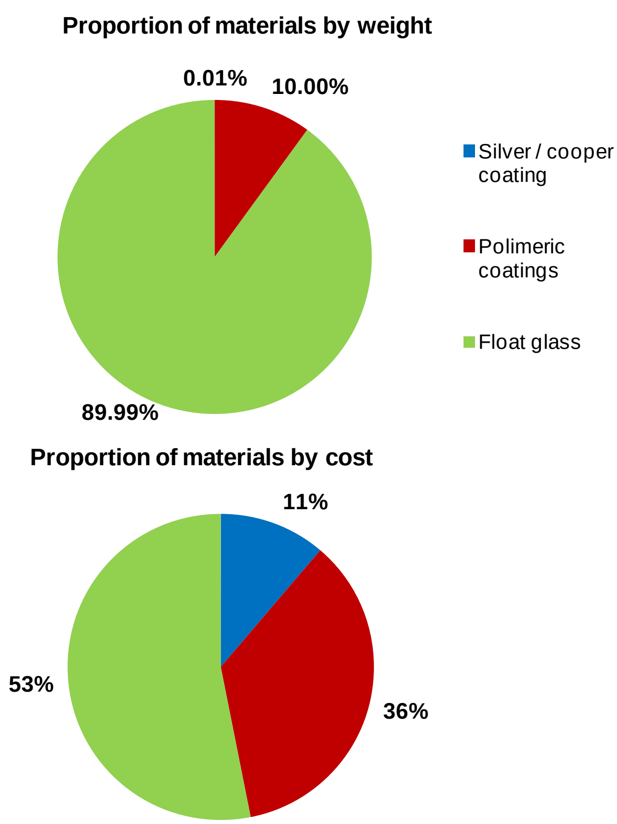


8.4.6 MATERIALS REQUIREMENTS

The main material requirement is float glass, which is available locally. Polymeric and cooper coating are not available locally and will have to be imported.

The percentage of silver requirements is less than 1 percent of the total weight of materials. Nevertheless, this percentage has a significant impact on materials' costs.

Figure 99 | Description of Material Requirements for CSP Mirrors by Weight and Cost per Plant *(%)*



8.4.7 CONCLUSION

CSP mirrors is an interesting industry for Egypt to develop in the short or medium term. It could be a competitive industry both nationally and for exports. However, there are a series of potential risks to note:

As an industry, there is a risk due to the complexity of manufacturing line and the highly skilled workforce required. From a labor point of view, CSP mirrors require a highly skilled workforce with solar energy expertise, which increases the price of labor.

Unless these industries are integrated in the existing float glass industry, the capital-intensive nature of the investments could be a barrier.

The availability and price of thermal energy would condition the final price of the mirrors.

Depending on the distance to be covered, transportation of float glass could increase the final costs.

8.5 Main Economic Costs and Benefits Associated with CSP: Pumps

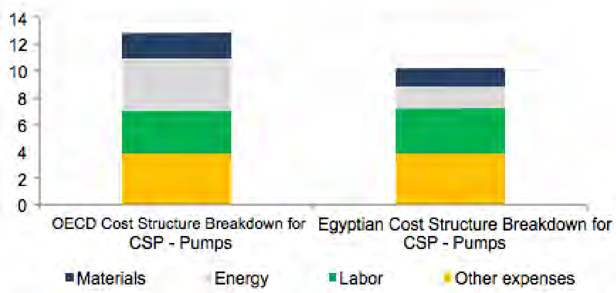
8.5.1 INTRODUCTION

CSP pumps industries for solar energy could be an opportunity to develop and expand the existing pumps factory industry in Egypt. CSP pumps could be an opportunity for small companies that could develop this industry and manufacture different new models.

8.5.2 COMPETITIVENESS OF THE INDUSTRY COMPARED TO OTHER COUNTRIES

Total costs for CSP pumps have been compared to total costs for the same industry in OECD countries. Results differ less by than 15 percent, which has not been considered significant. At the moment, Egypt still possesses an advantage regarding energy expenses when compared to OECD countries.

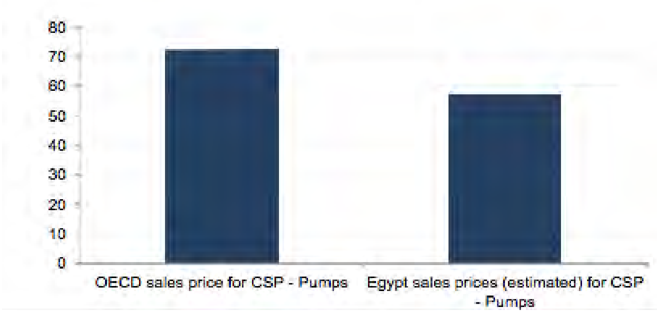
Figure 100 | Cost Structure Breakdown for CSP Pumps *(US$ mil)*



Other expenses include O&M, spare parts, and general.

As the overall estimated costs are not significantly different, the sales price in Egypt is similar to that in OECD countries.

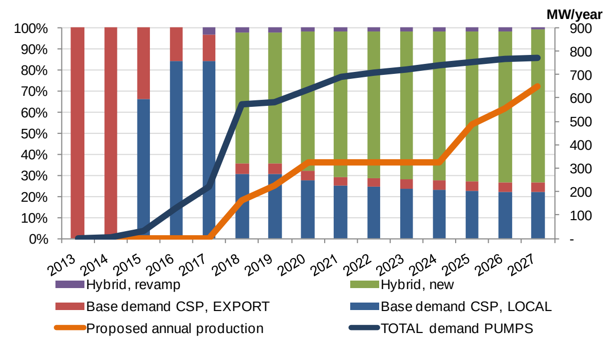
Figure 101 | Sales Price for CSP Pumps *(US$/MW)*

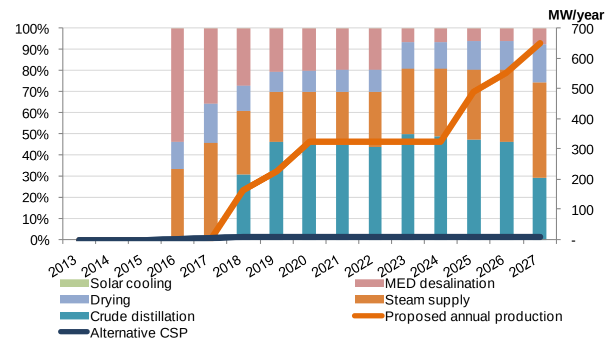


8.5.3 ANNUAL PRODUCTION AND INVESTMENT

An annual production of 325 tons per year has been estimated. Thus, to cover the estimated demand during from 2013 to 2027, 2 plants would be needed.

Figure 102 | Forecasted Demand and Annual Proposed Production for CSP Pumps, 2013-27

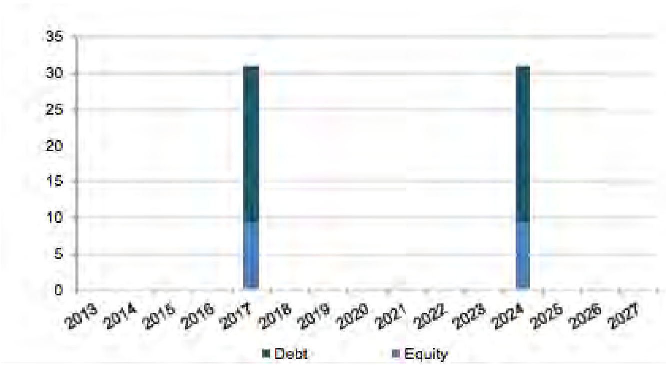




It has been estimated that 1 plant of this size requires an investment of approximately US$31 million.

It has been estimated that there would be sufficient demand to start producing by 2018, which means that investment would be needed in 2017. The second plant should start in 2025, for which investment would be required in 2024.

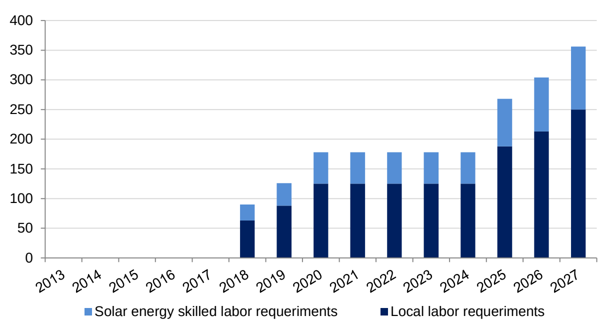
Figure 103 | Investment Requirements for CSP Pumps, 2013-27 *(US$ mil)*



8.5.4 LABOR CREATION

The CSP pumps industry has high labor-creation requirements. By 2027, more than 350 jobs would be created. Of these, 70 percent of them would be local employees. The remaining 30 percent would be a highly skilled workforce with specific training in carbon and stainless steel casting, machining and welding, and heavy duty machinery handling. Initially, this 30 percent could be met through international jobs. However, the objective would be to be able to fill these jobs in the future locally as well.

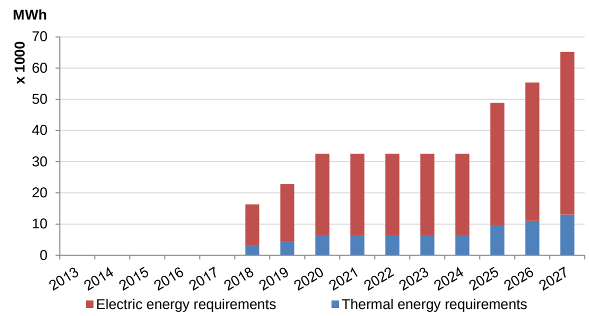
Figure 104 | Labor Requirements for CSP Pumps, 2013-27



8.5.5 ENERGY REQUIREMENTS

The CSP pumps industry has medium requirements for electricity and thermal energy. The electricity energy requirements are higher than for thermal.

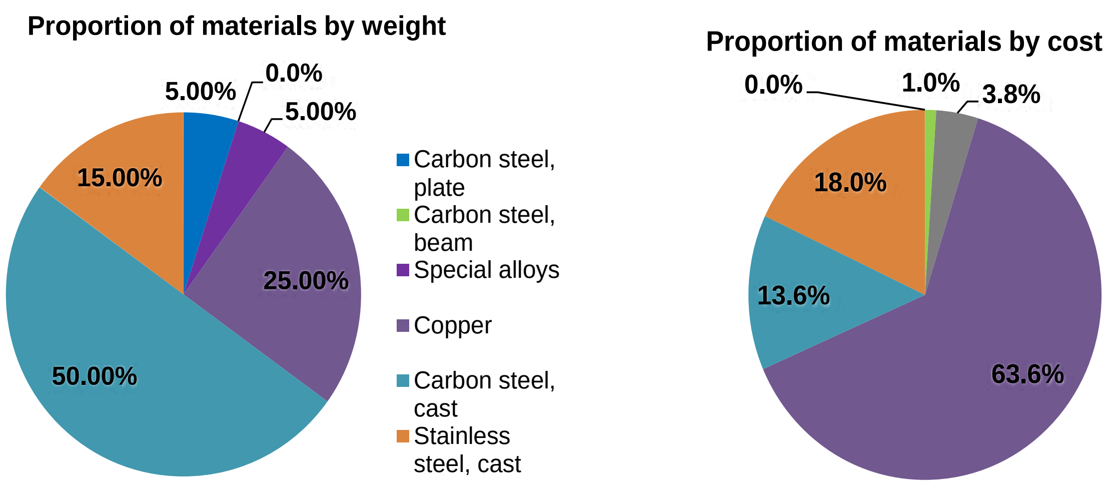
Figure 105 | Energy Requirements for CSP Pumps, 2013-27



8.5.6 MATERIALS REQUIREMENTS

Regarding quantity of material required, the main material is carbon steel cast, which is available locally. Special alloys and stainless steel are not available locally so must be imported.

Figure 106 | Description of Material Requirements for CSP Pumps by Weight and Cost per Plant *(%)*



8.5.7 CONCLUSION

CSP pumps could be an interesting industry for Egypt to start developing in the short or medium term. However, technical barriers such as complex design for molten salt pumps, the high precision requirements to manufacture under international standards, and the highly skilled workforce required could pose significant barriers that would need to be resolved for the industry to achieve traction.

For this industry to be developed, technology transfer, joint ventures, or foreign companies that own the technologies and the track record will be required.

8.6 Main Economic Costs and Benefits Associated with CSP: Heat Exchangers

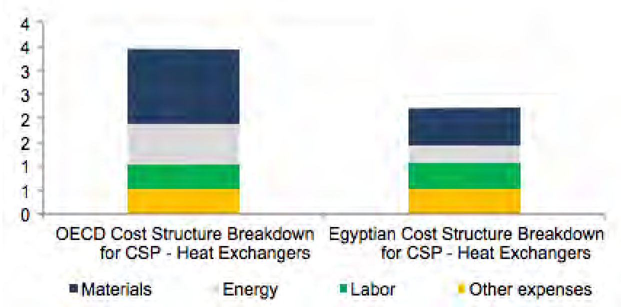
8.6.1 INTRODUCTION

CSP heat exchanger industries could be developed due to the existence of light duty heat exchangers of other metal fabrication industries that seem to exist in the country. As part of diversifying the production strategy of the industry toward the solar sector, current factories could find an opportunity because adapting them for the heat exchanger industries would reduce investment cost, and the new industries would profit from the skilled workforce and developed logistics.

8.6.2 COMPETITIVENESS OF THE INDUSTRY COMPARED TO OTHER COUNTRIES

Total costs for CSP heat exchangers have been compared with total costs for the same industry in OECD countries. It is important to highlight Egypt competitiveness in cost compare to OECD countries. Materials and energy prices could be a clear advantage to develop the industry in the country.

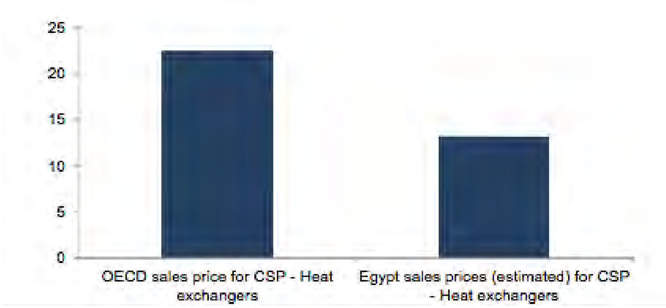
Figure 107 | Cost Structure Breakdown for CSP Heat Exchangers *(%)*



Other expenses include O&M, spare parts, and general.

If current prices are maintained during the next few years, the lower costs in the diverse MENA countries would permit a lower sales price compared to the price in OECD countries.

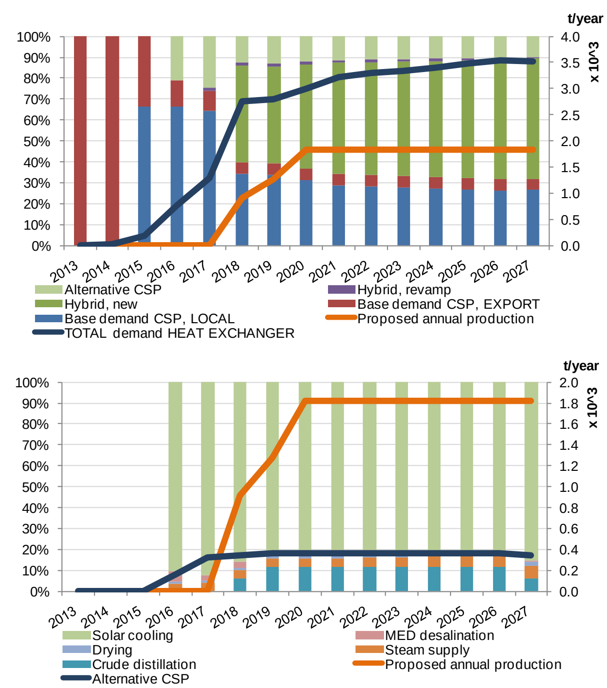
Figure 108 | Sales Price for CSP Heat Exchangers *(US$/MWth)*



8.6.3 ANNUAL PRODUCTION AND INVESTMENT

Annual production of 1,824 tons per year has been estimated; therefore, from 2013 to 2027, 1 plant would be needed to cover the demand.

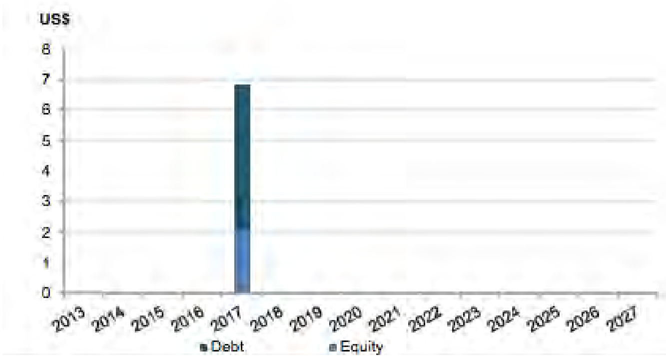
Figure 109 | Forecasted Demand and Annual Proposed Production for CSP Heat Exchangers, 2013-27



A plant of this size needs an estimated investment of approximately US$7 million.

Construction of the first plant should begin by 2018 and of the second plant by 2021. Thus, investment would be needed by 2017 and 2020, respectively.

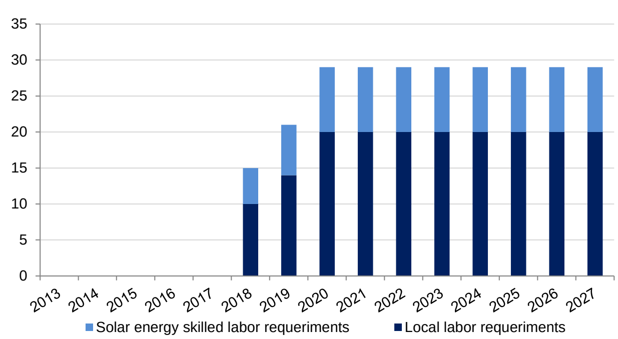
Figure 110 | Investment Requirements for CSP Heat Exchangers, 2013-27



8.6.4 LABOR CREATION

By 2027, almost 30 jobs would be created. A skilled workforce is required to do the stainless steel welding and heavy duty machinery handling. Therefore, if capacity building were done, by 2027 approximately 20 people could be local employees.

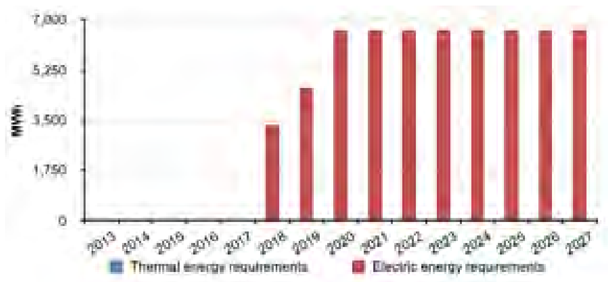
Figure 111 | Labor Requirements for CSP Heat Exchangers, 2013-27 *(required workers)*



8.6.5 ENERGY REQUIREMENTS

The CSP heat exchangers industry requires mostly electric energy. The plant energy requirements are low-medium, so could encourage the development of the industry.

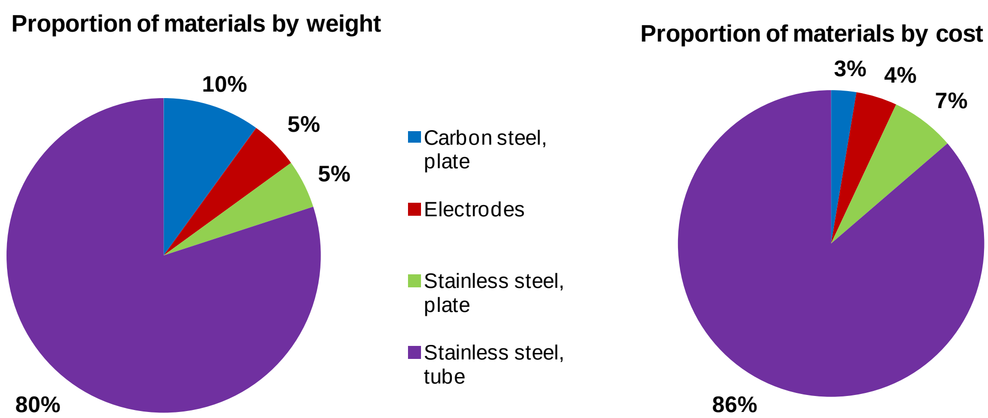
Figure 112 | Energy Requirements for CSP Heat Exchangers, 2013-27



8.6.6 MATERIALS REQUIREMENTS

More than 80 percent of the component requirement corresponds to stainless steel, which would need to be imported. Availability, quality, and cost of this material could seriously condition the final price of the component per unit.

Figure 113 | Description of Material Requirements for CSP Heat Exchangers by Weight and Cost per Plant *(%)*



8.6.7 CONCLUSION

CSP heat exchangers could be interesting if there is the opportunity to adapt some of the existing industries. If not, development of the CSP industry is conditioned on the availability, quality, and price of stainless steel and the development of technical high precision expertise to comply with the industry's international standards. These are the barriers that Egypt must address for the industry to develop.

Technology transfer, joint venture, or foreign company (owning the technology and track record) also will be necessary for this industry to be developed.

8.7 Main Economic Costs and Benefits Associated with CSP: Storage Tanks

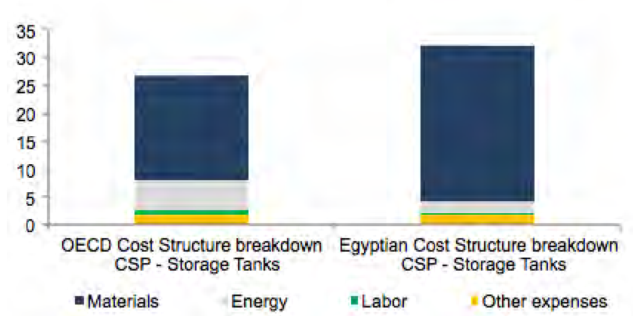
8.7.1 INTRODUCTION

CSP storage tanks must be manufactured under international standards for compatibility with other equipment, safety, performance, and quality assurance.

8.7.2 COMPETITIVENESS OF THE INDUSTRY COMPARED TO OTHER COUNTRIES

Total costs estimated for the development of the CSP storage tanks industry have been compared with total costs for the same industry in OECD countries. Results differ by less than 15 percent, which has not been considered significant. At the moment, Egypt still possesses an advantage regarding energy and labor expenses when compared to OECD countries.

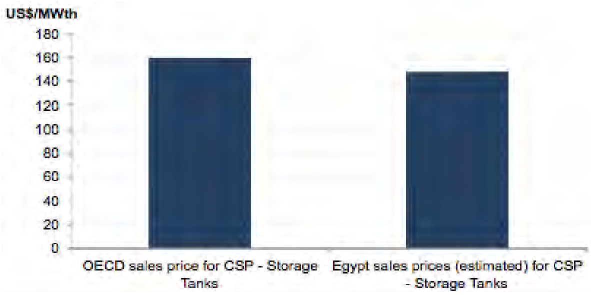
Figure 114 | Cost Structure Breakdown for CSP Storage Tanks (US$ mil)



Other expenses include O&M, spare parts, and general |

Because the overall estimated costs are not significantly different than in OECD countries, the sales price in Egypt is similar to that in OECD countries.

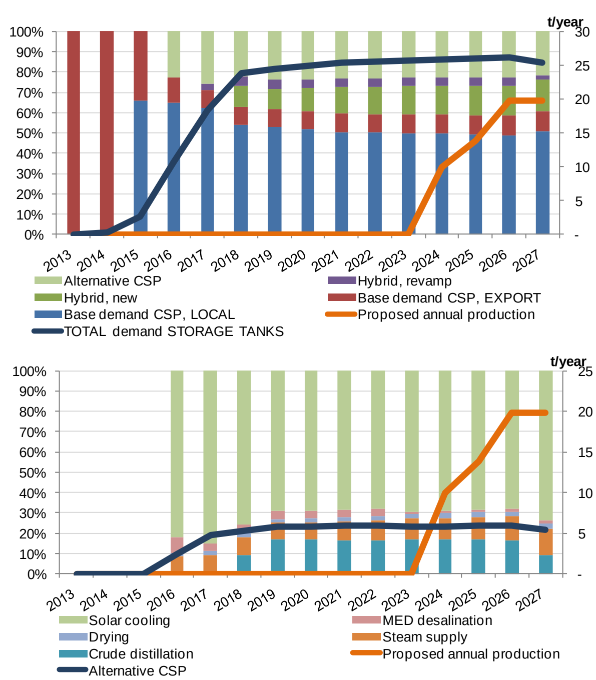
Figure 115 | Sales Price for CSP Storage Tanks



8.7.3 ANNUAL PRODUCTION AND INVESTMENT

Estimated annual production would be 19,800 tons per year. Only 1 plant would be needed fill the demand from 2013 to 2027.

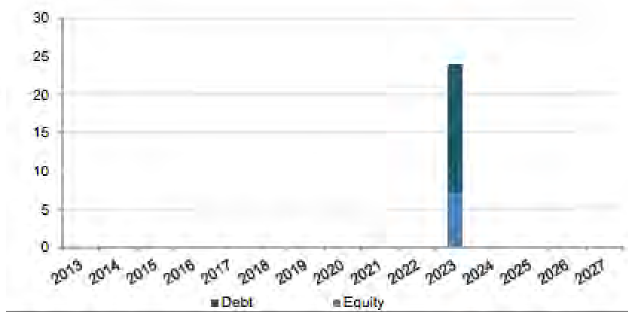
Figure 116 | Forecasted Demand and Annual Proposed Production for CSP Storage Tanks, 2013-27



A plant of this size would require an estimated investment of approximately US$24 million. Of which this amount, 30 percent would be equity and 70 percent loans.

Production should start by 2024, which means that investment would be needed by 2023.

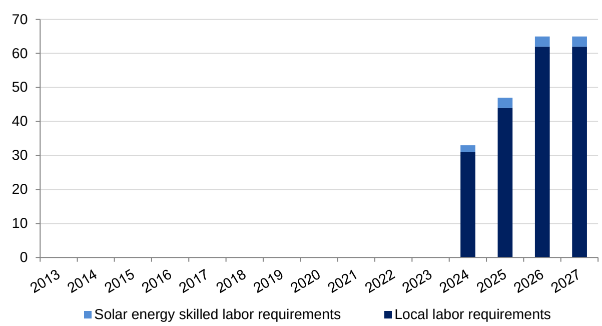
Figure 117 | Investment Requirements for CSP Storage Tanks, 2013-27 *(US$ mil)*



8.7.4 LABOR CREATION

By 2027, approximately 65 jobs would be created; significantly, 95 percent of them would be local.

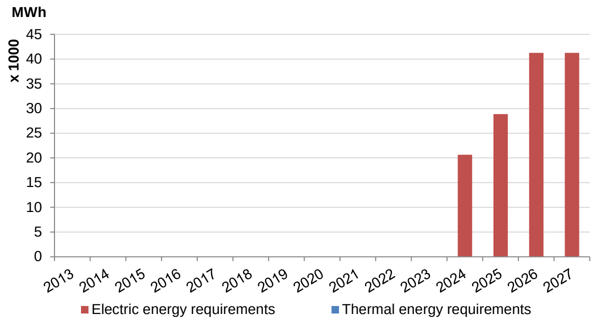
Figure 118 | Labor Requirements for CSP Storage Tanks, 2013-27 *(required workers)*



8.7.5 ENERGY REQUIREMENTS

The CSP storage tanks industry has low thermal energy requirements, mainly electricity.

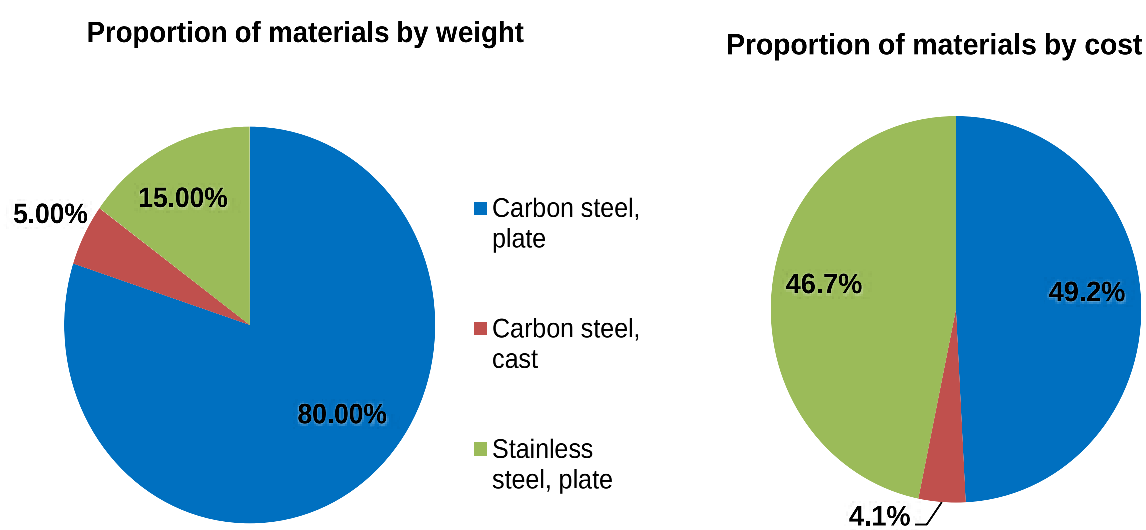
Figure 119 | Energy Requirements for CSP Storage Tanks, 2013-27



8.7.6 MATERIALS REQUIREMENTS

The main material requirement is carbon steel, which is available locally. Stainless steel is not available locally so would need to be imported.

Figure 120 | Description of Material Requirements for CSP Storage Tanks by Weight and Cost per Plant *(%)*



8.7.7 CONCLUSION

For the development of the CSP storage tanks industry to become feasible, Egypt must solve specific technical barriers such as the complex design of molten salt tanks, steam drum, and aerator. In addition, to be able to sell nationally as well as to export, manufacturing according to international standards to obtain compatibility with other equipment, safety, and performance in operation is required.

Although at the moment Egypt's electricity price is still competitive, the industry's high requirements for electric energy could be a future problem and could condition the final price of storage tanks.

8.8 Main Economic Costs and Benefits Associated with PV: Solar Glass

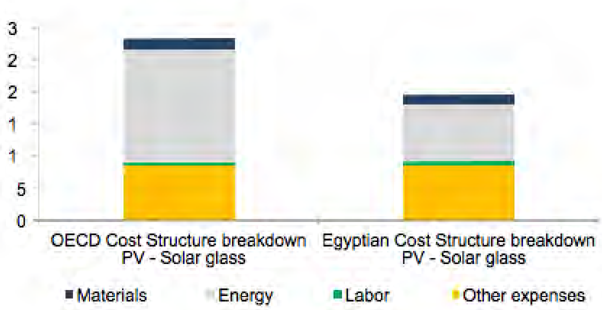
8.8.1 INTRODUCTION

Solar glass is usually less than 1 percent of total float glass. Therefore, to develop this industry, alternative demand needs to exist, in the form of demand from the building and automotive industries, to at least 70 percent of capacity.

8.8.2 COMPETITIVENESS OF THE INDUSTRY COMPARED TO OTHER COUNTRIES

Total costs for solar glass have been compared with total costs for the same industry in OECD countries. It is important to highlight Egypt's cost competitiveness with OECD countries. Energy cost is clearly an advantage to develop the industry in Egypt.

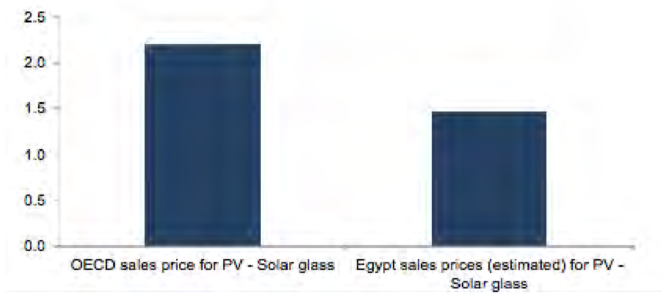
Figure 121 | Cost Structure Breakdown for PV Solar Glass *(US$ mil)*



Other expenses include O&M, spare parts, and general.

This difference in cost, mainly in materials and energy, would permit Egypt to achieve a sales price competitive with OECD countries.

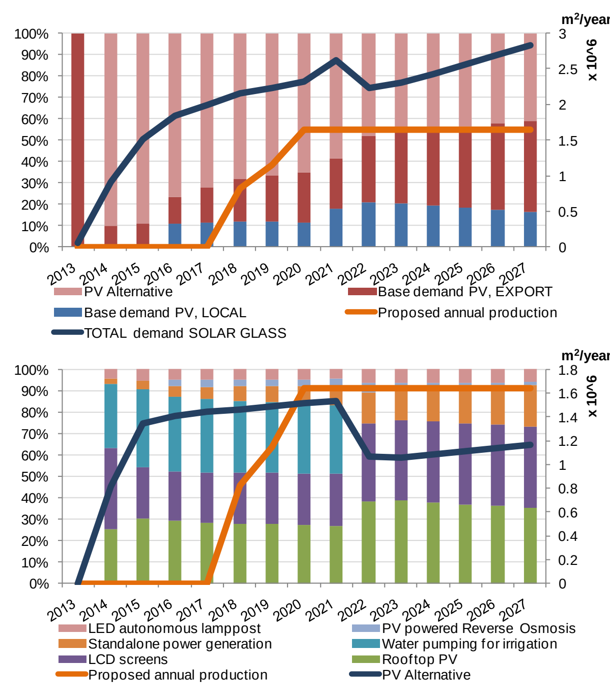
Figure 122 | Sales Price for PV Solar Glass *(US$/kg)*



8.8.3 ANNUAL PRODUCTION AND INVESTMENT

For the estimated annual production of 16,000 tons per year, from 2013 to 2027, 1 plant would be needed to cover the demand.

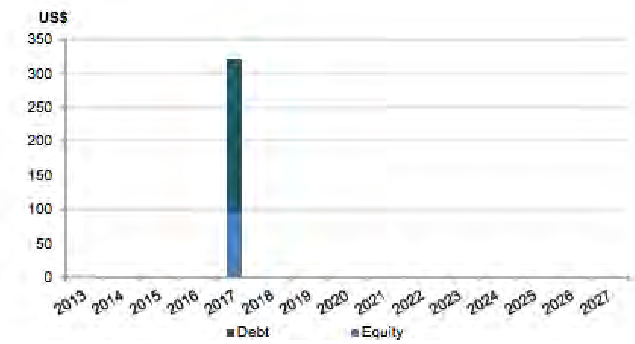
Figure 123 | Forecasted Demand and Annual Proposed Production for PV Solar Glass, 2013-27 *(%)*



A plant of this size is estimated to need an investment of approximately US$320,000.

By 2018, there will be enough demand to begin production. One year before launching the plant, it will be necessary to invest the required amount.

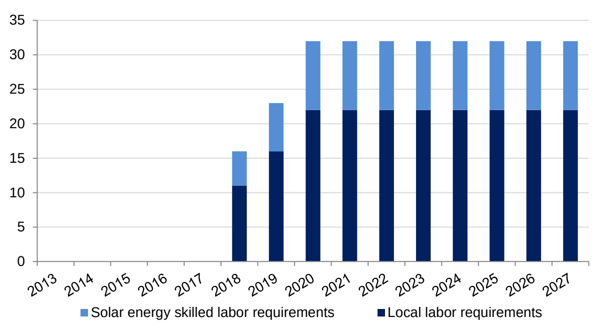
Figure 124 | Investment Requirements for PV Solar Glass, 2013-27



8.8.4 LABOR CREATION

By 2027, the 4 plants would enable the creation of more than 30 jobs. At least 70 percent of them would be local. Another 30 percent would need to be highly skilled, owing to the highly skilled workforce requirements.

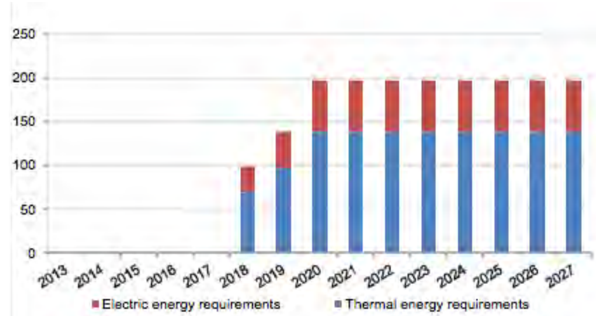
Figure 125 | Labor Requirements for PV Solar Glass, 2013-27 *(required workers)*



8.8.5 ENERGY REQUIREMENTS

The PV solar glass industry requires electric and thermal energy. Moreover, the quantity of thermal energy required is high.

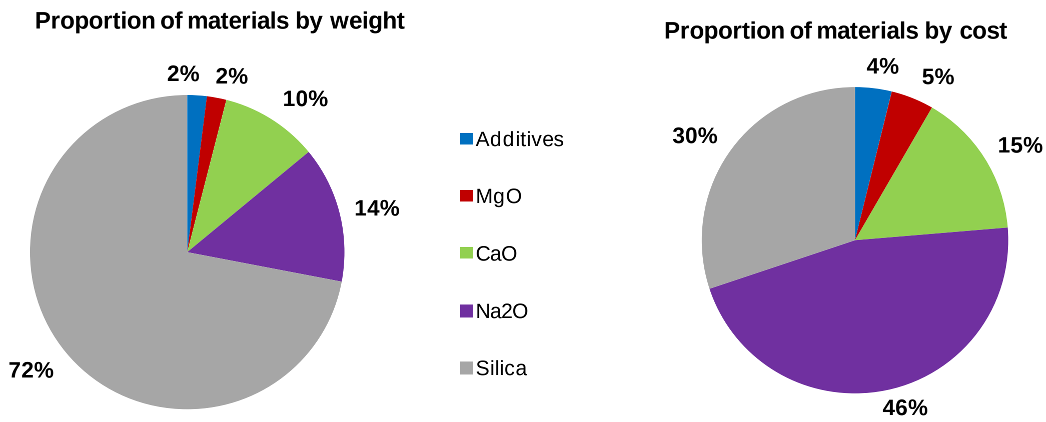
Figure 126 | Energy Requirements for PV Solar Glass Source, 2013-27 *(MWh)*



8.8.6 MATERIALS REQUIREMENTS

The main material requirement is silica, which is available locally. The rest of the materials also are available locally.

Figure 127 | Description of Material Requirements for PV Solar Glass by Weight and Cost per Plant *(%)*



8.8.7 CONCLUSION

Before launching the solar glass industry, additional analysis is required on the main barriers to entering it. They include the high overall investment due to the scale-up required for the manufacturing process. This scale-up could increase exposure if a competitor were to develop a more efficient manufacturing process or an alternative product.

It also is important to look for vertical integration or association opportunities with existing float glass line manufacturers to achieve competitive costs while ensuring the supply and quality of raw materials.

8.9 Main Economic Costs and Benefits Associated with PV: Inverter

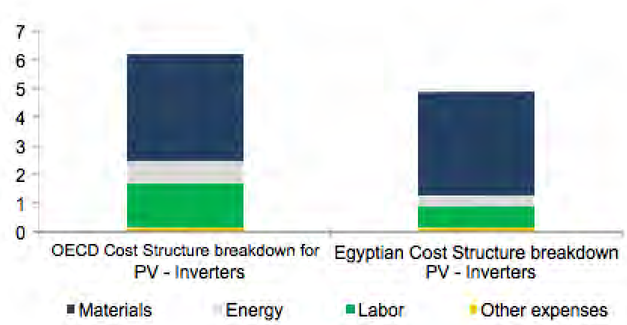
8.9.1 INTRODUCTION

Developing the inverter industries could be an opportunity to diversify companies so that they are less sensitive to oscillations of the PV market.

8.9.2 COMPETITIVENESS OF THE INDUSTRY COMPARED TO OTHER COUNTRIES

Estimated total costs for PV inverters in Egypt have been compared with total costs for the same industry in OECD countries. It is important to highlight Egypt's cost competitiveness with OECD countries. The lower costs of materials, labor, and energy prices in Egypt could be clear advantages to develop the industry there.

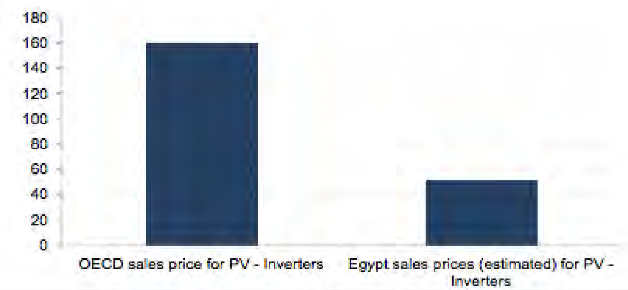
Figure 128 | Cost Structure Breakdown for PV Inverters *(US$ mil)*



Other expenses include O&M, spare parts, and general.

The differences in costs, mainly for energy and labor, would permit Egypt to achieve a lower sales price compared to prices in OECD countries.

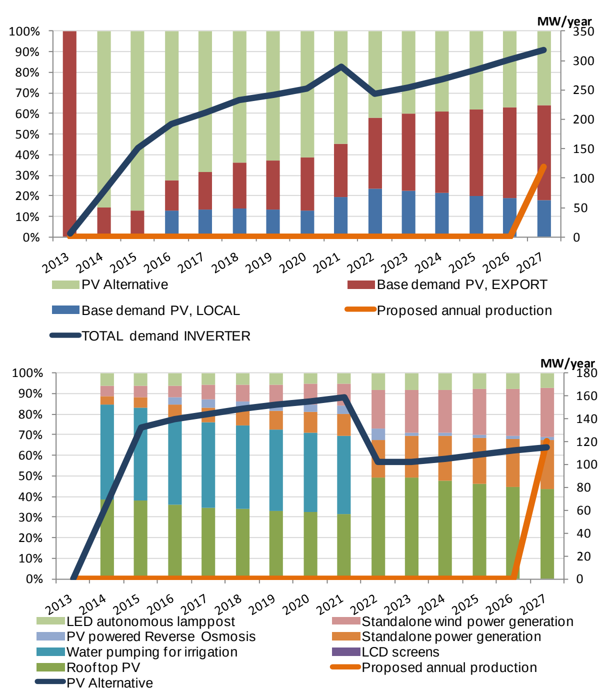
Figure 129 | Sales Price for PV Inverters *(US$/MW)*



8.9.3 ANNUAL PRODUCTION AND INVESTMENT

The estimated annual production of 120 tons per year from 2013 to 2027 would necessitate having only 1 plant.

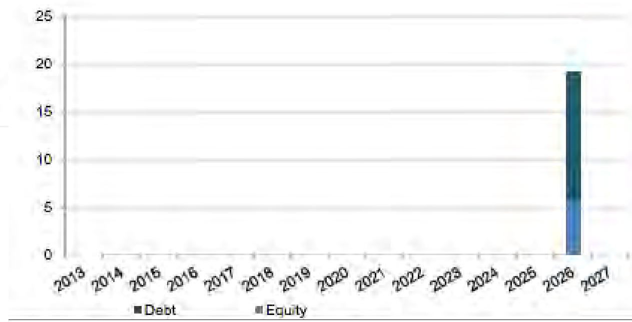
Figure 130 | Forecasted Demand and Annual Proposed Production for PV Inverter, 2013-27



A plant of this size will need an investment estimated at US$19 million, of which 30 percent will go to equity and 70 percent to loans.

Until 2027, demand will not be enough to begin production. One year before launching the plant, it will be necessary to perform the required investment.

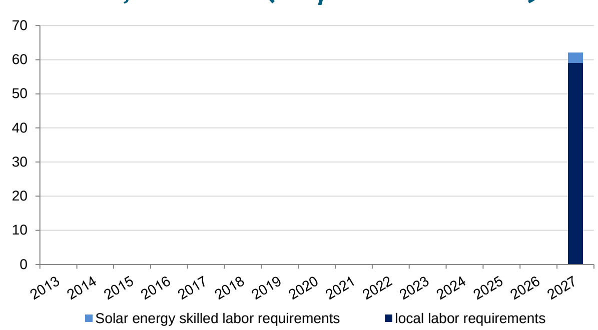
Figure 131 | Investment Requirements for PV Inverter, 2013-27 *(US$)*



8.9.4 LABOR CREATION

By 2027, the plant would allow for the creation of more than 60 jobs. At least 95 percent of them would be local.

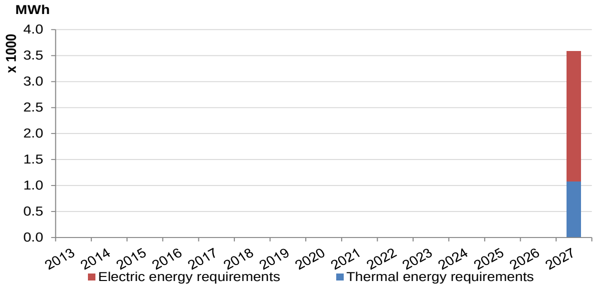
Figure 132 | Labor Requirements for PV Inverter, 2013-27 *(required workers)*



8.9.5 ENERGY REQUIREMENTS

The PV inverter industry requires electric and thermal energy.

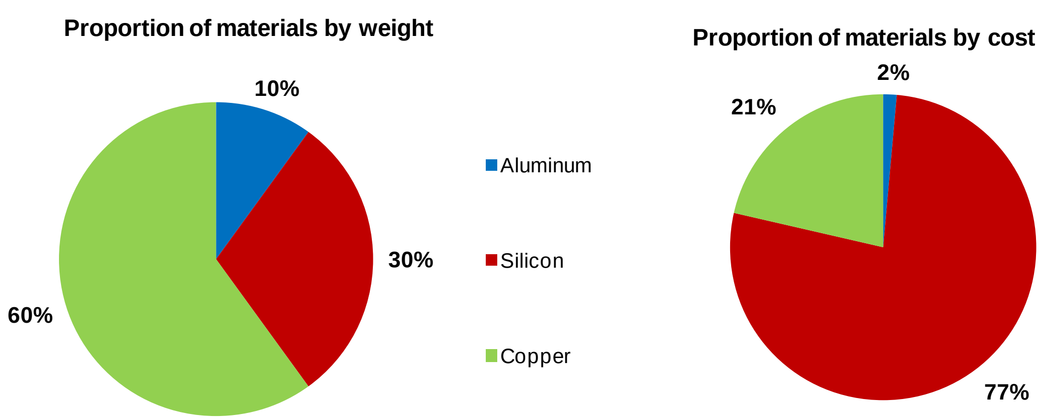
Figure 133 | Energy Requirements for PV Inverter, 2013-27



8.9.6 MATERIALS REQUIREMENTS

The main material requirement is cooper, which is available locally. Silicon is not available locally and will need to be imported.

Figure 134 | Description of Material Requirements for PV Inverters by Weight and Cost per Plant *(%)*



8.9.7 CONCLUSION

Before launching the inverter industry, further analysis is required on the main barriers to entering. They include the complex design to achieve performance and difficulties to gain market share due to the strong competitors that already exist in the market.

8.10 Aggregated Economic Costs and Benefits Associated with an Enlarged Solar Sector in Egypt

Solar components sector development would have an overall impact on:

- Labor creation
- GDP increase
- Upstream impacts: Materials and energy consumption
- Lower cost of the solar power plants.

8.10.1 LABOR CREATION

To assess the impacts of the solar sector on job creation, the following job qualifications have been taken into consideration:

- Highly qualified jobs, with wages assimilated to those of expatriates. These will be in the components manufacturing industries.
- Medium qualification jobs, with wages according to the Egyptian labor market:
  - In the components manufacturing industries.
  - As installers of large power plants[42] (either CSP or PV) and/or in construction companies.
  - As installers of small or domestic plants[43] and/or in specialized SMEs.

42. Average labor demand of 33 person-month/MW.
43. Average labor demand of 45 person-month/MW.

Figure 135 | Labor Creation in the PV Solar Sector, 2013-27

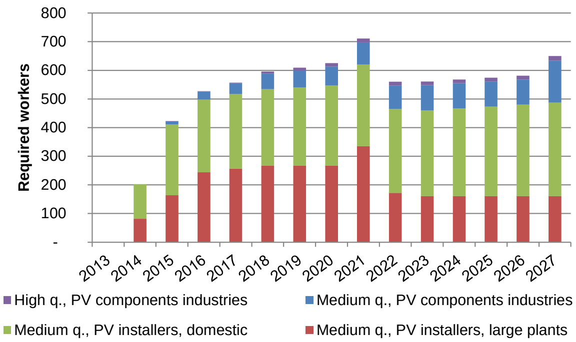
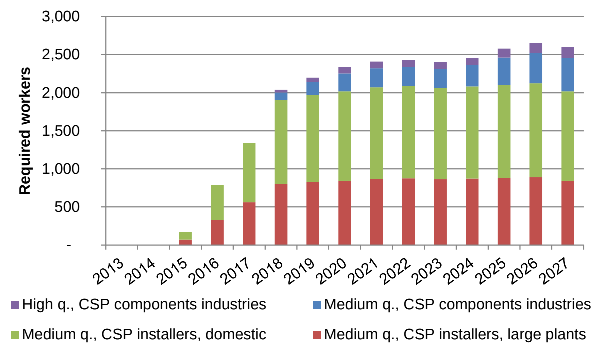


Figure 136 | Labor Creation in the CSP Solar Sector, 2013-27



For both PV and CSP, the main source of jobs for the long run is the installation of small and domestic plants.

8.10.2 GDP INCREASE

To assess the impacts of the solar sector on job creation, the following sources have been considered: Wages of workers in installation activities, in both large and small plants

Local share of component manufacturing industries revenue, including:

- Wages of local workers
- Energy expenditure, both electrical and thermal
- Material costs from local suppliers
- Profit
  - Engineering services provided by local companies for the solar plants developed in the country
  - For comparison, the inclusion of import expenditures of component manufacturing industries.

Figure 137 | Contribution to GDP from the Solar PV Sector, 2013-27

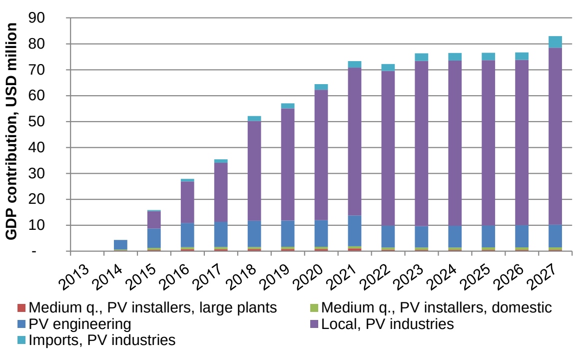
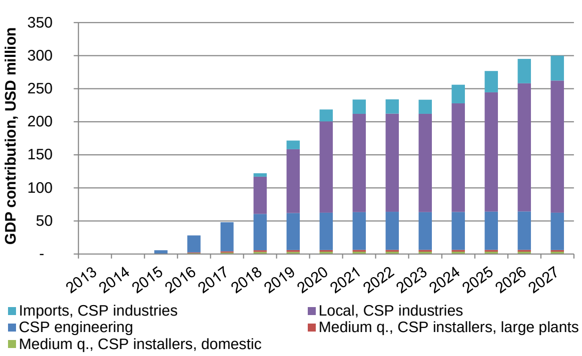


Figure 138 | Contribution to GDP from the Solar CSP Sector, 2013-27



For both PV and CSP, the main long-term contribution to Egypt's GDP would be the local share of the components manufacturing industries revenue.

8.10.3 UPSTREAM IMPACTS

8.10.3.1 MATERIALS REQUIREMENTS

The materials expected to be consumed by the component manufacturing industries for PV and CSP are presented in Figure 139 and Figure 140, respectively.

Figure 139 | Material Requirements for PV Industries, 2013-27

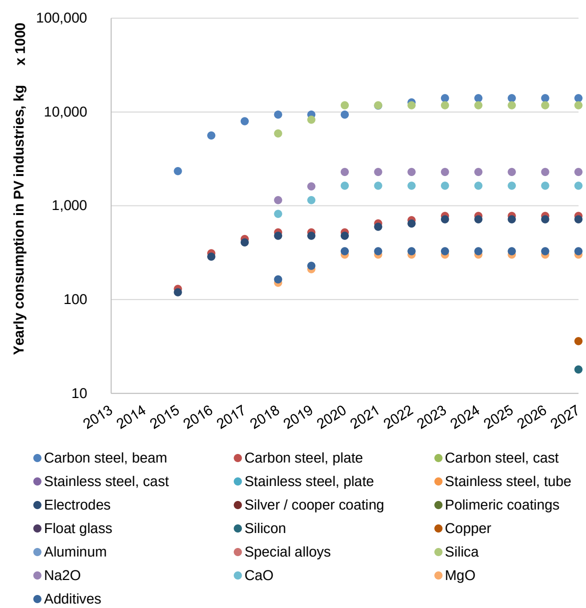
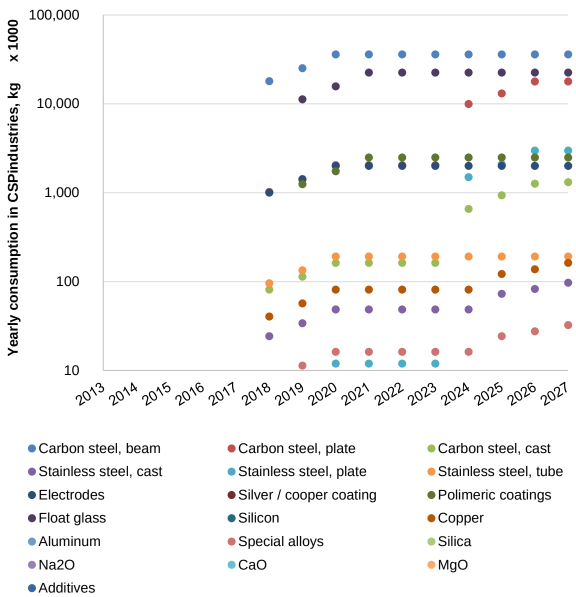


Figure 140 | Material Requirements for CSP Industries, 2013-27



The expected consumption of local supplies is below 1 percent of the country's production capacity (Chapter 2.2), so no short-term shortages are expected. On the other hand, the quality of the materials might be troublesome in, for example, extra-clear float glass for mirrors.

8.10.3.2 ENERGY REQUIREMENTS

Egypt has expressed intentions to discourage the installation of new energy-intensive industries. As a reference to determine the relative energetic intensity of the component manufacturing industries, an estimate was made of the actual average energy consumption of the Egyptian industrial sector per unit of GDP (MWh/US$ mil).

Figure 141 | Energy Intensity of Solar Component Manufacturing Industries

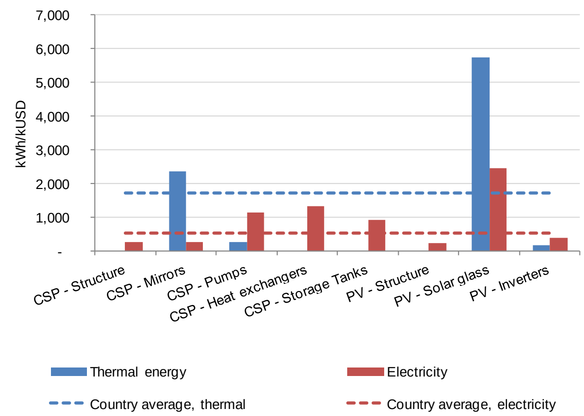


Figure 141 shows that inverters and structures have lower specific energy consumption than the global average, both thermal and electric. Solar glass, on the other hand, is above both averages.

8.10.4 CONCLUSION

Egypt has the capacity to enlarge its solar component manufacturing base. According to the assumptions in this study, expanding the sector would result in the direct creation of up to 3,000 jobs, most of them in installation-related activities.

Expansion also would increase GDP by over US$300 million/year. No shortages of materials supply are expected. On the other hand, energy could pose a problem because some of the proposed industries are energy intensive, and strongly depend on heavy duty, continuous production to achieve profitability.

PART E | Solar Component Manufacturing Case Studies

CHAPTER 9:

Solar Component Manufacturing in China

9.1 Executive Summary and Key Findings

China's policy to develop renewable energy (RE) is supported by programs and plans that have been regulated and institutionalized by national and local governments, and financial institutions.

The Chinese government's commitment, planning, incentives, and effective execution of the plans have generated sufficient confidence in local producers for them to devote efforts in the manufacture of components.

China sets policies that are similar in many respects to the policies of other leading countries to promote, foster, and encourage producers of RE technologies. Since 2001 China's significant growth in domestic demand has increased industrial production and exports of solar photovoltaic cells and modules.

The government's development policies, the participation of top universities and institutes, along with the participation of leading technologically developed countries and the support of international institutions, have encouraged and enabled China to both manufacture and export some key parts of CSP technology.

At present, China is implementing an ambitious program for innovation, technology, and science with these objectives:

- Promote basic research
- Promote development of new technologies
- Create infrastructure for scientific research
- Develop R&D human resources
- Reward scientific and technological excellence.

The evolution of Chinese development of renewable energy has been possible due to the establishment and implementation of the following:

- Plan and review national and international RE targets
- Distribute responsibilities between the central and local administration
- Encourage the development of R&D and international collaboration mechanisms
- Develop appropriate infrastructure
- Establish rates, loans, and generation rates for thermal solar energy
- Evaluate national and local costs and financial resources.

9.2 Policies and Activities of the Country to Support Local Solar Component Manufacturing

Solar PV and CSP development in China is closely related to the government's incentive policies. Since the end of the 1970s, several research institutes and universities in PRC, such as the Institute of Electricity Engineering of Chinese Academy of Sciences (IEE CAS), Shanghai Mechanics College, and Tianjin University, had engaged in fundamental research for CSP application. Tianjin and Shanghai, respectively, set up 1kW tower solar power modeling devices and 1kW plate panel Organic Rankine cycle solar power modeling device with low boiling point temperature mediums.

At the beginning of the 1980s, with the U.S. company, Space Electronic, Xiangtan Electric-Mechanical Plant developed 2 sets of 5 kW parabolic concentrating solar power generators. During the periods of China's eighth, ninth, and tenth National Five-Year Science and Technology (S&T) plans, the key technologies of CSP were listed as national key S&T projects and National Hi-Tech plan (the "863 Plan") projects (China MOST 1986). Since 1993, output of domestic PV production has soared by 20 -30 percent. PV development was not industrialized until the mid-1980s. In 1996, China's former State Planning Commission formulated plans for the Brightness Program. Its aim was to try to use PV modules and wind power systems to provide daily power for China's 23 million people who were living without electricity.

In 2001, due to natural resource scarcity, increase in prices, and pollution from traditional sources, China began a policy of diversification of energy sources to decrease its dependence on traditional fossil fuel.

From 2001-07, China focused its policy on promoting large-scale PV, improving the energy infrastructure, growing a domestic market, diversifying the energy supply, expanding energy security, and sustainably developing the economy and society.

In 2002 the NDRC (National Development and Reform Commission) initiated the Township Electrification Program to meet the power needs of remote border areas in Western China. This program marks the start of China's beginning to install and construct standalone renewable energy power systems. Consequentially, this policy greatly stimulated the growth of China's solar PV industry.

From 2004, China began to focus policies on the large-scale promotion of solar energy. The main activity during this period was the installation the solar panels in rural areas.

In June 2004, a small Parabolic Trough receiver vacuum tube heat collector with high temperature was developed by the Institute of Electricity Engineering of the Chinese Academy of Sciences (IEE CAS) and the Beijing Solar Energy Research Institute. The Dish-Stirling technology was first adopted in the IEE CAS High-Temperature Experiment Field in Tong County of Beijing. The latter technology was financed jointly during the 10th Five-year plan by the "863 Plan," the Himin Solar Energy Group, and Xinjiang New Energy Company.

In 2005 China formulated the Renewable Energy Law, which became effective on January 1, 2006. This law guarantees:

- National targets for the development of renewable energy
- A purchase policy, by which grid companies are required to sign an agreement to purchase RE and provide grid connection services
- An on-grid electricity price for renewables, similar to a national feed-in tariff system
- Cost sharing, in which the cost of RE generation and grid connection is divided between utilities and electricity end users, and is supported by a surcharge on sales
- Special Fund for Renewable Energy, which offers additional financial support and subsidies for research and development.

During 2006-09, the government's main activities to enact its policies were:

a. Planning

- Through collaboration and coordination between central and decentralized levels, develop a national plan to expand renewable energies
- Analyze renewable industry market and registry of renewable companies
- Conduct surveys from the State Council on the various renewable energy sources to coordinate technical regulation with related offices
- Set benchmark goals and develop a long-term national development strategy for renewable energy

b. Management (regulation)

- Assign a high-ranking body (Council of State) the role to promote the national plan for the development of renewable energy
- Establish the responsibilities of the national and the local authorities. In addition, regulate and implement the authority of energy officials at the national level (State Council) in relationship to the powers of the local energy authorities
- Regulate the protection of the rights and interests of the producers and users of energy

c. Incentives or assistance to entities of public or private property to develop and use renewable energy for local manufacturing of components

- Generate programs for scientific and technological development to increase scientific and technical research seeking to develop renewable energy. Establish and fund research and development (R&D)

- Subsidize and provide tax relief to solar companies
- Provide assistance and support to services industry technology
- Generate programs for reducing production costs and optimizing the quality of these energies.

TABLE 49 | MAJOR POLICY INSTRUMENTS IN CHINA'S 2006 RENEWABLE ENERGY LAW

Instrument	Specification
National renewable energy target	Establishes strategic position of RE; identifies scale of market development, types of technologies needed, and priority locations for development.
Grid-connection priorities	Grid companies must accept all power generated by RE with price fixed by government and are required to build systems to integrate RE with grid.
Classification of tariffs for renewable energy power	Government determines price based on 1 of 3 options: average cost, cost with advanced technologies, or bidding price.
Cost-sharing at national level	Costs for on-grid RE electricity and off-grid generators in rural areas shared by all grid consumers in country.
Renewable Energy Special Fund	Covers: Technology research, standards development, and pilot projects; household RE utilization projects in rural and pastoral areas; off-grid electrification projects in remote areas; RE resource assessments and evaluation; establishment of localized RE manufacturing industry. Special Fund comes from central and local finance as balance of cost sharing.
Policies on favorable credit treatment	Financial institutions may offer preferential loans with national financial interest subsidies to eligible energy development and utilization projects. National policy banks, national banks, bilateral aid funds, international multilateral aid banks, and financial organizations are able to supply favorable loans.
Policies on favorable tax treatment.	Preferential tax will be given to RE projects.

Source: Ng 2011.

During 2006-10, a 1MW solar power tower demonstration project in Yanqing County of Beijing was financed by the National 863 Plan, and implemented by IEE CAS, to explore the key technologies and equipment of solar power tower technology and verify its feasibility. With the implementation of the R&D and demo engineering of the tower system, concentrated solar thermal power (CSP) began to receive attention in China. The industry chain is forming gradually. At the beginning of 2011, Chinese government issued the feed-in tariff for the first 50MW CSP plant in Inner Mongolia. This outcome shows that, for a new technology to be recognized and paid attention by the government and industry, the demonstration is important.

In 2009 the government of China announced the Solar Roofs Program and the Golden Sun Demonstration Program. The Solar Roofs Program provides to the supplier an upfront subsidy of 50 percent of the bidding price to supply the critical components for roof top systems and Building Integrated PV. The Golden Sun Demonstration Program provides for off-grid systems for solar PV projects of more than 500MW within 2-3 years. As of 2012, both programs had gone through 4 phases.

TABLE 50 | GOLDEN SUN DEMONSTRATION PROGRAM, 2009-12

Phase	Year	Approved projects	Approved capacity (MW)	Subsidy (RMB/W)	
				SOLAR PV building	Off-grid
I	2009	98	201	14.5	20
II	2010	50	272	11.5	16
III	2011	140	690	C-Si:9.0,a-Si: 8.5	
IV	2012	167	1,709	5.5	>7.0
Total		455	2,872		

These two subsidy programs clearly demonstrate China's determination to support the adoption of solar PV.

To promote CSP technology and industry breakthrough, in September 2009, the National Alliance for Solar Thermal Energy was set up with the support of MOST (Ministry of Science and Technology) of PRC. The objectives of the National Alliance were to strengthen enterprises' independent innovation capability and competitiveness for key technologies.

The National Alliance is voluntarily constituted by enterprises, research institutions, and universities/colleges involved in CSP-related R&D, manufacture, services, and investment. To date, the members of the Alliance have been increased to 65, including 34 enterprises, 19 universities, and 12 research institutes.

The Alliance's main tasks for CSP technology are:

- Using intellectual property, develop 100MW CSP technology and trough vacuum tube.
- Research and master 100 MW solar tower power technology
- Set up trough concentrating heat absorption system and vacuum tube production lines
- Formulate the standards for CSP technology
- Set up general testing platform.

In July 2010, the first Fresnel system with 2,300 m^2 area was built in Dezhou of Shandong province, by Himin Group in cooperation with IEE CAS and China Huadian Engineering Company (CHEC).

On December 28, 2010, the groundbreaking ceremony of a 10MW CSP testing demonstration plant was held in Jayuguan of Gansu province. The plant was jointly invested by China Datang Corporation and Baoding Tianwei Group. Total investment was 300 million CNY plus 20 hectares (ha) of occupied land. In January 20, 2011, the first concession bid for a full-scale CSP demonstration project in PRC—the Inner Mongolia 50 MW trough CSP project—was opened. China Datang Corporation Renewable Power Co., Ltd., which had proposed 0.9399 CNY/kWh was the successful tender.

On October 17, 2010, Gansu Provincial Concentrated Solar Power Innovation Strategy Alliance was set up in Lanzhou, first, to promote CSP application and related equipment technology in Gansu province. The second objective was to strengthen exchange and cooperation among CSP-related enterprises in Gansu province and international and national institutions.

Organized by Gansu Provincial Industry and Information Commission, the Gansu Alliance was jointly established by 14 members. They include enterprises, universities, and research institutes, such as Datang Gansu Power Generation Co., Ltd., Aviation 501 Institute, and Langzhou Jiaotong University.

The targets of the Gansu Alliance are to:

- Create innovation schemes based on enterprises, oriented by market and combined with industry, universities, and institutes
- Integrate and share innovation resources, and strengthen cooperative R&D
- Overcome bottlenecks of key common CSP technologies
- Speed up commercialization of R&D results through technology transfer
- Strengthen competiveness of CSP industry
- Train and exchange personnel
- Cultivate integrated CSP industry.

In the span of a decade, China's PV solar panel production has risen dramatically: From supplying 1 percent of world PV production to becoming the world's largest exporter of solar panels, with over 40 percent of global market share (Richardson 2011).

Through its Development Plan for Renewable Energy and the high levels of PV technology production, China is taking steps to improve the domestic market to stimulate local solar component manufacturing. To stimulate domestic demand for PV technology, the government has announced targets to generate 15GW of power from solar capacity by 2015, and 20GW by 2020 (E-Young 2012).

Goals, objectives, and main activities for the development of RE to ensure the promotion of the market and RE industry from 2007 to 2020 are to:

- Ensure the promotion of the market and renewable energy industry. Increase market demand for RE (a) to create conditions for the development of an energy industry and (b) to self-promote technological development to advance manufacturing equipment and improve competitiveness. These measures will ensure a solid foundation for the long-term development of RE in China.
- Integrate the short- and long-term use of technology to maximize development potential. Integration will set the priority technologies applied to renewable energies and give importance to the less developed technologies that have good prospects for the future such as photovoltaic and biofuels.
- Harmonize policy incentives with market mechanisms. The government will establish economic incentives to promote the use of renewable energy technologies to solve the problems of cuts in service delivery and lack of access to electricity in rural areas.
- Adopt market mechanisms to encourage participation by investors. This adoption will increase the technical level of RE technology and progressively improve competitiveness to achieve large-scale development.
- Provision financial resources (managed through a special fund) to optimize the technologies used in the generation of RE:
  - Reduce costs
  - Develop and implement the projects to generate REs in remote areas that lack sufficient energy connections
  - Finance clean energy projects in rural areas
  - Install information networks to harness RE
  - Finance local production of the necessary equipment to develop RE development and improve the quality of the final product.
- Force local governments to develop plans exclusively to the promotion of renewable energies.
- Design and Implement incentive schemes and financial support for the local implementation of RE projects. The approval is for government aid rather than local scope.
- Provide preferential loans and subsidized interest rate for RE projects that are in the Renewable Energy Industry Registry. (It is a grant under the legislation and is mandatory for financial institutions.)
- Establish tax incentives and provide tax benefits for projects recorded in the Renewable Energy Industry Registry.

9.3 Extent of In-Country Demand Versus Demand for Exports of the Country's Solar Component Manufacturing Capacity, and its Evolution and Correlation with Policies and Markets Dvelopment

Since 1990, the Chinese government has implemented policies and strategies to stimulate solar PV and CSP growth. CSP development has benefited from a policy of financial support for R&D. During 2005-09, MOST (Ministry of Science and Technology) invested over 100 million yuan (CNY). MOST has worked with universities and top institutes to develop CSP technologies and elements such as Parabolic Troughs, towers, and dishes.

"China accelerated its transition from a centrally planned to a market economy and integration into the global economy, taking a series of important measures such as deepening economic restructuring in almost all the sectors, making the country strong through developing science and education and tapping human resources, implementing sustainable development strategy and western development strategy, strengthening social safety net, and combining bringing in and going global to encourage its economic and social development and opening up. By the end of the 20th century, China already had achieved its strategic development goals of the first two steps in the modernization drive, quadrupling its GDP and per capita GDP by 2000 from 1980 ahead of schedule" (UNCTAD 2005).

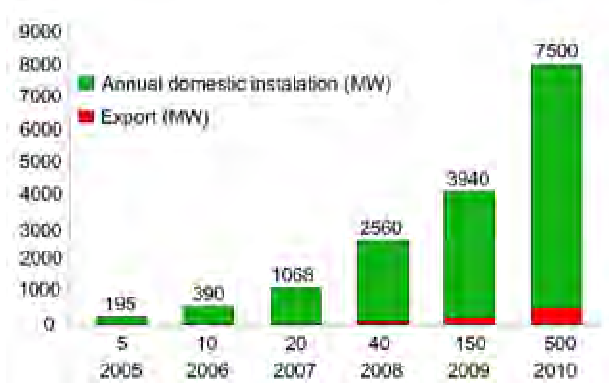
From the 1990s to 2000, Chinese solar manufacturers benefited from the new policies and strategies implemented by the government. The production of photovoltaic solar energy in China was small scale, and production was destined for an internal market of low demand.

In the 2000s, to promote, foster, and encourage producers of RE technologies, China set policies similar in many respects to those of other leading countries. During those years, China experienced significant growth in domestic demand and increased its industrial production and exports of solar photovoltaic cells and modules.

China's rapid growth in RE capacity has reflected its emphasis in the country's 11th and 12th Five-Year Plans (2006-10 and 2011-15). The proportion of renewable energy in total national energy consumption is targeted to be above 9.5 percent (British Chamber of Commerce in China/China-Britain Business Council 2012).

The following figures reflect that Chinese producers' PV technology output during the 2000s was bound overwhelmingly for foreign markets. Less than 5 percent of the solar PV production was absorbed by China's domestic consumers. Chinese companies recently have been producing half of the world's PV component output (The Pew Charitable Trusts 2011b).

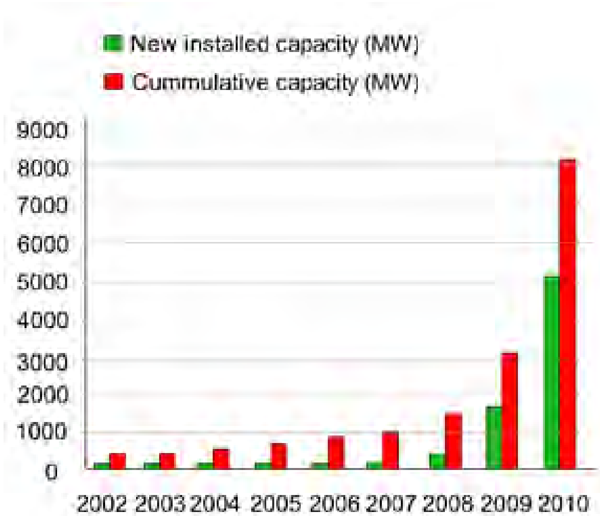
Figure 142 | China Solar PV, Domestic Installation vs | Export, 2005-10



Source: The Pew Charitable Trusts 2011b.

The domestic installed capacity of solar PV started from a very low base. Its growth rate began to accelerate only after 2008. Domestic installed capacity thus remains at an insignificant level both in international terms and in relation to Chinese PV producers' massive output.

Figure 143 | China Solar PV Capacity, 2002-10



Source: The Pew Charitable Trusts 2011b.

The Chinese government's policies for development, the participation of top universities and institutes along with leading technologically developed countries, and the support of international institutions have encouraged and enabled China to both manufacture and export key parts of CSP technology.

In the twentieth century, three basic circumstances facilitated the evolution of Chinese renewable energy production and the development of the RE industry:

- Government policies that increased Chinese presence in the international market[44]
- Increased emphasis on strategic industries that are capital, technology, and value intensive[45]
- Implementation of environmental policies to reduce the harmful impacts of rapidly growing Chinese industry.[46]

Together, these interrelated political developments have strongly influenced the objectives, outcomes, and consequences of China's renewable energies technology push.

In 2009 when Chinese manufacturers of modules had achieved substantial positions in the world market, the Chinese government set policies and programs to increase domestic demand and R&D grants to build capacity silicon manufacturing.

In recent years, due mainly to the economic crisis, European countries reduced subsidies for RE installation. Consequently, the demand for solar cells decreased. In 2010, at 33 percent, China was producing a majority of the world's silicon output, but little was being exported (SEIA 2011). These circumstances created Chinese industry's overcapacity and depressed prices and profits. To offset the decline in prices and export benefits, maintain social stability, promote exports, and hold its position in the international market, the Chinese government reestablished governmental grants and subsidies so that manufacturers of components could bear the manufacturing costs.

44. "The macroeconomic importance of exports began to increase, as the Chinese government more actively utilized net export-promoting policies regarding exchange rates and taxation" (Liu and Goldstein 2013).

45. "Beginning in the late 1990s, the Chinese government sharpened its focus on developing industries considered strategic for reasons of national security, economic infrastructure, or critical supply chains" (Mattlin 2009).

46. Recent directives have targeted energy conservation (2007 Energy Conservation Law); RE implementation (2005 Renewable Energy Law and a 2009 amendment); 2007 Medium and Long-Term Development Plan for Renewable Energy (China NDRC 2007); and emissions reduction (2009 and 2010 State Council Notice on Energy Conservation and Emission Reduction). In addition, the China Greentech Initiative (2009) identified key sectors to be developed, including cleaner conventional energy, renewables, green building, and cleaner transportation and industry generally. In a related development, the central government committed to reduce CO_2 emissions by 45% by 2020 (China State Council of China 2010), is enforcing limits on vehicular gasoline consumption, and is building an electric railway system.

The international recession demonstrated the vulnerability of Chinese industry to fluctuations in external demand for PV technology. China increased its objectives and incentives for domestic absorption. In 2011 China announced sharp increases in its targets for solar capacity installation for 2015 and 2020 to 9 GW and 50 GW, respectively (British Chamber of Commerce in China/China-Britain Business Council 2012).

TABLE 51 | CHINESE GOVERNMENT POLICY SUPPORT FOR RENEWABLE ENERGY INDUSTRY, 2005-11

Year	Policy	Details
2005	Renewable Energy Law	Renewable energy to account for 10% of total energy consumption in 2010, 20% by 2020. Increase share of total electricity from nonhydro- renewable energy from 1% in 2010 to 3% in 2020.
2006	Renewable Energy Electricity Price Sharing and Management	Electricity generated by renewable energy priced by the government. Portion above the market price for conventional electricity would be shared by all electricity consumers.
2007	Medium- and long-term development plan for renewable energy in China	Construct large-scale wind farms in Northern China and small-to-medium-sized wind farms in other areas. Set up off-shore wind power generation pilot projects with at least 100 MW capacity by 2010, 1000 MW capacity by 2020. Promote solar PV power plants in remote areas to address electricity shortage problems. Target 1,000 roof-top solar PV projects nationwide by 2010, 20,000 by 2020.
2007	Notice of construction of large-scale solar PV power plants	Construct model solar PV power plants with at least 5 MW capacity in Inner Mongolia, Yunnan, Tibet, Xinjiang, Gansu, Qinghai, Ningxia, and Shannxi provinces.
2008	National Energy Bureau created	Promote policy making for energy development and reconstruction; manage national oil reserves, natural gas, coal, and electricity. Propose strategic policies in renewable energy and energy conservation. Manage international cooperation and ensure adequate supplies of oil.
2008	Tenth Renewable Energy Five-Year Plan	Promote application of solar heat and solar PV energy in new buildings. Set target for aggregate installed capacity of wind energy to be at least 10.0 GW, and for solar PV energy to be at least 0.3 GW.
2009	State Council Notice on Energy Conservation and Emission Reduction	Enforce use of RE in new residential and office buildings. Reconstruct and upgrade industries with high energy consumption and high emissions. Merge or close small inefficient power-generation plants.

2009	Solar Energy Construction Subsidy Funds Management	Subsidize 20 CNY (US$2.94)/kWp. Subsidize solar PV products, which need at least 50 kWp installed capacity. Give priority to solar PV products applicable to new buildings, schools, hospitals, and other public infrastructure.
2009	Notice on Golden Sun Model Project	Subsidize total investment for qualified solar PV generation by 50%; subsidize projects in remote areas with no electricity by 70%. Subsidized projects must operate no fewer than 20 years Solar PV generation units must have at least 0.1 billion CNY (US$14.7 million) registered capital. Single projects must have installed capacity over 300 kWp.
2009	Renewable Energy Construction Model City Plan	Select and subsidize qualified model cities, with 50 million CNY-80 million CNY (US$7.35 million-11.76 million) per city. Model cities must have RE coverage in over 30% of the newly constructed area.
2010	National Energy Committee created	Highest level energy agency in China, directed by Premier Wen Jiabao, and Vice Premier Li Keqiang. Directly supervise Energy Bureau. Unify national strategy for energy, ensure energy security, and coordinate energy development.
2011	Twelfth National Energy Technology Five-Year Plan (2011-15)	Reduce costs of solar PV energy to compare with conventional energy. Create research and development capability for solar PV facilities with at least 1 MW capacity. Construct grid solar PV power generation system with 100 MW capacity.

Source: Li and others 2010.

9.4 In-Country Research and Development Capacity in Solar Component Manufacturing

In 1970 China began its own research and technical development. However, most of China's development at the time was aligned with the progress in other parts of the world.

The Chinese solar PV companies began with the downstream segments of the industry manufacturing components. Downstream segment manufacturing requires an energy- and labor-intensive process of turning wafers into cells, and cells into modules.

The downstream cells and modules segments industries have been characterized by lower entry barriers and intense competition.[47] PV cell and module production are labor and energy intensive, both factors with which China is well endowed. In addition, PV cell and module producers benefited from an influx of Chinese executives returning from abroad, where they had gained valuable experience in leading international solar technology firms. China entered this industry early and now dominates the market.

47. The 2010 4-firm concentration ratio in cells was only 24%. Both segments experienced rapid year-to-year turnover among the leading firms as Chinese companies entered the market (U.S. DOE NREL 2011).

During the 2000s, China's upstream manufacturing utilized the Siemens method, the state-of-the-art technique in silicon purification. Upstream segment manufacturing requires high levels of technological capability and investment which, in tandem, create sustainable competitive advantage for market leaders and significant barriers for would-be entrants. This process depends on extensive experience in "precisely controlling the parameters of all the chemical reactions" (de laTour and others 2011).

As a result, market concentration and profits have been high at this end of the PV value chain. In 2010 the top 4 firms—only 1 Chinese—accounted for 58.5 percent of the market, and 2009 profit margins exceeded 40 percent (Green Rhino Energy 2012).

TABLE 52 | RENEWABLE ENERGY INDUSTRY AND MARKET ENTRY DYNAMICS

	Technology characteristics	Global industry dynamics	Chinese entry path
Solar PV—(upstream) silicon, ingots, and wafers distinctive producer capabilities	Distinctive producer capabilities built through experience. Process control affects quality-cost nexus. Quality, intellectual property, R&D critical to value.	Highly concentrated, with persistent early-leader positions. Up-front expenses and expertise required to reduce backward integration threat. Profit margins wide.	Policy level: Subsidize R&D. Firm level: Build capabilities via domestic sales; pursue export quality.
Solar PV—(downstream) cells, modules	Turnkey production lines available. Capabilities available via hiring, vendor training. Energy, labor costs critical to value.	Fragmented; rapid change in market shares as Chinese firms enter. Attracting forward and backward integration. Profit margins thin.	Policy level: None required. Firm level: Purchase and hire for equipment and know-how; produce low-cost exports.

Sources: De laTour and others 2011; Green Rhino Energy 2012; Zhou and Wang 2009; Zhao and others 2012; IHS 2013.

In CSP technology, the participation of top universities and institutes along with leading technologically developed countries and the support of international institutions have benefited and enabled China. Industry in China has sufficient capacity to manufacture most of the inputs used in CSP projects: glass, metal frames, molten salts, and most central tower components. However, China does not have the same ability to make Parabolic Trough collectors. China is implementing processes to increase its manufacturing capacity at all stages of the production chain and to achieve production projections that satisfy the internal market.

9.5 Partnership Arrangement with International Solar Technology Expertise

Since 1999, Chinese R&D investment has increased annually by approximately 20 percent. In 2005 investment reached 1.3 percent of gross domestic product (GDP), compared to only 0.7 percent in 1998. This growth has been possible due to the fact that China´s leaders:

- Strongly believe in the potential of technology
- Fully understand the problems associated with current technological changes
- Adopt the necessary measures through technology programs and international R&D and innovation.

To continue growing in technology development, China is creating and implementing a highly ambitious program of innovation, technology, and science. Its objectives are to:

- Promote basic research
- Promote R&D of new technologies in selected areas
- Create the necessary infrastructure for scientific research
- Develop R&D human resources, and reward scientific-technological excellence.

TABLE 53 | CHRONOLOGICAL OVERVIEW OF KEY RESEARCH AND INNOVATION POLICY PROGRAMS, 1982-2003

Chronological Overview of Key Research and Innovation Policy Programs	
National Key Technology R&D Program	1982
Rude Key Laboratory Program	1984
Resolution on the Reform of Science and Technology (S&T) System (1985)	
Spark Program	1985
863 Program	1986
Torch Program	1988
National New Products Program	1988
National S&T Achievements Dissemination Program	1990
National Engineering Technology Research Centers	1991
Climb Program	1992
Endorsement of UAE by State Science and Technology Commission (SSTC)	1992
Science and Technology Progress Law	1993
211 Program Ministry of Education of the People's Republic of China (MOE)	1993
Decision on Accelerating S&T Progress (1995)	
Law for Promoting Commercialization of S&T Achievements	1996
Super 863 Program	1996
973 Program	1997
Chinese Academy of Sciences (CAS) Knowledge Innovation Program	1998
Decision on Developing High-Tech and Realizing Industrialization	1999
985 Program	1998
Innovation Fund for Technology-based Small and Medium Enterprises (SMEs)	1999
Guidelines for Developing National University Science Parks	2000
Action Plan for Promoting Trade by S&T	2000
Chinese National Laboratories (Program)	2003

Source: Spain CDTI 2010.

In 2006 Chinese government published the Strategic Plan for Science and Technology for Medium and Long Term (2006-20) (China MOST 2006). The Plan's objectives are to:

- Increase the innovative capacity of firms. Research, investigation, and development will be main pillars of its future economic growth.
- Achieve great discoveries in areas of interest worldwide as both technology and development for basic research.
- Reach 2.0 percent of gross domestic product (GDP) in 2010 and 2.5 percent in 2020 in R&D.
- Technology and innovation will contribute 60 percent of GDP.
- Reduce dependence on foreign technologies by more than 30 percent. (In 2005 the share of spending on imported technology, compared to the cost of R&D, was approximately 39 percent).
- Attain level of the top five countries in number of national patents.

China is a member of the Energy Working Group of the Asia Pacific Economic Cooperation (APEC), the Association of Southeast Asian Nations (ASEAN), the China, Japan and Republic of Korea Energy Cooperation, the International Energy Forum, the World Energy Conference, and the Asia-Pacific Partnership on Clean Development and Climate. China has taken on a wide range of international commitments; and an active role in exploring technology, environmental protection, renewable energy, and finding new energy sources.

China has established bilateral agreements and mechanisms for dialogue and cooperation in the field of renewable energy technology development with producer countries such as the European Union, Japan, Russia, and the U.S.

Representatives of China have signed with institutions and universities in other countries: formal arrangements, memoranda of understanding, collaborative partnership agreements, and letters of intent. Joint research projects also were considered an important collaborative mechanism. The joint research projects have financial support from the governments and research/industry partnerships (including partnerships between the countries' research organizations and Chinese industry partners).

Joint workshops, seminars, and symposia were noted by respondents as important means of facilitating collaboration. Many responses indicated that these events are underpinned by their formal collaborative arrangements. The possibility of face-to-face meetings with Chinese partners at these events is considered particularly valuable, giving international researchers the opportunity to strengthen partnerships by identifying new research goals and building research collaborations.

To incorporate foreign talent in China, nine cities have established incubators for international companies. International business incubators are created to provide appropriate environments for foreign experts in China to innovate and expand from there to international markets. Specialized incubators focus their activities on attracting particular industries promoted by national policies, such as renewable energy

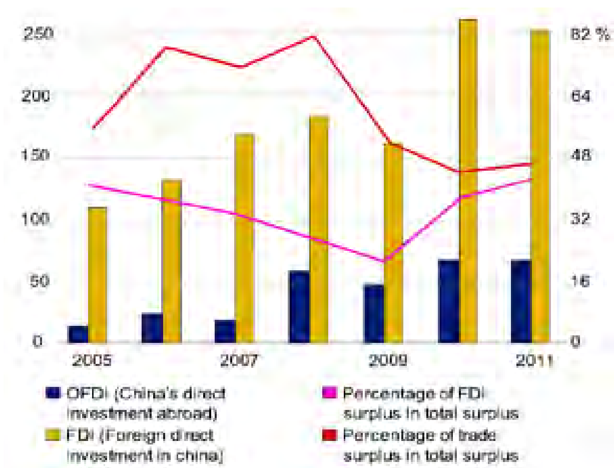
Multinational companies operating in China have been established at major universities, such as Tsinghua University, and are collaborating with the universities' laboratories. In many cases, the universities themselves are the ones that seek to collaborate with companies located in areas of high-tech development, incubators, and science and technology parks.

China wants to boost its investment in renewable resources by encouraging the incorporation of technology, management experience, and foreign capital. The country has enacted laws and policies to encourage business creation and develop Sino-foreign equity: Law on Sino-Foreign Equity Joint Ventures, Law on Sino-Foreign Cooperative Joint Ventures, and Law on Foreign Capital.

In 2002 China revised its Industrial Guidance Catalogue for Foreign Investment. The government set its policy on the appropriate use of the flow of foreign direct investment (FDI). The FDI will support a production model that relies on technology transfers (TTs) to achieve a substantial technological improvement of Chinese enterprises, and forces foreign companies to invest in local partners as "joint ventures."

Internationally, China is one of the leading investors in Europe and the United States. China also is increasing its overseas renewable energy investments through partnership arrangements with international solar technology experts.

Figure 144 | Trade, Investment, and Contribution to China's Balance of Payments Surplus, 2005-11



Source: Tan and others 2013.

CHAPTER 10:

Solar Component Manufacturing in Brazil

10.1 Executive Summary and Key Findings

Brazil possesses major potential in renewable energy resources, including solar, wind, biomass, and hydraulic potential. At the same time, Brazil is one of the fastest growing countries in its region. The 2010-19 forecasts point to an annual GDP growth of 5.1 percent (Meisen and Hubert 2010), which in turn would require a concurrent major expansion of the energy sector. One of Brazil's priorities is to ensure the continued renewability of its energy matrix, which, thanks to the country's large hydraulic potential, already is more than 70 percent renewable (Empresa de Pesquisa Energética 2009).

Brazil has significant experience with some renewable sources, specifically wind power. The country is developing a relevant wind component industry alongside the wind energy generation, solar energy and, more specifically, associated solar component manufacturing industries. These last are still at a very incipient stage. This status was expected to change because solar energy was part of the power tender carried out in October 2013, although finally no solar plants were among the winning bids (Empresa de Pesquisa Energetica 2013). In any case, the development of the industry will require coordinated effort on the part of the different players.

10.2 Policies and Activities of the Countries to Support Local Solar Component Manufacturing

As part of its strategy to maintain its historically renewable energy matrix, Brazil now is looking beyond hydraulic and biomass energy to wind and solar power, particularly. The Brazilian approach to solar energy is directed toward CSP and PV as well, although both are still incipient.

As of 2001, installed PV power in Brazil was 20 MWp (Empresa de Pesquisa Energética 2009). Most of this power was installed under the auspices of two programs: (a) *Light for All* (*Luz para Todos*) program headed by the Ministry of Energy and Mines (MEM) to supply electricity to isolated areas and communities in the Brazilian Amazon, and (b) Program for Energy Development of States and Municipalities (PRODEEM), launched by the federal government in 1995. Most of this capacity is in off-grid installations. The largest solar power plant, located in the city of Taua, is a 1 MW plant operated by MPX Energía.

Brazil has more experience in the development of wind energy. This case is worth highlighting due to the possible parallel with future solar energy and component manufacturing capacity development, particularly on how to capitalize on strengths and avoid weak points.

Brazil has an installed capacity of 1,509 MW of wind power (IRENA and GWEC 2012), more than half of that installed in Latin America. The first projects were installed mainly with financing from PROINFA, a program managed by Eletrobras to support the development of investments in alternative sources of electricity. PROINFA's main objective was to increase the quota of renewable energy in Brazil. The first phase (2002-09) included tenders of 1,100 MW each for wind, biomass, and small hydro plants.[48]

However, after the first phase of PROINFA, the Brazilian government moved to specific electricity auctions (tenders) for wind power generation as a mechanism for driving new wind power capacity. Since 2009, reverse price auctions have been the main mechanisms employed in Brazil to incentivize the development of wind power. The auctions have steadily led to a fall in the price per MWh of wind energy to the point at which wind power is now competitively priced.[49] Advantages of the auction system are that it rewards efficiency in the process and ensures transparency and fairness, encouraging bidding by as many prospective bidders as can qualify and avoiding collusion.[50]

The Brazilian wind energy tenders have generated significant interest from various multinational and Brazilian companies establishing themselves in Brazil for the manufacture/assembly of equipment. Brazilian tenders do not include local component development requirements. Partly due to this fact, funding from the Brazilian National Development Bank does have additional local requirements. These have both positive and negative connotations. The requirements are positive in that the conditions encourage (almost guarantee) the development of the industry and energy projects. The requirements are negative in that they put an additional strain on project development and could exclude companies that could otherwise be strong players in the sector.[51]

The final results remain to be seen as the contracted wind farms are built over the next few years. Because the Brazilian tenders have elicited considerable interest, they have made prices more competitive than may have been thought possible, while developing the local wind component industry. Brazil already has developed the industrial competence to produce wind turbines from 250 W to 3 MW for both domestic use and export (Ramos Martins 2011). Among the companies involved are IMPSA WIND, Wobben WindPower, General Electric do Brasil, ENERSUD, ELETROVENTO, and TECSIS, as well as some international players. It is expected that the sector will implement a manufacturing base capable of producing from 2.0 GW-2.5 GW of wind power equipment per year (IRENA and GWEC 2012).

Based on the success of the wind sector, Brazil is hoping to replicate the same success for solar energy[52] and solar component manufacturing. In 2013 the government announced that solar projects, both CSP and PV, would be able to participate in the auction held in October 2013. However, solar had neither its own reserved demand nor special incentive, so it had to compete on equal terms with wind. The final results of the auction included no solar plants among the winning bids (Empresa de Pesquisa Energetica 2013).

48. The wind quota was increased to 1,422 MW via re-management of the noncontracted portion of biomass projects.

49. Additionally, Brazil has employed tax incentives in the form of an exemption from tax liability of approximately 30% of the investment (IEA-PVPS Executive Committee 2007).

50. However, the Brazilian tenders are not without problems. There are still doubts as to whether all the MW awarded can be delivered at the very competitive prices offered in the auction. The reason is that, in the Brazilian auction system, the determining criterion for the winning bid is the lowest tariff (that is, the lowest price/MWh) to meet the forecasted demand.

51. At the end of 2012, Banco Nacional de Desenvolvimento Economico e Social, Brazil's development bank, increased local-content requirements for wind turbine manufacturers. Under these requirements, developers asking for loans need to source 60% of the turbine components locally, and assemble or produce at least 3 of the 4 main wind-farm elements (towers, blades, nacelles, and hubs) locally as well.

52. In April 2012, ANEEL (Brazilian National Agency of Electrical Energy) approved an important piece of legislation for the solar industry, putting in place regulation for net metering for solar systems up to 1MW and granting utilities an 80% reduction in distribution taxes for power generated by solar plants up to 30MW in size, in an attempt to incentivize sector development.

10.3 The Extent of In-Country Demand Versus Demand for Exports of the Countries' Solar Component Manufacturing Capacity and Its Evolution and Correlation with Policies and Markets Development

Due to the current nonexistence of a solar component industry in Brazil, plants to be developed in the short term will have to import components. However, using the example from wind, Brazil very likely will take the opportunity to ensure that, in the medium term, in-country demand is met as much as possible through local manufacturing capacity.

However, a few major suppliers already are working in the country and could supply key solar components.[53] These suppliers include:

- Condensers and heat exchangers: Alfa Laval and Spirax Sarco
- Pumps: Ensival Moret, Flowserve, Ruhrpumpen
- Solar glass (TF): Pilkington, Saint Gobain, Guardian.

10.4 In-Country Research and Development Capacity in Solar Component Manufacturing

Research and development in solar is not new in Brazil. As early as 1979, after the second world oil crisis, the Brazilian government began to encourage research efforts in solar energy, particularly solar cells. However, efforts waned over the next decades. It was only in 1995, with the implementation of PRODEEM, that solar research picked up.

53. Excludes small companies positioning themselves for installation, engineering, and general project development.

Brazil is now increasing its emphasis on green technology research, including solar energy and solar components. In 2004 the Solar Energy Technological Nucleus of the Pontifical Catholic University of Rio Grande do Sul, the Ministry of Science and Technology, the Secretariat of Energy, Mines and Communication as well as the Secretariat of Science and Technology from Rio Grande do Sul, the Municipality of Porto Alegre, and the State Electrical Utility Rio Grande do Sul (CEEE) established the Brazilian Centre for Development of Photovoltaic Solar Energy. Among other issues, the center is working on silicon solar cell processing, developing static concentrators, and designing standalone systems (Moehlecke and Zanesco n.d.). The third area is of particular interest to Brazil due to the large number of isolated communities living in the Brazilian Amazon.

In 2012 the Studies and Projects Financing Agency (FINEP), a public company administered by Brazil's Ministry of Science, Technology and Innovation, launched the Sustainable Brazil Programme. The latter will distribute some US$10 million in lines of credit for initiatives to preserve natural resources. The program responds to a demand perceived by FINEP, which over the last 8 years has provided US$2.3 million in financing for projects with a "green" component.

Recently, several Brazilian solar R&D projects have made it into the news. One example is the plastic solar panels printed with photovoltaic cells created by scientists at CSEM Brazil, a research institute based in Minas Gerais.[54] This project had the support of the Minas Gerais State Research Foundation (FAPEMIG); venture capital firm, FIR Capital; and the Centre Suisse d'Electronique et de Microtechnique (CSEM).

54. The technology to produce these organic photovoltaic cells has been studied in Europe and the United States for a number of years but now has been further developed in Brazil (Marcondes 2013).

10.5 Partnership Arrangement with International Solar Technology Expertise

The private sector also wants to stay abreast of new innovation opportunities. As an example, the Brazilian Electrical and Electronics Industry Association (ABINEED) has set up the Photovoltaic Sectoral Group. The group intends to identify and propose strategies and demands that, from the point of view of private companies, would help drive the sector.

Joint ventures also are developing between Brazilian and international companies to jointly carry out solar projects. An example is the case of the 1.1MW project announced in 2013 to be built jointly by Petrobras and SunEdison, a California-based company with 989 MW of interconnected electricity around the world. SunEdison specializes in wafer and cell manufacture but also develops, finances, installs, and operates solar plants. The construction of the plant is part of an initiative led by Petrobras within the structure of the Research and Development Program of the Brazilian Electricity Regulatory Agency. The plant then will be operated by the SunEdison Renewable Operations Center.

Another joint venture is that between Gehrlicher Ecoluz Solar do Brasil, the Chinese equipment provider Yingli, and U.S.-based United Solar Ovonic Corp, which will be installing solar panels at the Pituacu sports stadium in the city of Salvador in a project financed by the Companhia de Eletricidade do Estado da Bahía and the state government.[55]

Foreign-made equipment will not be eligible for loans at below-market rates from Brazilian Development Bank (BNDES) may be a barrier. It has been suggested that Chinese module makers, for example, which are being shut out of Brazil, may be shifting sales to Chile (Nielsen 2012).

55. Brazil planned to use some of the events in the country, such as the 2014 FIFA World Cup, to showcase its potential as an emerging solar country.

PART F | Recommendations for a Road Map for Development of Solar Industry in Egypt

CHAPTER 11:

Recommendations for the Development of Solar Industries in Egypt

11.1 Introduction

The analysis and insights obtained during both the information-gathering mission in Egypt and the later workshop have highlighted a series of issues that need to be addressed for Egypt to be able to develop the solar component industry for key components.

Eight issues have been identified as priorities to address:

Issue 1: Visibility of the pipeline
Issue 2: Capital availability
Issue 3: Qualified labor requirements
Issue 4: Technology transfer
Issue 5: Clustering
Issue 6: Materials supply
Issue 7: Exports
Issue 8: Certification and accreditation.

The specific actions that can be carried out, taking into account the Kom Ombo project and the newly announced large-scale PV projects in Egypt, are described separately.

TABLE 54 | ISSUE DEFINITION AND OBJECTIVES

Issue	Stakeholders	Definition	Objective
Visibility of the pipeline	Policy makers: Ministry of Electricity and Energy (MoEE) New and Renewable Energy Authority (NREA) Egyptian Electricity Holding Co. (EEHC) Egyptian Electricity Regulatory Agency (EgyptERA) Ministry of Industry and Foreign Trade (MIFT) Ministry of Investment (MoI)	The private sector has little visibility on the developing pipeline, so it does not perceive the demand (both public and private) and does not react.	Give visibility on the pipeline to the private sector, so that it perceives the demand as credible and can react appropriately.
Capital availability	Financial institutions: Commercial banks (local banks and non-local banks) Specialized banks and financial institutions operating in the fields of investment and credit for industry, and development Policy makers: Ministry of Finance (MoF) Ministry of Investment (MoI) Ministry of Industry and Foreign Trade (MIFT) Private sector	The capital market is difficult to access (both in terms of equity and loan), and expensive (two-digit zone).	Ensure enough capital is available to develop the sector competitively, with appropriate payback periods.
Qualified labor requirements	Policy makers: Ministry of Industry and Foreign Trade (MIFT) Ministry of Electricity and Energy (MoEE) New and Renewable Energy Authority (NREA) Ministry of Education Ministry of Higher Education and Scientific Research Private sector	Training is required to ensure international quality standards are met, including both skilled engineers and managers for the manufacturing process and specific training for installation and maintenance.	Develop training programs to ensure all necessary capabilities are in place to development the sector.
Technology transfer	Policy makers: Ministry of Industry and Foreign Trade (MIFT) Egypt Technology Transfer and Innovation Center (ETTIC) Industry Modernization Center (IMC) Ministry of Higher Education and Scientific Research Academia: Academy of Scientific Research Research Centers Universities and technical institutes Private sector	Local industry is lacking some of the know-how required on both the manufacturing processes and the solar market.	Identify know-how requirements, and acquire the know-how over the shortest period.

Clustering	Policy makers: Ministry of Industry and Foreign Trade (MIFT) Industrial Development Authority (IDA) Federation of Egyptian Industries (FEI) Ministry of Investment General Authority For Investment (GAFI) Private sector	Company dispersion leads to lost opportunities in synergies and economies of scale.	Define, design, and develop clustering opportunities to maximize synergies in the sector and encourage new entrants.
Materials supply	Private sector	The increase in demand of local materials caused by the development of the solar component industry could impact material supply and price.	Monitor this phenomenon and give visibility to upstream actors in the sector so that they can be prepared in both quality and quantity.
Exports	Policy makers: Ministry of Industry and Foreign Trade (MIFT) Egyptian Export Promotion Center (EEPC) Export Credit Guarantee Company (ECGE) Export Development Bank of Egypt (EDBE) Ministry of Finance Ministry of Investment Private sector	Egyptian exports might be affected by internal customs duties, destination customs duties, or other requirements imposed by destination countries.	Identify key export markets and develop future agreements to minimize this risk.
Certification and accreditation	Policy makers: Ministry of Industry and Foreign Trade (MIFT) Egyptian Organization for Standardization and Quality (EOS) Egyptian Accreditation Council (EGAC) Ministry of Electricity and Energy (MoEE) New and Renewable Energy Authority (NREA) Egyptian Electricity Regulatory Agency (EgyptERA) Private sector	The adoption of international quality standards is necessary for both exports and the internal market.	Design and facilitate the development of Egyptian standards, encouraging communication between national and international laboratories.

Specific recommendations to address each of the key issues above have been formulated as an action plan that details short-, medium- and long-term initiatives and actions.

TABLE 55 | ACTION PLAN AND TIMELINE

Time	Immediate actions (1 year) 2013–2014	Medium Term actions (3 years) 2014–2017	Long Term actions (3 years) 2017–2020
1. Visibility of the pipeline	• **Carry out an analysis of possible mechanisms** to develop the pipeline • **Select** and **put in place the mechanism** of choice • **Develop** a credible **action plan** • **Make permit** and **license** processes **more agile**	• **Implement technical and environmental regulation** to facilitate pipeline development • **Analyze effectiveness of the mechanisms** and measures implemented • **Inform society of the milestones** being achieved	• **Review mechanisms** and/or introduce new ones • **Focus on external pipeline development**
2. Capital availability	• **Identify and disseminate possible international and national sources of financing** for solar industries • **Put** interested **industrial parties in touch with financial institutions** and other sources of finance • **Assist** industrial project developers in the **development of business plans**	• **Develop an investment fund** to drive the sector • **Develop local bank capabilities** and knowledge on these sectors • **Elaborate case studies and success stories** based on international examples, to disseminate nationally • **Participate in the development of a** regional Clean Innovation Center	• **Review financing rates, participation on the part of local banks,** etc. to evaluate next steps • **Create new mechanisms**, eg. Multi-currency swaps, partial guarantees, to continue driving finance to solar industries
3. Qualified labor requirements	• **Perform a detailed analysis** of required **capabilities and gaps** • **Kick off a "training the trainers"** technical **capability development** program • **Kick off a management program** focused on the solar industry	• **Develop national, regional and international collaboration programs** with universities and academic institutions • **Increase** the breadth **and depth of training programs** according to market development	• **Perform a review of required capabilities and gaps** to identify missing capabilities • **Put in place** any required **programs to meet these gaps** • **Develop programs** to transform Egypt into a **capability trainer in the region**
4. Technology transfer	• **Identify technological gaps in the local industry** required for solar industry development • **Coordinate a local platform of interested industrial players and academics** in order to generate interest and establish the most effective ways of bridging the gaps	• **Coordinate activities to bridge technological gaps** with the solar industry cluster being developed • **Support the cluster** to generate the matches between interested industries • **Put together and disseminate success stories**	• **Perform a review of technological knowledge and gaps** to see how many are left to bridge • **Develop new mechanisms** to close the gaps
5. Clustering	• **Identify interested industrial partners and a champion** to lead the cluster • **Create cluster** with **virtual infrastructure** • **Catalyze the creation** of the cluster	• **Support the cluster and disseminate** information about it • **Prepare for the existence of a physical cluster,** including infrastructure, etc.	• **Create new clusters** based on the original cluster
6. Materials supply	• **Engage with local upstream materials partners from the start,** to give them visibility on sector requirements for both quality and quantity • **Engage with international upstream materials partners** for materials not available in Egypt	• **Analyse and consider new mechanisms for improving material flow** to the industry	• **Review** whether material supply to the industry is an issue • If applicable, **put in place additional policies or mechanisms** to help flow • Analyze further opportunities for Egypt to export materials in the region
7. Exports	• **Identify preliminary list of potential markets** for Egyptian solar components • **Identify existing or potential barriers** for said exports	• **Analyze possible mechanisms that could be applied** • **Apply said mechanisms** and, in parallel, **develop bilateral or multilateral agreements** with other countries	• **Review success of export policy** and identify new actions if program has not been successful • **Review preliminary list of potential markets** to expand to others
8. Certification and accreditation	• **Analyse existing Egyptian technical standards** applicable to the industry for **availability and quality** • **Develop a list of requirements and identify actors** who can assist in developing said standards	• **Assist in the development of standards** • **Encourage collaboration** between different parties • **Disseminate results** nationally and internationally	• **Develop accreditation activities** • **Continue encouraging collaboration** to stay on top of new technological developments

11.2 Issue 1: Visibility of the Pipeline

Potential targets and objective: To make Egypt's plan a reality, giving visibility of the pipeline to the private sector, so that the latter perceives a credible demand and can react appropriately. It includes visibility both on 2027 Solar Plan targets of 2,800 MW of CSP and 700 MW of PV; and on private demand stemming from other solar applications.

Figure 145 | Visibility of Pipeline Action Plan

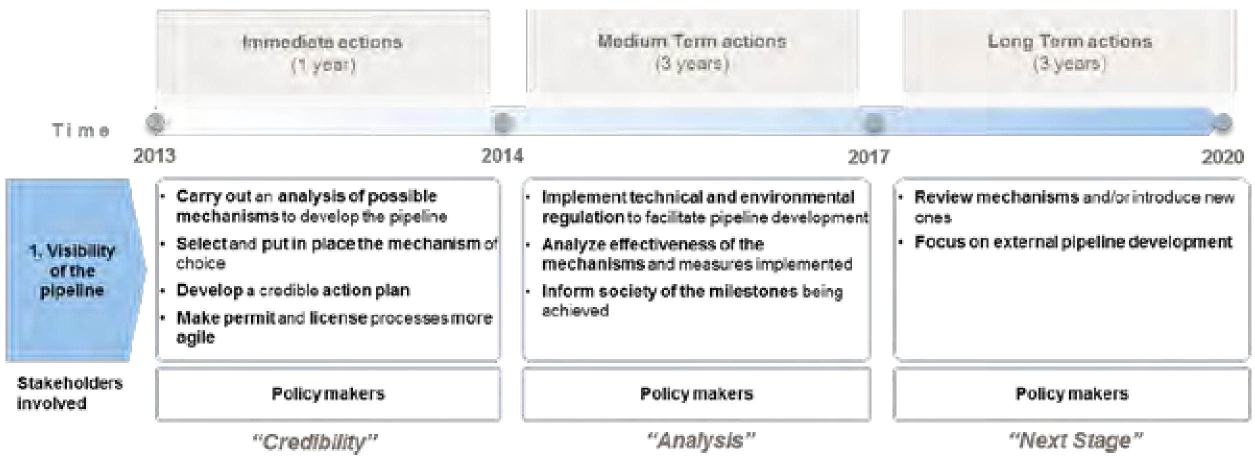


TABLE 56 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 1

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Analyze possible mechanisms to develop the pipeline.[8] Within the Egyptian context, analyze the main mechanisms and incentives that other countries have used to develop renewable energies––Feed-In Tariff, Feed-In Premium, Tenders, Clean Energy Quota (production and/or consumption-based), pilot and demo projects, green certificates––considering the advantages and disadvantages of each and their forecasted impacts. The objective is for policy makers to have clear inputs from which to select the best set of mechanisms for the Egyptian context.	Lack of clear incentive mechanism(s) to turn the targets into a reality, guaranteeing demand and allowing for financing.
2.	Select and put in place the mechanism(s) of choice. From the above analysis, policy makers shall define the set of tools and a communication strategy to develop investor awareness.	See barrier in number 1 above.
3.	Develop a credible action plan. In conjunction with the establishment of the selected incentive mechanisms, policy makers need to develop a detailed, credible action plan to allow investors visibility into how the incentive mechanism is designed to reach the 2027 target. The action plan should detail either indicative or binding intermediate targets at appropriate intervals. In this way, milestones and achievements in the sector can be communicated transparently to all stakeholders. Targets and actions should address the different technologies for CSP and PV and their applications.	Lack of visibility of the pipeline.
4.	Make permit and license processes more agile. Policy makers should streamline permits and licenses required to develop these kinds of projects to minimize administrative burden on project developers and incentivize a faster development of the pipeline. Streamlining would include environmental requirements, access to land, and access to grid license processes, thus reducing costs and risks.	Long administrative lead times, complex access to land, and access to grid.
5.	Inform society of the milestones being achieved. Policy makers should set up a communication strategy to update society, potential investors, financial institutions, and others of plan's achievements, any delays, and any needed corrective actions.	See previous paragraph.
6.	Identify success stories or pilot projects, promote and communicate them The solar cluster or the appropriate agencies of the Ministry of Industry can support the development of some high-visibility and potential projects to serve as references and to start the industry.	Lack of visibility of the pipeline.

TABLE 57 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 1

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Implement technical and environmental regulation. Where changes to technical or environmental regulation are required––for example, regarding regulatory clarity for grid access and connection, independent power producer, self-production––policy makers should work to solve doubts and implement required changes.	Lack of regulatory clarity for certain procedures, such as grid access and connection policies.
2.	Analyze effectiveness of the mechanisms implemented. Two to three years after implementation of the mechanisms, policy makers should be in a position to do a first analysis of the effectiveness of the mechanisms implemented, for number of MWs, cost, and benefits achieved by the projects.	Lack of visibility of the pipeline and to project developments.

TABLE 58 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 1

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Review mechanisms and introduce new ones. Depending on the success and cost of the selected mechanisms, and on the developing cost and maturity of the different technologies, policy makers should review the mechanisms to see whether they should be maintained or whether any changes or revisions should be applied.	Lack of clear incentive mechanism(s).
2.	Focus on external pipeline development. Once project development in Egypt is heading in the right direction, using the experience gained during these years, policy makers should direct their attention to developing the external pipeline and making sure that Egypt becomes a strong, international competitor in the solar energy sector.	Strong international competition in the sector.

11.3 Issue 2: Capital Availability

Potential targets and objective: To ensure enough capital, at competitive rates, is available to develop the sector, ensuring appropriate payback periods. The objective is to use all available sources of financing, including public, private, national and international, to reduce perceived risk and allow Egyptian solar industrial projects to be financed on a competitive basis with international projects.

Figure 146 | Capital Availability Action Plan

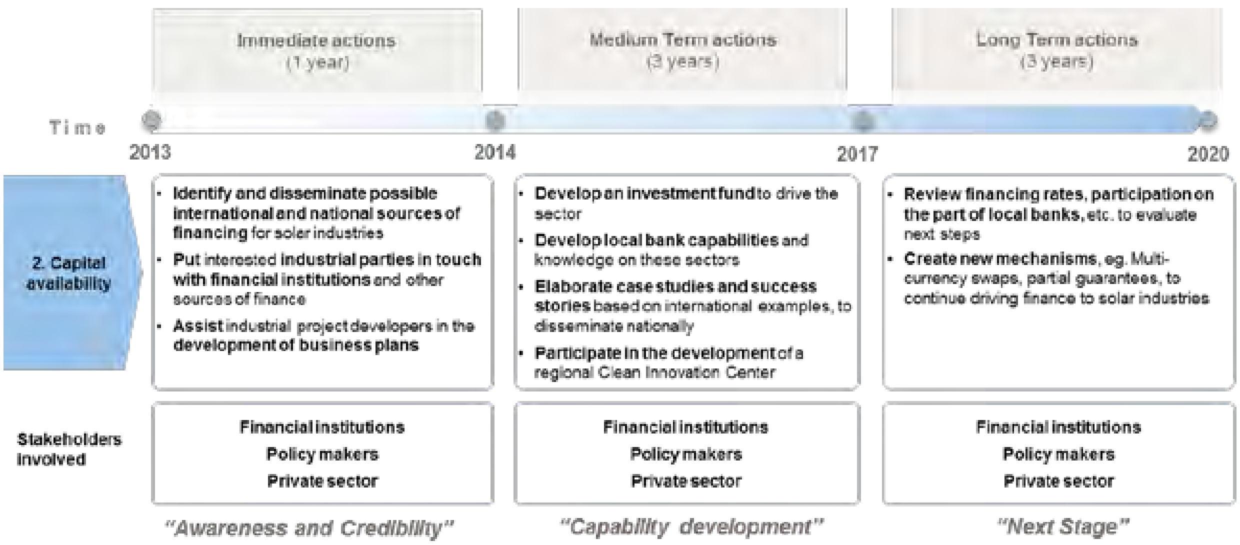


TABLE 59 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 2

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Identify and disseminate possible international and national sources of financing for solar industries. Multilateral and local financial institutions and a solar cluster can work together to compile and empower existing mechanisms and communicate them to industrial partners and potential investors, alerting them to financing opportunities.	Lack of insight into different sources of finance available.
2.	Promote contact among interested industrial parties and financial institutions or other sources of finance. As part of this role of creating awareness, a solar cluster and appropriate public bodies can create the opportunity for industrial partners in the sector and financial institutions to meet to discuss.	Lack of access, particularly for smaller companies, to financial institutions and/or other sources of finance; high interest rates.
3.	Assist industrial project developers in the development of business plans. Provide advice (a) on business plan development to interested companies, including advice on how to make the transition from informal to formal business; and (b) on financial planning services to ensure that their business plans are ready for investment.	See previous paragraph.

TABLE 60 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 2

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Develop an investment fund to drive the sector. Analyze and, if appropriate, create and feed a revolving fund to support the solar component manufacturing sector. Subsidies could be granted at different stages in the project, including to researchers, entrepreneurs, and new branches of existing companies. These subsidies would support the development and adaptation to the local solar technologies market of new concepts and testing. Subsidies also ensure the viability of new concepts in the market, that is, areas in which a traditional financing institution still might have trouble entering. This fund could be followed by venture capital and financing.	Lack of finance available particularly for initial phases, to validate viability of new concepts in the market.
2.	Develop local bank capabilities and knowledge of these sectors. Extend capability development to the financial sector so that local banks become knowledgeable in the technologies and risks.	Lack of knowledge by local financing institutions increases financing rates.
3.	Elaborate case studies and success stories based on international examples, and disseminate nationally. Develop case studies to show how other countries have developed lending for their domestic solar sectors, including mechanisms used.	See previous paragraph.
4.	Participate in the development of a Regional Clean Innovation Center. A Regional Clean Innovation Center can enable knowledge dissemination about issues relating to financing for solar industries on a Regional scale.	See previous paragraph.

TABLE 61 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 2

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Review financing rates, participation of local banks to evaluate next steps. Financing rates for the solar sector evolution can be one criterion by which to assess the success and failures of the sector and to evaluate next steps required to reduce risk.	Lack of information on available financing rates.
2.	Create new mechanisms, such as multicurrency swaps and/or partial guarantees, to continue driving finance to solar industries. Create mechanism to implement risk guarantee programs with local banks and facilitate working capital programs and other innovative mechanisms, including multicurrency swaps.	High currency risks for investors; fluctuating inflation rate.

11.4 Issue 3. Qualified Labor Requirements

Potential targets and objective: To develop training and capacity building programs at all required levels (including engineers, installation technicians, policy makers, and financial institution experts) to ensure that all necessary capabilities are in place for the development of the sector in Egypt. The objective is two-fold: (a) staff the key roles required in the solar industry organizations to be set up and (b) increase productivity to ensure alignment with international productivity standards to make the industry in Egypt competitive.

Figure 147 | Qualified Labor Requirements Action Plan

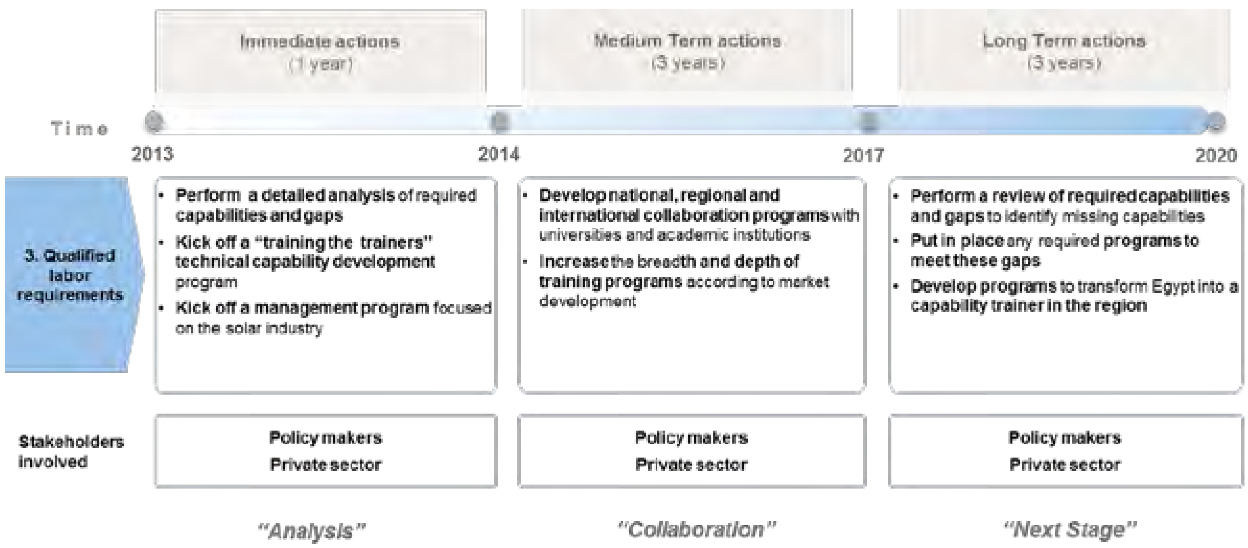


TABLE 62 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 3

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Perform a detailed analysis of required capabilities and gaps. Under its coordination, the Ministry of Industry, with the collaboration of the private sector, should perform a critical assessment of domestic capabilities and gaps for the different solar industries and technologies. Capabilities analyzed should include those necessary for the main job profiles related to the solar industries, including for both manufacturing and system integration.	Lack of clarity as to which of the technical capabilities required for the sector are available in Egypt. Probable lack of technical knowledge of solar energy component design and manufacturing.
2.	Kick off a "training of trainers" (ToT) technical capability development program. Under the coordination of the Ministry of Industry, and involving the private sector and academia, the objective is to take advantage of existing capabilities to train new trainers through a multiplier effect.	See above; absence of specialized centers to train and develop specific skills.
3.	Kick off a management program focused on the solar industry. In coordination with a Regional Climate Innovation Center, for example, set up a program to offer business planning and support to individuals and companies interested in the sector to get them ready to set up and grow companies in the solar industry. Programs could include general management capabilities, project development, and marketing.	Lack of management capabilities, which can stop industries, including solar, from developing.

TABLE 63 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 3

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Develop national, Regional, and international collaboration programs with universities and academic institutions. Under the coordination of the Ministry of Industry and Education, and with Egypt's main universities, develop collaboration programs at the national, Regional, and international levels that take education further than the classroom using the "learning by doing" ethos.	Lack of clarity on which technical capabilities required for the sector are available in Egypt. Probable lack of technical knowledge on solar energy component design and manufacturing.
2.	Increase the breadth and depth of training programs according to market development. As the market strengthens and different industries gain traction, develop training programs that (a) parallel these developments, including training seminars on specific (commercial and technical) topics, and (b) are organized for different audiences. Courses should be aligned with private sector development and offer specialized knowledge on specific industries that are hiring, so that students and recent graduates are prepared to join the work force as soon as they complete their studies.	See previous paragraph.

TABLE 64 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 3

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Perform a review of required capabilities and gaps to identify missing capabilities. With the experience acquired during the preceding years, and in light of how the sector and its industries have developed, carry out an in-depth assessment of capabilities to identify which ones Egypt has acquired fully and which are still gaps.	Lack of domestic capabilities may hinder the development of the sector.
2.	Put in place all programs required to meet these gaps. Under the auspices of the Ministry of Industry and the Ministry of Education, redouble efforts to address the missing gaps to ensure that lack of domestic capabilities do not hinder the development of solar industries. For example, training programs should ensure that Egypt reaches international quality standards in manufacturing.	See previous paragraph.
3.	Develop programs to transform Egypt into a capability trainer in the Region. Package the lessons and experience acquired during the preceding years to develop international programs, perhaps within a Regional Climate Innovation Center,	At the Regional level, MENA lacks specific technical capabilities to develop clean technologies.

11.5 Issue 4. Technology Transfer

Potential targets and objective: To identify know-how requirements, and acquire the know-how in the shortest time to get to the market through, among others, interaction with Egyptian academic experts and development of international joint venture agreements.

Figure 148 | Technology Transfer Action Plan

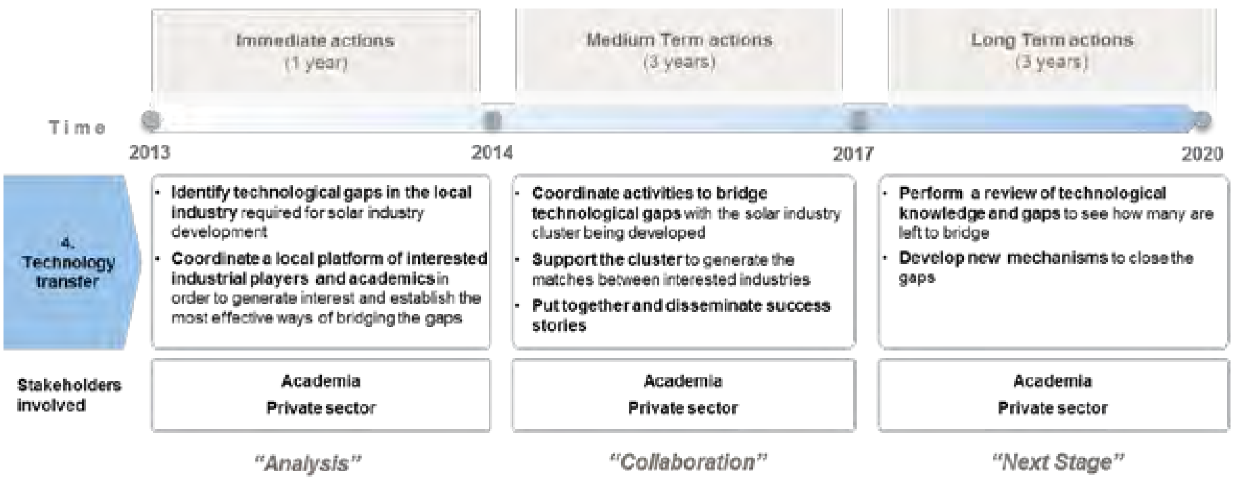


TABLE 65 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 4

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Identify technological gaps in the local industry required for solar industry development. Carry out a detailed assessment to identify technological gaps and barriers that could stop the solar industry from developing on a large scale.	Hidden technological gaps. Lack of experience in manufacturing solar components.
2.	Coordinate a local platform of interested industrial players and academics to generate interest and establish the most effective ways of bridging the gaps. Coordinate a multi-actor platform (involving policy makers, academics, multilateral organizations, private sector) in which each interested party can play a role in generating interest and establishing the most effective ways of developing these industries on a large scale. A solar cluster, if established, could take the lead	Lack of visibility of the pipeline and of activities developed from technological companies

TABLE 66 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 4

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Coordinate activities to bridge technological gaps with the solar industry cluster being developed. Concentrating on the top R&D and technological gaps, develop a joint research program between academics and private sector industrial players. Concentrate on, among others, innovations to develop solar technologies adapted to the local conditions regarding maintenance, grid, temperature, and demand requirements.	See above; R&D often not a priority for companies.
2.	Support the solar cluster to generate the matches between interested industries. Policy maker support of the cluster can include financial support, for example, through a Social and Technology Fund, dedicated to financing new developments when demand for a product is demonstrated.	See previous paragraph.
3.	Analyze, assemble, and disseminate success stories. Analyze international and, once they start appearing, national success stories of how technological gaps were bridged for specific solar component industries, thus making other companies, and society at large aware of these success cases and, more specifically, of the opportunities that exist to replicate them.	Lack of insight into the pipeline and activities developed from technological companies.[a]

Note:
Throughout this report, "companies" refers to "companies with the expertise to develop and/or innovate industrial processes related to solar energy, either component manufacturing processes or power plant configuration."

TABLE 67 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 4

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Perform a review of technological knowledge and gaps to see how many are left to bridge. With the experience acquired during the preceding years, and in light of how the sector and its industries have developed, carry out an in-depth assessment of remaining technological gaps.	Persisting lack of technological or other know-how capabilities may hinder the development of the sector.
2.	Develop new mechanisms to close the gaps. Consider new mechanisms that involve partnerships among policy makers, academia, and the private sector, to close all remaining technological or know-how gaps. These mechanisms could include regulatory measures, subsidies, and clustering. The development of joint ventures among various private sector players also can play an important role.	See previous paragraph.

11.6 Issue 5. Clustering

Potential targets and objective: To define, design, and develop clustering opportunities to maximize synergies in the sector and encourage new entrants. One objective is the development of a solar energy cluster to bridge technological knowledge gaps in the industry.

Figure 149 | Clustering Action Plan

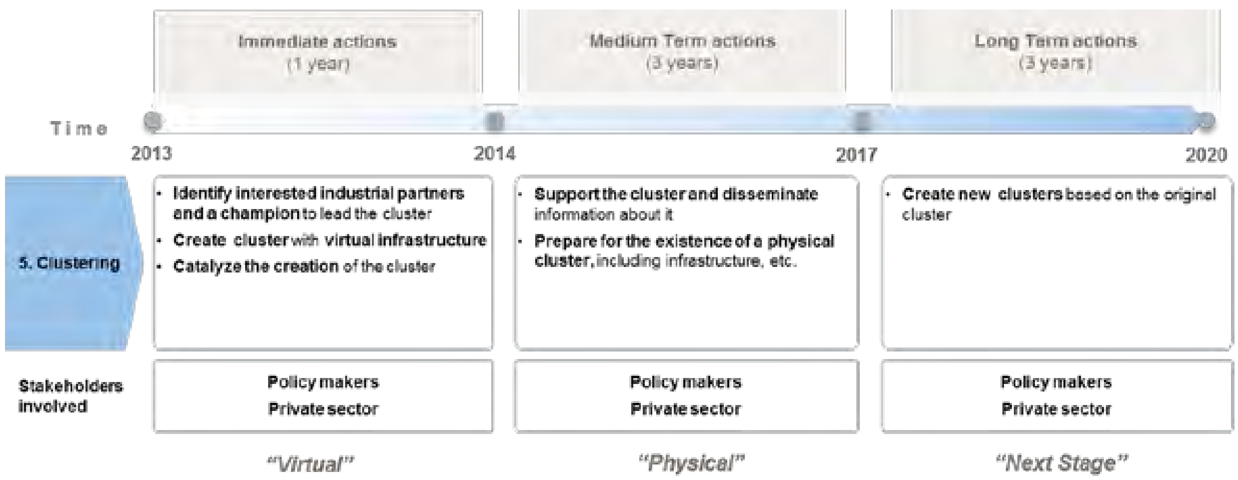


TABLE 68 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 5

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Identify interested industrial partners and a champion to lead the cluster. Although the Ministry of Industry could support, the champion of the cluster could be a private sector stakeholder[a] and the process be driven by private sector.	Lost synergies and missed economies of scale due to company dispersion.
2.	Create cluster with virtual infrastructure. To avoid delays and put the thinking and the collaboration ahead of the physical infrastructure, the cluster can be created as a virtual cluster. Another advantage of beginning with a virtual cluster is that geographic proximity is not a necessity at the start.	See previous paragraph.
3.	Catalyze the creation of the cluster. Working together, multilateral institutions, policy makers, and private sector can catalyze the creation of the cluster, thus fostering networking and developing cooperation among members and interested observer organizations.	See previous paragraph.

Note:
During the May 2013 mission in Egypt, PGESCo was identified as a possible champion for the solar energy cluster.

TABLE 69 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 5

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Support the cluster and disseminate information about it. Supporting the cluster could include disseminating information about it and its purpose, linking with other Regional and international clusters, supporting joint projects proposed by the cluster, and disseminating value and innovation opportunities derived from the cluster.	Lack of support a main reason that clustering attempts fail.
2.	Prepare for the existence of a physical cluster. To improve the chances of a physical cluster, plan for and develop the requisite infrastructure to facilitate it. Preparation could require additional legislation to facilitate the cluster's creation, the physical space, and the infrastructure investment. Unlike virtual infrastructure, for a physical cluster, geographic proximity plays a very important role. Thus, the space and location should be thought out carefully. This cluster could be part of a planned high technology cluster.	Lost synergies and economies of scale due to company dispersion.

TABLE 70 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 5

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Create new clusters based on the original cluster. If the growth of the industry allows for it, the success of one cluster can catalyze the creation of a new cluster or clusters, such as other renewable energy clusters in Egypt, However, nearby countries also could benefit from Egypt's experience and good practices to create their own clusters.	Lost synergies and economies of scale due to company dispersion.

11.7 Issue 6. Materials Supply

Potential targets and objective: To help actors in the sector, particularly upstream actors, prepare in both quality and quantity for the amount of materials that the solar industry will require.

Figure 150 | Materials Supply Action Plan

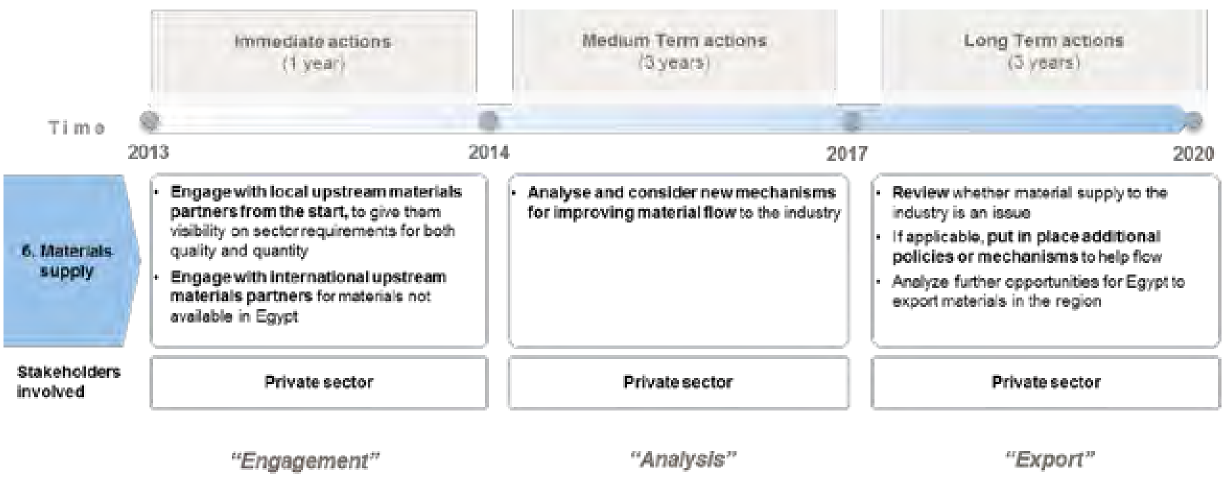


TABLE 71 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 6

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Engage from the start with local upstream materials partners. Engagement by private sector industries with local upstream materials partners provides visibility on sector requirements for different materials. The foci are quality and quantity. The objective is to ensure sustainable supply of important materials, giving industrial and financial partners a higher degree of certainty concerning supply. The solar cluster could lead this action.	Increase in demand could cause a shortage of a certain materials (in general, or for a specific quality that the sector requires).
2.	Engage with international upstream materials partners. For materials not available in Egypt, engage with international partners, creating long-term relationships that ensure sufficient availability of key materials required by the industry. By developing long-term relationships with international actors, the risk of price and quality fluctuations also is significantly reduced.	Volatility of international markets.

TABLE 72 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 6

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Analyze and consider new mechanisms to improve material flow to the industry. The private sector can propose new mechanisms to policy makers to improve material flow to the industry for specific materials of interest. These mechanisms could include reductions or exemptions from customs duty taxes, special fiscal conditions, and other mechanisms that encourage material flow and ensure sufficient availability for the industry.	Increase in demand could cause a shortage of a certain material (in general, or for a specific quality that the sector requires).

TABLE 73 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 6

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Review whether material flow to the industry is an issue. Conduct an assessment to evaluate to what extent industry development has impacted flows of key materials (such as steel, glass). Potential issues to look out for in the analysis include price increases or general price volatility; and, in the more extreme cases, material shortages that can impact the solar industry and other sectors. This analysis should be carried out jointly with upstream materials partners, and the solar cluster could have a leading role.	Increase in demand could cause a shortage of a certain material (in general, or for a specific quality that the sector requires).
2.	If applicable, put in additional mechanisms and policies to help flow. If it is determined that solar industry development has impacted material flows for key materials, consider additional mechanisms and policies to ensure a correct flow.	See previous paragraph.
3.	Analyze future opportunities for Egypt to export materials in the MENA Region. An analysis of future opportunities to export materials in the MENA Region, which should be developed jointly with the Ministry of Industry, could include development of incentives and bilateral agreements to exports.	See previous paragraph.

11.8 Issue 7. Exports

Potential targets and objective: To identify key export markets, both Regional and international, and to maximize the chance of successful exports by Egyptian solar industrial companies.

Figure 151 | Exports Action Plan

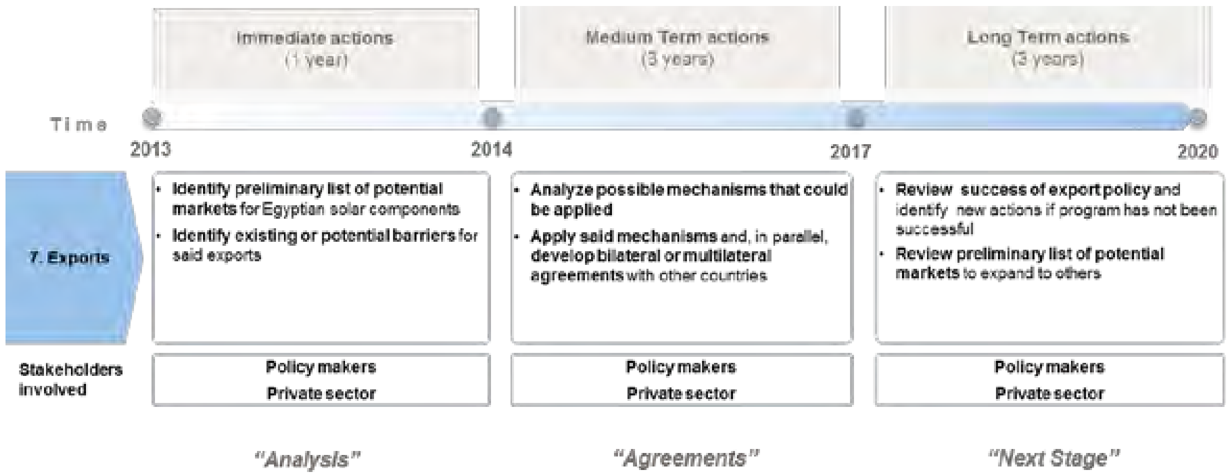


TABLE 74 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 7

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Identify preliminary list of potential markets for Egyptian solar components. Perform an assessment of potential markets for solar components, beginning with nearby countries in the MENA Region and Europe that could benefit from importing Egypt's solar components to develop solar energy.	Exports may be affected by customs duties and other measures imposed by destination countries that reduce export competitiveness.
2.	Identify existing or potential barriers for said exports. Barriers could include customs duties, stringent certification requirements.a	See previous paragraph.

Note:
As an example, Gulf countries have been known to demand certified compliance with local regulations for imports, something that reduces competition to local producers.

TABLE 75 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 7

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Analyze possible mechanisms that could be applied. Analyze mechanisms that could be applied to facilitate Egyptian exports, including removal of customs duties and the establishment of other monetary or qualification incentives.	See previous paragraph.
2.	Apply said mechanisms and, in parallel, develop bilateral or multilateral agreements with other countries. Carry out high-level negotiations to remove barriers to Egyptian exports in foreign countries.	See previous paragraph.

TABLE 76 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 7

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Review success of export policy and, if program has not been successful, identify new actions. To ground-truth existing policies and agreements with priority markets, carry out an assessment to evaluate to what extent Egyptian solar component exports are growing, and to which countries most components are being exported.	See previous paragraph.
2.	Review preliminary list of potential markets for expansion. With the objective of growing Egypt's export base of solar components, review and add to the list of potential markets for expansion.	See previous paragraph.

11.9 Issue 8. Certification and Accreditation

Potential targets and objective: To develop Egyptian standards, something that is considered necessary to develop both exports and the national market.

Figure 152 | Certification and Accreditation Action Plan

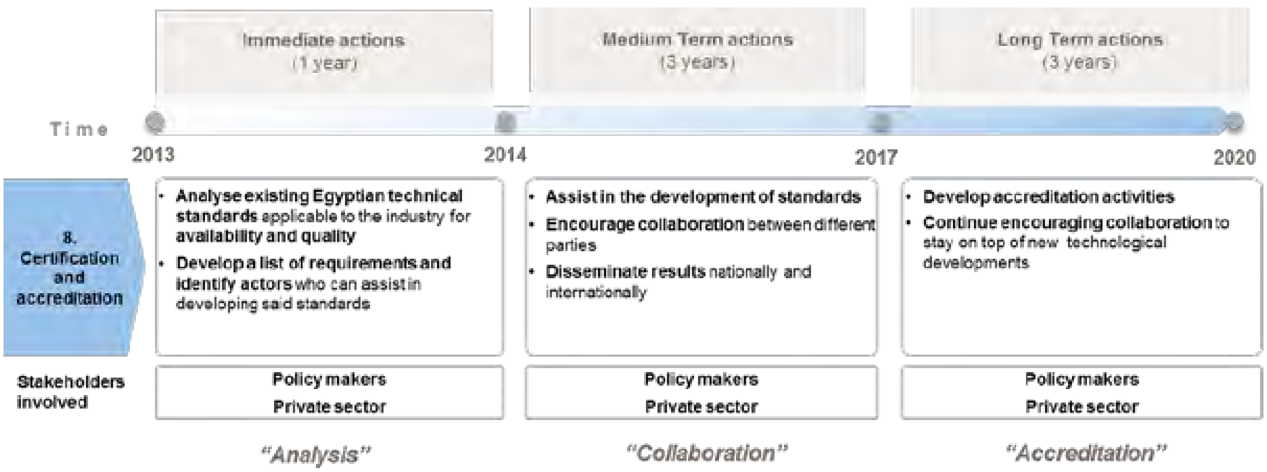


TABLE 77 | DETAILED RECOMMENDATIONS FOR IMMEDIATE ACTIONS REGARDING ISSUE 8

	Immediate Actions (Year 1)	Key Barriers Addressed
1.	Analyze existing Egyptian technical standards applicable to the industry for availability and quality. Perform an analysis of existing technical standards applicable to the industry to see which options are already available and which ones need to be developed, as well as the track record of any available standards. Concurrently, analyze existing standards in nearby countries as a reference.	Track record and certification are necessary in most bidding processes; international standards often are required.
2.	Develop a list of requirements and identify actors who can assist in developing said standards. If new standards are required, set up a working group comprising policy makers, private sector, and academics to identify technical and other requirements to develop said standards.	Egypt has Regional, but not national, certification entities.a

Note:
Egypt has an Institute for Standards, which comes under the Ministry of Industry.

TABLE 78 | DETAILED RECOMMENDATIONS FOR MEDIUM-TERM ACTIONS REGARDING ISSUE 8

	Medium-Term Actions (Years 2-4)	Key Barriers Addressed
1.	Assist in the development of standards. Coordinate the work of the groups and organizations that will develop the standards for the solar industry, prioritizing standards for the technologies and industries that are most interesting in the short term (for example, CSP mirrors and CSP and PV structures). Consider, as one alternative, the involvement of the solar cluster (virtual and/or physical).	See previous paragraph. Lack of specific testing and certifying facilities.
2.	Encourage collaboration among parties. The solar cluster could mediate among parties and make sure that all relevant players are included in developing the standards. Take advantage of the existence of early movers in the sector to collaborate with them in the development of standards; Collaborate with international laboratories, universities, and experts to maximize knowledge-sharing.	See previous paragraph.
3.	Disseminate results nationally and internationally. Develop a communications plan to disseminate results nationally, Regionally, and internationally, to ensure that entities globally are aware of Egypt's efforts in the field of accreditation and certification.	Track record and certification are necessary in most bidding processes; international standards often are required.

TABLE 79 | DETAILED RECOMMENDATIONS FOR LONG-TERM ACTIONS REGARDING ISSUE 8

	Long-Term Actions (Years 5-8)	Key Barriers Addressed
1.	Carry out accreditation activities. Coordinate the start of the work of the accreditation and certification offices and laboratories.	See previous paragraph.
2.	To stay on top of new technological developments, continue to encourage collaboration. Maintain collaboration and communication activities with international accreditation laboratories to follow and comply with potential changes in international requirements.	See previous paragraph.

11.10 Actions Related to Kom Ombo

The Kom Ombo project, as well as the newly announced large-scale PV projects in Egypt (Shorouk News 2013), can be the starting point for Egypt's solar component industry.

To profit fully from the positive effects that these projects may bring, suggestions follow on the areas of required TA activities to help enhance local manufacturing potential of solar energy components in Egypt. The World Bank could support the preparation of the Kom Ombo CSP project to increase the proportion of local components. To facilitate the implementation from engineering through to operation, the following recommendations are made:

This TA comprises preparatory and support actions oriented toward developing local capacity and enabling the necessary structures.

- The preparatory actions focus on identifying the gaps and opportunities jointly with the involved stakeholders:
- Identify gaps in local industry that are required to be filled for the solar industry to develop
- Identify possible international and national sources of financing for solar
- Identify success stories
- Identify interested industrial partners in clustering and a champion to lead the cluster
- Analyze existing Egyptian technical standards applicable to the industry for availability and quality.

It is proposed that the following actions be developed in collaboration with the stakeholders. The objectives are to develop their capacity, empower the solar cluster, support its first activities, and enable the basic structures.

In collaboration with public stakeholders, prepare a plan for the development of the cluster including the identification of the cluster champion:

- In collaboration with NREA and the Ministry of Industry, identify the mechanisms to develop a sustainable pipeline of projects in Egypt and their effects (cost and benefits); prepare a communication strategy for both Kom Ombo and the plan
- Disseminate among the local industries the possible business opportunities associated with the Kom Ombo project
- Set up workshop on Kom Ombo project with the participation of national and international players
- Promote contact among interested industrial parties and financial institutions or other sources of finance through workshops and dissemination activities
- In collaboration with the solar cluster, prepare workshops to exchange ideas, develop capacity, and create a network of solar industries
- Identify promising solar component projects and support the initial stages
- Identify pilot energy supply projects that could lead to solar component industry development; support the initial stages
- Prepare and initiate a "training of trainers" (ToT) technical capability development program
- Support the development of national, Regional, and international collaboration programs among R&D centers, universities, and academic institutions
- Disseminate success stories
- Catalyze the development of technical standards and certifying bodies.

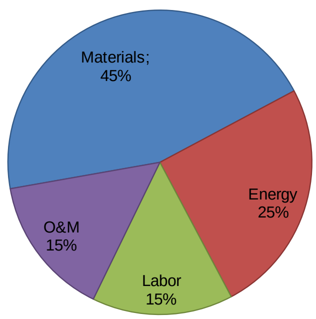
This holistic institutional capacity development program not only will ensure the sustainability of the Kom Ombo project but also will enable the growth of solar expertise, solar industries, and other key economic sectors supporting solar projects.

Appendix 1 | Solar Industries Datasheets

CSP INDUSTRIES

Sector: CSP	Subsystem: Power Block	Solar industry: Condenser

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	0.5 - 1%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	45%		
Energy	25%		
Labor	15%		
O&M	15%		



	Value	Unit
Component Market Price (Average Sales Price)	25 - 35	kUSD/MWth
Typical demand from a reference customer	75 - 85	MWth, 1 piece
Average production for a factory	200 - 300	MWth/yr
Investment	10 - 20	kUSD / (MWth/yr)
Production requirements		
Materials	100%	
Stainless steel, tube	80%	
Stainless steel, plate	15%	
Electrodes	5%	
Energy	100%	
Electric	100%	
Thermal	0%	

Top Companies	Origin
Foster Wheeler	Switzerland
GEA	Germany
HAMON	Belgium

Barriers to entry

1. Guarantees of turbine manufacturer
2. Technical barrier: complex design to achieve performance
3. Highly skilled workforce required

Key Factors

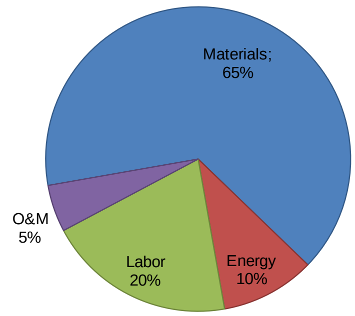
1. Stainless steel market
2. High precision manufacturing under international standards

Sector: CSP	Subsystem: Power Block	Solar industry: Electrical generator

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	1.5 - 2.5%		50MW parabolic with 7h TES

Cost Structure breakdown

Materials	65%
Energy	10%
Labor	20%
O&M	5%



	Value	Unit
Component Market Price (Average Sales Price)	100 - 150	kUSD/MWe
Typical demand from a reference customer	50	MWe, 1 piece
Average production for a factory	2,000 - 3,000	MW/yr
Investment	30 - 50	kUSD / MW/yr

Production requirements

Materials	100%
Copper	50%
Carbon steel, cast	35%
Lubricant oil	5%
CrMo steel	10%
Energy	100%
Electric	90%
Thermal	10%

Top Companies	Origin
ABB	Switzerland
GE Power	US
Mitsubishi	Japan
Siemens	Germany

Barriers to entry

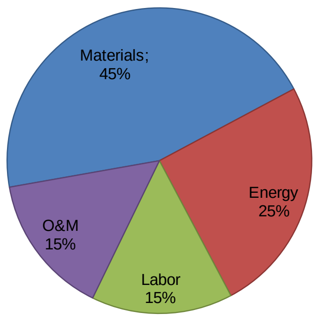
1. Technical barrier: complex design to achieve performance
2. Fluctuations in copper market
3. Highly skilled workforce

Key Factors

1. Copper market
2. Power electronics

Sector: CSP	Subsystem: Power Block	Solar industry: Heat exchangers

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	2.5 - 4%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	45%		
Energy	25%		
Labor	15%		
O&M	15%		



	Value	Unit
Component Market Price (Average Sales Price)	20 - 25	kUSD/MWth
Typical demand from a reference customer	300	MWth, 1 set SGS + heat recovery + molten salt
Average production for a factory	350 - 400	MWth/yr
Investment	10 - 20	kUSD / (MWth/yr)
Production requirements		
Materials	100%	
Carbon steel, plate	10%	
Stainless steel, tube	80%	
Electrodes	5%	
Stainless steel, plate	5%	
Energy	100%	
Electric	100%	
Thermal	0%	

Top Companies	Origin
Aalborg CSP	Denmark
Alfa Laval	Sweden
Foster Wheeler	Switzerland
GEA	Germany
HAMON	Belgium

Barriers to entry

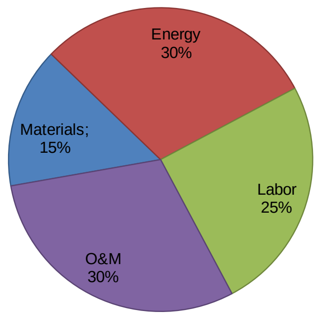
1. Highly skilled workforce required

Key Factors

1. Stainless steel market
2. High precision manufacturing under international standards
3. Adapt existing industries

Sector: CSP	Subsystem: Power Block	Solar industry: HTF Pumps

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	0.5 - 1%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	15%		
Energy	30%		
Labor	25%		
O&M	30%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	45 - 55	kUSD/MW	
Typical demand from a reference customer	1	set of 3 to 5 main pumps, antifreeze, recirculation	
Average production for a factory	300 - 500	MW/yr	
Investment	35 - 45	kUSD / MW/yr	
Production requirements			
Materials	100%		
Carbon steel, cast	40%		
Stainless steel, cast	5%		
Copper	40%		
CrMo steel	10%		
Lubricant oil	5%		
Energy	100%		
Electric	75%		
Thermal	25%		

Top Companies	Origin
Flowserve	US
KSB	Germany
GE Oil & Gas	US
Sterling Fluid	Germany
Sulzer	Switzerland

Barriers to entry

1. Highly skilled workforce required

Key Factors

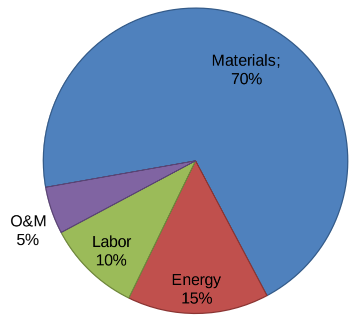
1. High precision manufacturing under international standards
2. Motor and power electronics

Sector: CSP	Subsystem: Solar Field	Solar industry: HTF Thermal Oil

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	3.5 - 4.5%		50MW parabolic with 7h TES

Cost Structure breakdown

Materials	70%
Energy	15%
Labor	10%
O&M	5%



	Value	Unit	Comments
Component Market Price (Average Sales Price)	8 - 10	USD/kg	
Typical demand from a reference customer	16 - 20	10^3 kg/MW	50MW parabolic with 7h TES
Average production for a factory	225	MW/yr	
Investment cost for a factory	30 - 50	million USD / (MW/yr)	

Production requirements

Materials	100%
Diphenyl oxide	73.5%
Diphenyl	26.5%
Energy	100%
Electric	5%
Thermal	95%

Top Companies	Origin
Dow Chemical	US
Solutia (Monsanto)	US

Barriers to entry

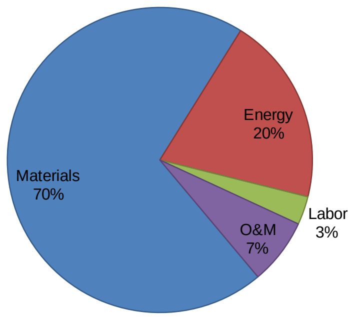
1. Byproduct in chemical industry (phenol) with large productions (40 to 600 kt/year)
2. Market dominated by a small number of competitors
3. Low market opportunities to sell this product to other industries and sectors

Key Factors

1. Adapt existing industries

Sector: CSP	*Subsystem: Solar Field*	*Solar industry: Mirror*

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	5 - 6%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	70%		
Energy	20%		
Labor	3%		
O&M	7%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	25 - 35	USD/m2	
Typical demand from a reference customer	8 - 12	10^3 m2/MW	50MW parabolic with 7h TES
Average production for a factory	300	MW/yr	
Investment	100 - 200	kUSD / (MW/yr)	
Production requirements			
Materials	100%		
Silver / copper coatings	0%		
Polimeric coatings	10%		
Float glass	90%		
Energy	100%		
Electric	10%		
Thermal	90%		

Top Companies	Origin
AGC Solar	Belgium
Flabeg Gmbh	Germany
Guardian Ind.	US
Rioglass Solar	Spain
Saint-Gobain	France

Barriers to entry

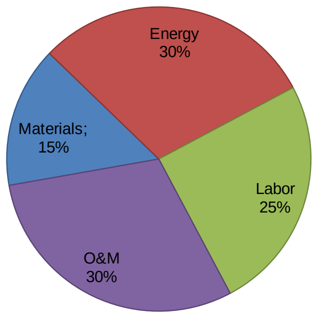
1. Technical barrier: complex manufacturing line
2. Highly skilled workforce required
3. Capital-intensive unless integrated in existing float glass

Key Factors

1. Energy
2. Transport
3. Adapt existing industries

Sector: CSP	Subsystem: Power Block	Solar industry: Pumps

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	0.5 - 1%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	15%		
Energy	30%		
Labor	25%		
O&M	30%		



Component Market Price (Average Sales Price)	20 - 25	kUSD/MW	
Typical demand from a reference customer	1	set circulation, condensate, main pressure, molten salts, other minor	
Average production for a factory	300 - 500	MW/yr	
Investment	35 - 45	kUSD / MW/yr	
Production requirements			
Materials	100%		
Carbon steel, plate	5%		
Carbon steel, cast	50%		
Stainless steel, cast	15%		
Copper	25%		
CrMo steel	5%		
Energy	100%		
Electric	55%		
Thermal	45%		

Top Companies	Origin
Ensival Moret	France
Flowserve	US
GE Power	US
KSB	Germany
Ruhrpumpen	Germany

Barriers to entry

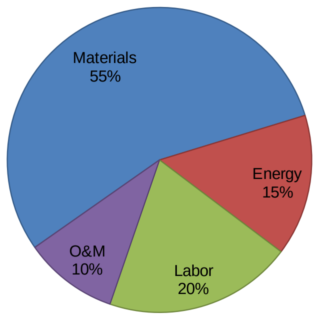
1. Technical barrier: complex design for molten salt pumps
2. Highly skilled workforce required

Key Factors

1. High precision manufacturing under international standards

Sector: CSP	*Subsystem: Solar Field*	*Solar industry: Receiver*

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	6.5 - 7.5%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	55%		
Energy	15%		
Labor	20%		
O&M	10%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	800 - 1,000	USD/piece	
Typical demand from a reference customer	400 - 500	pieces/MWp	50MW parabolic with 7h TES
Average production for a factory	100 - 200	MW/yr	
Investment	0.4 - 0.6	million USD / (MW/yr)	
Production requirements			
Materials	100%		
Stainless steel, tube	52%		
Borosilicate glass, tube	46%		
Collars,flanges and bellows	2%		
Absorbing coating	-		negligible weight
Getters	-		negligible weight
Anti reflective coating	-		negligible weight
Energy	100%		
Electric	25%		
Thermal	75%		

Top Companies	Origin
SCHOTT Solar AG	Germany
Siemens (Solel Solar System)	Germany
Archimede	Italy

Barriers to entry

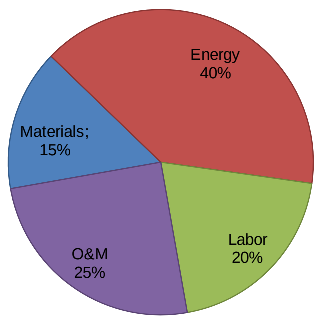
1. Technical barrier: highly specialized coating process with high accuracy
2. Technical barrier: vacuum-tight glass to metal welding process and materials
3. High specific investment for manufacturing process
4. Low market opportunities to sell this product to other industries and sectors
5. Highly skilled workforce required

Key Factors

1. Transport

Sector: CSP	Subsystem: Thermal Energy Storage	Solar industry: Solar salt

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	8 - 10%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	15%		
Energy	40%		
Labor	20%		
O&M	25%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	800 - 900	USD/t	
Typical demand from a reference customer	500 - 600	t/MWe	50MW parabolic with 7h TES
Average production for a factory	300	MW/yr	
Investment	n/a	million USD / MW/yr	

Production requirements

Materials	100%
Sodium nitrate (NaNO3)	60%
Potassium nitrate (KNO3)	40%
Energy	100%
Electric	40%
Thermal	60%

Top Companies	Origin
SQM	Chile
Haifa	Israel

Barriers to entry

1. A mineral vein must exist within the territory

Key Factors

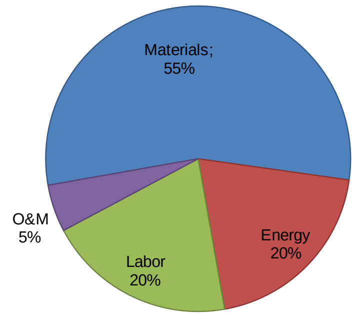
1. Purity of the vein, valorization of byproducts

Sector: CSP	Subsystem: Power Block	Solar industry: Steam turbine

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	3.5 - 4.5%		50MW parabolic with 7h TES

Cost Structure breakdown

Materials	55%
Energy	20%
Labor	20%
O&M	5%



	Value	Unit
Component Market Price (Average Sales Price)	200 - 250	kUSD/MWe
Typical demand from a reference customer	50	MWe, 1 piece
Average production for a factory	200 - 300	MW/yr
Investment	60 - 100	kUSD / (MW/yr)

Production requirements

Materials	100%
Carbon steel, plate	5%
Carbon steel, beam	5%
Carbon steel, cast	20%
Stainless steel, cast	50%
Special alloys	20%
Energy	100%
Electric	10%
Thermal	90%

Top Companies	Origin
Alstom	France
GE Power	US
Harbin	China
MAN Turbo	Germany
Mitsubishi	Japan
Siemens	Germany

Barriers to entry

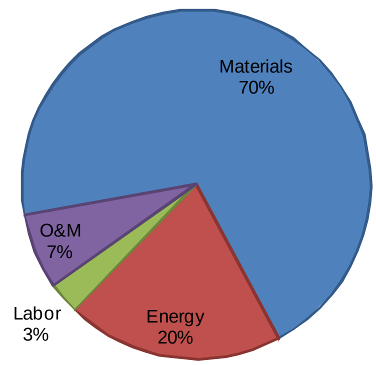
1. Technical barrier: complex design to achieve performance
2. Highly skilled workforce required
3. High specific investment for manufacturing process

Key Factors

1. Long Term Service Agreements and performance guarantee

Sector: CSP	Subsystem: Power Block	Solar industry: Storage Tanks

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	3 - 5%		50MW parabolic with 7h TES
Cost Structure breakdown			
Materials	70%		
Energy	20%		
Labor	3%		
O&M	7%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	150 - 200	kUSD/MW	
Typical demand from a reference customer	1	set incl. expansion vessel, overflow tanks, ullage vessels, molten salts, steam drum, deaerator, other	
Average production for a factory	300	MW/yr	
Investment	70 - 90	kUSD / (MW/yr)	
Production requirements			
Materials	100%		
Carbon steel, plate	80%		
Carbon steel, cast	5%		
Stainless steel, plate	15%		
Energy	100%		
Electric	100%		
Thermal	0%		

Top Companies	Origin
Caldwell Tanks	US
Duro Felguera	Spain
IMASA	Spain

Barriers to entry

1. Technical barrier: complex design of molten salt tanks and deaerator

Key Factors

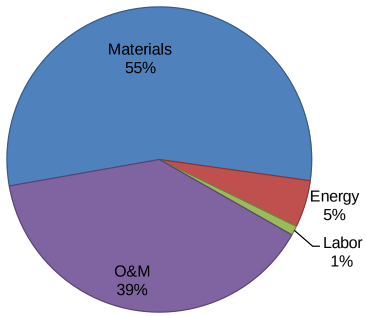
1. Manufacturing under international standards

Sector: CSP	Subsystem: Solar Field	Solar industry: Structure & Tracker

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	15 - 17%		50MW parabolic with 7h TES

Cost Structure breakdown

	Value
Materials	55%
Energy	5%
Labor	1%
O&M	39%



	Value	Unit	Comments
Component Market Price (Average Sales Price)	2 - 3	USD/kg	
Typical demand from a reference customer	180 - 220	10^3 kg/MWp	50MW parabolic with 7h TES
Average production for a factory	150 - 250	MW/yr	
Investment	75 - 85	kUSD / (MW/yr)	

Production requirements

	Value
Materials	100%
Carbon steel, beam	90%
Carbon steel, plate	5%
Electrodes	5%
Energy	100%
Electric	100%
Thermal	0%

Top Companies	Origin
Albiasa Solar	Spain
Asturfeito	Spain
Gossamer	US
Ideas en Metal	Spain
MADE	Spain
SBP	Germany
Sener	Spain
Siemens	Germany

Barriers to entry

1. Hot-dip galvanizing of large structures (>12 m) can be a bottleneck
2. Technical barrier: complex design to achieve stiffness
3. Technical barrier: complex design of hydraulic circuit and components

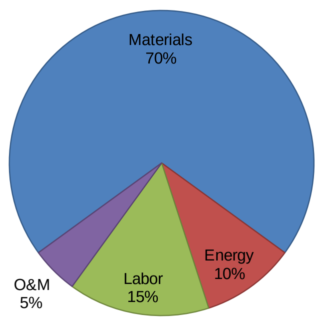
Key Factors

1. Carbon steel market
2. Transport
3. Galvanizing
4. Adapt existing industries

PV INDUSTRIES

Sector: PV	Subsystem: Crystalline silicon	Solar industry: Cells

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	17%		
Cost Structure breakdown			
Materials	70%		
Energy	10%		
Labor	15%		
O&M	5%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	85 - 95	kUSD/t	
Typical demand from a reference customer	6.5 - 7.5	t/MWp	
Average production for a factory	45 - 50	MWp/yr	
Investment	700 - 750	kUSD / (MWp/yr)	
Production requirements			
Materials	100%		
Wafers	90%		
Silver	1%		
Aluminum	4%		
Etching agents	5%		
Energy	100%		
Electric	10%		
Thermal	90%		

Top Companies	Origin
Canadian Solar Inc	Canada
Gintech Energy Corporation	Taiwan
JA Solar Holdings Co	China
Kyocera	Japan
Hanwha (Q-Cells)	South Korea
Sharp	Japan
SolarWorld AG	Germany
Suntech Power	China
Yingli Green Energy	China

Barriers to entry

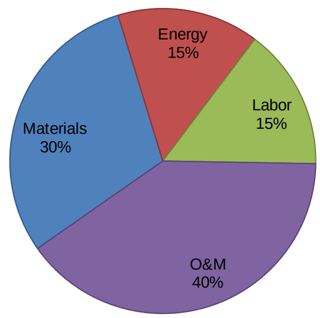
1. Technical barrier: highly specialized surface treatment (etching)
2. High specific investment for manufacturing process
3. Overcapacity in the sector, downward pricing pressure, vertical integration in most cells manufacturing companies
4. Highly skilled workforce required

Key Factors

1. Vertical integration to achieve competitive costs

Sector: PV	Subsystem: Crystalline silicon	Solar industry: Ingots / Wafers

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	15%		
Cost Structure breakdown			
Materials	30%		
Energy	15%		
Labor	15%		
O&M	40%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	50 - 60	kUSD/t	
Typical demand from a reference customer	5.5 - 6.6	t/MWp	
Average production for a factory	150	t/yr	
Investment	600	kUSD / (t/yr)	
Production requirements			
Materials	100%		
Silicon, high purity	100%		
Dopants	0%		negligible weight
O&M Consumables	100%		
Carbon	50%		cost fraction
Steel wire	25%		cost fraction
Crucible	25%		cost fraction
Energy	100%		
Electric	15%		
Thermal	85%		

Top Companies	Origin
Canadian Solar Inc	Canada
LG-siltron	South Korea
MEMC	US
Shin-Etsu	Japan
Siltronic	Germany
SUMCO	Japan

Barriers to entry

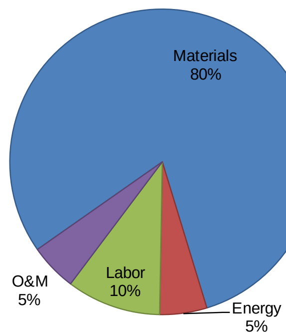
1. High specific investment for manufacturing process
2. Overcapacity in the sector, downward pricing pressure, vertical integration in 75% of wafer manufacturing companies
3. Global demand in 2011 covered above 90% with already installed capacity of the five top suppliers

Key Factors

1. Alternative market (electronics) requires higher purity than solar, additional purification process required
2. Vertical integration to achieve competitive costs

Sector: PV	Subsystem: Crystalline silicon	Solar industry: c-Si Modules

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	13%		
Cost Structure breakdown			
Materials	80%		
Energy	5%		
Labor	10%		
O&M	5%		



	Value	Unit
Component Market Price (Average Sales Price)	0.9 - 1.4	USD/Wp
Typical demand from a reference customer	1 - 100	MWp
Average production for a factory	300	MWp/yr
Investment	45 - 55	kUSD / (MWp/yr)
Production requirements		
Materials	100%	
Cells	10%	
Glass	60%	
Aluminum	25%	
Encapsulant	5%	
Energy	100%	
Electric	80%	
Thermal	20%	

Top Companies	Origin
Kyocera	Japan
Motech Industries	Taiwan
Sanyo Component Europe GmbH	Germany
Schott Solar	Germany
Sharp	Japan
SolarWorld AG	Germany
Sunpower Corp	USA
Suntech Power	China
Trina Solar	China
Yingli Green Energy	China

Barriers to entry

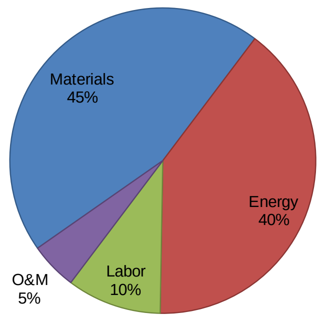
1. Overcapacity in the sector, downward pricing pressure, vertical integration in most module manufacturing companies

Key Factors

1. Distinguishing features, quality control
2. Vertical integration to achieve competitive costs and ensure cell supply and quality

Sector: PV	Subsystem: Crystalline silicon	Solar industry: Polysilicon

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	15%		
Cost Structure breakdown			
Materials	45%		
Energy	40%		
Labor	10%		
O&M	5%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	25 - 30	kUSD/t	
Typical demand from a reference customer	5.5 - 6.6	t/MWp	
Average production for a factory	16,000	t/yr	
Investment	30 - 60	kUSD / (t/yr)	
Production requirements			
Materials	100%		
Silicon, metallurgical grade	90%		depends on process followed
Hydrochloric acid	5%		depends on process followed
Hydrogen	5%		depends on process followed
Energy	100%		
Electric	20%		
Thermal	80%		

Top Companies	Origin
GCL-Poly	China
OCI	South Korea
Wacker	Germany
Hemlock	US
REC FBR	Norway
MEMC	US

Barriers to entry

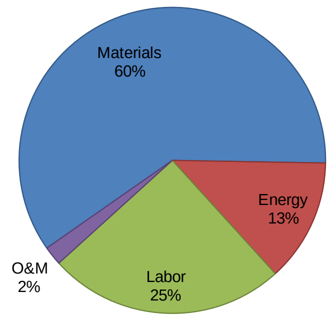
1. Technical barrier: highly specialized deposition process with high purity
2. High specific investment for manufacturing process
3. Overcapacity in the sector, downward pricing pressure
4. Global demand in 2011 could have been covered with already installed capacity of the six top suppliers

Key Factors

1. Alternative market (electronics) requires higher purity than solar. Capability to reach purity (Siemens, others in development)

Sector: PV	Subsystem: Common systems	Solar industry: Inverter

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	14%		
Cost Structure breakdown			
Materials	60%		
Energy	13%		
Labor	25%		
O&M	2%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	150 - 200	kUSD/MWp	
Typical demand from a reference customer	1 - 100	MWp	
Average production for a factory	250	MWp/yr	
Investment	70 - 90	kUSD / (MWp/yr)	
Production requirements			
Materials	100%		
Silicon	30%		
Copper	20%		
Aluminum	50%		
Special alloys	-		negligible weight
Energy	100%		
Electric	30%		
Thermal	70%		

Top Companies	Origin
Danfoss	Denmark
Fronius	Austria
GE Energy	USA
Ingeteam	Spain
Kaco New Energy	Germany
Siemens	Germany
SMA Solar Technologies	Germany
Solar Max	Switzerland

Barriers to entry

1. Technical barrier: complex design to achieve performance
2. Most inverter manufacturers are large power electronics companies which diversified into the solar market

Key Factors

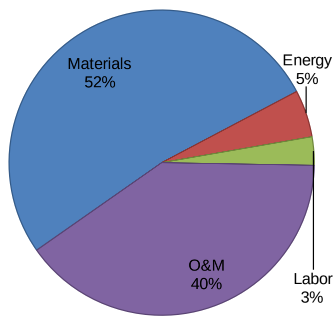
1. Distinguishing features, quality control
2. Maximum power point tracking and anti-islanding protection

Sector: PV	Subsystem: Common systems	Solar industry: Support Structure

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	13 - 17%		Up to 30% if 2-axes tracking

Cost Structure breakdown

Materials	52%
Energy	5%
Labor	3%
O&M	40%



	Value	Unit	Comments
Component Market Price (Average Sales Price)	2 - 3	USD/kg	Fixed structure or 1-axis tracking
Typical demand from a reference customer	60 - 100	t/MWp	
Average production for a factory	10 - 200	MWp/yr	
Investment	80 - 100	kUSD / (MWp/yr)	

Production requirements

Materials	100%
Carbon steel, beam	90%
Carbon steel, plate	5%
Electrodes	5%
Energy	100%
Electric	100%
Thermal	0%

Top Companies	Origin
Conergy	Germany
Hilti	Spain
Mecasolar	Spain
Sun Power	USA

Barriers to entry

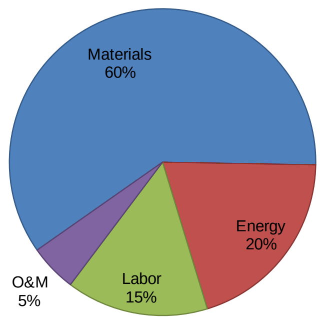
1. Technical barrier: complex design to achieve reliability and low maintenance for tracker

Key Factors

1. Carbon steel market
2. Transport
3. Galvanizing
4. Adapt existing industries

Sector: PV	Subsystem: Thin films	Solar industry: TF Materials

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	35%		
Cost Structure breakdown			
Materials	60%		
Energy	20%		
Labor	15%		
O&M	5%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	700	USD/kg	
Typical demand from a reference customer	220	kg/MWp	
Average production for a factory	60	MWp/yr	
Investment	300 - 350	kUSD / (MWp/yr)	
Production requirements			E.g.: materials for CdTe cell
Materials	100%		
Tellurium	50%		
Cadmium	45%		
Sulphur	-		negligible weight
Indium	5%		
Tin	-		negligible weight
Energy	100%		
Electric	30%		
Thermal	70%		

Top Companies	Origin
5N Plus Inc	Canada
Advanced Technology and Materials	USA
Hitachi Metals	Japan

Barriers to entry

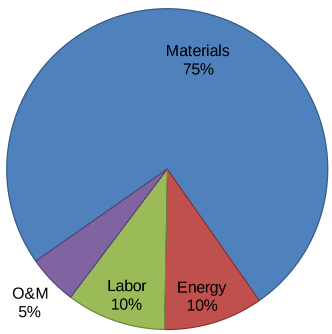
1. Raw material supply depends on existing zinc and copper industries

Key Factors

1. Vertical integration or association with zinc and copper industries
2. Transport
3. Purity of final product
4. Valorization of byproducts
5. TCO: alternative markets (LCD displays, etc.)

Sector: PV	Subsystem: Thin films	Solar industry: TF Modules

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	10%		Including TF materials (35%), Solar glass (20%), total 65%
Cost Structure breakdown			
Materials	75%		
Energy	10%		
Labor	10%		
O&M	5%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	0.5 - 1	USD/Wp	
Typical demand from a reference customer	0.5 - 100	MWp	
Average production for a factory	100 - 1000	MWp/yr	
Investment	0.8 - 1.5	million USD / (MWp/yr)	
Production requirements			
Materials	100%		
Solar glass	99%		
Photoactive layer	-		negligible weight
TCO	-		negligible weight
Back contact	-		negligible weight
Polymeric backsheet	1%		
Energy	100%		
Electric	30%		Largely depending on deposition technique
Thermal	70%		

Top Companies	Origin
First Solar (CdTe)	US
Best Solar (TF Si)	China
Moser Baer (TF SI)	India
Sharp (TF Si)	Japan

Barriers to entry

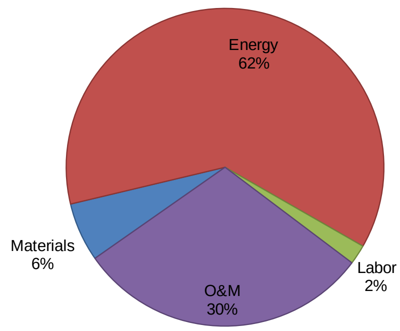
1. High specific investment for manufacturing process
2. Technical barrier: highly specialized deposition processes with high purity and thickness control
3. Overcapacity in the silicon sector has led prices below thin films, with higher performance

Key Factors

1. Vertical integration or association with existing Solar glass line
2. R&D to improve performance
3. Niche market: weight-constrained applications
4. Niche market: flexible substrates

Sector: PV	Subsystem: Thin films	Solar industry: Solar glass

	Value	Unit	Comments
Weight in the value chain (as a % of total wealth)	20%		
Cost Structure breakdown			
Materials	6%		
Energy	62%		
Labor	2%		
O&M	30%		



	Value	Unit	Comments
Component Market Price (Average Sales Price)	1.5 - 2.5	USD/kg	
Typical demand from a reference customer	8 - 20	t/MWp	One / two glass sheets
Average production for a factory	200	MWp/yr	Adaptation of an existing float glass line
Investment	1 - 2	kUSD / (MWp/yr)	
Production requirements		Note: composition of final product, some raw materials will lose volatile fraction	
Materials	100%		
Silica	72%		Low iron content (impurities)
Na2O	14%		Sources: Na2CO3, trona
CaO	10%		Sources: CaCO3, (dolomite)
MgO	2%		Sources: dolomite
Fining agents and additives	2%		E.g. Sb2O3, Na2SO4, NaCl, TiO2
Energy	100%		
Electric	30%		
Thermal	70%		

Top Companies	Origin
AGC Solar	Belgium
Pilkington	UK
Saint Gobain solar	Germany
Guardian	US

Barriers to entry

1. High overall investment for manufacturing process due to scale
2. Solar glass is usually < 1% of total float glass. Alternative demandmust exist to achieve, at least, 70% cap. factor

Key Factors

1. Vertical integration or association with existing float glass line
2. For CIS/CIGS: stable Na composition, integration of Mo coating
3. For CdTe and TF-Si: Integration of TCO deposition to access alternative markets (LCD displays, etc.)
4. Transport
5. Energy
6. Alternative markets: crystalline modules

Appendix 2 | Suggested CSP Industries Description

Heat Exchangers

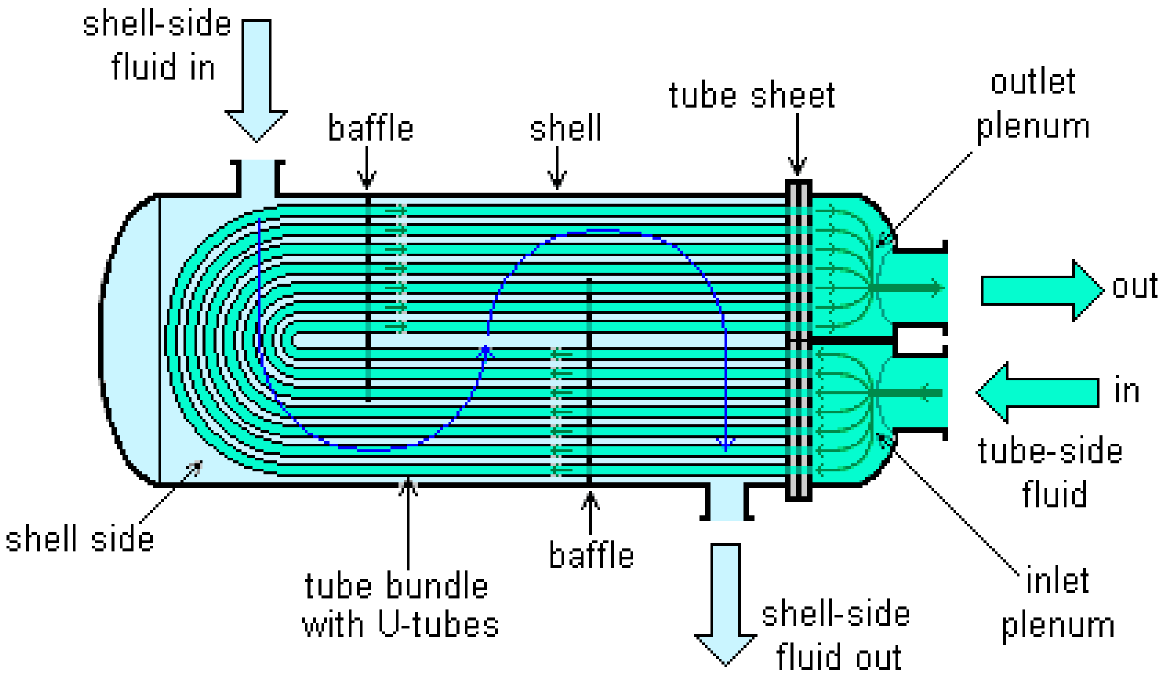
PRODUCTION PROCESS AND FACTORS

Two different sets of heat exchangers are required in the Power Block. First, heat transfer fluid (HTF)-water heat exchangers (usually referred to as SGS, or steam generation system) are required to generate the high-pressure and temperature steam that will drive the turbine. Second, water-water heat exchangers are used to recover the heat from turbine bleeds to preheat the condensate or feed water, thus increasing the Rankine cycle efficiency. If a Thermal Energy Storage (TES) system is included, a reversible, molten salt-HTF heat exchanger also is necessary. Carbon steel and stainless steel are required for its manufacture, as well as copper and aluminum in smaller amounts. Materials and supplies usually account for over 95 percent of total manufacturing costs (Grenada 2011).

High-temperature and pressure-heat exchangers usually are shell-and-tube type. These exchangers comprise the following elements:

- **Tubes**: Heat exchanger tubes often are manufactured to industry standard diameters. The materials commonly used are low carbon steel, copper, copper-nickel, stainless steel, titanium, or special alloys. Tubes can be drawn and thus are seamless, or welded. High quality electro-resistant welded tubes display good grain structure at the weld joints. Extruded tubes with fins and interior rifling are sometimes specified for certain heat transfer applications. A U-tube design is found in applications when the thermal difference between the fluid flows otherwise would result in excessive thermal expansion of the tubes.
- **Tube sheet**: Tube sheets are constructed from a round, flattened sheet of metal. Holes for the tube ends are then drilled for the tube ends in a pattern relative to each other. Tube sheets typically are manufactured from the same material as tubes, and attached with a pneumatic or hydraulic pressure roller to the tube sheet. At this point, tube holes can be both drilled and reamed, or they are machined grooves (the latter significantly increases tube joint strength).
- **Shell**: The shell is constructed from either pipe or rolled plate metal. For economic reasons, steel is the most commonly used material. When applications involve extreme temperatures and corrosion resistance, other metals or alloys are specified. Roundness typically is increased by using a mandrel and expanding the shell around it, or by double-rolling the shell after welding the longitudinal seam.
- **Head**: Heads typically are fabricated or cast. They are mounted against the tube sheet with a bolt and gasket assembly, although many designs include a “machine grooved” channel in the tube sheet sealing the joint. The materials typically used in the cast bonnets are steel, bronze, Hastelloy, and nickel plated or stainless steel.
- **Baffles**: To fit, all baffles must have a diameter slightly smaller than the shell. However, tolerances must be tight enough to avoid a performance loss as a result of fluid bypass around the baffles. Baffles usually are stamped/punched, or machine drilled depending on size and application. Material selection must be compatible with the shell-side fluid to avoid failure as a result of corrosion.

Figure A2.1 | Schematic of a U-tube Heat Exchanger

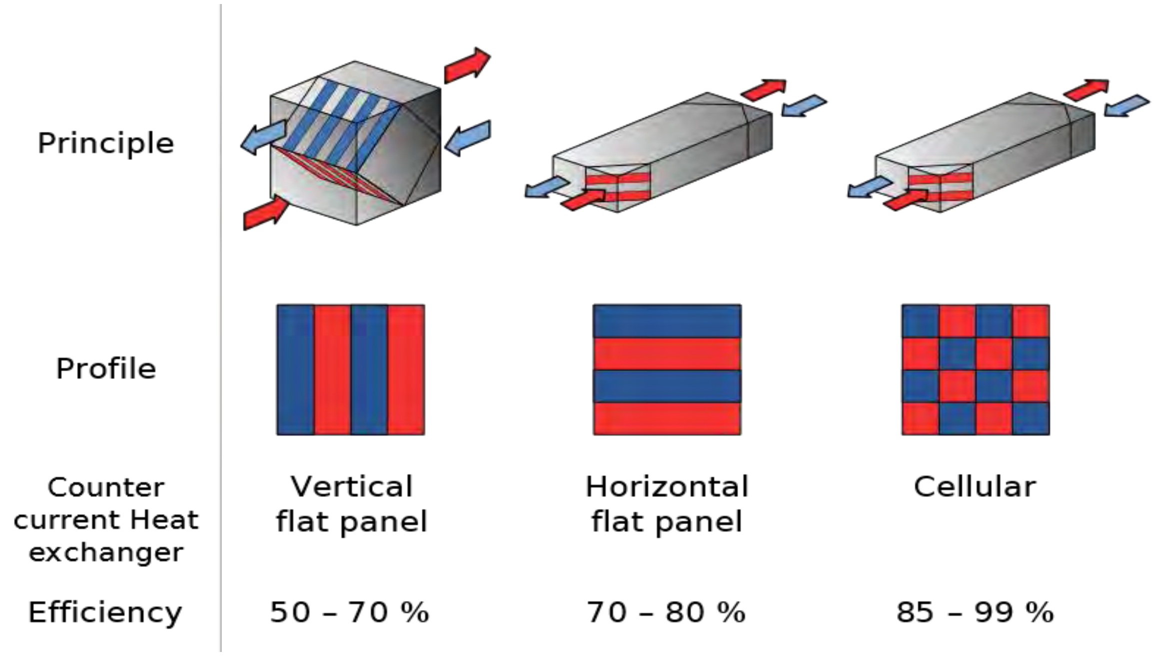


Source: Public domain.

Less-demanding heat exchangers, such as those used in condensate preheating, can be plate-type. A plate heat exchanger consists of a series of thin, corrugated plates that are joined by gaskets, welded, or brazed together depending on the application of the heat exchanger. The plates are compressed together in a rigid frame to form an arrangement of parallel flow channels with alternating hot and cold fluids. These exchangers comprise the following elements:

- **Plates**: The plates are manufactured by single piece pressing of metal plates. Regarding the material, plates usually are made of stainless steel (AISI, or American Iron and Steel Institute, 304 or 316) due to its temperature and corrosion resistance as well as its mechanical properties. Depending on the application, higher grade materials such as titanium may be used. The plates are pressed to form troughs at right angles to the direction of flow of the liquid that runs through the channels in the heat exchanger. These troughs are arranged so that they interlink with the other plates that form the channel with gaps of 1.3-1.5 mm between the plates.
- **Gaskets**: The purpose of the gaskets is to space the plates, thus procuring a good seal. Gaskets are made of rubber (such as ethylene propylene diene monomer, or EPDM; or acrylonitrile-butadiene rubber, or NBR, or Viton®) and cemented into a section around the edge of the plates. When high pressures or incompatible materials are expected, plates are welded without gaskets.
- **Head and follower**: The head and the follower are the ends that enclose the plate pack. They usually are cast from stainless steel.

Figure A2.2 | Schematic of a Plate Heat Exchanger



Source: Public domain.

TECHNOLOGICAL BARRIERS

The design of the heat exchangers must comply with multiple constraints and have the flexibility to operate even in partial loads. The limited pressure drop allowed in the tube, shell, or both sides; the complex heat transfer in phase-change conditions; and the maintenance required to avoid fouling make its design a complicated one.

This barrier can be overcome if the design and manufacturing procedures and quality control comply with the specifications of the engineering supplier. Because third-party guarantees are involved, a local partnership with experienced companies providing design drawings and specifications might be the best approach.

MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of heat exchangers for CSP projects:

- **Aalborg CSP**: Danish company, Aalborg CSP A/S, is the result of the merger between the engineering, procurement, and construction (EPC) company, BK Aalborg A/S, and the engineering company, BK Engineering A/S. The merger took place January 1, 2011. Aalborg CSP's core business areas are design and delivery of steam generators for concentrated solar power (CSP), CSP module system, gas- and oil-fired steam boilers, and engineering services. The projects vary from component deliveries to complete turnkey installations including piping, valves, instrumentation, electrical, steel, gallery, pumps, and commissioning. No data is available about the company's size or turnover. Nevertheless, it has references of over 250 MWe installed since 2008 and over 75 MWe expected for 2013 and 2014.
- **Alfa Laval**: Alfa Laval AB is a Swedish company founded in 1883. It is a leading producer of specialized products and solutions used to heat, cool, separate, and transport such products as oil, water, chemicals, beverages, foodstuffs,

starch, and pharmaceuticals. Alfa Laval divides its operations between equipment (capital sales) and process technology (contracts with longer duration). Alfa Laval is listed on Nasdaq OMX, and in 2012 posted annual sales of approximately EUR 3.5 billion (Alfa Laval AB 2013). The company has approximately 16,400 employees.

- **Foster Wheeler**: Foster Wheeler AG (previously Foster Wheeler, Inc.) is a global conglomerate with its principal executive offices in Geneva, Switzerland and its registered office in Baar, Switzerland. It is focused on engineering, procurement, and construction (EPC) for power facilities. The company comprises two business groups: Global Engineering and Construction (E&C) Group and Global Power Group. As of February 2013, the market capitalization of the company was approximately US$2.7 billion (Foster Wheeler AG 2013), and it employed approximately 13,000 persons.
- **GEA**: GEA Group Aktiengesellschaft is one of the largest system providers for food and energy processes with approximately EUR 5.7 billion revenue in 2012, of which 1.6 billion came from its Heat Exchangers division (Alfa Laval AB 2013). As an internationally operating technology group, the company focuses on process technology and components for demanding production processes in various end markets. The group generates approximately 70 percent of its revenue from the long-term growing food and energy industries. The company's workforce comprised approximately 24,500 employees worldwide as of December 31, 2012.
- **HAMON group**: Founded in 1927, Hamon & Cíe International is a Belgium-based engineering, procurement, and contracting company (EPC). It provides specific process equipment and the associated after-sales services for cooling systems, air quality systems, process heat exchangers, industrial chimneys, heat recovery steam generators, and waste heat boilers. Targeted customers are mainly power generation; oil, gas, and petrochemical industries; and, in a more general way, heavy industries (iron and steel, cement factories, glass factories, incinerators). In 2012 the group had a revenue of EUR 474 million (Hamon & Cíe International S.A. 2012) and approximately 1,650 employees worldwide.

LOCATION OF MANUFACTURING FACILITIES

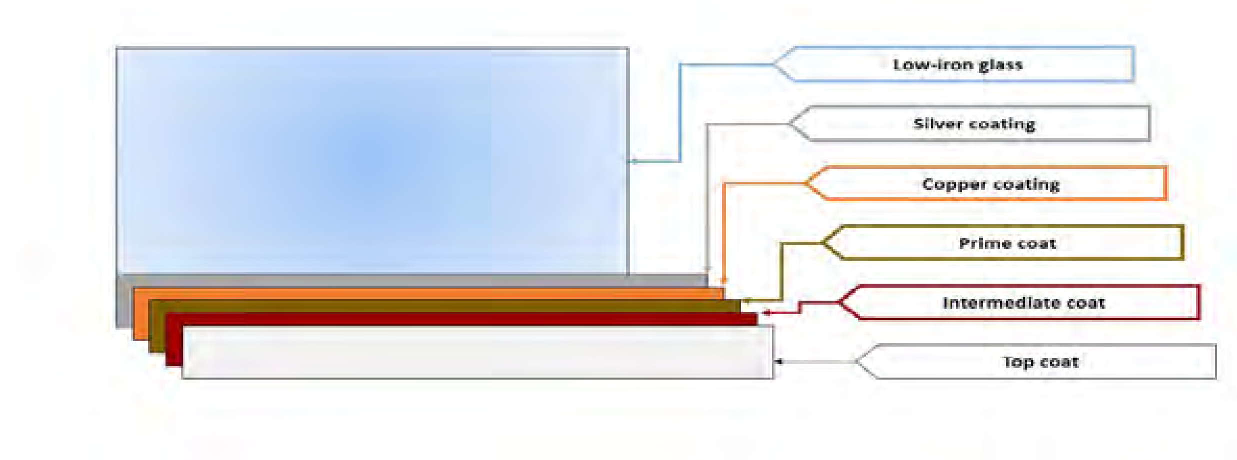
- The above-mentioned companies work at the global scale, either through subsidiaries or by means of distribution partnerships with local companies. However, their manufacturing facilities are concentrated in a few countries.
- **Aalborg CSP**: Aalborg CSP A/S has manufacturing facilities in Denmark, although their equipment can be manufactured in several countries according to EN (European Standard) or ASME (American Society of Mechanical Engineers) standards through partnerships with local manufacturers (Aalborg CSP A/S 2011).
- **Alfa Laval**: At end-2012, the Alfa Laval Group had 32 major manufacturing units; 15 in Europe, 9 in Asia, 6 in the US, and 2 in Latin America (Alfa Laval AB 2012).
- **Foster Wheeler**: Foster Wheeler AG has manufacturing facilities in China, Poland, Spain, and Thailand (Foster Wheeler AG n.d.).
- **GEA**: GEA Group Aktiengesellschaft has manufacturing facilities in China, France, Germany, Hungary, Qatar, South Africa, Spain, and the US, as well as partnership agreements in Russia, South Korea, and South Eastern Asia (GEA n.d.).
- **HAMON group**: Hamon & Cíe International has manufacturing facilities in China, France, Germany, Indonesia, Saudi Arabia, UAE (United Arab Emirates), and the US.

Mirror

PRODUCTION PROCESS AND FACTORS

Mirrors are used to reflect the direct solar radiation incident on them and concentrate it onto the receiver placed in the focal line of the Parabolic Trough collector. The mirrors are made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness and parabolic shape. Additional layers protect the silver coating against corrosion and erosion.

Figure A2.3 | Schematic of a CSP Mirror Structure



Mirror-backing coatings are produced by traditional wet-chemistry processes. The clean glass is sensitized with $SnCl_2$; the Ag layer is applied by chemical reductive processes; the Cu layer is applied by chemical processes; the mirror-backing paint layers are applied by various techniques; and the applied paint is force-cured by heating.

New processes are under development, such as a copper-free process, which replaces the copper layer used to inhibit silver-layer corrosion in mirror manufacturing with the application of a layer of tin oxide (SnO_2). The copper-free process has multiple advantages compared to the older copper protective layer. The chemical resistance is improved; the SnO_2 still allows adhesion of the paint layer; the SnO_2 is a good diffusion barrier for oxygen and water and is immune to further oxidation; the Ag/SnO_2 system does not suffer from the known problems of copper/silver inter-diffusion implicated in mirror degradation; and the process does not produce copper-containing waste streams that must be environmentally processed and treated for recycling.

The mirror-backing paint systems and resulting coatings typically are based on solvent-borne alkyd resins, which are relatively complex paint systems and are proprietary to the paint manufacturers. The paint formulations that afford the best protection against the corrosion of the copper layer protecting a silvered mirror contain lead pigments as the active corrosion-inhibitor component. Historically, solar systems built 10-20 years ago used glass mirrors with multiple-layer paint systems, in which 1 layer contained specially formulated, highly leaded (10 percent-20 percent lead by weight) paints.

Highly leaded paints containing more than 10 percent lead by weight no longer are available due to environmental and health concerns. Most leaded paints now contain 0.5 percent-2 percent lead by weight. Companies are adapting their mirror lines to run a new low-lead paint system, in which the lead is reduced to the point that the durability remains equivalent. The **prime coat** of the new three-layer paint system now contains 2.5 percent lead; the **intermediate coat** contains 1 percent lead; and the white **top coat** is still acrylic based and has high ultraviolet (UV) stability (Kennedy and others 2007).

Unfortunately, although the coatings with a lead content are robust, they have been mostly phased out because lead pigments are toxic so their use is discouraged for environmental health reasons. Mirror-backing paint companies have developed new **lead-free** paint systems that perform quite well in accelerated tests, but, notably, are intended for indoor conditions. A (Ni^{2+} and Co^{2+})-bis-hydrogen cyanamide is considered one of the best-performing, lead-free, corrosion-inhibitor pigments on the market. A second type of lead-free mirror back-coating incorporates antioxidant pigments, which also are cyanamide derivatives of metals, within a melamine-based resin. A third type of lead-free mirror back-coating can be applied as a film and hardened to form a protective layer on the back of the mirror. It comprises a fluid organic resin and a corrosion inhibitor.

TECHNOLOGICAL BARRIERS

The coating technologies are important for the ultimate performance of the mirror. So is obtaining highly transparent low-iron glass. However, the main technological barrier in the mirror industry is shaping the glass. The actual standard manufacturing precision of the parabolic shape is above 99.9 percent interception factor. This, combined with a high impact resistance and the restrictive composition required for high transmittance, makes necessary a large manufacturing ability.

MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of mirrors for CSP projects:

- **AGC Solar**: The AGC Group, with the Asahi Glass Company at its core, is a global business group. Its main industries are flat glass, automotive glass, display glass, electronics and energy, and chemicals. The group employs some 50,000 people worldwide and generates annual sales of more than EUR 11,199 million through business in approximately 30 countries.
- **Flabeg**: FLABEG Holding GmbH is a German company founded in 1882 as Fürth Glass Factory. It is a technology leader in the field of glass finishing. It is among the leading global manufacturers of low-glare mirrors and cover plates for the automotive industry, as well as solar and high-technology glass applications.
- **Guardian**: Guardian Industries began as the Guardian Glass Co. in 1932, making windshields for the automotive industry. Today, Guardian Industries Corp. is a diversified global manufacturing company headquartered in Auburn Hills, Michigan, with leading positions in float glass; fabricated glass products; fiberglass insulation; and other building materials for commercial, residential, and automotive markets. The group declared US$4.9 billion revenues in 2011 and had approximately 17,000 employees (Forbes 2011).
- **Rioglass**: Created in 1991 in Spain, Rioglass is a privately owned glass maker. After initially supplying short- and medium-run vehicle manufacturers, Rioglass has become a significant

player in the European automotive glass market. The solar division was created in 2007 and has approximately 200 employees.

- **Saint Gobain**: Saint-Gobain S.A. is a French multinational corporation founded in 1665 in Paris. Originally a mirror manufacturer, it now also produces a variety of construction and high-performance materials. The solar energy division, Saint-Gobain Solar Power, designs and manufactures mirrors for CSP. The group Saint Gobain declared EUR 2.9 billion in 2012 and employs more than 190,000 persons.

LOCATION OF MANUFACTURING FACILITIES

The above-mentioned companies work at a global scale, either through subsidiaries or by means of distribution partnerships with local companies. However, their manufacturing facilities are concentrated in a few countries.

- **AGC Solar**: The AGC Group has 10 manufacturing sites all over the world, of which 1 is totally dedicated to solar mirrors manufacturing, namely, Zeebrugge in Belgium (AGC Solar 2013).
- **Flabeg**: FLABEG Holding GmbH has 13 manufacturing sites all over the world. Five (5) are totally or partially dedicated to solar mirrors manufacturing: Furth im Wald and Köln in Germany, Shanghai in China, Pittsburgh, PA in the US, and New Delhi in India (Flabeg Holding GmbH 2013).
- **Guardian**: Guardian Industries has over 100 manufacturing facilities all over the world. Most are in North America, but it has presence in China, India, Japan, Thailand, Egypt, Saudi Arabia, UAE, South Africa, Argentina, Brazil, Colombia, Costa Rica, Venezuela, and several European countries.
- **Rioglass**: Rioglass has 7 manufacturing centers all over the world. Three are totally dedicated to solar mirrors manufacturing: Rioglass Solar 1 and 2 in Spain, and Rioglass Solar, Inc. in Arizona, US (Rioglass Solar S.A. 2013).
- **Saint Gobain**: Saint Gobain S.A. has two manufacturing facilities dedicated to solar mirrors manufacturing: Saint-Gobain Glass Deutschland GmbH and Saint-Gobain Solar-Portugal (Saint Gobain Solar Power 2011).

Storage Tanks

PRODUCTION PROCESS AND FACTORS

A large number of tanks and pressure vessels are required in a CSP plant. They include raw and treated water storage tanks; the deaerator, the steam drum, and condensate tank for the Rankine cycle; and the HTF storage, expansion, and ullage vessels and other minor tanks for sewage and water treatment intermediate steps. If a TES system is included, molten salt "hot" and "cold" storage tanks also are necessary. Carbon steel and stainless steel are required for their manufacture.

Most of these tanks are small enough to be manufactured in a workshop and transported, but others such as molten salt tanks must be erected on site. Both the hot tank and the cold tank will be manufactured from steel plates (stainless steel for the hot tank and carbon steel for the cold one) that have been laminated and curved.

TECHNOLOGICAL BARRIERS

Designing and manufacturing pressure vessels according to the ASME Boiler and Pressure Vessel Code or an equivalent standard should pose no challenge to any experienced manufacturer. On-site welding and testing, on the other hand, requires skilled welders to ensure the highest quality within a tight erection schedule.

The second main issue regarding molten salt tanks is the design and construction of the foundations. The high temperature of the tanks requires that the base of the tanks is vented to prevent excessive temperature that could damage the concrete.

MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of storage tanks for CSP projects:

- **Aitesa**: Aitesa S.L. is a Spanish company founded in 1985, with over 25 years of experience in design and manufacturing of heat transfer equipment over a wide range of pressures, temperatures, and fluids.
- **Caldwell Tanks**: Caldwell Tanks was founded in 1887. It designs, fabricates, and builds tanks for the water, wastewater, grain, coal, and energy industries. Caldwell has approximately 500 employees as of 2012.
- **Duro Felguera**: Duro Felguera, S.A. is an international company founded in Spain in 1858. It is specialized in turnkey projects for the industrial and power generation sector, as well as equipment manufacturing. The Duro Felguera group declared EUR 109.5 million revenues in 2011 and has approximately 2,000 employees.
- **IMASA**: IMASA Ingeniería y Proyectos, S.A., headquartered in Oviedo (Spain), was founded in the 1970s as a company dedicated to the implementation of projects[56] and the maintenance and erection of industrial plants. At present, IMASA leads several multidisciplinary companies involved in different industrial sectors. These companies generate a turnover exceeding EUR 300 million with a workforce of over 1,500 professionals.

LOCATION OF MANUFACTURING FACILITIES

The above-mentioned companies' manufacturing facilities are concentrated in a few countries.

- **Aitesa**: Aitesa has long-term partnership agreements with metal fabrication facilities in Spain and Thailand (Aitesa S.L. 2013).
- **Caldwell Tanks**: Caldwell has three major facilities, all in the US: fabrication facilities in Louisville, KY and Newnan, GA and a painting facility in Harrodsburg, KY (IEA n.d.).
- **Duro Felguera**: The Duro Felguera group has five manufacturing facilities in Spain. One of them is dedicated to heavy-duty metal works for boiler and pressure vessel manufacturing (Duro Felguera S.A. 2013).
- **IMASA**: IMASA Ingeniería y Proyectos, S.A. has more than 10 manufacturing facilities in Spain. One of them is dedicated to heavy-duty metal works for boiler and pressure vessel manufacturing (IMASA 2013).

56. "Projects" here refers to any project that requires deposits or pressure vessels, thus practically any industrial project.

Structure and Tracker

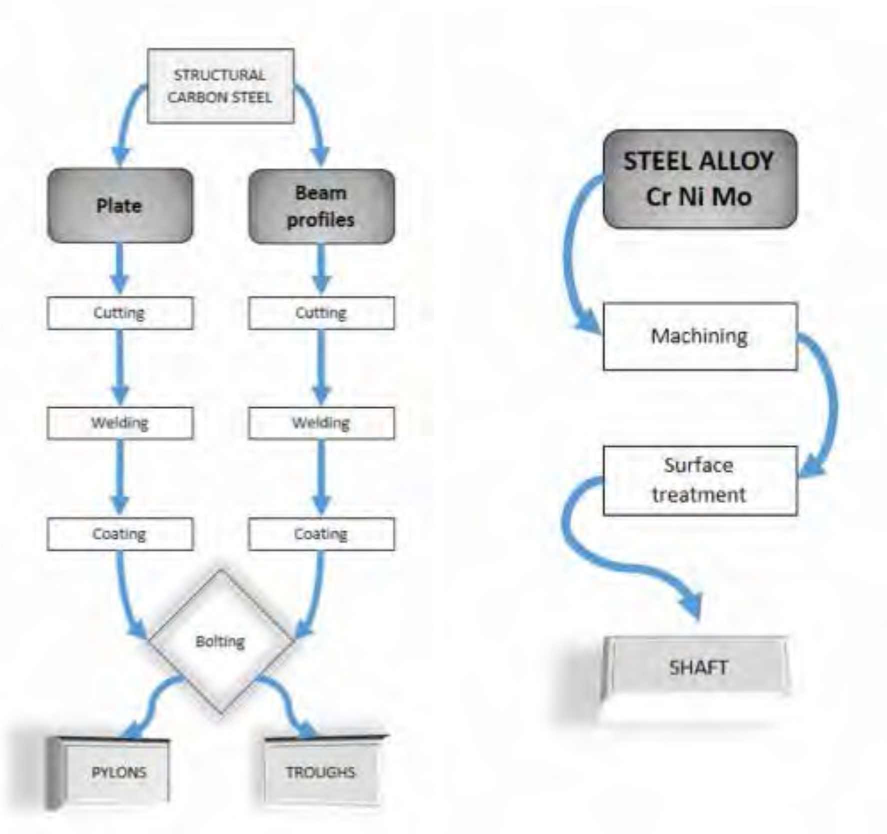
PRODUCTION PROCESS AND FACTORS

The solar tracking system changes the position of the parabolic collector (or, in solar tower plants, the heliostats) to follow the apparent position of the sun during the day, thus enabling the concentration of the solar radiation onto the receiver. The system consists of a hydraulic (or, in solar tower plants, electric) drive unit that rotates the optical element around its axis and a local control that governs it. The structure, in turn, must keep the shape and relative position of the elements, transmitting the driving force from the tracker, and avoiding deformations caused by their own weight or other external forces such as the wind.

Galvanized structural carbon steel is the usual material for the structures. Commercial beam profiles are cut, welded, and hot-dip galvanized. The same is true for plates. On-site assembly is done by bolting together the different pieces.

Rack- or crown-and-pinion electric drives are the most commonly used to move the heliostats. For parabolic collectors, a hydraulic drive is used to handle the heavy loads.

Figure A2.4 | Schematic of CSP Structure and Tracker Manufacturing



TECHNOLOGICAL BARRIERS

The design of the structure can be subcontracted or locally developed. In any case, despite the tight tolerances required, steel structures should pose no challenge to any experienced local manufacturer. On the other hand, hot-dip galvanizing of large structures (over 12 m long[57]) could become a bottleneck in the supply chain.

Regarding the tracker manufacturing, high-precision machining and surface treatment of the hydraulic drive shaft require specialized tools and experienced workforce to achieve the required quality.

57. Double-end dipping in smaller tanks is possible but seriously reduces the throughput of the galvanizing plant.

MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of structures and/or trackers for CSP projects:

- **Albiasa**: Through its parent company Albiasa Gestión Industrial, S.L. is a Spanish group founded in 1974. It has developed an active capital assets engineering business. It has had especially intense activity in the iron and steel industry, after entering the renewable energies field through the company, ALBIASA SOLAR, S.L., in 2004.
- **Asturfeito**: Asturfeito S.A. is a Spanish company founded in 1989. It specializes in structure and equipment manufacturing. Its subsidiary, Asturmatic, focuses on hydraulic, pneumatic, and electric equipment and control systems. The company declared EUR 25 million sales in 2012 and has approximately 160 employees (Asturfeito S.A. 2013).

- **Gossamer**: Gossamer Innovations is a structural design company based in the U.S. Its designs are manufactured through a network of local workshops and suppliers and have been used in approximately 200 MWe installed capacity.
- **Ideas en Metal**: Ideas en Metal S.A. is a family-owned Spanish company specializing in the design and manufacture of space frames, storage systems, and other metal products that are made primarily from sheet and pipe, and manufactured in series. The company was founded in 2001 and since has supplied all or part of the structures for over 1,300 MWe installed capacity (Ideas en Metal S.A. 2013).
- **MADE**: Made Torres is part of the Invertaresa Group established in 1940. MADE is an industrial company of reference both nationally and internationally. It is one of the leaders in the manufacture of structures for the CSP sector, having supplied approximately 350 MWe installed capacity.
- **SBP**: Schlaich Bergermann & Partner, based in Stuttgart, is a world-renowned structural engineering firm founded in 1980. The company manages the patent rights on the Parabolic Trough designed by the EuroTrough consortium,[58] one of the most installed solar collectors worldwide.
- **Sener**: Sener Grupo de Ingeniería, S.A. is a Spanish engineering company founded in 1956. It has extensive experience in the development of thermosolar plants, state-of-the-art combined cycle electric plants, regasifications of liquid gas, nuclear energy, biofuels, oil refining, chemical and petrochemical, and plastics. SENER has a workforce of more than 5,000 professionals and a turnover above EUR 1,000 million in 2011 (Vadillo 2011).
- **Siemens**: Siemens A.G. is a German multinational engineering and electronics conglomerate headquartered in Munich. It is the largest Europe-based electronics and electrical engineering company. Siemens' principal activities are in industry, energy, transportation, and healthcare. In recent years, the company has increased its solar portfolio including most CSP components such as structures and trackers, receivers, mirrors, and turbines. Siemens and its subsidiaries employ approximately 360,000 people across nearly 190 countries and reported global revenue of approx. EUR 73.5 billion in 2011.

LOCATION OF MANUFACTURING FACILITIES

The above-mentioned companies work on the global scale, through either subsidiaries or distribution partnerships with local companies. However, the manufacturing facilities are concentrated in a few countries.

- **Albiasa**: Albiasa Solar S.L. is a structure design company. Its designs are manufactured through a network of local workshops and suppliers.
- **Asturfeito**: Asturfeito S.A. has its main manufacturing facility in Spain (Asturfeito S.A. 2013).
- **Gossamer**: Gossamer Innovations is a structural design company based in the US. Its designs are manufactured through a network of local workshops and suppliers.
- **Ideas en Metal**: Ideas en Metal S.A. has five manufacturing facilities in Spain (Ideas en Metal S.A. 2013).
- **MADE**: Made Torres has its main manufacturing facility in Spain, with a capacity of up to 50,000 t/year.
- **Sener**: Sener Grupo de Ingeniería, S.A. is an engineering company. Its designs are manufactured through a network of local workshops and suppliers.
- **SBP**: Schlaich Bergermann & Partner, based in Germany, is a structural engineering firm. Its business model is the exploitation of the patent rights on the EuroTrough Parabolic Trough design.
- **Siemens**: Siemens AG is a German multinational company. Siemens and its subsidiaries have manufacturing facilities in nearly 190 countries.

58. The companies and research institutions in the EuroTrough consortium are Fichtner Solar, Flabeg Solar International, SBP, and DLR (Germany); CRES (Greece); Iberdrola, Abengoa/Inabensa, and PSA-CIEMAT (Spain); and Solel (Israel).

Appendix 3 | Suggested PV Industries Description

Support Structure

PRODUCTION PROCESS AND FACTORS

This industry is similar to the CSP structure and tracker industry. The main differences are:

- A fair number of trackers are made without hydraulic drives (electric devices are used instead)
- Tolerances are less restrictive in manufacturing and assembly.

When building-integrated applications are considered, aluminum can be used for structures due to weight restrictions.

TECHNOLOGICAL BARRIERS

The design of the structure can be subcontracted or locally developed. In either case, steel structures should pose no challenge to any experienced local manufacturer.

MAIN COMPETITORS

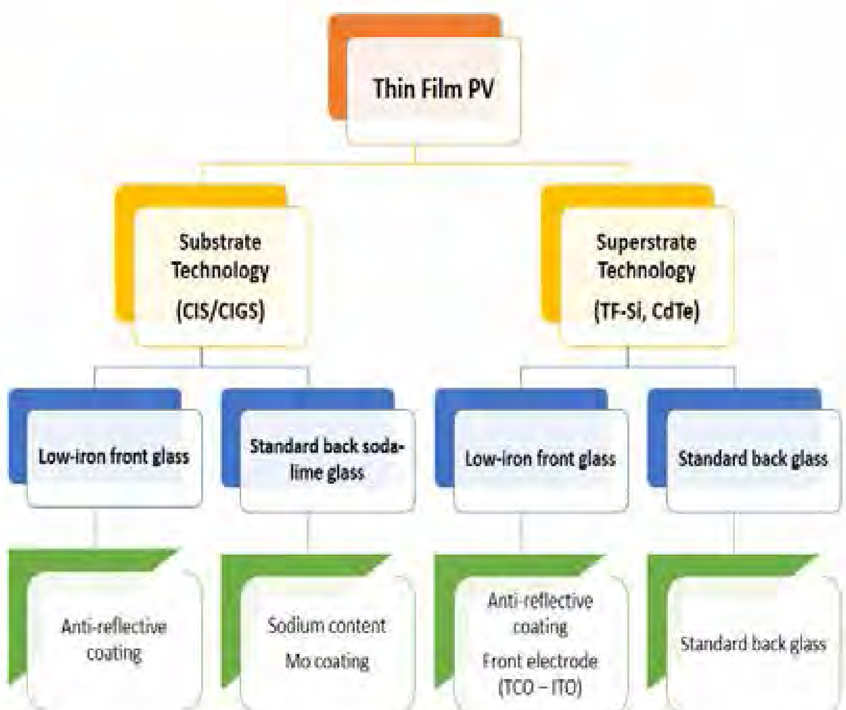
The companies identified as actual or potential suppliers of support structures for PV projects are the same shown in the CSP structure and tracker industry. However, as the usual size of PV projects is smaller than for CSP, the market is shared with many small and medium local companies.

Solar Glass

PRODUCTION PROCESS AND FACTORS

Solar glass can be defined depending on the final use (Figure A3.1).

Figure A3.1 | Types of Solar Glass



General requirements can be defined for any of these applications, including

- Tight tolerances in overall dimensions, warp
- Surface quality, smoothness, and planarity to avoid coating problems
- Edge shape and quality required for assembly
- Durability and small loss of properties with aging
- Reliability and repeatability.

For the substrate-manufactured modules (copper/indium sulfide or CIS; or copper/indium/gallium di-selenide, or CIGS), the back glass must endure high-temperature processes such as molybdenum deposition. A certain amount of sodium is required in the CIS/CIGS photoactive layers, and the usual method to provide it is the thermal diffusion of the existing sodium in soda lime glass. However, soda lime glass is not a high-tech material (it is commonly used in windows). For solar applications, a stable composition and higher quality of surface and edge treatments are required.

The **front glass** for substrate-manufactured modules requires low absorption (thus requires low-iron glass), mechanical resistance, and low reflection. To reduce reflective[59] losses and increase absorption rates,[60] referred to collectively as "light trapping effects," a **textured surface** is convenient. In single-crystalline modules, the photoactive surface is textured, so a flat glass with antireflective coating is used. In thin-film modules, the photoactive surface is likely to be flat, so a "thick" (larger than the coherence[61] length of light) texture is commonly used, as opposed to the "thin" texture that can be used in the substrate.

In the **superstrate-manufactured** modules (TF-Si and CdTe), the front glass undergoes a transparent conducive oxide (TCO) deposition as a first step. For TF-Si, a hazy finish is advantageous, smooth for CdTe. The requirements of low absorption, mechanical resistance, and textured surface still apply for the outer side. However, the **inner surface quality** must be as high as in the back glass for substrate-manufactured modules.

The **back glass** for superstrate-manufactured modules is the **less demanding**, with only general requirements with which to comply. In some manufacturing processes, this rear glass is replaced by a metallic or plastic cover.

TECHNOLOGICAL BARRIERS

Availability of high purity prime matters for low-iron glass manufacturing could become a bottleneck in the supply chain.

59. Primary reflection is reduced because the texture increases the chances of the reflected angle leading the light back onto the surface, rather than out to the surrounding air. Secondary reflection (on underlying surfaces) is reduced because the reflected beam likely will find different surface angles in the entrance and exit paths, thus increasing the chances of the reflected angle leading the light back onto the underlying surface.
60. By causing an oblique incident angle on the photoactive surface, texturizing increases the effective path of the light.
61. A thick texture has light-trapping properties due to ray optics, whereas thin textures show interference and polarization effects.

In addition, tolerances are tighter, and the overall process manufacturing quality required is higher than for conventional applications such as automotive or domestic glass.

MAIN COMPETITORS

The following companies have been identified as actual or potential suppliers of Solar glass for PV projects:

- **AGC Solar**: The AGC Group, with the Asahi Glass Company at its core, is a global business group. Its main industries are flat glass, automotive glass, display glass, electronics and energy, and chemicals. The group employs some 50,000 people worldwide and generates annual sales of more than EUR 11,199 million through business in approximately 30 countries.
- **Guardian**: Guardian Industries began in 1932 as Guardian Glass Company, which manufactured windshields for the automotive industry. Today, Guardian Industries Corp. is a diversified global manufacturing company headquartered in Auburn Hills, Michigan. It has leading positions in float glass, fabricated glass products, fiberglass insulation, and other building materials for commercial, residential, and automotive markets. The group declared US$4.9 billion revenues in 2011 and had approximately 17,000 employees (Forbes 2011).
- **Pilkington**: Pilkington is a division of Nippon Sheet Glass Co., Ltd., a Japanese company that is one of the world's largest manufacturers of glass and glazing products for the automotive, architectural and technical glass markets. With approximately 29,500 permanent employees, it has principal operations in 29 countries and sales in over 130 (Nippon Sheet Glass Co., Ltd. 2013).
- **Saint Gobain**: Saint-Gobain S.A. is a multinational corporation founded in 1665 in Paris. Originally a mirror manufacturer, it now also produces a variety of construction and high-performance materials. The solar energy division, Saint-Gobain Solar Power, designs and manufactures mirrors

for CSP. The group, Saint Gobain, declared EUR 2.9 billion in 2012 and has more than 190,000 employees.

- **Schott**: Schott AG is an international technology group with more than 125 years of experience. Its products include components and systems made from specialty glasses and materials. The group declared global sales of EUR 2 billion in 2011/12 and has 16,000 employees worldwide.

LOCATION OF MANUFACTURING FACILITIES

The above-mentioned companies work at a global scale, either through subsidiaries or by means of distribution partnerships with local companies. However, their manufacturing facilities are concentrated in a few countries.

- **AGC Solar**: The AGC Group has 10 manufacturing sites all over the world. Five are dedicated to float glass manufacturing: Dalian in China, Mol and Moustier in Belgium, Rayong in Thailand, and Spring Hill in the U.S. Three sites are dedicated to patterned glass and anti-reflective coating: Manila in Philippines, Roux in Belgium, and Suzhou in China.
- **Guardian**: Guardian Industries has over 100 manufacturing facilities all over the world. Although most of them are in North America, the company has presence in China, India, Japan, Thailand, Egypt, Saudi Arabia, UAE, South Africa, Argentina, Brazil, Colombia, Costa Rica, Venezuela, and several European countries.
- **Pilkington**: Pilkington has manufacturing facilities in over 30 countries. They include Argentina, Brazil, Canada, Chile, Colombia, Dominican Republic, Mexico, Uruguay, United States, Venezuela, Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Spain, Sweden, Switzerland, United Kingdom, Kuwait, Seychelles, UAE, China, India, Japan, Malaysia and Vietnam (Pilkington 2013).
- **Saint Gobain**: Saint Gobain S.A. has 11 manufacturing facilities dedicated to solar glass manufacturing, in Australia, Belgium, Canada, China, France, Italy, Luxembourg, Sweden, United Kingdom, and United States (Saint Gobain Solar Power 2011).
- **Schott**: Schott AG has over 60 manufacturing facilities worldwide. One, Schott Solar AG in Mainz, Germany, is dedicated to solar glass manufacturing (Schott AG 2013).

Appendix 4 | Industry on Kom Ombo

Introduction

Egypt has shown interest in developing solar energy to contribute to the national energy mix while avoiding CO_2 emissions.

A concentrated solar power (CSP) plant expected to be constructed is Kom Ombo. To enhance the contribution of Egypt's local industries, an assessment of the expected equipment that can be manufactured in Egypt was made. This assessment included:

- Identification of components that could be manufactured in Egypt
- Definition of quantities required for Kom Ombo project
- Expected costs of equipment in current manufacturing facilities and Egypt
- Expected savings and percent of equipment supplied by Egyptian industry.

Key Assumptions

LOCAL COMPONENTS

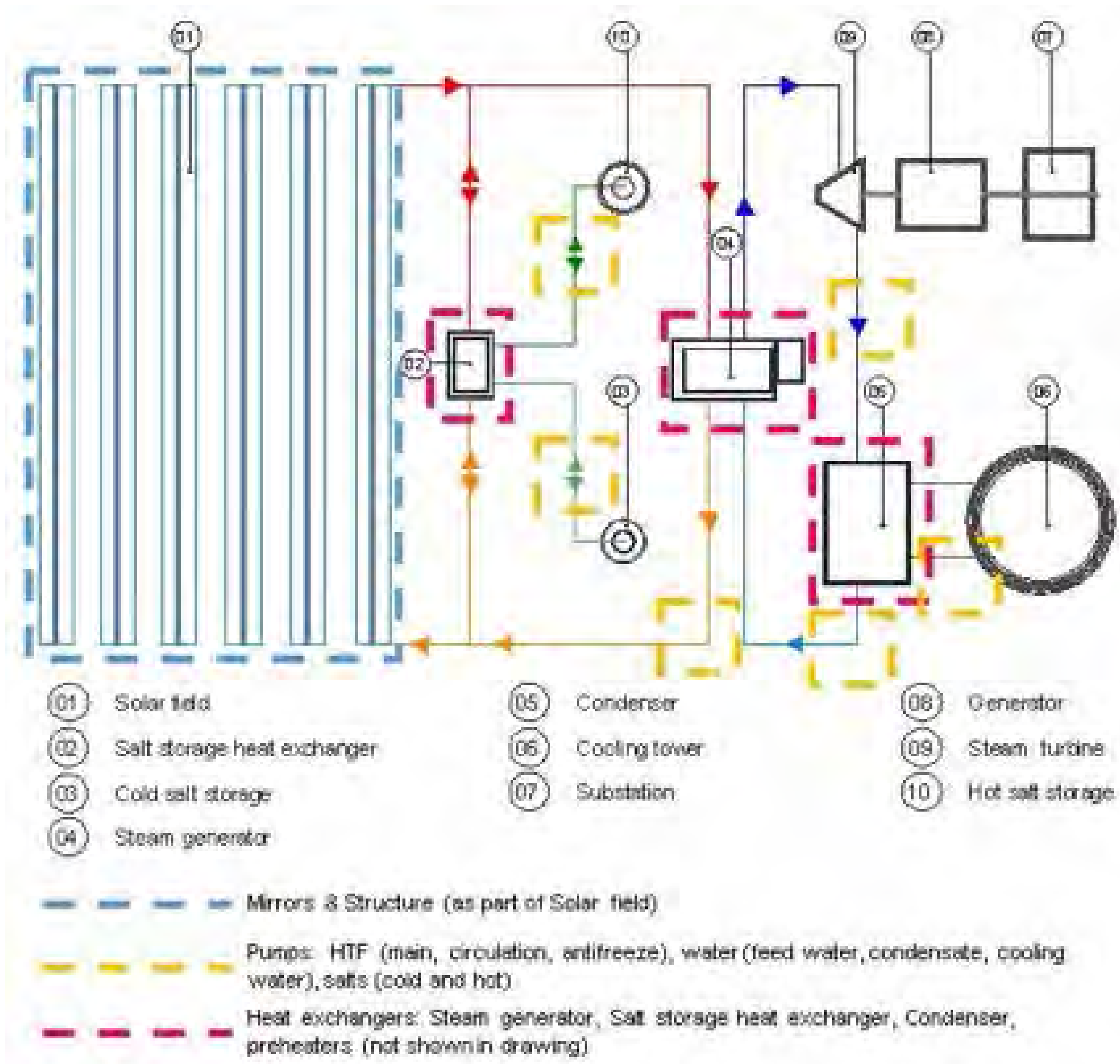
The local components study is focused only on specialized components required to install CSP power plants. General equipment such as balance of plant (BOP), buildings, and common services are not included in the study.

According to previous works developed by the consortium STA-Accenture, the following components could be manufactured in Egypt:

- CSP structure: Withstanding structure of solar collectors.
- CSP mirrors: Reflectors to be installed in the Parabolic Trough collectors.
- Pumps, including:
  - Heat transfer fluid (HTF) pumps in the Solar Field
  - Molten salts pumps in the molten salts storage tanks
  - Feed water pumps: Main water pumps that increase water pressure up to 100 bar and located at the output of deaerator
  - Auxiliary pumps (such as condensate pumps).
- Heat exchangers, including:
  - Steam generation systems (SGS), in which the HTF transfers the heat to the water to obtain steam at 390ºC and 100 bar
  - Molten salts heat exchangers, used to charge (heat molten salts with HTF) or discharge (heat HTF with molten salts) the storage system
  - Condenser
  - HP and LP preheaters used to heat cold feed water (≈50 ºC) from the condenser output to the inlet of the steam generation system (≈230 ºC) in several stages.

The elements included in this study are shown in Figure A4.1.

Figure A4.1 | Plant Diagram Showing Location of Main Equipment That Could Be Supplied by Egypt's Local Industry



KOM OMBO PROJECT

The main characteristics of Kom Ombo project follow:

Technology:	CSP with Parabolic Trough collectors
Thermal storage:	7.5h
Expected power:	100 MW.

Components required for Kom Ombo project

As a reference scenario, the cost of installing a 50MW CSP-Parabolic Trough plant in Europe was considered. To obtain component requirements, the same plant was scaled up to align with Kom Ombo's expected power and storage. These European data are the main data required to forecast the costs of the Kom Ombo project:

Total mirror surface:	1,000,000	m^2
Total structure weight:	20,400,000	kg

Total thermal power required in heat exchangers:

	760	MWth

Total electrical power required by pumps:

	15	MWe.

MODEL ASSUMPTIONS

To evaluate the expected impact on the component costs, the model developed during preparation of the present report, "Local Manufacturing Potential for Solar Technology Components in Egypt," carried out for the World Bank has been used.

The model estimates the equipment manufacturing costs in Egypt plus profit. The model is later compared to the sales price in OECD countries.[62] The main assumptions made in the model were:

- Total investment costs for factory installations are the same in OECD countries as in Egypt.
- Typical factory size has been used for each industry. This size has been defined according to the maximum installed electrical power of CSP plants that a factory can supply per year[63]:

Mirrors:	250	MW/year
Pumps:	400	MW/year
Heat exchangers:	50	MW/year.

The amortization period of factory installations is 5 years; the loan corresponds to 70 percent of required investment costs; and the interest rate is 13 percent.

The output of the model is the expected cost per unit of production:

Mirrors:	US$/m2
Structure:	US$/kg
Pumps:	US$/MWe
Heat exchangers:	US$/MWth.

MODEL RESULTS

The model outputs according to the assumptions follow (Table A5.1):

62. The model is calibrated using the reference sales price in the OECD.
63. For example: One mirror factory could supply mirrors to 3 CSP plants such as Kom Ombo (3x100 MW). One pump factory could supply pumps to 4 CSP plants such as Kom Ombo (4x100 MW). Two heat exchanger factories would be required to provide heat exchangers to 1 Kom Ombo power plant (0.5x100 MW).

TABLE 80 | SALES PRICE COMPARISON IN MIRROR INDUSTRY

Mirrors	Units	International Estimated Market Price	EGYPT
Requirements	m^2	1,000,000.00	
Cost	$\$/m^2$	$30.00	$19.41
Total*		$30,000,000.00	$19,407,073.00
Expected Savings		$10,592,926.12	

TABLE 81 | SALES PRICE COMPARISON IN STRUCTURE INDUSTRY

Mirrors	Units	International Estimated Market Price	EGYPT
Requirements	Kg	20,400,000.00	
Cost	$/kg	$2.50	$2.39
Total*		$51,000,000.00	$48,693,652.62
Expected Savings		$2,306,347.38	

TABLE 82 | SALES PRICE COMPARISON IN HEAT EXCHANGER INDUSTRY

Mirrors	Units	International Estimated Market Price	EGYPT
Requirements	Mwe	15,00	
Cost	US$/Mwe	$483,333.33	$404,625.59
Total*		$7,250,000.00	$6,069,383.86
Expected Savings		$1,180,616.14	

TABLE 83 | SALES PRICE COMPARISON IN PUMPS INDUSTRY

Mirrors	Units	International Estimated Market Price	EGYPT
Requirements	MWth	760,00	
Cost	$/ MWth	$22,500.00	$13,947.82
Total*		$17,100,000.00	$10,600,345.36
Expected Savings		$6,499,654.64	

As a result, the expected savings account for approximately US$20,500,000.

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