The World Bank

Middle East and North Africa Region
Assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects

January 2011

Authors of the report:

Ernst & Young et Associés:
Alexis Gazzo, Pierre Gousseland, Jérôme Verdier
Contact person: Alexis Gazzo (alexis.gazzo@fr.ey.com)

Fraunhofer Institute for Solar Energy Systems ISE:
Christoph Kost, Gabriel Morin, Maximilian Engelken, Julian Schrof, Peter Nitz, Jens Selt, Werner Platzer
Contact person: Christoph Kost (christoph.kost@ise.fraunhofer.de)

Fraunhofer Institute for Systems and Innovation Research ISI:
Mario Ragwitz, Inga Boie, Dorothea Hauptstock, Wolfgang Eichhammer
Contact person: Mario Ragwitz (mario.ragwitz@isi.fraunhofer.de)

World Bank contact persons:

Chandrasekar Govindarajalu (cgovindarajalu@worldbank.org)
Philippe Roos (proos@worldbank.org)
Fowzia Hassan (fhassan2@worldbank.org)

Table of contents

Acronyms

AfDB	African Development Bank
BOT/BOO	Build-Own-Transfer, Build-Own-Operate (Business Model/Role in power plant business)
CSP	Concentrated Solar Power
CTF	Clean Technology Fund
DNI	Direct Normal Irradiance
DSG	Direct Steam Generation
EPC	Engineering, Procurement and Construction
GDP	Gross Domestic Product
GEF	Global Environment Facility
HCE	Heat Collecting Elements (Receiver of Parabolic Trough Power Plant)
HTF	Heat-transfer-fluid
ISCCS	Integrated Solar Combined Cycle Systems
JEDI	Jobs and Economic Development Impact
LCOE	Levelized Cost of Electricity
LFC	Linear Fresnel Collector
MDBs	Multilateral Development Banks
MENA	Middle East and North Africa
MENA CSP IP	MENA CSP Scale-up Investment Plan
MENA CTF country	MENA country that submitted projects for CTF funding (Algeria, Egypt, Morocco, Jordan, Tunisia)
MW_{el} / MW_e	Mega-Watt electric (used for indicating plant capacity)
MWh_{th}/ MM_t	Mega-Watt thermal (usually solar field thermal power)
NREA	Egyptian New and Renewable Energy Authority
NREL	New Renewable Energy Laboratories
O&M	Operation and Maintenance
PV	Photovoltaic
PPA	Power Purchase Agreement
PTC	Parabolic Trough Collector
SCA	Solar collector assembly
SCE	Solar Collector Element (one module of parabolic trough collector)
SEGS	Solar Electric Generating System
SWOT	Strengths, Weaknesses, Opportunities, Threats
TES	Thermal Energy Storage
UNFCCC	United Nations Framework Convention on Climate Change

Foreword

The Middle East & North Africa (MENA) region has amongst the world's best conditions for concentrated solar power (CSP): abundant sunshine, low precipitation, plenty of unused flat land close to road networks and transmission grids. It is also close to Europe, where green electricity is much valued.

However, high initial capital costs remain a significant issue for adoption of CSP technology. To make CSP projects in MENA cost effective in the short to medium term, a combination of factors is necessary, including local incentives, concessional finance and export of green electricity to Europe. The MENA CSP scale-up Investment Plan (MENA CSP IP), supported by the World Bank and the African Development Bank (AfDB), is intended to strategically utilize concessional financing from the Clean Technology Fund (CTF) to accelerate global adoption of the technology in the region. It was endorsed by the CTF Trust Fund Committee on December 2, 2009, and will support expansion programs in five countries of the MENA region, Algeria, Egypt, Jordan, Morocco and Tunisia.

In the longer term, to make concessional finance less critical, generation costs will need to be dramatically lower. This implies that investment costs, and therefore manufacturing costs of the main components and systems, need to decrease. It will be made possible by a combination of technical innovation, economies of scale, and experience curve effect. The potential for such cost decrease is considerable, as CSP is a young industry, with a limited number of large or experienced players. MENA, like other emerging regions of the world, has technical and industrial capabilities which are likely to form a good basis on which to build CSP-related activities, as shown for example by the strong auto parts industry in several countries of the region. It could become home to a new, high potential industry, serving the local markets, as well as existing markets in Southern Europe, in the US and elsewhere. The region could benefit from significant job and wealth creation, while the world energy sector would benefit from increased competition and lower costs in CSP equipment manufacturing.

To assess the local manufacturing potential for CSP components in the MENA region, a study was commissioned by the World Bank with donor support from the Energy Sector Management Assistance Program (ESMAP). It was carried out during the year 2010 by Ernst & Young (France) and the Fraunhofer Institute (Germany). A stakeholder workshop was conducted on September 30th, 2010, in Cairo, and feedback was received from the client countries, industry participants and donors. The AfDB and World Bank teams actively participated in the review and finalization of the study.

Executive Summary

Concentrated Solar Power (CSP) is a renewable energy technology which, after a period of stagnation, has started to penetrate the energy market, particularly in Spain and the United States but also in the Middle East and North Africa Region (MENA) as well as other regions of the world. To run CSP projects in MENA competitively in the short and medium term, a portfolio of different support schemes for CSP plants is necessary, including climate finance and concessional loans, revenues from solar electricity exports to Europe, and national incentives (like long-term power purchase agreements (PPA), feed-in tariffs, or tax rebates).

As a concrete step toward realizing these strategies, a "MENA CSP scale-up Investment Plan" (MENA CSP IP) was prepared by the World Bank and the African Development Bank (AfDB), and endorsed by the Clean Technology Fund (CTF) Trust Fund Committee on December 2, 2009. This plan is a landmark climate change mitigation program aimed at co-financing nine commercial-scale power plants (totaling around 1.2 GW) and two strategic transmission projects in five countries of the MENA Region (Algeria, Egypt, Jordan, Morocco and Tunisia, called the "MENA CTF" countries in the rest of this report). The vision is for the Mediterranean MENA countries ultimately to become major suppliers and consumers of CSP-generated electricity. The MENA CSP IP is conceived as a transformational program, leading to the installation of at least 5 GW of CSP capacity in MENA by 2020, based on the 1.2 GW triggered by the MENA CSP IP. The first projects are expected to start commercial operations by 2014, and initially to supply domestic markets in MENA countries.

MENA could become home to a new industry with great potential in a region with considerable solar energy resources. If the CSP market increases rapidly in the next few years, the region could benefit from significant job and wealth creation, as well as from enough power supply to satisfy the growing demand, while the world's renewable energy sector would benefit from increased competition and lower costs in CSP equipment manufacturing.

The transformational opportunity from local manufacturing of CSP in MENA countries could benefit from the following interrelated factors:

- MENA CSP is well placed to benefit from the massive scale-up of concessional climate financing envisaged under the United Nations Framework Convention on Climate Change (UNFCCC), and recently reaffirmed at the Copenhagen and Cancun conferences. The CTF allocation for the MENA CSP IP could be the seed money for financing a more ambitious scale-up. CSP in MENA and other regions could benefit from the recent Cancun agreements in 2010 which have opened the way for a much larger funding framework. The climate conference of Cancun agreed on a Green Climate Fund of $100bn a year of climate funding from 2020 onwards that will be generated from a "wide variety of sources, public and private, bilateral and multilateral, including alternative sources." This could include a range of mechanisms such as auctioning carbon credits and levies on international aviation and shipping.
- MENA CSP is central to the high-level political agreement between MENA and the European Union to make solar energy trade a fundamental pillar of MENA-EU economic integration, and it therefore presents a major opportunity for MENA to earn export revenue. MENA CSP could be key to realizing the EU's GHG emissions reduction and energy security objectives. The April 2009 EU Renewable Energy Directive, with its provisions for the import of renewable energy to achieve the mandatory renewable energy targets of EU member states, is a first step in that process, as are the Desertec Industry Initiative and the Transgreen/Medgrid Initiative. The political initiative of the Mediterranean Solar Plan may act as an umbrella for initiatives such as Desertec at a bilateral level.
- MENA's oil-producing countries are embarking on CSP investment programs to liberate oil and gas from the power sector for higher value-added uses and exports, and in the longer term for CSP energy export.

The combination of these factors could uniquely advantage MENA as a global location of choice for CSP production and, while creating demand for installed capacity, could strongly drive local manufacturing.

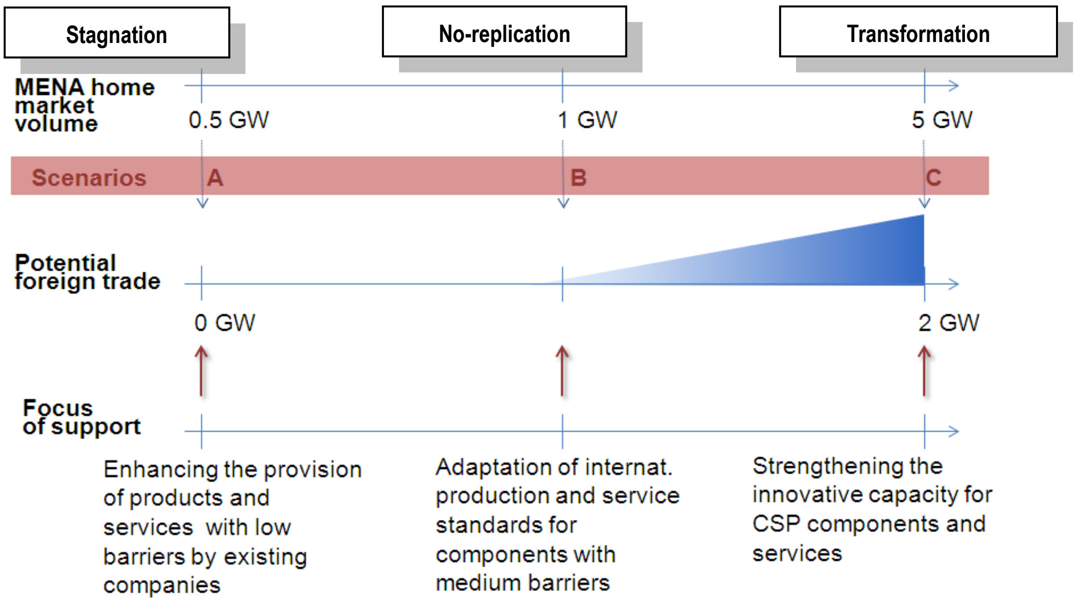
The analysis provided in this report is based on the assumption that the volume of the installed CSP capacity within the MENA region is a main precondition for the emergence of local manufacturing. The opportunity for local manufacturing of different components in the value chain depends on scenarios that represent critical levels of market development. The market volume is described for the five MENA CTF countries investigated in detail in this study in the form of three scenarios (figure ES-1). For the MENA region as a whole it can be assumed that the market volume could be twice as large as in the MENA CTF countries alone.

Scenario A—Stagnation: The home market volume of the five MENA CTF countries amounts to 0.5 GW only. Strong obstacles to local manufacturing of CSP components remain in MENA countries and most components, particularly those whose production requires high investment costs, are imported from more advanced markets. This scenario implies an incomplete realization of the MENA CSP IP.

Scenario B—No-replication: The home market volume of the five MENA CTF countries amounts to 1 GW in 2020, which is strictly the MENA CSP IP target without any significant replication effect. In this scenario, the market offers some opportunities for the development of local manufacturing of CSP components and provision of CSP services.

Scenario C—Transformation: This scenario implies the full success of the MENA CSP IP, and the development of a strong local manufacturing industry, with 5 GW of CSP by 2020 in the MENA CTF countries, as well as 2 GW worth of exported components. Such a scenario may materialize under favorable conditions only. A more conservative level of installed power may be found somewhere between the "no-replication" scenario and the "transformation" scenario; the purpose here was to estimate a range rather than to come up with a precise figure for how many GW out of the 5+2 underlying this scenario will be realized by 2020.

Figure ES-1 Market scenario context for the analysis of local manufacturing opportunities



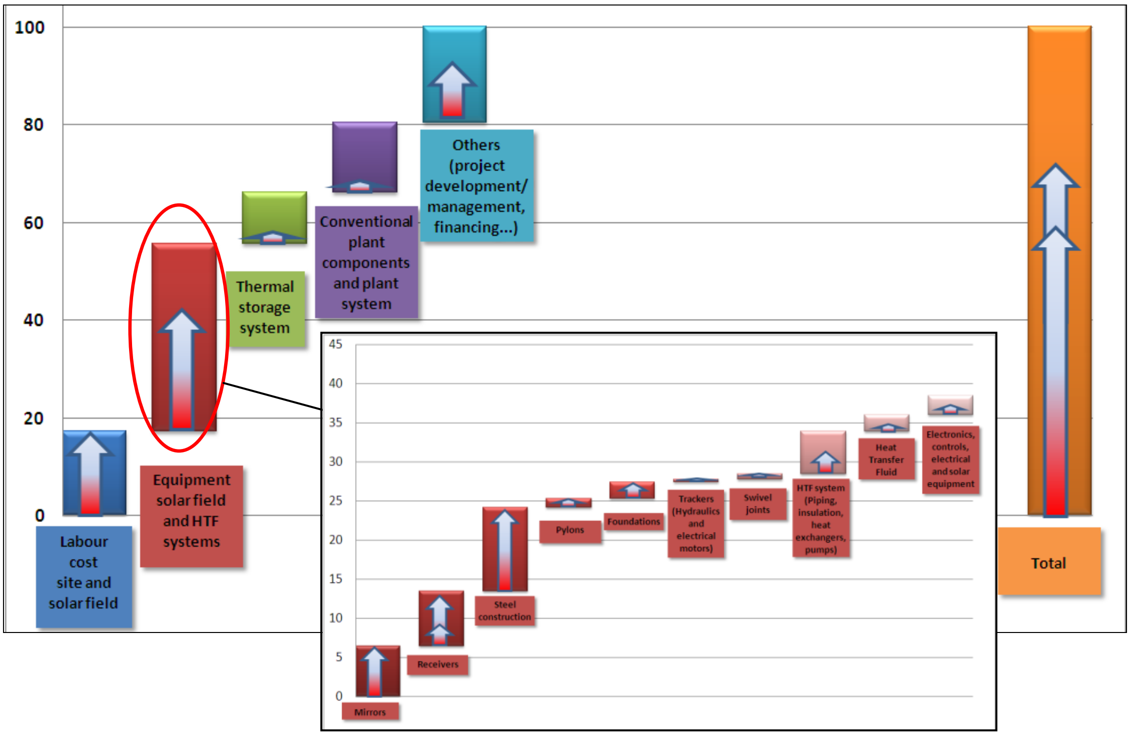
Source: Authors

In the framework of these scenarios, the report provides answers to four main questions:

1. **Which parts of the value chain of CSP technologies are suitable for local manufacturing and how do international companies that are active along the value chain perceive such an opportunity?** The main CSP technology manufacturers are already involved in three ongoing CSP projects in the region (Morocco, Algeria, and Egypt). Given their strategies and interests, it is likely that these manufacturers will also participate in future MENA CSP markets. Depending on the market size in MENA countries, these companies show substantial interest in building up manufacturing capacities in the region. This report analyzes the complexity and required technological knowledge for manufacturing the main CSP components in light of their production and manufacturing processes. Key components and services, as well as secondary components, were identified for local manufacturing under favorable conditions (figure ES-2).

   In addition to construction and civil works, most components could be manufactured locally, starting with mounting structures and non-CSP-specific elements such as piping, then adding mirrors and possibly float glass; local production of receivers will take more time to develop. In combination with an evaluation of CSP costs, this analysis provided the background for further assessment.

Figure ES-2 Local manufacturing shares by component (total plant and solar field) achievable by MENA countries within a decade



Source: Authors

Note: represents percent of total investment of a typical CSP plant of 50 MW; the arrows indicate estimations of the attainable local shares per component

2. **Are industries already located in MENA suitable for local manufacturing of CSP components and the provision of CSP-related services?** To answer this question, all relevant industries were analyzed. Regardless of the obstacles identified to participation of local MENA industries, expert interviews with MENA companies and with the existing CSP industry showed an increasing potential for local manufacturing of components for CSP, if the CSP market grows continuously in MENA.

   The participation of local firms in the provision of construction and engineering services for new CSP plants in the MENA region has been identified as an activity with promising prospects in the future. Several industrial sectors that have the potential to integrate the CSP value chain in the MENA region are dynamic and competitive at a regional, and sometimes at an international, level. The success of these industries is facilitated by the development of joint ventures between large international companies and local firms, but also by the local implementation of subsidiaries of international players. In the past, the development of MENA CTF industries was driven by the low cost of labor and energy, and also by the geographic proximity to Europe. The landscape is already changing; pure subcontracting is now shifting toward more local R&D and the production of high-tech components. The shift toward higher technology content will require increased international cooperation. **MENA CTF countries are aiming to be considered as "centers of excellence" instead of low-cost and low-skilled workshops.**

3. **How can the potential of industries for local manufacturing of CSP components be encouraged by stimulation measures?** To answer this question, this report presents roadmaps and action plans for the key components and services of the CSP value chain. The success of the MENA CSP IP will be very important to realizing this potential. Unless this initiative reaches its goal of at least 1 GW CSP in the region by 2020, local manufacturing is unlikely to proceed at a rapid pace. However, the initiative alone will not be sufficient. Technological, entrepreneurial, policy, and market developments, which are crucial for the establishment of local manufacturing in MENA, must be driven by national strategies.

National strategies for industrial development and energy policy should be well coordinated and involve, in addition to clear targets for the market diffusion of CSP, substantial R&D efforts, the creation of strategy funds for industrial development of CSP industry sectors, and stronger regional integration of policies. To enhance the innovative capacity of the industrial sectors, more technology parks/clusters and regional innovation platforms should be created. This would particularly help small and medium-sized firms to overcome innovation barriers and to gain access to the latest technological advances.

Business models should build on the comparative advantages of certain industrial sectors in MENA countries and also involve international cooperation agreements, e.g. in the form of joint ventures and licensing. In the case of receivers, subsidiaries of foreign companies will most likely be a relevant business model at the beginning. The investment in new production lines based on highly automated processes for the mounting structure and in white glass production as well as an adaption of techniques for coating and bending mirrors will be the crucial first step.

In order to invest in such developments, market actors will need good access to CSP-related information and certainty about the market development. Technical feasibility studies regarding production line upgrades could be an important element to assist enterprises. Furthermore, the creation of a regional CSP or renewable energy association dealing with issues such as the CSP market development, manufacturing options and the latest technological advances might be an essential element in this respect. Entering local manufacturing will involve comprehensive education and training programs for the industrial workforce in relevant sectors. Universities should be encouraged to teach CSP-technology-based courses to educate potential workforces, particularly engineers and other technical graduates related to the CSP branch.

4. **What are the potential benefits to the MENA CTF countries of local manufacturing of CSP components and the provision of CSP-related services?** To assess the potential benefits of a steady growth of the CSP market in MENA, a dynamic economic modeling approach was used to determine the impact on economic value creation, foreign trade, and job creation. The model considers a continuous local market, based on the three different growth scenarios described above. In the different market scenarios, the share of local manufacturing was dynamically modeled with respect to the required market size and the continuous growth of local technical know-how. **It is shown that MENA countries would obtain large economic and social benefits from a steady CSP market growth.**

   The technical know-how in renewable energy technologies would increase with a growth in the CSP market, which would induce further positive effects including significant job creation. In the transformation scenario, the total potential of the local manufactured added value of CSP plants could reach almost 60 percent of the value chain by 2020, and a total local economic impact of US$14.3 billion was identified (additional industrial value added). In scenario C in 2025 the number of permanent local jobs could rise to between 64,000 and 79,000 (45,000 to 60,000 jobs in the construction and manufacturing sector plus 19,000 jobs in operation and maintenance). Looking only to the time horizon of the CTF projects (2020), in total 34,000 employees might be working in the CSP industry permanently. In contrast, in scenario B a permanent workforce of 4,500 to 6,000 local employees is in place by 2020. This shows that jobs created in the construction and maintenance of CSP plants and local manufacturing of components are interlinked. **Large economic benefits for MENA countries could also be created by growing export opportunities for components related to a developing CSP market (over US$3 billion by 2020 for exported components equivalent to 2 GW).**

Report Summary

The need for a Concentrated Solar Power (CSP) home base in MENA countries

Concentrated Solar Power (CSP) is a renewable energy technology which, after a period of stagnation, has started to penetrate the energy market, particularly in Spain and the United States, but also in the Middle East and North Africa Region (MENA) as well as other regions of the world. To run CSP projects in MENA competitively in the short and medium term, a portfolio of different support schemes for CSP plants is necessary, including climate finance and concessional loans, revenues of solar electricity exports to Europe, and national incentives (including long-term power purchase agreements (PPA), feed-in tariffs or tax rebates).

As a concrete step toward realizing these strategies, a “MENA CSP scale-up Investment Plan” (MENA CSP IP) was prepared by the World Bank and the African Development Bank (AfDB), and was endorsed by the Clean Technology Fund (CTF) Trust Fund Committee on December 2, 2009. It is a landmark climate change mitigation program aiming to co-finance nine commercial-scale power plants (totaling around 1.2 GW) and two strategic transmission projects in five countries of the MENA region (Algeria, Egypt, Jordan, Morocco and Tunisia, called the “MENA CTF” countries in the rest of this report). The total cost of the MENA CSP IP is US$5.6 billion, of which the CTF will provide co-financing of US$750 million. The vision is for the Mediterranean MENA countries ultimately to become major suppliers and consumers of CSP-generated electricity. The MENA CSP IP is conceived as a transformational program, aimed at overcoming market and technical barriers, in order to offer the CSP industry a credible commitment that allows them to develop a large scale, multi-country portfolio of projects. It is intended to stimulate the installation of at least 5 GW of CSP capacity in MENA by 2020 based on the 1.2 GW triggered by the MENA CSP IP. The first projects are expected to start commercial operations by 2014, and initially to supply domestic markets in MENA countries.

MENA could become home to a new industry with great potential in a region with considerable solar energy resources. If the CSP market increases rapidly in the next few years, the region could benefit from significant job and wealth creation as well as from sufficient power supply to satisfy the growing demand, while the world’s renewable energy sector would benefit from increased competition and lower costs in CSP equipment manufacturing.

There are several transformational opportunities for local manufacturing in MENA countries:

- MENA CSP is well placed to benefit from the massive scale-up of concessional climate financing envisaged under the United Nations Framework Convention on Climate Change (UNFCCC), and recently reaffirmed at the Copenhagen and Cancun conferences. The CTF allocation for MENA CSP could be the seed money for financing a more ambitious scale-up. CSP in MENA and other regions could benefit from the recent Cancun agreements in 2010 which have opened the way for a much larger funding framework. The Cancun climate conference agreed on a Green Climate Fund of $100 billion a year of climate funding from 2020 onwards that will be generated from a "wide variety of sources, public and private, bilateral and multilateral, including alternative sources." This could include a range of mechanisms such as auctioning carbon credits and levies on international aviation and shipping.
- MENA CSP is central to the high-level political agreement between MENA and the European Union to make solar energy trade a fundamental pillar of MENA-EU economic integration, and it therefore presents a major opportunity for MENA to earn export revenue. MENA CSP could be key to realizing the EU's GHG emissions reduction and energy security objectives. The April 2009 EU Renewable Energy Directive, with its provisions for the import of renewable energy to achieve the mandatory renewable energy targets of EU member states, is a first step in that process, as are the Desertec Industry Initiative and the Transgreen/Medgrid Initiative. The political initiative of the Mediterranean Solar Plan may act as an umbrella for initiatives such as Desertec at a bilateral level.
- MENA's oil-producing countries are embarking on CSP investment programs to liberate oil and gas from the power sector for higher value-added uses and exports, and in the longer term for CSP energy export.

These factors could uniquely advantage MENA as a global location of choice for CSP production and could strongly drive local manufacturing while creating demand for installed capacity. [1]

The main objectives of this study are:

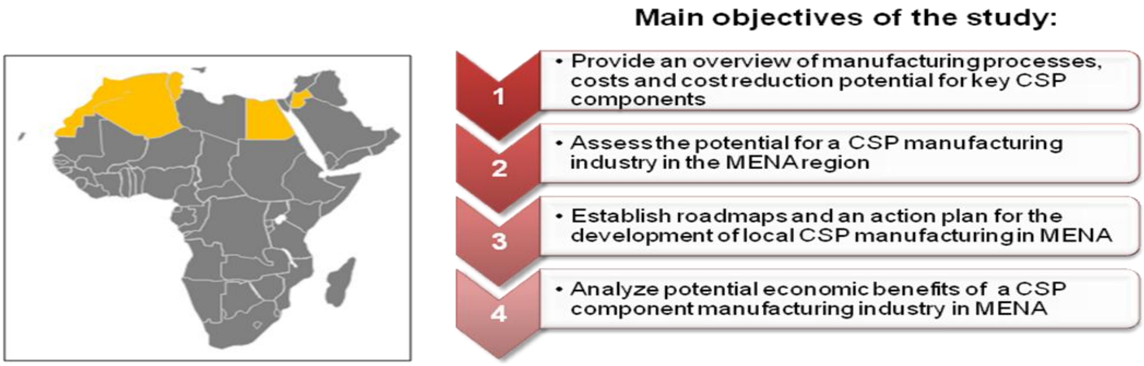
- to provide an overview of manufacturing processes for key CSP components as well as a cost analysis for CSP components and systems, and for CSP plants as a whole, including the potential for cost reduction
- to further assess the potential in the MENA region for building and developing a CSP component and equipment manufacturing industry, focusing on the five MENA CTF countries, but with a broader view to the MENA region
- to propose roadmaps and an action plan to help develop the potential of locally manufactured CSP components in the existing industry and for new market entrants

---

[1] The term “local manufacturing“ comprises both local industries and subsidiaries of international players established in a country to produce locally.

- to analyze potential economic benefits of developing a CSP component manufacturing industry and CSP manufacturing at the construction site of new CSP plants

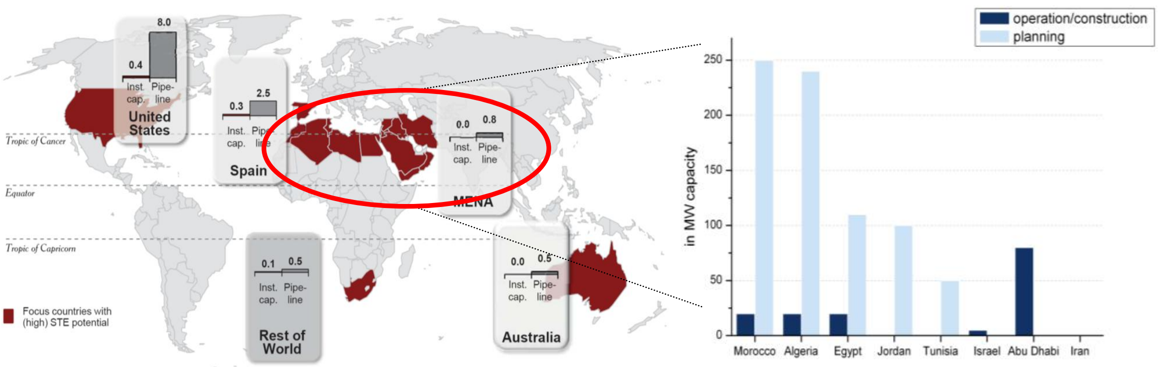
Figure S-1 Main Objectives of the Study



The CSP market environment: Positive trend

After twenty years of operation in the Solar Electric Generating System (SEGS) plants in California, the worldwide market growth of renewable energies gave CSP technology a new outlook in countries with high direct radiation. Beginning with the Spanish and US electricity markets, many projects are now under development. Electricity-producing CSP plants doubled their capacity with new installations since 2007; by the middle of 2010, a total of over 800 MW of CSP plants were in operation. Although the United States and Spain strongly dominate the CSP market, national support incentives for CSP has caused the market to boom over the past few years. Australia and countries in MENA and Asia are developing their first projects.

Figure S-2 a) Global CSP capacity existing by mid-2010 and projected through 2015
b) MENA CSP capacity: projects under operation[2]/construction and in planning phase[3]



Source: Estela, 2010

The MENA CSP IP and its co-financing by the CTF play a vital role in stimulating CSP plans in the MENA region. Table S-1 shows the CSP projects in the MENA CSP IP pipeline as of October 2010. In total, for the five MENA CTF countries considered in this study, nearly 1.2 GW of CSP power plants are expected to be developed in the coming years.**Error! Bookmark not defined.**

---

[2] The CSP operational power tends to change quite rapidly, especially in Spain and the US: Protermosolar provided in December 2010 the following figures: Spain Total operational 674 MW (Tower: 21 MW, Parabolic Trough 13x50 MW=650 MW, Fresnel+Stirling 3 MW), USA 505 MW(Parabolic Trough 354 + 64 + 75 MW = 493 MW, Fresnel + Stirling 7 MW, Tower 5 MW).

[3] Higher figures have been forwarded in some MENA countries, e.g. 2000 MW in Morocco. This figure only includes planned plants which are sufficiently well documented, e.g. through calls for tender. Also, frequently it is not clear how large the CSP share in those plans could be.

Table S-1 Planned projects for MENA CSP IP

Country	Project (Name)	Capacity (MW)	CTF financing (US$ million)
Algeria	Megahir	80	
	Naama	70	
	Hassi R'mel II	70	
Egypt	Kom Ombo	100	
Jordan	Ma'an	100	
	Mashreq CSP transmission	-	
Morocco	Ouarzazate	500	
Tunisia	IPP-CSP	100	
	ELMED-CSP	100+	
	STEG-CSP	50	
	Tunisia-Italy transmission	-	
Total		**~ 1,170**	**750**

Source: The World Bank

Status of CSP technology: Diverse solutions, significant cost reduction potential

Since parabolic trough plants have become commercially bankable, the highest share of announced new projects worldwide (up to 9,000 MW) uses this technology. The focus throughout this study is therefore on parabolic trough plants. Some projects using central receivers with high solar towers are also under development, mainly in the United States. Dish engines still have some cost disadvantages, but US developers hope to overcome this by mass production and thousands of single installations in a large area (total capacity 800-1,000 MW). Although Fresnel technology has the same solar field design, but its mirrors have lower production costs, this technology still lags in volumes of announced projects (the first 30 MW plant in the south of Spain will create commercial experience). Due to considerable advances in all four types of CSP technologies, calls for tenders should promote all technologies that match minimum requirements (including experience with the technology). This will allow innovative and cost-efficient technologies to prove their potential, will bring down the cost of CSP, and will help to materialize more CSP capacity with a given amount of financing. Most findings are also applicable to all CSP technologies, because the working principles, the materials, and the production processes do not vary significantly. Most trough, Fresnel, tower (and partially dish) technologies consist of steel structures, glass mirrors, and absorber tubes using a sputtered selective coating. All systems track the sun, have high optical/geometric accuracy requirements, use relatively high-temperature materials and processes, and have electric generators that need to be coupled to the electric grid. Hence:

- **processes and components serving different technologies will be most relevant to local manufacturing concerns;**
- **and newer technologies such as Fresnel may offer opportunities for local innovators to enter the market where international players are still less well positioned.**

Table S-2 Current CSP projects in the world market

[MW]	Operational Error! Bookmark not defined.	Under construction	Planning phase[4]	Total
Tower	44	17	1,603	1,664
Parabolic	778	1,400	8,144	10,322
Fresnel	9	30	134	173
Dish & Stirling	2	1	2,247	2,250
Total	833	1,448	12,128	14,409

Source: Sun & Wind Energy 2010

A recent study carried out by the European CSP industry association Estela and by AT Kearney (Estela, 2010) analyzed the latest cost reduction potential by interviewing the existing CSP industries regarding technology improvements and effects of economies of scale. The results are shown in table S-3. Overall the levelized cost of electricity (LCOE) could decrease by 45–60 percent by 2025 according to AT Kearney. Economies of scale, efficiency increases, and technology improvements are the main drivers for this development. Many factors will contribute to these total technology and cost improvements by values of 15 to 25 percent including:

- **an increasing number of plants being built in sustainable and reliable markets,**
- **competitive market mechanisms, including established and innovative CSP technologies**
- **further research and development.**
- **On average, the expected annual cost decrease is about 3–4 percent—placing CSP between wind energy (with expected cost decreases of about 2 percent a year) and photovoltaic (PV) (with a cost reduction path exceeding 10 percent annually).**

---

[4] Planning phase: Projects are announced by project developers or owners. Pre-engineering is taking place, but real construction and all administrational authorizations have not been finalized yet.

Table S-3   Potential reductions in levelized cost of electricity to 2025

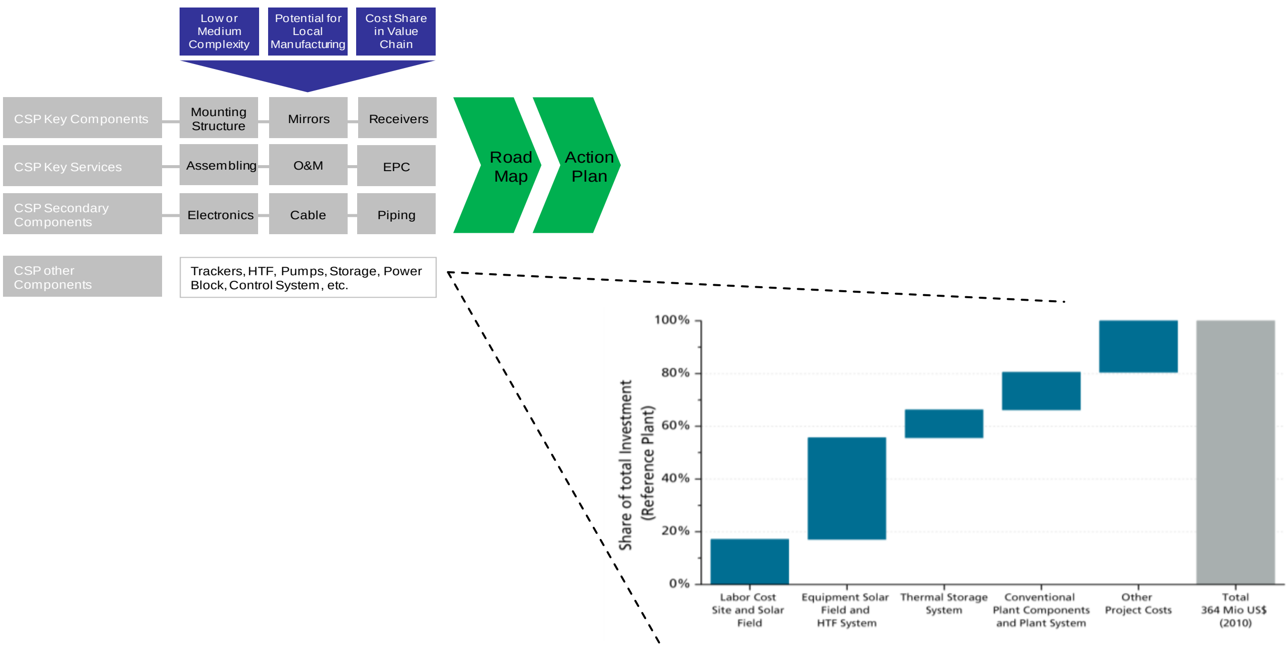
	Reduction in total plant Levelized Cost of Electricity LCOE (2025)			**45-60%**		
	Economies of scale			21-33%		
	Efficiency increase			10-15%		
	Technology improvements			18-22%		
Technology improvements	Mirrors parabolic	Mirrors flat	Receivers	Steel structure	Storage tank	Molten salt
2020	25%	25%	25%	30%	20%	15%

Source: Estela 2010

The CSP value chain

An evaluation of the MENA region's potential for developing a home base for CSP requires a detailed analysis of the CSP value chain: the technologies and services, the production processes, and the main industrial players. It is further important to review the cost of CSP and the contributions from individual components of the CSP value chain. Based on the complexity level and the potential for local manufacturing, as well as the share of added value in the CSP value chain, a number of key components and services can be identified that are most promising: key components include mounting structures, mirrors, and receivers, and key services range from assembling and engineering, procurement and construction (EPC) to operation and maintenance (O&M). Single countries of the MENA region have already developed some production capabilities of secondary components—including electronics, cables and piping—which might contribute to the local supply of future CSP projects, although their share in the overall value chain might be of minor importance. Figure S-3 shows the different components and services linked to the production and use of CSP, and their shares in the value chain.

Figure S-3   Main CSP components and services and their share in the value chain



Source: Kistner 2009, Nava 2009, Schnatbaum 2009,VoteSolar 2009

Note: Investment cost data based on estimated investment cost of an Andasol-like power plant with a rated power of 50 MWel, a thermal storage capacity of 7.5 hours and a solar field size of 510 thousand m^2

The components of the solar field are the most capital-intensive and constitute the largest part of the value chain (38.5%). The price of a collector is mainly determined by the cost of the receiver (7.1%), the reflector (6.4%) and the metal support structure (10.7%), but solar field piping (5.4%) and HTF (2.1%) also involve considerable investment. To install these components and build the whole power plant, it is necessary to employ a staff of about 500 people, based on Andasol 1, while more advanced technologies rely on fewer workers. The majority of the workforce is blue collar workers who assemble the collectors and perform grounds and construction work of general building infrastructure. Further, logistic experts need to provide the whole transport system, which must be resistant to bottlenecks which are a cost multiplier in the work flow. Overall management is provided by experienced specialists, to ensure on-time and cost-efficient planning. Labor constitutes about 17 percent of costs. If storage is included, 10 percent of total investment is due to this system. The relative contribution of other costs is also affected by storage because a storage plant is usually equipped with a much larger solar field. Other costs include project development (2.9%), project management (7.7%), financing (6%) and risk allowances (3%). This cost block is strongly project-related and can change due to project characteristics.

- ☞ **Although the components of the solar field are the most capital-intensive and largest part in the value chain, there are opportunities for local manufacturing and services all along the value chain.**

The international players in the CSP value chain

The value chain analysis gives an overview of international companies currently active in CSP. These companies show a high potential to participate in future MENA CSP markets. Some players are already involved in the ongoing CSP projects in Morocco, Algeria and Egypt.

- ☞ **Local manufacturing can take place if technical and economic requirements for local and international companies are met. Most important is a sustainable CSP market, which will have to be facilitated by political measures. Local manufacturing is related to market size as the output of a single component factory is often high.**

Table S-4 Value chain analysis

	Industry structure	Economics and costs
Project development	• Small group of companies with technological know-how • International actors have fully integrated activities of concept engineering; often with project development, engineering, financing.	• Mainly labor-intensive engineering activities and activities to obtain permits.
EPC contractors	• Strong market position for construction, energy, transport and infrastructure projects.	• Large infrastructure companies (high turnover)
Parabolic mirrors	• Few, large companies, often from the automotive sector • Large factory output	• Large turnover for a variety of mirror and glass products
Receivers	• Two large players • Factories also in CSP markets in Spain and US	• Large investment in know-how and machines required
Metal support structure	• Steel supply can be provided locally • Local and international suppliers can produce the parts	• High share of costs for raw material, steel or aluminum
	Market structure and trends	**Key competiveness factor**
Project development	• Strongly depending on growth/expectations of individual markets • Activities world-wide	• Central role for CSP projects • Technology know-how • Access to finance
EPC contractors	• Maximum 20 companies • Most of the companies active on markets in Spain and the US	• Existing supplier network
Parabolic mirrors	• A few companies share market, all have increased capacities • High mirror price might decline	• Bending glass • Manufacturing of long-term stable mirrors with high reflectance • Inclusion of up-stream float glass process
Receivers	• Strongly depending on market growth • Low competition today; new players about to enter the market	• High-tech component with specialized production and manufacturing process
Metal support structure	• Increase on the international scale expected • Subcontractors for assembling and materials	• Price competition • Mass production / Automation

	Strengths	Weaknesses	Opportunities	Threats
Project development	• Reference projects • Technology know-how	• Dependency on political support	• Projects in pipeline	• Price competition with other renewables
EPC contractors	• Reference projects • Well-trained staff • Network of suppliers	• High cost	• Projects in pipeline • Achieve high cost reduction	• Price competition with other renewables
Parabolic mirrors	• Strong position of few players • High margins (high cost reduction potential)	• Cost of factory • Continuous demand required	• New CSP markets • Barriers for market enrty	• Unstable CSP market • Flat mirror technology (Fresnel / Tower)
Receivers	• High margins (high cost reduction potential)	• Dependency on CSP market • High entry barrier for new players (know-how/ invest)	• High cost reduction potential through competition	• Unstable CSP market • Low market demand • Strong market position of few players; new players to become commercial
Metal support structure	• Experience • New business opportunities for structural steel • Low entry barriers	• High cost competition	• Increase of efficiency and size	• Volatile CSP market

Opportunities for MENA industries of manufacturing CSP components in the value chain

The report analyzes in depth the complexity and investment intensity of a selection of production processes to give a broad overview of which CSP components can be most easily adapted for local manufacturing by local or international industry, and would consequently have the highest potential for manufacture in MENA countries in the short- and mid-term. For each manufacturing process or service, barriers and bottlenecks can be identified that could impede local MENA industries' entry to the CSP market in MENA. Table S-5 provides an overview of technical and economic barriers to manufacturing CSP components that will need to be minimized with special roadmaps and action plans if the greatest potential of MENA in CSP is to be realized.

Table S-5 Technical and economic barriers to manufacturing CSP components

Compo-nents	Technical barriers	Financial barriers	Quality	Market	Suppliers	Level of barriers
Civil work	Low technical skills required	Investment in large shovels and trucks	Standard quality of civil works, exact works	Successful market players will provide these tasks	Existing supplier structure can be used for materials	**Low**
EPC engineers and project managers	Very highly skilled professionals: engineers and project managers with university degrees		Quality management of total site has to be done	Limited market of experienced engineers	Need to build up an own network	**Medium**
Assembly	Logistic and management skills necessary Lean manufacturing, automation	Investment in assembly-building for each site, investment in training of work force	Accuracy of process, low fault production during continuous large output Low skilled workers	Collector assembly has to be located close to site	Steel parts transported over longer distance Competitive suppliers often also local firms	**Low**
Receiver	Highly specialized coating process with high accuracy Technology-intensive sputtering step	High specific investment for manufacturing process	High process know-how for continuous high quality	Low market opportunities to sell this product to other industries and sectors	Supplier network not strongly required	**High**
Float glass production (for flat and curved mirrors)	Float glass process is the state-of-the-art technology but large quantities and highly energy intensive Complex manufacturing line Highly skilled workforce to run a line	Very capital-intensive	Purity of white glass (raw products)	Large demand is required to build production lines	Supplier network not strongly required	**High**
Mirror *flat* (float glass)	Complex manufacturing line Highly skilled workforce to run a line	Capital-intensive	Long-term stability of mirror coatings	High quality flat mirrors have limited further markets Large demand is required to build production lines	Supplier network not strongly required	**High**
Mirror *parabolic*	*See flat mirrors* Plus: Bending: highly automated production	*See flat mirrors* + bending devices	*See flat mirrors* High geometric precision of bending process	Large demand is re-quired to build produc-tion lines Parabolic mirrors can only be used for CSP market	Supplier network not strongly required	**High**
Mounting structure	Structure and assembly are usually pro-prietary know-how of companies Standardization/automation by robots or stamping reduces low skilled workers, but increases process know-how	Automation is capital-intensive Cheap steel is competitive advantage	For tracking and mounting: stiffness of system required	Markets with large and cheap steel Transformation industries are highly competitive	Raw steel market important	**Low**
HTF	Chemical industry with large productions. However, the oil is not highly specific	Very capital-intensive	Standard product, heat resistant	Large chemical com-panies produce thermal oil	Not identified	**High**
Connection piping	Large and intensive industrial steel transformation processes Process know-how	Capital-intensive production line	High precision and heat resistance	Large quantities	Not identified	**Medium**
Storage system	Civil works and construction is done locally Design and architecture Salt is provided by large suppliers	Not identified	Not identified	Low developed market, few project developers in Spain	Not identified	**Medium**
Electronic equipment	Standard cabling not difficult Many electrical components specialized, but not CSP specific equipment Equipment not produced for CSP only	Not identified	Not identified	Market demand of other industries necessary	Often supplier networks because of division	**Low**

The analysis of the value chain leads to the following conclusions:

- A growing market has been identified for all groups in the value chain (raw materials, components, engineering, engineering, procurement and construction contractors, operator, owner, investors, and research institutions).
- High technological know-how and advanced manufacturing processes are necessary for some key components, like parabolic mirrors or receivers, which nevertheless offer the highest reward in terms of value added.
- Some sectors and companies, like receiver suppliers, strongly depend on CSP market demand and growth. Other firms have built their production and manufacturing capacities to respond to the demand of other markets (CSP is a niche for them).
- Some components (piping, HTF, electronics, power block) are produced by companies without extensive CSP know-how or background because this equipment is used for many other applications (chemical, electronic, and electric industries).
- The potential of MENA CSP may be achieved by the manufacture of components by local, regional and international companies, and the construction of CSP plants in the MENA region by local construction companies and subsidiaries of the international CSP industry.
- Production capabilities for some key components (mirrors and receivers) moved to the current CSP markets in Spain and the United States as soon as the market (or the prospects for the market) had attained a sufficient size. They could move to MENA when the CSP market takes off in the region.

Evidence from the CSP value chain of local manufacturing in MENA and other CSP markets

Three CSP plants (all integrated with gas-fired combined cycle turbines) are under construction or in the commissioning phase in Kuraymat (Egypt), Ain Beni Mathar (Morocco) and Hassi R'mel (Algeria). As these are the first plants of their type in the region, examining their use of local manufacturing provides insights about the share of local content that can be achieved and could diminish the learning curve of future plants. For comparative purposes, the local component of plants in Spain, the United States and China are also evaluated:

- ***Kuraymat (Egypt):*** About 60 percent of the value for the solar field is generated locally. Civil works, the mounting structure, the tubes, electrical cables, grid connection, the engineering, procurement and construction responsibility (engineering strongly supported by Fichtner Solar and Flagsol), the operation and utility is all done by local industry. However, some of the key components are still provided by international industry (for example, the mirrors, receiver, heat transfer fluid, and steam generator). Egypt is making efforts to achieve more local content in newly established wind parks. In tenders and bidding procedures, projects with a large share of locally produced components are prioritized. This approach could also be introduced for CSP projects.
- ***Aïn Beni Mathar (Morocco):*** All main components and equipment for the project are imported from international market players. Low participation of local industry in the first projects leads to low technology transfer. Many international component suppliers have taken their first steps in the MENA market by selling their components in Morocco. Cost advantages for local components and services could not be identified.
- ***Hassi R'mel (Algeria):*** A very large share (up to 90 percent) of all equipment and components is imported: there is no local share in the manufacturing of the solar field. Civil work at the Algerian site costs up to 30 percent more than in Spain. Abener is expecting that future projects can use a locally produced steel mounting system. Although some know-how for project development of conventional power plants exists in Algeria, the engineering, procurement and construction (EPC) contractor is always an international company. A local company, Sarpi, provides electronic equipment for the plant. An Algerian engineering company (Algesco) will provide turbine maintenance during operation; the main O&M is done by Abener. Although this analysis finds that the Algerian industry could play a role in local manufacturing, the share of local involvement in the current project is very low. Even components and services with a lower technology level have been provided by international companies.
- ***USA:*** The US government recently gave a loan guarantee of US$1.45 billion to Abengoa to build a 260 MW_{el} CSP power plant in Arizona (Solana) with the condition that the project was to utilize a maximum share of American components, leading Abengoa to raise the local share to 70 percent.
- ***Spain****:* For the first large commercial plant Andasol 1 in 2006, the share of Spanish suppliers was below 50 percent. Four years later, the new plants had more than 75 percent local suppliers (personal communication Protermosolar).
- ***China:*** Among several other countries, China has successfully used local content requirements to increase the local manufacturing of renewable energy components. In 2005, the Chinese National Development and Reform Commission (NDRC) stipulated that new wind farms must meet a 70 percent local content requirement on value added. Local content clauses are removed once internationally competitive local industries have been established.

These examples show a large range of local manufacturing shares in CSP projects. The local share has been very limited for Hassi R'Mel and Aïn Beni Mathar, as most components were imported by the EPC contractors. This can be explained by the fact that the first aim of these projects was not to develop the local CSP-related industry, but to deliver a functional ISCCS within tight deadlines. On the other hand, the Kuraymat ISCCS achieved 60 percent local production. The key to that success was the involvement of a local EPC contractor, Orascom Industries, and the support of Fichtner Solar and Flagsol for the conceptual design, engineering, and technical advice on the assembly. As Orascom is an Egyptian company, it was easier to involve local subcontractors, like NSF for the steel structure. The local companies involved in that project have gained knowledge and should be able to use it for future projects.

☞ **The Kuraymat ISCCS plant in Egypt could become a reference project for pure CSP plants in the region. Despite unfavorable conditions for CSP, approximately 60 percent local value generation for the solar field shows that the local industry is already capable of developing and building CSP projects.**

Although the project development for the solar field was done by international companies because of a lack of local experience with the development of CSP plants, in the future, it is likely that local engineering offices and EPC contractors will be able to transfer the experience gained in this project to future projects.

A promising approach to develop local CSP production would be to combine:

- International cooperation to facilitate know-how transfer.
- Involvement of a local EPC contractor to facilitate local companies stepping into the CSP value chain.
- Funds to compensate companies for the potential extra costs related to using local components. Although it can be more cost- and time-efficient to import components, making the effort to involve local companies in a first project, even at additional cost, can be a profitable investment as these companies will gain experience for involvement in future projects.

Potential for local subsidies and local manufacturing of international companies and production thresholds

International companies will have an important role to play in the development of local industries. EPC companies and project developers already active in the region have local offices in MENA countries close to the CSP projects and their customers. The companies employ local and international workers and engineers for projects in the countries. Comparable with conventional power plants, CSP companies also expect a high share of project development, management, and engineering from international companies with extensive technical expertise and project experience. Figure S-4 provides an overview of the possible local content of different parts in the value chain as seen by international players.

cCxc

Component	Local manufacturing possible?	Services and power block	Local manufacturing possible?
Mirrors	Yes, large market	Civil works	Yes, up to 100%
Receivers	Yes, long-term	Assembling	Yes, up to 100%
Metal structure	Yes, today	Installation works (solar field)	Partly, up to 80%
Pylons	Yes, today	Power block	No
Trackers	Partly	Grid connection	Yes, up to 100%
Swivel joints	Partly	Project development	Partly, up to 25%
HFT systems	No, except pipes	EPC	Partly, up to 75%

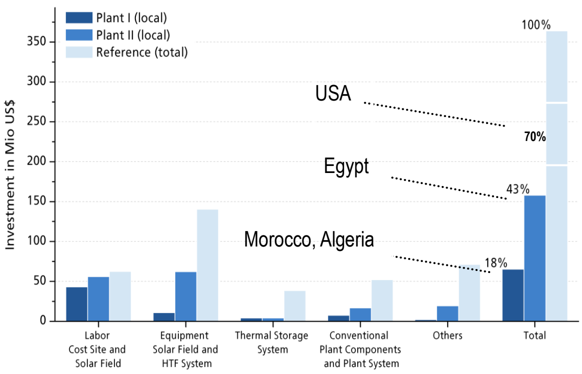


Figure S-4 Possible local content by component of CSP power plants

The status quo of local manufacturing for CSP projects in the MENA region and the potential for local manufacturing for the different blocks in the value chain is evident from figure S-4 above, which shows that overall local content in the value chain ranges from 18–43 percent while examples from the US show that 70 percent could be reached. The importance of the size of the domestic CSP market is underlined by table S-6.

Table S-6 Thresholds for a typical factory for core CSP components

	Components of the value chain	Annual output of a typical factory (MW/year)	Investment per factory (millions of euros)	Jobs per factory (jobs p.a.)	Specific jobs (jobs/MW)
Components	Receiver	200–400	40	140	0.3–0.7
	Mirrors	200–400	30	300	0.7–1.5
	Steel structure	50–200	10	70	0.3–0.5
	HTF	Very high	-	-	-

- ☞ **Below the thresholds listed in table S-6, it may be difficult to attract core CSP manufacturing unless export markets can be exploited to support market deployment. This also points to the importance of regional specialization and cooperation as long as the domestic markets are still on the rise.**

In interviews, international companies emphasized several support mechanisms that would improve the situation of CSP in the MENA Region:

- Long-term security for planning and financing by feed-in tariffs or comparable mechanisms, including export contracts to Europe
- Improvement of legal situation for orders and projects in the MENA Region
- Guarantees from European countries or international financial organizations to reduce country-specific risk and financial costs

Achieving a sustainable market will require more than grants or concessional loans, which are for only a limited number of projects. Instruments like feed-in tariffs or PPAs with a long-term perspective or tender procedures with a constant annual installation volume over at least 5 to 10 years would facilitate long-term planning. Without a long-term perspective, international companies have low interest in investing in the region; investment decisions depend more on the existence of a predictable and stable market than on secondary factors like skilled workers or business networks.

SWOT analysis of MENA industries relevant for key CSP components

A SWOT analysis of MENA industries suitable for CSP is summarized in the table S-7; more details by industry are given in the report.

Strengths	Weaknesses
• Low labor cost (especially for low-skilled workers)	• Insufficient market size for creation of local manufacturing
• One of the highest solar potentials in the world (desert areas)	• Administrational and legal barriers
• Strong GDP growth over the 5 past years in all MENA countries	• Lack of financial markets for new financing
• High growth in the electricity demand will require large investments in new capacities	• Higher wages for international experts/engineers
• Strong industrial sector in Egypt	• Higher capital costs
• Particular proximity of Spain and Morocco	• Energy subsidized up to 75% in some countries (although subsidies are decreasing)
• Existing float glass sector in Algeria	• No fiscal, institutional and legislative framework for RE development (laws for renewable energies under development for long periods)
• Large export industry in Tunisia and Morocco with long experience with Europe (e.g., automotive industry and, to a lesser extent, aeronautics)	• Despite numerous regulations, implementation and enforcement of environmental regulations often deficient
• First CSP/ISCCS plants in three MENA countries constructed by 2010	• Need for strong network, business and political connections
	• Lack of specialized training programs for renewable energies
	• Partly insufficiently developed infrastructure
Opportunities	**Threats**
• Further cost reduction of all components	• Training of workforce and availability of skilled workers not sufficient
• Attractiveness to external investors by large market demand	• Technical capacities of local engineering firms
• Solar energy: Moroccan Solar Plan (2 GW), Tunisian Solar Plan, premises of an Egyptian Solar Plan, etc.	• Lack of awareness of management on opportunities in CSP sector
• Possibility of technology transfer/spillover effects from foreign stakeholders in MENA	• Access to financing for new production capacities
• Political will to develop a local renewable energy technologies industry	• Presence of public actors in clean-tech value chain while private actors more absent
• Export potential (priority given to export industries)	• Competition with foreign stakeholders: historical presence of German players and strong interest of USA in the Egyptian market
	• Higher costs compared to international players
	• Higher transport losses/costs due to insufficient infrastructure
	• Competition with other emerging countries

Table S-7 A SWOT analysis of MENA industries suitable for CSP

- ☞ **Several industrial sectors that have the potential to integrate the CSP value chain in the MENA Region are dynamic and competitive on a regional, and sometimes international, scale.**

The glass industry, particularly in Egypt and Algeria, has been a regional leader for a long time and is still increasing its production capacity. The cable, electrical, and electronic industry can also claim the same position, especially in Tunisia and in Morocco. The success of these industries is facilitated by the development of joint ventures between large international companies and local firms, as well as by the local implantation of subsidiaries of international players. In the past, the development of MENA CTF industries was driven by the low cost for labor and energy (the latter in particular for Algeria and Egypt) and by the geographic proximity to Europe. In order to position themselves for the CSP market, MENA CTF industries face several challenges, mainly in adapting their capacity to higher technology content (for example in the glass industry). The landscape is already changing; the situation of pure subcontracting is now shifting toward more local R&D and the production of high-tech components. MENA CTF countries are aiming to be considered as "centers of excellence" instead of low-cost and low-skilled workshops.

The shift toward higher technology content will require increased international and regional cooperation. Whereas cooperation between western countries and MENA is thriving, cooperation between MENA countries' industries is relatively low. Initiatives have been undertaken to develop intra-MENA cooperation, in aeronautics for example, but have never been very successful. Shared research and technology development between public bodies (e.g., universities) and corporations could be strongly enhanced, for instance, by developing technology platforms and clusters.

Many industrial companies still have a limited understanding of the market potential offered by CSP deployment. Raising the awareness and interest of these potential players will require clarification of the market for CSP in the MENA region and beyond. Furthermore, investigating the possibilities of flexible production lines might contribute toward mitigating other risks related to the CSP market's evolution. For example, steel structure manufacturers usually adapt their production tools to different products with little effort.

Industry capabilities for CSP components and services

- **Regardless of identified obstacles to participation of local MENA industries, the expert interviews with MENA companies and with the existing CSP industry carried out during this study have shown increasing potential for local manufacturing of components for CSP and the provision of construction and engineering services for new CSP plants, if the CSP market grows steadily in the MENA Region.**

Key findings regarding the status quo and future perspectives of local manufacturing for CSP plants are:

- Successfully constructed ISCCS projects have increased CSP experience and know-how in MENA.
- Some components and parts for the collector steel structure were supplied by the local steel manufacturing industry (Algeria, Egypt, and Morocco).
- The workforce has been trained on the job; engineering capacities have also experienced some progress.
- Specialization of each country would be beneficial because local demand will probably be relatively low in short/medium terms.
- Several parts of the piping system in the solar field—for the interconnection of collectors and power block—can already be produced locally by regional suppliers.
- The development of a CSP mirror industry in MENA countries has significant potential.
- Involvement of international companies will play an important role in the mid-term development of the CSP industry in MENA countries because it will build up local production facilities.
- Minimum factory outputs have to be taken into consideration for local manufacturing of special components (glass, receivers, salt, thermal oil).

The main drivers for development of CSP local manufacturing in the MENA region are similar to markets in Spain or the United States (table S-8).

Table S-8 Requirements for enhancing local manufacturing of CSP components

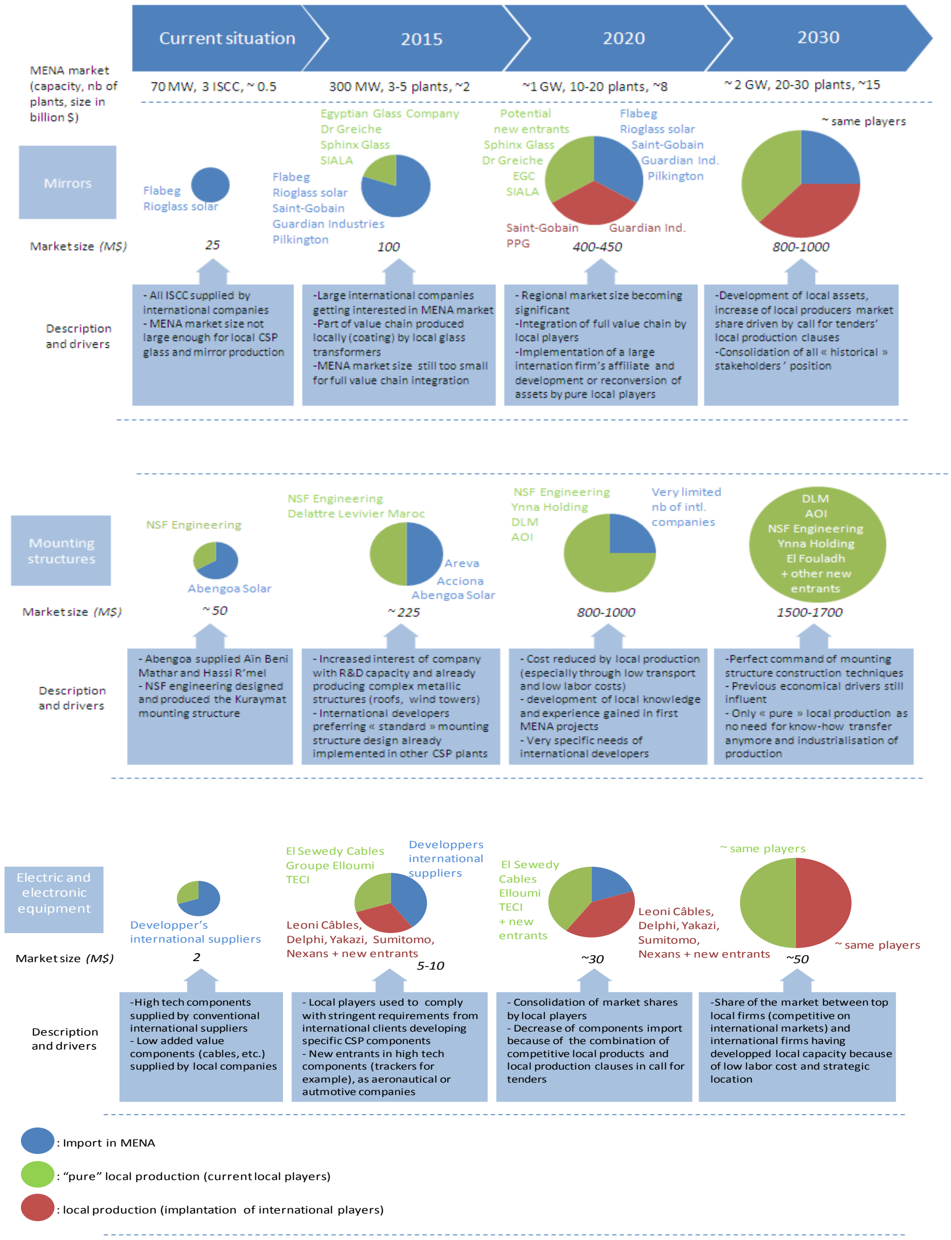
Component	Attractiveness of local markets, local demand	Technological know-how	Training education	Financial investment	Competitive location factors	Improvement of quality and assurances standards	Investment regulatory framework
Civil Works					X	x	
Installations			x			x	
EPC engineers		x	x			x	
Assembling		x				x	
Receiver	x	x	x	x	X	x	x
Mirrors (flat & parabolic	x	x	x	x	X	x	x
Mounting structure				x	X	x	
HTF	x	x			X		
Connection piping	x	x	x	x	X	x	
Storage system		x	x			x	
Electronic equipment	x	x	x		X	x	

The prospects for local manufacturing can be summarized for each component:

- ***Construction and civil works:*** In the short term, all construction at the final plant site with the basic infrastructure, installation of the solar field, and construction of the power block and storage system could be accomplished by local companies (17 percent of total CSP investment for a reference plant or approximately US$1 million per MW).
- ***Mounting structure:*** The mounting structure can be supplied locally if local companies can adapt manufacturing processes to produce steel or aluminum components with the required high accuracy.
- ***CSP-specific components with higher complexity:*** In the short to medium term, local industry is generally capable of adapting production capacities and creating the technological knowledge to produce mirrors (glass bending, glass coating and possibly float glass process) of high quality and high technical standard as required for parabolic mirrors in parabolic trough plants. This might require international cooperation for specific manufacturing steps in the short term. Later, local provision of components could include high-quality mirrors, receivers, electronic equipment, insulation, and skills for project engineering and project management. In particular for the receiver (absorber) technology, the most promising option will be for international companies to move closer to the rapidly increasing markets.

Figure S-5 describes a possible evolution of local CSP industries for the key components (mirrors, mounting structure, electrical and electronic equipment) in the CTF MENA region, taking into account the market size for different components.

Figure S-5 Evolution of local CSP industries for key components in the CTF MENA region



The mapping of players for CSP components other than mirrors, mounting structures, and electric/electronic components should be less dynamic. On the one hand, components that are not specific to CSP (e.g., cables, balance of plant) will be supplied by players who are currently active in conventional markets. Market shares should evolve according to traditional market drivers such as MENA industries' competitiveness, change rate, availability of low cost materials. On the other hand, very high-tech components that are specific to CSP (HTF, receivers) will continue to be supplied by a very limited number of international companies; the mapping for these components should not change significantly.

Scenarios for local manufacturing in MENA countries

In the report, detailed roadmaps and action plans are developed for the key components and services of the CSP value chain. The action plan, with a time horizon until 2020, is developed based on three scenarios.

- ☞ **It is assumed that the volume of the installed CSP capacity within the MENA region (home market volume) is a main precondition for the emergence of local manufacturing, thus the scenarios represent critical levels of market development for local manufacturing. The home market volume and the potential amount of export (external market volume) are regarded as indicators for the development of a successful policy scheme.**

The scenarios chosen here represent critical levels of market development for local manufacturing. The market volume is described for the five countries investigated in detail in this study. For the MENA region as a whole, it can be assumed that the market volume could twice as large as in the MENA CTF countries alone. The three scenarios proposed are:

Scenario A—Stagnation: The home market volume of the five MENA CTF countries amounts to 0.5 GW only. Strong obstacles to local manufacturing of CSP components remain in the country markets, and most components, particularly those whose production requires high investment costs, are imported from more advanced markets. This scenario implies an incomplete realization of the MENA CSP IP.

Scenario B—No-replication: The home market volume of the five MENA CTF countries amounts to 1 GW in 2020, which is strictly the MENA CSP IP target, without any significant replication effect. In this scenario, the market offers some opportunities for the development of local manufacturing of CSP components and provision of CSP services. This scenario aims at an adaptation of international production standards and techniques in existing industries, and leads to a region-wide supply of suitable CSP components produced locally in the MENA region. The base level of 1 GW, which would mainly be determined by the CTF alone, does not include any additional CSP development triggered beyond the initiative in a narrow sense. This base level would therefore constitute a foundation on which more comprehensive policies can spur a larger CSP development in the region.

Scenario C—Transformation: The home market volume of the five countries amounts to 5 GW and the export of components reaches a volume corresponding to 2 GW installed CSP capacity. National CSP promotion plans have been developed quickly, international initiatives are strongly represented and/or private investors are notably active in the region. Policy actions should support innovations and the development of intellectual property rights in the field of CSP components. A strong export orientation should be motivated to take advantage of the proximity to other emerging markets.

Assumptions for scenario C are based on past developments for the annual growth rates of total installed capacities for other renewable technologies, such as wind and PV (about 60 percent annual growth rates over a decade in the case of ambitious policies, and about 20-30 percent for countries with less ambitious policies, table S-9), as well as on world-market projections for CSP.

Figure S-6 Market scenario context for the analysis of local manufacturing opportunities

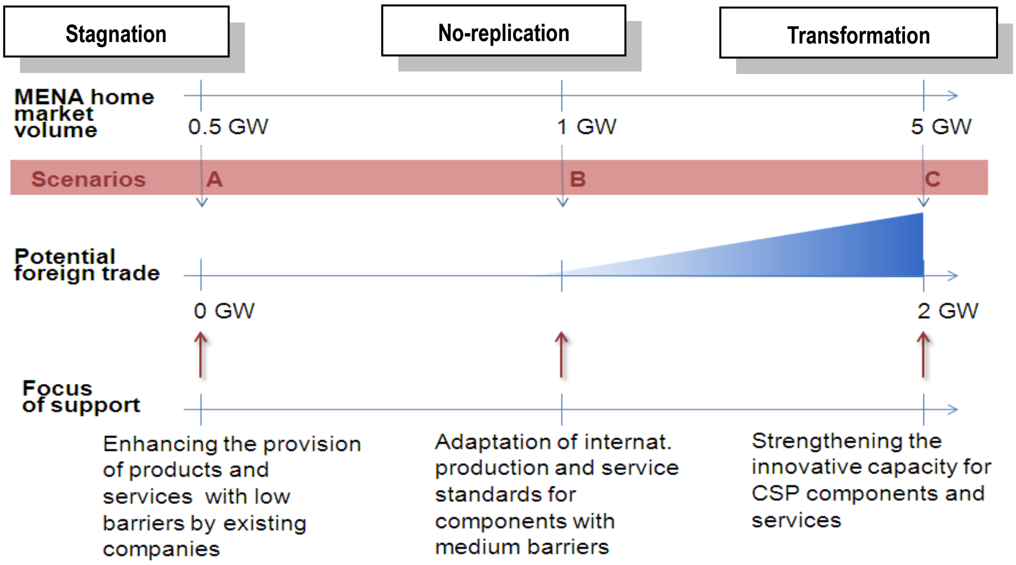


Table S-9 Average annual growth in cumulative installed capacities for wind energy, PV and CSP

Wind Power	**1991/2000**	**2000/2009**	**Exact period**
Germany	56%	17%	
Spain	90%	27%	
Denmark	22%	4%	
USA	-	63%	2003/2009
China	-	60%	
India	-	28%	
Brazil	-	66%	2003/2009
Egypt	-	36%	2003/2009
Morocco	-	29%	2003/2009
Turkey	-	155%	2005/2009
Solar PV	**2000/1991**	**2009/2000**	
Germany	57%	64%	
USA		28%	
Japan		18%	2004/2009
CSP			
World		41%	2007/mid-2010
World		59%	2007/2015
Scenario A		24%	2010/2020
Scenario B		32%	2010/2020
Scenario C		61%	2010/2020

Source: Fraunhofer ISI based on various sources

It is important to compare the scenario settings described above with the production thresholds of typical factories for core CSP components (see section on "Potential for local subsidies and local manufacturing of international companies and production thresholds"). We saw that typical thresholds for key components are in the range of 200–400 MW per year for mirrors or receivers, and 50-200 MW per year for mounting structures. This implies that the total MENA market should reach, in the ten years up to 2020, a level of total installed CSP capacity of 2–4 GW in the first case and 0.5-2 GW in the second case. Assuming half are installed in the five MENA CTF countries, the thresholds are 1–2 GW up to 2020 if mirrors or receivers are considered for local production, and 0.25–1 GW in the case of mounting structures (i.e., between scenarios B and C).

- **This shows that the "no-replication" scenario is at the lowest level to fulfill those thresholds, and that the CTF effort must at least trigger a doubling of the CSP installations in these five MENA CTF countries.**

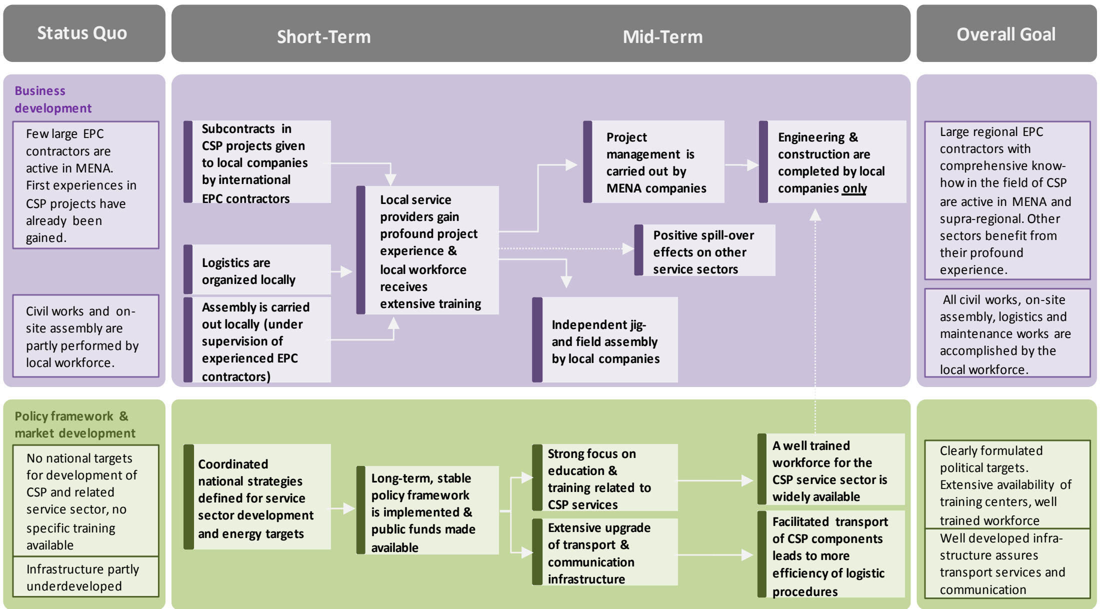
- **The "transformation" scenario, on the other hand, may materialize only under favorable conditions and a more conservative level of installed power may lie somewhere between the "no-replication" scenario and the "transformation" scenario. It was, however, the purpose here to estimate a range rather than to come up with a precise view on how many GW out of the 5+2 GW underlying the "transformation" scenario will be constructed by 2020.**

Based on the assessment and identification carried out of existing and potential domestic and foreign players (manufacturing companies, financial investors, etc.), the report identifies potential routes to developing local manufacturing capabilities. The aim of the roadmaps is to show, based on the current situation, possible technological and entrepreneurial developments in the regional manufacturing of each component in the short, medium, and long term and to identify overall, long-term objectives in these fields. The underlying essential preconditions for all components include a reliable CSP market growth and a stable political framework. Detailed roadmaps are developed for:

- **Key components:** The highest value added for the region can be expected from these components which include CSP mirrors (see next page), mounting structures, and receiver tubes.
- **Key services:** EPC and other services.
- **Secondary components:** For components such as piping and cables countries have already developed competitive advantages (e.g. production of electric cables in Tunisia and Egypt). These components do not represent a major share of value added, but can still contribute significantly in absolute terms, particularly due to possible exports.

The roadmaps are separated into technological developments (e.g. changes in production lines, production skills, and production capacities), business developments (e.g, cooperation agreements, R&D activities and other entrepreneurial decisions) and underlying market and policy developments. For each of these levels, the most important critical steps and milestones are presented and interrelations between the different levels are indicated. The measures needed to overcome critical steps and reach the milestones are subsequently discussed in an action plan. The timeframe of the roadmaps covers short-term developments which could be realized within the next 2–5 years, mid-term developments in 6–10 years, and long-term developments which might be realizable after 2020. These targets, particularly in the long-term, depend on the development of a CSP market as described in the previous section. Some technological milestones might only be reached if there is robust growth in the CSP market.

Figure S-7 Potential roadmap for EPC and services in CSP-projects in the MENA region

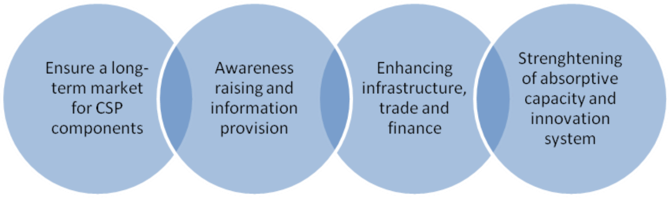


Potential roadmap for the production of CSP-mirrors in the MENA region

Action plan for stimulating CSP manufacturing and services in the MENA region

In this section a detailed action plan for stimulating CSP manufacturing and service provision in the MENA region is developed for all relevant actors.

The creation of a stable policy framework and a sustained domestic market are the major preconditions for the development of a sustainable CSP-industry. In the long run, the annually installed capacity should be on a GW scale to allow for the development of production lines, particularly in the case of mirrors and receivers. The success of the MENA CSP IP is key to achieving this target. Also, a strong regional integration of the CSP value chain, making use of the countries' comparative advantages and including dismantling of trade barriers and coordination of national policies, is crucial to overcome barriers related to critical quantities (threshold values for a profitable production) in the manufacturing of CSP components.



The focus of support depends on the expected market size. In the case of a quasi stagnation of the CSP market in the region (scenario A—stagnation), support should focus on enhancing the manufacturing of low-tech components and basic services for which the market barriers are relatively small and no large investments are required (e.g., mounting structures, civil works, and assembly). Assuming a moderate but stable growth of the CSP MENA market (scenario B—no replication), an adaptation of international production standards and techniques in existing industries should be targeted to achieve a region-wide supply of at least some suitable CSP components produced locally in the MENA region (e.g., mounting structures, piping, cables/electronic equipment and a wide range of related services). Under the more desirable "transformation" scenario (scenario C), policy actions should strongly support innovation and the development of intellectual property rights in the field of CSP components to profit from first-mover advantages and to develop technologies specifically tailored to MENA conditions. A strong export orientation should be encouraged to benefit from the proximity to other emerging markets. Under this scenario, the production of a wide range of CSP components could be achieved (parabolic mirrors and potentially receivers).

National strategies for industrial development and energy policy must be well coordinated. They should include clearly defined and broadly communicated targets for the market diffusion of CSP, substantial R&D efforts, and the creation of highly specialized strategy funds for industrial development of CSP industry sectors.

- **Financial aid will be necessary**, especially for the technical adjustment of production facilities (including feasibility assessments) and the implementation of training courses for the local workforce. A provision of low interest loans, grants, and tax incentives specifically designed to foster the local manufacturing of renewable energy components would help MENA companies to enter the CSP business[5]. Funds could also be provided to facilitate knowledge transfer (e.g., via purchase of licenses). It is considered unlikely that local companies will enter into the production of CSP receivers due to the high complexity of this component; tax incentives (e.g., in the form of reduced corporate and land registration taxes and facilitated VAT refunds) could help to attract international companies to the MENA region for this specialized production.
- **Market actors will need good access to CSP-related information and certainty about market development.** The creation of a regional CSP or renewable energy association dealing with issues such as the CSP market development, manufacturing options, and the latest technological advances will facilitate access to information.
- **An enhanced innovative capacity will be key.** The creation of a larger number of technology parks/clusters and regional innovation platforms is necessary to grow innovative capacity of industrial sectors and to foster company networking and R&D. This will help small and medium-sized firms in particular to overcome innovation barriers and to gain access to the latest technological advances.
- **Individual business models should build on the comparative advantages of certain sectors in MENA countries and also involve international cooperation agreements**, e.g. in the form of joint ventures and licensing, to accelerate the development of comprehensive CSP know-how in the region and to benefit from the broad experience of existing companies. Especially in the case of receivers, subsidiaries of foreign companies will most likely be a relevant business model at the beginning. Governments could assist the private sector in finding appropriate partners for such cooperative ventures.
- **The careful introduction of local (domestic) content clauses within CSP project tenders will foster a long-term demand for CSP components.** This will be particularly useful in encouraging the deployment of local EPC contractors who have better access to local supply chains and service networks, and who might therefore play a key role in raising the share of local value added in future CSP projects. Requirements in bidding procedures could be adjusted to prioritize local contractors.
- **Comprehensive education and training programs for the industrial workforce in relevant sectors will be critical for entering into local manufacturing of CSP components.** Universities should be encouraged to teach CSP-technology-based courses to educate the potential workforce, particularly engineers and other technical graduates.
- **Implementing quality assurance standards for CSP components in the medium to long term should be considered** to ensure regional and international quality requirements and to strengthen the competitiveness of future MENA CSP industries,.

Table S-10 summarizes the potential measures addressed to different actors to stimulate the production of CSP components and provide CSP-related services in the MENA region.

[5] The most critical steps in the upgrade of production facilities for CSP components have been identified as the implementation of automated processes for the production of precisely manufactured mounting structures, the supply of high quality white float glass, and the adaption of techniques for coating and bending of parabolic CSP mirrors.

Table S-10 Action plan for stimulation of production of CSP products in the MENA region

Actors/financers: Δ = national authorities, ▲ = internat. donors, ◊ = national CSP players, ♦ = international CSP players

Goals	Intermediate Steps	Necessary processes/assistance	Target groups	Potential actors	Implementa-tion timeframe
Upgrade & increase of industrial and service capacities	Provision of information on CSP market size and opportunities of production and service adjustment	Implementation of national and regional CSP associations that foster networking, accelerate business contacts and provide information	Current and potential future producers of intermediate products and CSP components, research organizations	Δ ▲ ♦◊	Short to medium term
		Establishment of superordinated national institutions responsible for CSP targets to enhance and coordinate policy development in the regional context and to provide assistance	See above	Δ	Short to medium term
		Creation of internet platforms, newsletters on technical issues and market development, information centers and other informational support	See above	Δ ▲	Short to medium term
	Assessment of technical feasibility for firms to upgrade current production to CSP component production and service provision	Foundation of consortia of technical experts that support companies which show interest in CSP manufacture or provision of funds to consult external technical experts	Current producers of intermediate products and CSP components	Δ ▲	Short to medium term
	Implementation of investment support mechanisms for adaptation of production lines	Financial support of a certain share of the necessary investment for implementation of upgrade of production facilities (e.g. "renewable energy innovation fund")	Current local producers of intermediate products	Δ ▲	Short to medium term
		Provision of long-term low-interest loans for companies willing to invest in innovation of production lines	Current local producers of intermediate products and potential future producers	Δ ▲	Short to medium term
		Facilitation of foreign investments by simplification of bureaucracy and assistance	International players	Δ	Short to medium term
	Price incentives	Tax incentives for production/export of CSP components (e.g. reduction or exemption on customs duties for raw materials, parts or spare parts of CSP components, refund of customs duties with export)	Local producers, national and international companies	Δ	Medium term
		Tax credits or deductions for investments in production lines related to CSP and investments in R&D	National and international companies	Δ	Medium term
		Lowered trade barriers for RE/CSP components and intermediate products to accelerate the trade of components	See above	Δ	Medium term
		Tax credits on firm-level training measures	See above	Δ	Short to medium term
	Further incentives	Local and regional content obligations for components and services in CSP projects	See above	Δ	Medium term
		Foster integration of secondary components suppliers in region	See above	Δ	Short term
Activation of further potential market players and service providers	Strong focus in national and regional industrial policy on CSP development	Formulation of clear national targets regarding the development of CSP industries	National and international industrial players in general	Δ	Short to medium term
		Provision of administrative and legislative support for company start-ups and foreign investments, and formation of relevant institutions	National and international industrial players in general	Δ ▲	Short to medium term
		Financial support mechanisms for national company start-ups in the sector of renewable energy manufacturing	National players	Δ ▲	Short to medium term
		Introduction of regional quality assurance standards for CSP products to decrease uncertainty	National and international companies	Δ ▲ ♦◊	Medium to long term

	Awareness raising	Awareness-raising initiatives (e.g. conferences, workshops, other marketing activities) and formation of relevant institutions	National and international industrial players in general	∆▲♦	Medium to long term
Facilitation of skill enhancement and knowledge transfer	Promote creation of joint ventures between existing manufacturers and potential regional newcomers	Facilitation of networking and knowledge transfer by creating networking platforms and organization of business fairs	Regional and international manufacturers	∆♦◊	Short to medium term
	Support of training activities for local workforce	Review of existing national training facilities, upgrade/creation of specific institutions if needed		∆▲	Short to medium term
		Provision of short basic training courses for civil workers (e.g. involved in assembly activities)	Regional companies, particularly low-skilled workforce	∆▲	Short to medium term
		Support the training of regional workforce by financial support if external training facilities are involved	Regional companies, international companies	∆▲	Short to medium term
		Promotion of financial incentives for 'train the trainers' programs	Regional companies, international companies	∆▲	Short to medium term
	Support of higher education	Establishment of study courses with regard to solar energy techniques/CSP and other required skills related to RE/CSP	Regional students and engineers, O&M workforce	∆▲	Short to medium term
		Creation of master programs at foreign universities and student exchange programs with regard to RE/CSP	Regional students	∆▲	Short to medium term
		Review of management and project planning capabilities and creation of training courses	Students, potential CSP workforce (e.g. existing EPC contractors)	∆▲	Medium to long term
	Support of private and public R&D	Improvement of renewable energy related R&D legislation, and national legislation exchange (e.g. through RCREE)	Manufacturers, private and public research institutions (e.g. universities)	∆▲	Short to medium term
		Foundation of research institutions and technology clusters with regard to CSP technologies, to foster regional knowledge distribution and innovation	See above	∆▲♦◊	Medium to long term
		Implementation of CSP testing plants and project-parallel research activities at CSP sites	CSP-project developer, national and international CSP component producers, public and private research facilities	∆▲♦◊	Short to medium term
		Promotion of international science networks and exchange of scientific experts in the field of CSP component design (particularly important for collectors and receivers)	Scientists at national and international institutions	∆▲	Medium to long term
		Enhancement of links between industry and research facilities (universities)	Scientists at national and international institutions, regional companies, international companies	∆▲♦◊	Medium to long term

Potential economic benefits of developing a CSP industry in North Africa

The economic benefits of developing a CSP industry were evaluated for the three CSP scenarios (stagnation, no replication, and transformation) for North Africa with the following distribution of CSP plants over time based on the reference plant taking into account cost degression effects (table S-11).

Table S-11 Newly installed CSP plant capacity in MENA by 2020

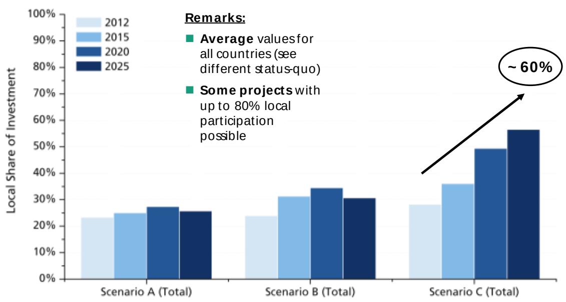
in MW		2011- 2014	2015 - 2017	2018 - 2020	**Total by 2020**	Total by 2025
Scenario A	domestic	80	160	260	**500**	1,050
Scenario B	domestic	160	320	520	**1,000**	1,550
Scenario C	domestic	800	1,600	2,600	**5,000**	14,500
	component export (MW equivalent)	250	600	1,150	**2,000**	5,180

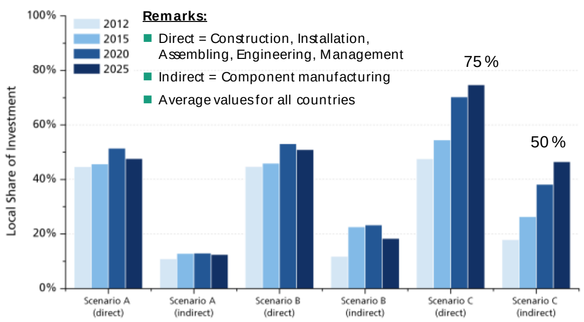
Note: The exports refer to components expressed in terms of equivalent CSP plants

Local economic benefits by industrial development in the MENA region, in particular with respect to labor and foreign trade impacts are:

- ***Average share of local manufacturing in the CSP value chain in the MENA region:*** Under the conditions of scenario B ("no-replication"), which does not include additional policy impacts triggered by the MENA CSP IP, and even more under the low-level development of scenario A, the impact on local manufacturing is comparatively low; most CSP components would remain imported, and only construction, project management, and basic engineering services might increase. In the more favorable "transformation" scenario, with significant market growth, the total potential of local added value of CSP plants will increase constantly and could reach almost 60 percent in 2025 as an average value for all CSP projects. This could increase the local share of some projects up to 70 percent of the total value. After 2025, the share of local manufacturing is assumed to increase further due to more technology transfer and learning through the realization of more CSP plants in the region.

Figure S-8 a) Share of total local manufacturing potential in scenario A, B, C
b) Total local manufacturing potential for construction and components
c) Direct and indirect local economic impact in scenarios A, B and C





- ***The economic impact on GDP:*** The level of local share influences the economic impact and job impact of CSP development in the MENA region. Economic impact is strongly related to the market size of CSP in the MENA region. The "transformation" scenario creates a local economic impact of US$14.3 billion, roughly half of which is from indirect impacts in the CSP value chain (excluding component export), compared to only US$ 2.2 billion in scenario B ("no-replication").

in Mio US$ (cumulated)	2012	2015	**2020**	2025	Local share by 2025	Cost reduction by 2025
Scenario A	30	193	916	1,498	25.7 %	~ 16 %
direct	20	125	571	946		
indirect	10	68	344	551		
Scenario B	61	465	**2,163**	3,495	30.6 %	~ 16 %
direct	39	251	1,167	1,959		
indirect	22	213	996	1,535		
Scenario C	368	2,803	**14,277**	45,226	**56.6 %**	~ 40 %
direct	206	1,403	6,999	21,675		
indirect	162	1,401	7,278	23,551		

- ***Labor impact:*** In scenario B ("no- replication") a permanent workforce of 4,500 to 6,000 local employees is created by 2020. In contrast, in scenario C ("transformation") in 2025 the number of permanent local jobs could rise to between 65,000 and 79,000 (46,000 to 60,000 jobs in the construction and manufacturing sector plus 19,000 jobs in operation and maintenance). Looking only to the time horizon of the CTF projects (2020), in total 34,000 employees (including employment for component export) might be working in the CSP industry permanently. Table S-12 shows details for the local employment in scenarios B and C excluding exports of components.

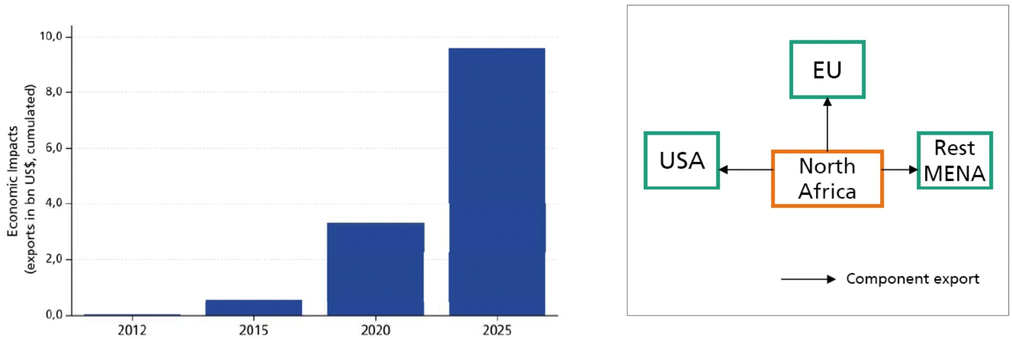
Table S-12 Local employment in scenarios B and C

Employment all 5 MENA countries: scenario B			
one-year jobs			
	2015	2020	2025
Construction and interconnection labour	3,593	14,917	22,727
Construction related services	58	320	485
Equipment and supply chain	471	2,175	3,046
Total Construction and Supply Chain-related	**4,121**	**17,413**	**26,258**
permanent employment			
	2015	2020	2025
Construction and interconnection labour	1,296	3,093	1,552
Construction related services	20	76	33
Equipment and supply chain	203	456	172
Total Construction and Supply Chain-related	**1,519**	**3,624**	**1,756**
permanent employment			
	2015	2020	2025
Operation & Maintenance (O&M)	**315**	**1,313**	**2,036**
permanent employment			
	2015	2020	2025
Total Construction/Supply Chain/O&M	**1,834**	**4,938**	**3,792**

Employment all 5 MENA countries: scenario C			
one-year jobs			
	2015	2020	2025
Construction and interconnection labour	16,973	72,345	209,557
Construction related services	463	2,657	8,173
Equipment and supply chain	3,269	15,938	48,687
Total Construction and Supply Chain-related	**20,706**	**90,939**	**266,416**
permanent employment			
	2015	2020	2025
Construction and interconnection labour	6,170	15,184	35,589
Construction related services	172	634	1,431
Equipment and supply chain	1,308	3,495	8,764
Total Construction and Supply Chain-related	**7,650**	**19,313**	**45,783**
permanent employment			
	2015	2020	2025
Operation & Maintenance (O&M)	**1,576**	**6,567**	**19,102**
permanent employment			
	2015	2020	2025
Total Construction/Supply Chain/O&M	**9,226**	**25,880**	**64,885**

- ***Foreign trade impact:*** Additional impacts for job creation and growth of GDP could come from export opportunities for CSP components. Exporting the same components as are manufactured for local markets to EU, USA or MENA (2 GW by 2020, 5 GW by 2025) could lead to additional revenues of more than US$3 billion by 2020 and up to US$10 billion by 2025 for local CSP industries.

Figure S-9 Economic benefit and job effect by export outside MENA region



Other markets for renewable energies, such as the photovoltaic (PV) industry in Germany or the wind industry in Denmark, have contributed to the creation of a local industry. Some emerging countries like China and India have significantly boosted their own industries for renewable energies. India, for example, is creating a powerful local wind industry—with new jobs and economic benefits for the country—that has supplied the home market as well as the international wind power market in recent years. A similar development in the MENA Region could be promoted by the action plan for CSP projects and their local manufacturing presented in this report. However, the increase in CSP demand with stepped-up MENA investment could also allow strong competitors in technology supply to compete successfully with local MENA products, as has happened with Chinese PV modules or, to a lesser extent, with Turkish solar water heaters. This could then jeopardize the emergence of local CSP-related industries in the MENA region. To face competition, particularly with China or India, MENA countries would need to strengthen and develop competitive advantages:

- Rapid delivery and low transport costs are strong assets, as shipping from China or India can take days. Although rapid delivery was decisive for the MENA automotive industry, it might be less crucial for CSP as logistics are less tight.
- Enhanced R&D would help to improve CSP components, by driving down their cost and increasing their quality, thereby making them more competitive with Chinese or Indian production.

- MENA industries could tailor their CSP components production to specific local environmental conditions (i.e., desert conditions) whereas non-MENA countries would lack this knowledge.

The development of local production clauses in CSP calls for tenders that comply with international free trade agreements would help to limit competition with international low-cost competitors, but this requires careful consideration of possible negative impacts on learning curves due to a lack of competition.

The main precondition for developing the local manufacture of CSP components in the MENA Region will be to develop and grow the CSP market itself. The MENA CSP IP is a first step toward this goal.

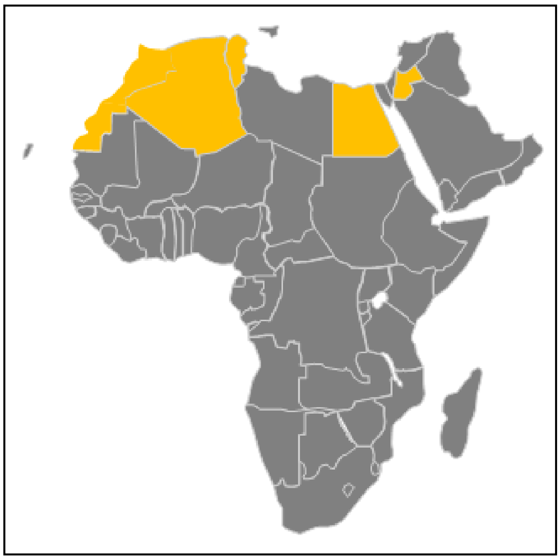
Main Report

Context and objectives of the study

Concentrated Solar Power (CSP) is a renewable energy technology which, after a period of some stagnation, has started to penetrate the energy market in recent years, particularly in Spain and the United States, but also in the Middle East and North Africa (MENA) and other regions of the world. In the MENA region, an increasing interest in CSP has appeared in the last few years, with projects under implementation in Morocco, Egypt, and Algeria. All projects currently being developed in North Africa use the Integrated Solar Combined Cycle (ISCC) configuration. ISCC plants use the output of a solar field to boost a conventional combined-cycle gas turbine plant. Projects in Egypt and Morocco have been promoted with the support of the World Bank and the Global Environment Facility (GEF) and have solar field capacities under construction, each in the range of 20 to 30 MW. These plants are expected to be commissioned by the end of 2010.

Earlier studies of the project consortium in 2009[6] have analyzed various market and policy strategies for realizing renewable energy and CSP projects in the current market environment in the MENA region. To run CSP projects in MENA competitively in the short and medium term, a portfolio of different support schemes for CSP plants is necessary, including international support through concessional loans or revenues from solar electricity exports to Europe, combined with national incentives like long-term power purchase agreements (PPAs), feed-in tariffs, or tax rebates.

Figure 1 Countries covered by the study (in yellow)



As a concrete step toward the realization of these strategies, a MENA CSP scale-up Investment Plan (MENA CSP IP)[7] was prepared by the World Bank and the African Development Bank (AfDB), and endorsed by the Clean Technology Fund (CTF)[8] Trust Fund Committee on December 2, 2009. It is a landmark climate change mitigation program aimed at co-financing nine commercial-scale power plants (totaling around 1.2 GW) and two strategic transmission projects in five countries in the MENA region: Algeria, Egypt, Jordan, Morocco, and Tunisia (henceforth referred to as “MENA CTF” countries). The vision is for the Mediterranean MENA countries to ultimately become major suppliers and consumers of CSP-generated electricity. The MENA CSP IP is conceived as a transformational program, leading to the installation of several GW of CSP capacity in MENA by 2020 based on the 1.2 GW triggered by the MENA CSP IP. The first projects are expected to start commercial operations by 2014, and to initially supply domestic markets in MENA countries.

The MENA CSP IP is accessible to other Multilateral Development Banks (MDBs);[9] the initiative strives to trigger further investment from the private sector in CSP technology, (through the DESERTEC Industry Initiative (DII),[10] for example).

The proposed transformational approach to overcome market barriers is to offer the CSP industry a credible commitment that allows it to develop a large-scale multi-country portfolio of projects. The driving idea behind such a commitment is the assumption that such aggregation will induce local mass production techniques that will create local added value and lower costs, and will improve performance of CSP technology and its components.

The Clean Technology Fund Investment Plan proposes CTF co-financing of $750 million, which will mobilize an additional $4.85 billion from international financial institutions and other sources. Approval of the CSP projects (Table 1) is scheduled by the end of 2012 to

---

6 Ernst & Young for the EU Commission and Fraunhofer ISI for the World Bank

7 http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/MENAEXT/0,,contentMDK:22412791~menuPK:247603~pagePK:2865106~piPK:2865128~theSitePK:256299,00.html

8 The Clean Technology Fund (CTF) invests in projects and programs that contribute to the demonstration, deployment and transfer of low carbon technologies with a significant potential for long-term greenhouse gas emissions savings (http://www.climateinvestmentfunds.org).

9 Multilateral Development Banks are institutions that provide financial support and professional advice for economic and social development activities in developing countries. The term MDBs typically refers to the World Bank Group and four Regional Development Banks: the African Development Bank, the Asian Development Bank, the European Bank for Reconstruction and Development and the Inter-American Development Bank Group.

10 http://www.desertec.org/en/

accelerate CSP development in the Middle East and North Africa up to 2020. During this study these projects have been discussed in depth with local authorities and potential companies in the corresponding countries.

In order to further disseminate CSP technology, a solid local foundation is needed in developing countries because—unlike other renewable energy technologies such as photovoltaic (PV) or wind energy—its potential is more limited in many of the major developed countries. To facilitate the establishment of such a basis for CSP it is necessary that the countries perceive a benefit from the technology for their economic development. MENA could become home to a new, high-potential industry in a region with large solar energy resources. When the CSP scale-up program is implemented, it could serve the local market demand.

At the same time, the program could also serve other countries in the region (through development of "local champions"), and improve existing markets in Southern Europe, the United States, and elsewhere. If the CSP market increases rapidly in the next years, the region could benefit from significant job and wealth creation as well as from sufficient power supply to satisfy a growing demand, while the world's renewable energy sector would benefit from increased competition and lower costs in CSP equipment manufacturing.

Table 1 List of CSP projects in the pipeline for CTF in MENA region

Country	CTF Investment Plan[11]			CTF Investment Plan Update		
	Project (Name)	**Capacity (MW)**	**CTF financing (US$ million)**	**Project (Name)**	**Capacity (MW)**	**CTF financing (US$ million)**
Algeria[12]	Megahir	80		Megahir	80	
	Naama	70		Naama	70	
	Hassi R'mel II	70		Hassi R'mel II	70	
Egypt	Kom Ombo	70		Kom Ombo	100	
	Marsa Alam	30				
Jordan	Ma'an Province	100		Ma'an	100	
	Mashreq CSP Transmission	-		Mashreq CSP transmission	-	
Morocco	Tan Tan	50		Ouarzazate	500	
	Ain Beni Mathar	125				
	Ouarzazate	100				
Tunisia	IPP-CSP Project	100		IPP-CSP	100	
	ELMED-CSP	100+		ELMED-CSP	100+	
				STEG-CSP	50	
	Tunisia-Italy transmission	-		Tunisia-Italy transmission	-	
Total		**~ 900**	**750**		**~ 1,170**	**750**

11 As approved by CTF Trust Fund Committee on December 2, 2009.
12 Algeria's intentions vis-à-vis CTF financing are currently unclear, and the earmarked funds may be reallocated.

There are many factors that combine to make local manufacturing in MENA countries a transformational opportunity:

- MENA CSP is well placed to benefit from the massive scale-up of concessional climate financing envisaged under the United Nations Framework Convention on Climate Change (UNFCCC) and recently reaffirmed by the Copenhagen Accord. The CTF allocation for MENA CSP could be the seed money for a financing scale-up. This would greatly help the economies of scale in CSP manufacturing, which would allow CSP to become one of the first competitive 24/7/365[13] renewable energy technologies.
- MENA CSP is central to the high-level political agreement between MENA and the European Union to make solar energy trade a fundamental pillar of MENA-EU economic integration, and therefore presents a major opportunity for MENA to earn export revenue.
- MENA CSP could be key to the realization of the EU's GHG emissions reduction and energy security objectives. The April 2009 EU Renewable Energy Directive, with its provisions for the import of renewable energy to achieve the mandatory renewable energy targets of EU member states, is an important step in that process, as are the Desertec Industry Initiative and the Transgreen/Medgrid Initiative.
- The political initiative of the Mediterranean Solar Plan may act as an umbrella for initiatives such as Desertec or others at a bilateral level.
- MENA's oil-producing countries are embarking on CSP investment programs to liberate oil and gas from the power sector for higher value-added uses and exports, while providing long-term potential for CSP energy exports.
- The MENA CSP IP could benefit from the recent Cancun agreements, which have opened the way for a much larger funding frame. The climate conference of Cancun agreed on a Green Climate Fund of $100bn a year of climate funding from 2020 that will be generated from a "wide variety of sources, public and private, bilateral and multilateral, including alternative sources." This could include a range of mechanisms, such as auctioning of carbon credits and levies on international aviation and shipping.

This combination of factors could give MENA a unique advantage as a global location for CSP production and, while creating demand for installed capacity, it could strongly drive local manufacturing.

The World Bank has mandated Ernst & Young, the Fraunhofer Institute for Solar Energy Systems (ISE), and the Fraunhofer Institute for Systems and Innovation Research (ISI) to investigate the potential for local manufacturing in the MENA region, which is the most promising area for its development due to the excellent solar conditions and the proximity to the potential export market for solar electricity in Europe. The main objectives of this study, “Assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects” for the World Bank, are as follows:

- The study should provide an overview of manufacturing processes for key CSP components as well as a cost analysis for CSP components and systems and for CSP plants as a whole, including the potential for cost reduction.
- It should further assess the potential in the MENA region for building and developing a CSP component- and equipment-manufacturing industry, focusing on Morocco, Algeria, Tunisia, Egypt and Jordan (i.e., those countries that have already submitted CSP projects for financing by the CTF (see **Error! Reference source not found.**)), but with a broader view to the MENA region.
- An action plan should be proposed to develop the potential of locally manufactured CSP components in the existing industry and of new market entrants.
- Finally, the study should analyze potential economic benefits of developing a CSP component manufacturing industry and CSP manufacturing at the construction site of new CSP plants.

Analyzing the manufacturing processes of CSP components and systems provides a suitable basis for understanding the effects, including possible industrial development, that the CSP Scale-up Initiative will create in the MENA region. Other markets for renewable energies have already been shown to create local industry in the new innovative field of renewable energies; for example, the photovoltaic industry in Germany or the wind industry in Denmark. Emerging countries like China and India are also playing an interesting role by boosting their own renewable-energies industries. India, for example, is creating a powerful local wind industry, (with new jobs and economic benefits for the country), that supplies the home market as well as the international wind power market.[14] A similar development in the MENA region could be promoted by the action plan for CSP projects and their local manufacturing, as discussed in this report.

[13] 24 hours a day/ 7 days a week/ 365 days a year

[14] Lewis & Wiser, 2007

Part I: Competitive environment – MENA countries and CSP industry

1 Review of CSP technologies

This chapter describes the technologies of concentrated solar thermal power (CSP) to provide the basis for the subsequent socio-economic analysis for the MENA-economies. Section 1.1 gives a general overview of CSP technologies. Section 1.2 presents the CSP market with its main commercial and industrial players along the value chain. In section 1.3, the main manufacturing processes are described. Lastly, section 1.4 analyzes the cost structure of a typical CSP plant.

Parabolic trough plants are the most commercial CSP technology, and amount at present to 94 percent of the CSP market and installations (CSP-Today, 2010). This is why the following sub-sections mainly focus on this technology. However, most findings apply directly or in analogy also for other CSP technologies because of technological similarity.

1.1 Overview of the CSP technologies

In a nutshell, CSP power plants produce electricity by converting concentrated direct solar irradiation into energy. Unlike photovoltaic cells or flat plate solar thermal collectors, CSP power plants cannot use the diffuse part of solar irradiation which results from scattering of the direct sunlight by clouds, particles, or molecules in the air, because it cannot be concentrated..

The process of energy conversion consists of two parts:

- The concentration of solar energy and converting it into usable thermal energy
- The conversion of heat into electricity

The conversion of heat into electricity is generally realized by a conventional steam turbine (Rankine cycle). Concentrating solar collectors are usually subdivided into two types, with respect to the concentration principle:

- Line-focusing systems, such as the parabolic trough collector (PTC) and linear Fresnel collector. These systems track the sun position in one dimension (one-axis-tracking), see **Error! Reference source not found.**.
- Point-focusing systems, such as solar towers or solar dishes. These systems realize higher concentration ratios than line-focusing systems. Their mirrors track the sun position in two dimensions (two axis-tracking), see Sources: Abgengoa, 2010 and DLR, 2010.

Error! Reference source not found. and Sources: Abgengoa, 2010 and DLR, 2010 show reference plants; the captions of the pictures include the approximate dimensions of the plants.

Figure 2 Line-focusing systems: Left: Parabolic trough collector: 64 MW_{el} power plant *Nevada Solar One*; dimensions: collector aperture width 5 m (Morin, 2010). Right: Linear Fresnel Collector: 1.4 MW_{el} plant *PE1* in Murcia, Spain; dimensions: Receiver height above mirror field: 7 m (Novatec, 2010)

Sources: Morin, 2010 and Novatec, 2010

Figure 3 Point-focusing systems: Left: Solar Tower plant PS10, 11 MWel in Seville, Spain; 624 so-called heliostats, 120 m^2 each, focus the sunlight onto a receiver on top of a 100 m high tower (Abgengoa, 2010). Right: Dish Stirling prototype plants of 10 kW_{el} each in Almería, Spain; diameter 8.5m (DLR, 2010)

Sources: Abgengoa, 2010 and DLR, 2010

1.1.1 Parabolic trough collector technology

Parabolic trough technology is commercially the most advanced of the various CSP technologies. Since the 1980s and early 1990s, nine parabolic trough plants—the Solar Electric Generating System (SEGS) plants, with a total capacity of 354 MWel—have been in operation in the Californian Mojave Desert in the United States. In the past five years, several trough plants have been built, such as a 64 MWel power plant near Boulder City, in the United States, and several 50 MWel power plants in Spain. The first commercial parabolic trough plant installed in Spain was the 50 MWel plant Andasol 1, which includes a thermal storage with a capacity of 7.5 hours of full load operation (**Error! Reference source not found.**). An overview of the commercial power plants that are developed, built and operated globally is available at SolarPaces (2010).

Figure 4 Parabolic trough power plants Andasol 1 (front) and Andasol 2 (rear) in Spain with a capacity of 50 MW each and a storage size of 7.5 full-load hours. The power block and the storage are in the center of each solar field.

Source: SMI, 2010

The parabolic trough collector (PTC) consists of a receiver, mirrors, a metal support structure, pylons, and foundations. The parabolic-shaped and facetted mirrors concentrate the sunlight onto the receiver tube. The parabolic shape is usually implemented by four mirror facets, consisting of glass sheets (4 mm thick) which are thermally bent and coated with a reflective silver layer, with additional protective layers on the back side of the silver. The absorber inside the receiver is realized in the form of a coated steel tube. The coating is spectrally selective in the sense that it absorbs the solar (short wave) irradiation well and emits almost no infrared (long wave) radiation, which reduces heat loss (Hildebrandt, 2009). The absorber tube is surrounded by an evacuated glass tube which is highly transmissive for the sun light due to an anti-reflective coating. The absorber tube and the encasing glass tube together are called the receiver. In today's commercial trough systems the entire collector—including the receiver—is tracked according to the moving sun position.

There are several innovations in PTC technology under development or in prototype status. The current developments focus on cost reductions in the assembly and production process (e.g., automized production), lighter collector structures, new materials for collector structures (such as aluminum), and new heat-transfer fluids (e.g., molten salt and direct steam).

Examples of innovative products and companies include the HelioTrough, using a larger collector aperture and a slightly larger absorber tube with a diameter of 8.9 cm instead of 7.0 cm (Riffelmann, 2009); the Skytrough, using a high-reflectance polymer film instead of glass mirrors and an aluminum sub-structure instead of steel (Brost, 2009); and the new mirror technology Vegaflex of Xeliox and Almeco (Almeco, 2010), using a stiff aluminum sandwich sub-structure with a metallic reflector. Further details on technological improvements of parabolic trough technology can be found in ATKearney, 2010.

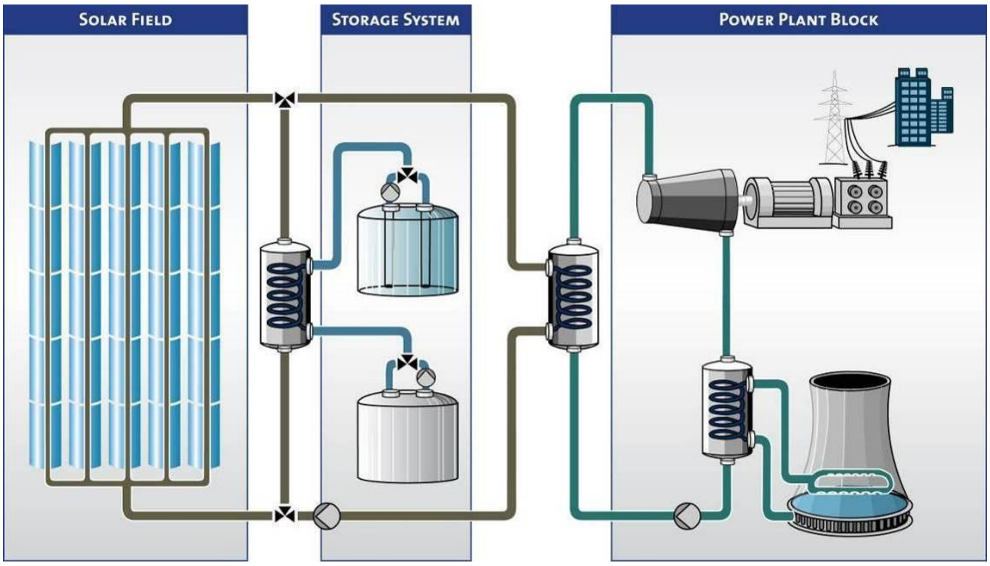
1.1.2 Parabolic Trough Power Plant System—Working principle and the option of thermal energy storage

One main advantage of solar thermal power plants over other renewable power technologies, such as photovoltaic and wind energy converters, is the option of energy storage. Unlike the storage of electric energy, thermal energy storage is practically and economically feasible already today, even in large-scale applications. Solar thermal power plants can be equipped with thermal energy storage with a full-load storage capacity in the range of several hours. Usually, the storage is filled during the day, and emptied again after sunset, so that electricity is still produced even after sunset. This allows for plant operation in concordance with load requirements from the grid, because in many countries there is an electricity demand peak after sunset. During such demand peaks, electricity prices are usually far higher than base-load prices, creating a very important added value of CSP and storage.

Various thermal storage technologies are in principle feasible for solar thermal power plants, based on different physical mechanisms (such as sensible heat storage, latent heat storage, and chemical energy storage), and by applying different types of storage materials (such as molten salt, oil, sand, and concrete). The storage material needs to be cheap, because large quantities are required. A comprehensive overview of storage principles and technologies suitable for solar thermal power plants is given in Gil, 2010 and in Medrano, 2010. It should also be noted that different heat transfer fluids (HTFs) used in the solar field require and allow different storage options.

Thermal storage is in principle applicable not only to parabolic trough power plants, but also to the other CSP technologies. However, the only power plants that are in operation today using thermal storage are the Andasol power plants shown in **Error! Reference source not found.**. The Andasol plants use a two-tank molten salt storage; see working principle in **Error! Reference source not found.**. It stores heat by heating up a medium (sensible heat storage).

Figure 5 Sketch of a two tank molten salt solar thermal energy storage embedded into a CSP power plant



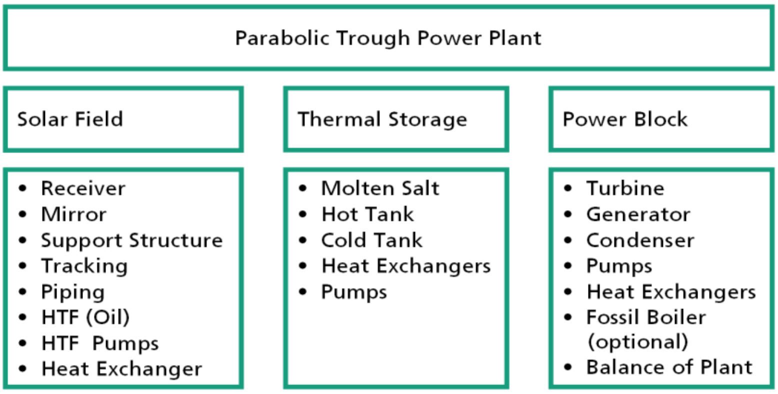
When loading the storage, the hot heat-transfer fluid, coming from the solar field, passes through a heat exchanger and heats up the molten salt. In turn, the storage is unloaded by transferring the heat from the salt back to the heat-transfer fluid. Many operation strategies are feasible for the operation of the plant and the storage. The most common one is to feed primarily the turbine directly with the heat from the solar field. Whenever excess solar heat is available, it is stored. Other options may also aim at storing the solar energy from the morning hours instead of directly converting it into electricity, and thereby using the storage for shifting rather than for maximizing the plant's operational hours.

1.1.3 Components of Parabolic Trough Power Plants

The main components of parabolic trough power plants are shown in **Error! Reference source not found.**. A more detailed description of the single components can be found in the annex (beginning at page 167) to provide the basis for the subsequent analyses of the manufacturing processes, of the cost of components and processes, and of the potential to produce components in MENA countries.

The analysis of the components is based on state of the art technology, which consists of a parabolic trough using thermal oil as heat-transfer fluid and the power block. Optionally, a thermal energy storage can be used (see **Error! Reference source not found.**).

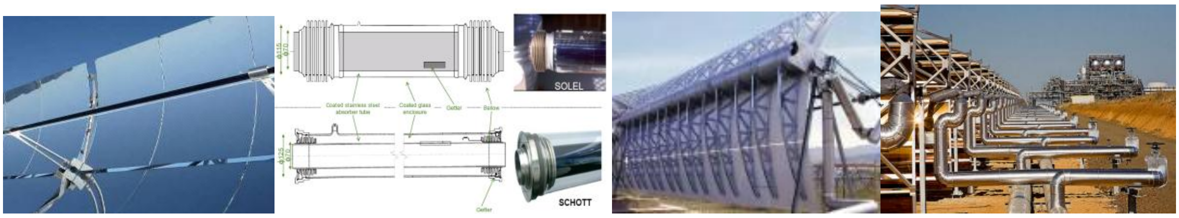
Figure 6 Components of a parabolic trough power plant are the solar field and the power block. Optionally, thermal storage can be integrated.



CSP involves many components and much labor which can generate high local value in the MENA region. The largest share of both investment and operation and maintenance costs relates to the solar field (see section 1.4). The power block side uses mostly specialized equipment that does not differ from plant components that are used in conventional power stations. Apart from civil engineering and basic construction, works are performed by a few international players (see section 1.2). The thermal storage as an optional plant component has only a few commercial installations worldwide so far. The major cost in the storage is the salt itself (Herrmann, 2004), which can be delivered by a few companies with access to the raw materials, such as the Chilean company SQM (SQM, 2010).

As CSP power plants are designed to last for at least 20 years (feed-in-tariff contracts in Spain last 20 years), stability of each component is essential. The components have to resist the harsh desert climate without degradation.

Figure 7 Mirrors, receivers, support structure, and piping for CSP plants



Sources: Morin, 2010; Castaneda, 2006; Estela Solar, 2010; NREL, 2008

Other CSP concepts – Linear Fresnel, Solar Tower, and Solar Dish

Beyond the most commercial trough technology, which represents 94 percent of the installed CSP plant capacity today (CSP-Today, 2010), other technologies are becoming more commercial and will probably increase their market shares in the near future.

Linear Fresnel collector plants

Linear Fresnel collectors (LFCs) are a variation of parabolic trough collectors. Their main difference from parabolic trough collectors is that LFCs use several parallel flat mirrors instead of parabolic bent mirrors to concentrate the sunlight onto one receiver, which is located several meters above the primary mirror field. The horizontally aligned reflectors use flat glass mirrors that are slightly curved through elastic bending. Each mirror line is individually tracked according to the position of the sun.

The receiver also consists of a long, selectively coated absorber tube, without any need for the flexible hoses or rotating connectors required by a parabolic trough. Due to the optical principles of Fresnel collectors, the focal line is distorted by astigmatism (Mertins, 2009). This requires a secondary mirror above the tube to refocus the rays missing the tube in a secondary reflection onto the tube. Another concept is based on several parallel tubes forming a multi-tube receiver, thereby increasing the width instead of using a secondary reflector.

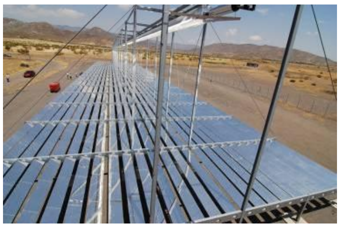
Compared to trough plants, commercial LFC technology is relatively novel. Several prototype collectors and prototype power plants have been installed in the past few years, but no fully commercial LFC power plants are yet in operation. Novatec, however, is currently building a commercial 30 MW_{el} power plant in Spain. Several concepts with different geometric and design characteristics have been developed by a number of companies, see Table 2.

The main differences between the Fresnel concept and the parabolic trough collector include:

- LFCs use cheap, flat mirrors (6-20 €/m^2) instead of expensive parabolic curved mirrors (25–30 €/m^2); furthermore, flat glass mirrors are a standardized mass product.
- LFCs require less heavy steel material, using a metal support structure with limited or no concrete (making for easier assembly).
- On-site installation of LFCs is predicted to be faster.
- Wind loads are smaller for LFCs, which leads to easier structural stability, reduced optical losses, and less mirror-glass breakage.
- The receiver on LFCs is stationary, whereas the trough receiver moves with the entire trough system around the centre of mass. This necessitates flexible connections to the piping, which is technically challenging and maintenance intensive.
- The receiver is the most expensive component in both parabolic trough collectors and in LFCs; however, the mirror surface per receiver is higher in LFCs than in PTCs.
- The optical efficiency of LFC solar fields (referring to direct solar irradiation on cumulated mirror aperture) is lower than that of PTC solar fields due to geometric principles: In order to reach a certain solar concentration, the LFC mirrors are packed more densely than in PTC plants. The advantage of reduced mirror spacing is that it requires less land; the disadvantage is that mutual mirror shading and mirror blocking of the reflected sun-light occurs. Furthermore, the sun rays are not hitting the LFC mirror perpendicularly, which leads to cosine losses.

It is expected that the mentioned cost advantages will more than compensate for the efficiency drawbacks of LFC technology, but this will have to be proven in commercial plants. Linear Fresnel collectors seem to be more open for redesign and adaptation to local conditions. Local content is probably higher than for the parabolic trough due to the simpler components. All commercial Fresnel collectors use pressurized water / steam as an environmentally friendly heat-transfer fluid. A power plant with direct steam generation thus requires fewer heat exchangers than one using HTF thermal oil.

Table 2 Different concepts of linear Fresnel collectors

Name of Company	Aperture width	Photograph	Receiver	Location
Novatec BioSol (Morin 2010)	12 m (16 mirrors of 75 cm)		Single tube absorber with secondary concentrator	1.4 MW plant in operation in Calasparra, region Murcia, Spain
Fresdemo collector of SPG and MAN (Bernhard 2009)	15 m (25 mirrors of 60 cm)		Single tube absorber with secondary concentrator	Demonstration collector at Plataforma Solar de Almería, Andalucía, Spain
Areva Solar (Areva 2010)	approx. 20 m (10 mirrors of approx. 2 m)		Multi-tube receiver, no secondary concentrator	5 MW_{el} power plant at Kimberlina, California, USA
PSE / Mirroxx (process heat <200°C) (PSE 2010)	5.5 m (11 mirrors of 50 cm)		Single tube absorber with secondary concentrator	Collectors in Freiburg (Germany), Bergamo (Italy), Seville (Spain), Tunisia, Masdar (UAE)

Solar Tower Plants

Solar Tower Plants, also called Power Towers (see **Error! Reference source not found.**), concentrate the direct solar irradiation onto a tower-mounted receiver where the heat is captured, typically generating high temperatures. This heat drives a thermo-dynamic cycle, in most cases a water-steam cycle, to generate electric power. The collector system uses a huge number of sun-tracking mirrors, called heliostats, to reflect the incident sunlight onto the receiver where a fluid is heated up. Today's receiver types use water/steam, air, or molten salt to transport the heat. Depending on the receiver concept and the working fluid, the upper working temperatures range from 250°C to 1000°C.

Figure 8: 11 MWel Power Tower by Abengoa, hundreds of Heliostats concentrate the sun (up to 500 times) onto an absorber on the top of the tower

Source: Abengoa, 2010

The first commercial solar tower plant (see **Error! Reference source not found.**) uses water as the heat-transfer fluid (HTF) and generates saturated steam to power its turbine. A promising pre-commercial concept that is currently under development uses compressed air as the heat transfer medium in combination with a gas turbine (Buck, 2008). In this case, the receiver replaces the combustion chamber of a conventional gas turbine. In the long run, high solar efficiencies in combination with a combined cycle—i.e., a combined gas and steam turbine cycle—are possible. The typical size of solar tower plants usually ranges from 10 MW_{el} to 100 MW_{el}. The larger the plants are, the greater is the absolute distance between the receiver and the outer mirrors of the solar field. This induces increasing optical losses due to atmospheric absorption as well as unavoidable angular mirror deviation due to production tolerances and mirror tracking. In addition to the Spanish company Abengoa Solar, which developed, installed, and operates the solar tower technology shown in **Error! Reference source not found.**, several new solar tower technologies have been developed in the last few years and are currently being proven in prototype power plants by the companies BrightSourceEnergy, Sener, eSolar, and Aora.

Dish Stirling plants

Dish Stirling plants use a parabolic dish concentrator made of reflector facets to concentrate direct solar irradiation onto a quasi-punctual thermal receiver. Usually, a Stirling engine in combination with a generator unit, located at the focus of the dish, transforms the thermal power to electricity (see **Error! Reference source not found.**).

There are currently two types of Stirling engines: kinematic and free piston. Kinematic engines work with hydrogen as a working fluid and have higher efficiencies than free piston engines. Free piston engines work with helium and do not produce friction during operation, which enables a reduction in required maintenance. Multi-cylinder free piston developments promise cost reduction and overall concept simplification. The size of a single Dish engine typically ranges from 5 to 50 kW_{el} (Laing, 2002).

Dish Stirling technology presents the highest efficiency (Direct Normal Irradiance [DNI] on reflector area to power generation) among CSP systems. Stirling Energy Systems, together with Sandia National Laboratories, achieved a new world record of solar-to-grid system conversion of 31.25 percent (Taggart, 2008).

A benefit of Dish Stirling technology over other CSP models is the dry cooling[15] that is used in most constructions, enabling electrical supply in arid regions. Another clear advantage over parabolic trough and linear Fresnel technologies is adaptability to slopes. A CSP power plant of MW scale can easily be installed in a mountainous region like the Greek islands. These two points—dry cooling and adaptability to mountainous regions—are the major advantages of Dish Stirling, opening an economically valuable niche to this modular scalable technology, even though the levelized cost of electricity is still higher. Another really interesting area of application is the replacement of diesel engines supporting mini grids. Since the dish Stirling concept is based on a modular scalable energy output, it presents an ideal renewable alternative to relatively expensive and oil-demanding diesel energy supply.

In the United States, large scale centralized power plants in the power range of several hundred Megawatts, consisting of thousands of Dish-Stirling units, were announced many years ago, but have not yet been produced.

[15] Dry cooling concepts also exist with other CSP technologies, but the standard technology is based on wet cooling systems.

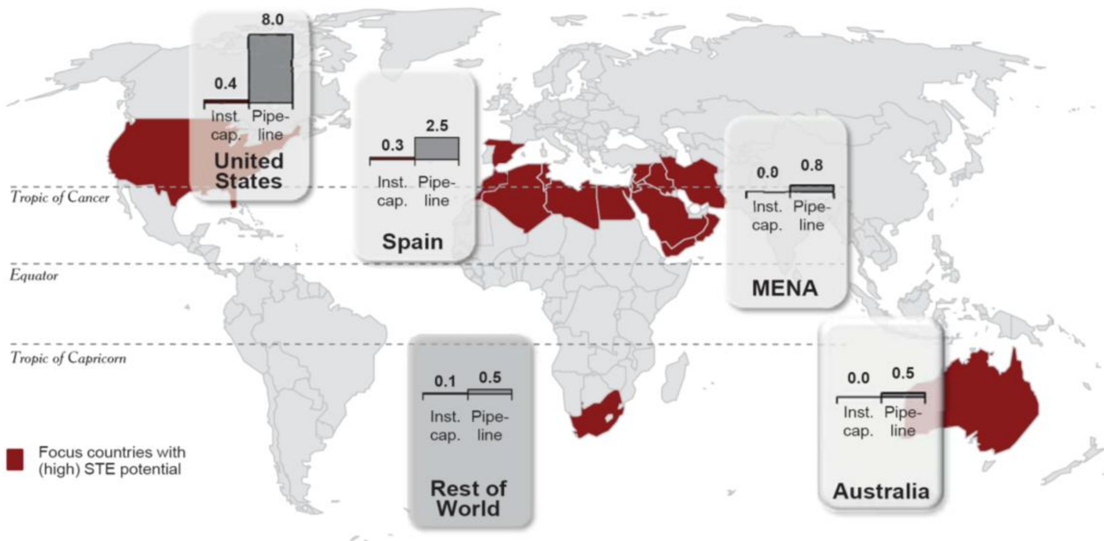
Figure 9Maricopa Dish Stirling Farm in Arizona, the park has a rated power of 1.5 MWel consisting of 60 Dish-Stirling units

Sources: Stirling Energy Systems, 2010, srpnet.com, 2010

1.1.4 Status of CSP project development

After twenty years of operation in the Solar Electric Generating System (SEGS) plants in California, the world-wide market growth of renewable energies has given CSP technology a new prospective in countries with high direct radiation. Starting in the Spanish and U.S. electricity markets, many projects are now under development and under construction. As parabolic trough plants gain status as a commercially bankable technology, this technology has announced the highest share of new projects world-wide (up to 9000 MW). However, some new projects have also been announced using Central Receivers with high solar towers, mainly in the United States. Dish Engines still show some cost disadvantages, but U.S. developers hope to overcome these cost aspects through mass production and thousands of single installations in a large area (total capacity 800-1000 MW).

Figure 10 Global CSP capacity - Existing and through 2015



Source: Estela, 2010 [16]

[16] The CSP operational power tends to change quite rapidly, especially in Spain and the US: Protermosolar provided in December 2010 the following figures: Spain Total operational 674 MW (Tower: 21 MW, Parabolic Trough 13x50 MW=650 MW, Fresnel+Stirling 3 MW), USA 505 MW(Parabolic Trough 354 + 64 + 75 MW = 493 MW, Fresnel + Stirling 7 MW, Tower 5 MW).

Although Fresnel technology has a similar solar field design and mirrors with lower production costs, due to a late development of direct steam generation (DSG) about 10 years ago, it is behind in volume of announced projects (the first 30 MW plant in the South of Spain will create commercial experience). However, compared to that, no single DSG project with parabolic trough has been announced. Table 3 shows the size of the CSP market according to the project status and lists the current CSP projects in the world market by applied technologies.

Table 3 Current CSP projects in the world market

	Operational [16] [MW]	Under construction [MW]	Planning phase[17] [MW]	Total [MW]
Tower	44	17	1,603	1,664
Parabolic	778	1,400	8,144	10,322
Fresnel	9	30	134	173
Dish & Stirling	2	1	2,247	2,250
Total	833	1,448	12,128	14,409

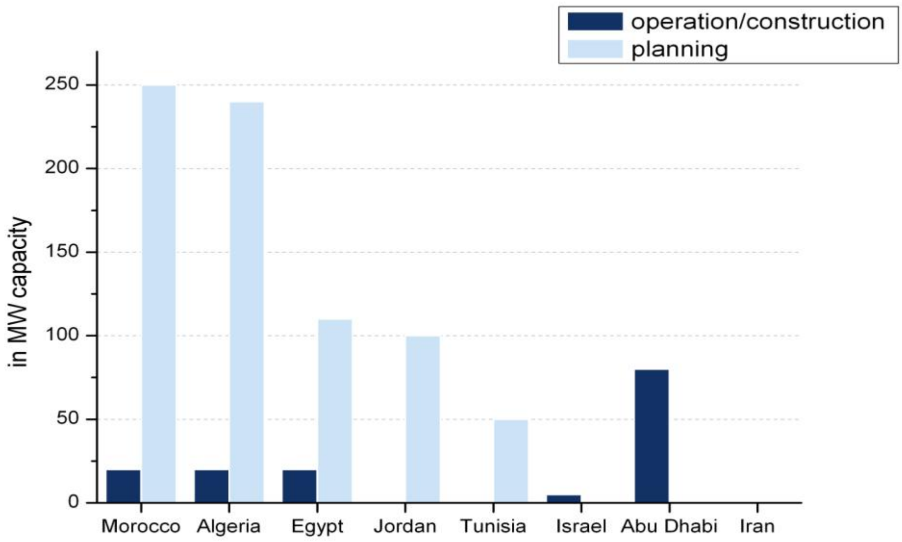
Source: Sun & Wind Energy 2010

By the middle of 2010 over 800 MW of CSP plants were in operation (see **Error! Reference source not found.**); the electricity producing plants have consequently doubled their capacity with the new installation since 2007, after the installation of the SEGS plants in California. In all categories, (operational, construction, and planning phase), parabolic trough technology is leading the world market, but the alternatives—Fresnel, solar tower, and Dish-Stirling—might enter the market quickly after further technology breakthroughs and achieved cost reductions.

The two markets in the USA and Spain are strongly dominating the CSP market (see **Error! Reference source not found.**). Based on national support incentives for CSP, the market has shown a boom in recent years. Other countries in MENA (see **Error! Reference source not found.**), Australia, and Asia are developing their first projects; if implementation is successful, further projects are expected in all of these countries.

17 Planning phase: Projects are announced by project developers or owners. Pre-engineering is taking place, but real construction and all administrational authorizations have not been finished yet.

Figure 11 MENA CSP capacity: projects under operation/construction and in planning phase[18]



There are, however, some threats to these developments, especially on two fronts:

- Due to the long-term impacts of the financial and economic crisis, a larger number of planned installations are not being realized. This could hamper the cost degression of the technology and its penetration in the MENA region.
- Other renewable energy sources show far greater dynamics: by the end of 2010, wind energy may have passed the 200 GW level of installed capacity, photovoltaic (PV) will reach 32 GW. Although CSP is seen as a complementary renewable option to wind and PV, there is also an increasing element of competition, especially with PV.

Installed capacity (GW)	End 2009	Mid 2010	End 2010
Wind energy	159,2	175,0	200,0
Photovoltaic (PV)	22,9		32,0
CSP		0,8	

Sources: World Wind Association 2010 (http://www.wwindea.org/home/index.php); Solarbuzz 2010 (http://www.solarbuzz.com/)

[18] Higher figures have been forwarded in some countries, e.g., 2000 MW in Morocco. This figure only includes planned plants that are sufficiently well documented, e.g., through calls for tender. It is not always clear how large the CSP share in those plans could be.

1.2 Structure and characteristics of international players in the CSP value chain

1.2.1 The CSP core value chain

This section gives an overview of the existing CSP value chain. It will describe the international CSP market, the key players in completed and ongoing CSP projects, and the CSP component manufacturing industries in the main markets (Europe and the United States).

The CSP core value chain consists of six main phases:

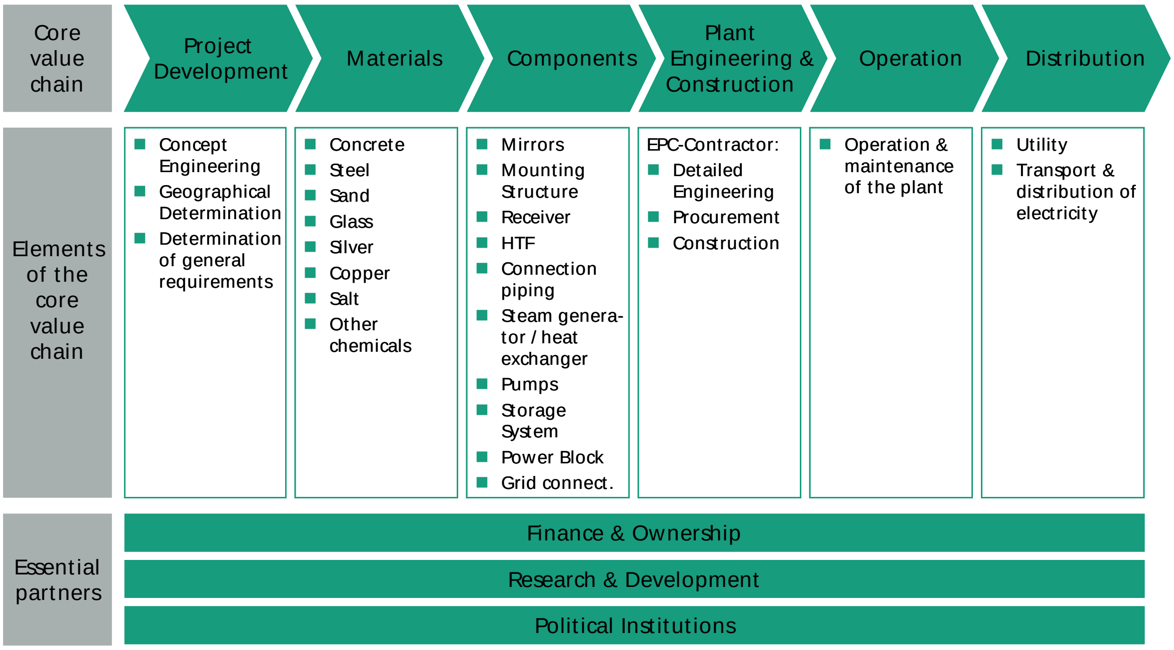
- Project Development
- Materials
- Components
- Plant Engineering & Construction
- Operation
- Distribution

There are also three cross-cutting activities, which are not directly part of the value chain, but rather serve a super ordinate function. They support the project from the beginning to the end or accompany the technology development and specifications over many years:

- Finance & Ownership
- Research & Development
- Political Institutions

In addition, these cross-cutting activities also offer prospects for local employment.

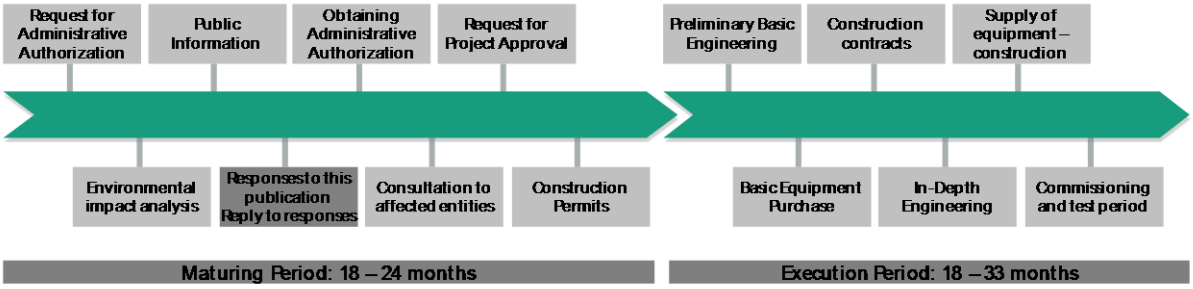
Figure 12 Basic structure of the CSP value chain including cross-cutting activities



Project development

The first phase of a CSP project is the ***project development***. The decision-making process begins with technical and economic feasibility studies, the site selection, and financing opportunities, which provide the basic scope of the project. After drawing up a first draft incorporating these basic decisions, the conceptual engineering of the project starts with a proposal for the technical specifications. Once the conceptual design is established, the permission process and contract negotiations can begin. These phases are closely interlinked with the financing of the whole project. In current projects, engineering experts specializing in power plant projects offer all the services needed for the project development. Often the project development phase tends to be the longest, due to the fact that feasibility studies, the permission process, and public decision-making processes take a lot of time. Typically, between one and three years pass between the first tender and the final project start (FichtnerSolar AG 2010 and Solar Millennium AG 2010).

Figure 13 Project development of a CSP plant



Source: Fraunhofer ISE

Materials

The second phase of the CSP core value chain involves the selection and gathering of the ***raw materials and further transformed materials.*** While some materials are provided by the world market, others are supplied locally, depending on costs and logistical aspects. Quantitatively, concrete, steel, and glass are the materials most needed for a CSP plant. For a 50 MW reference plant, for example, about 10,000 tons of concrete, 10,000 – 15,000 tons of steel, and 6,000 tons of glass are required. For the Kuraymat plant in Egypt as well as for plants in Spain, concrete and steel have been provided by local suppliers. These are the materials principally required for a CSP plant: glass for the mirrors, steel for the mounting structure, chemicals for the heat-transfer fluid (HTF), and insulating materials together with different metals for the piping.

Table 4 Material and land requirements for CSP reference plant

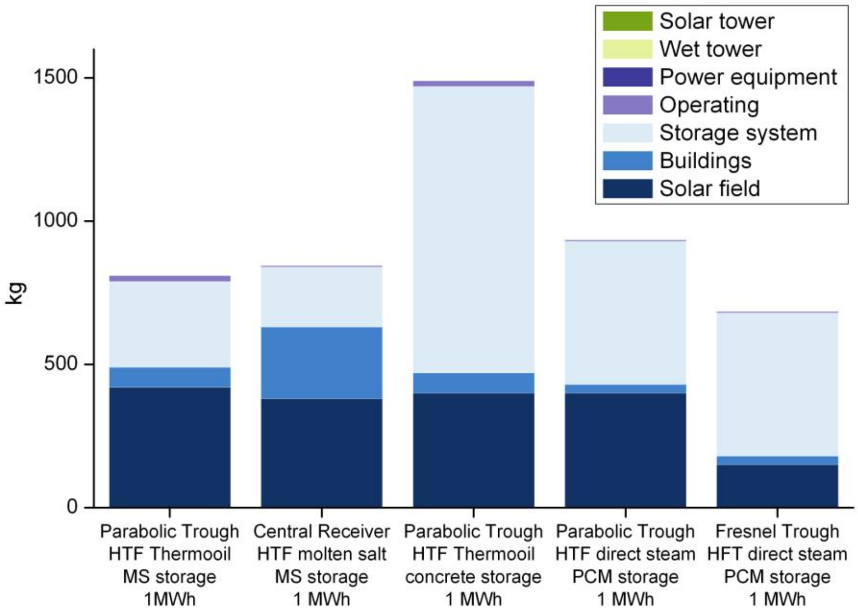
	Parabolic Trough Plant 50 MW with 7 hours storage
Steel	10,000 – 15,000 tons
Glass	6,000 tons
Storage Medium (Salt)	25,000 – 30,000 tons
Concrete	10,000 tons
Insulation Material	1000 tons
Copper[19]	300 tons
Land	2 km²

Source: Author

The German Aerospace Center (DLR) compared the materials required for different CSP technologies (Viehbahn, 2008). The material needs were normalized to 1 MW_{el} in plant size and 1 hour of thermal storage capacity in order to balance technology specifics (such as differences in efficiency), see **Error! Reference source not found.**.

19 Personal communication from Protermosolar. Although this figure is lower than for other materials, copper has a much higher value than other materials; for example, it has 10 times the value of steel at present.

Figure 14 Comparison of components of the basic solar thermal power plants, scaled to 1 MWel and one hour of storage capacity



note: The combinations of collector and storage technologies shown in **Error! Reference source not found.** is exemplary. The molten salt storage (MS) is the only commercial storage technology shown. The storage systems based on concrete and phase change material (PCM) is at prototype status, today.

Source: Viehbahn, 2008

Like Table 4, **Error! Reference source not found.** shows that the storage system accounts for a large portion of the used material. This is true for all shown technologies, despite the relatively small assumed storage size of one hour. The solar tower plant uses a higher fraction of buildings (due to the tower itself). The linear Fresnel technology uses strikingly little material. This is because of a very light collector design, but also because of the absence of the heavy concrete foundations used for all other technologies shown.

Components

This section describes the ***components***, the third phase in the value chain. Conceptually, a CSP plant can be divided into two parts: the solar field and the traditional power block. The key components of the solar field are the metal support structure for the mounting, the mirrors, and the receivers. Since the CSP market worldwide is still at a very young stage, only a few companies exist which can supply these components.

Solar Field of CSP Plant

- The metal support structure is made of steel or aluminum and is provided by traditional steel and aluminum companies. The structure has to meet certain requirements for the structural stability against wind loads in order to ensure the precise alignment of the mirrors over the entire length of the collector row, which can reach up to 150 meters.
- Mirrors for the CSP industry can be either flat (towers, linear Fresnel) or bent (parabolic trough, dish). Bending and mirror coating are standard processes of the glass industry, and can essentially be performed on standard equipment. Mirrors have to be highly precise. Even marginal reflection losses of direct radiation lead to a lower degree of electrical efficiency and therefore jeopardize the economic efficiency of the whole project. Commercially viable CSP mirror plants must have a minimum capacity (more than 200 - 400 MW_{el} equivalents per year). Typical glass and mirror companies have a wide range of customers in many industries, e.g., automotive glass, technical glass, solar mirrors, and different kinds of special-purpose glass. According to Guardian, the level of complexity for solar products is comparable to automotive requirements (shapes are more complex in the automotive segment, but geometric specifications are stricter for solar mirrors). Although raw flat glass and mirrors are traded globally, the cost of transporting heavy items in a competitive industry is a barrier; locating mirror production near consumption centers is therefore likely to happen once markets reached sufficient size.

- Receivers are the most complex part of the solar field. They have to absorb as much light as possible while reflecting as little thermal energy as possible. The transition from glass to metal has to have the same coefficient of thermal expansion. Very few companies worldwide produce this specific component. The steel in receivers has to be specifically selected for good durability and compliance with coating requirements. This steel would impose strong requirements on local production.

Mirrors, receivers, and the mounting support structure represent the main elements of the solar field. In addition, an important role is played by the heat-transfer-fluid system, which includes the heat-transfer fluid (HTF), the piping, insulation materials, and pumps.

In most of the current CSP plants, thermal oil is applied as the HTF. It is produced by large chemical companies. Approximately 13 tons per MWe installed power are needed. Insulation material (about 20 tons per MWe) is widely used and consequently a large number of producers can be identified. The quality of the insulation is highly important as it directly influences the thermal efficiency, and consequently the plant output. Some CSP projects try to use molten salt, which entails some technical advantages (large storage capacity) but a couple of disadvantages as well (e.g., freezing of salt).

In a CSP plant, the hydraulic pumps that circulate the oil or molten salt in the 20 km to 200 km long piping system, and the heat exchangers that transfer the thermal energy into steam, are rather complex and expensive components. International companies with a large degree of know-how in this sector provide these components. Some publications include the HTF systems as part of the solar field; others display it separately, as will be done in this study.

Electrical components, electronic cables, and hydraulic adjustment units (for mirrors) used in the solar field and the power block for all adjustment and control processes have to be precise and of good quality to assure a plant lifetime of at least 25 years.

Power block of CSP plant

The key component of the power block is the steam turbine. Technically, turbines could be considered the most complex and difficult part of a CSP plant. Normally turbines are manufactured by big industrial companies with long-term experience in the field. Due to the extremely specialized requirements of turbines, shipping costs are irrelevant and suppliers can be found all over the world. The power block used for CSP is very similar to that used for combined cycle power plants.

The grid connection is organized and fulfilled by the EPC contractor or other subcontractors that build the access to the local and regional power grid. By means of standardized substations and transformers, the system is connected to the medium voltage or high voltage grid for larger transmission to the final end consumer.

Engineering and construction

The fourth phase of the value chain involves the ***plant engineering & construction.*** This is performed by the engineering, procurement, and construction (EPC) contractor. The EPC contractor is responsible for the whole plant construction. As project manager, he selects all the suppliers and awards most of the jobs to subcontractors. Sometimes, even before the contracting entity chooses the final EPC, candidates have already chosen certain component suppliers due to logistical, time-sharing, or political motivations. Normally all component suppliers as well as the subcontractors who carry out the detailed engineering and the civil works are chosen by the EPC contractor. The main task of the project manager is to coordinate all partners. EPC contractors are usually subsidiary companies of industrial groups and can resort to building companies and engineering consultants in their own company group. The civil works for the total plant are also often closely connected to the EPC contractor, as many companies have their own subsidiaries or joint ventures to undertake these tasks. Large infrastructure companies for buildings, power plants, and other infrastructure projects provide the basic services for civil works, such as preparing the ground, building the supporting infrastructure (streets, houses), and creating the foundation of the power plant. For these civil works, and for the assembly and installation of the collectors, a large number of low skilled workers is required on the construction site. For example, at a Spanish power plant, 500 workers were needed for these works. In North Africa, due to lower productivity, the number of employees can increase to up to 1000-1200. EPC contractors have often been general contractors, building different kinds of plants and industry projects, for many years; they therefore have a wide range of experience to draw upon. In current projects the EPC contractor even serves, in part, as financer and owner, and for the first years is also responsible for the operation and maintenance (O&M), which binds him to the plant.

Operation

The fifth phase, ***Operation,*** includes the operation and maintenance (O&M) of the plant for up to 25-30 years. This is often performed by local sub-contractors and, as mentioned before, sometimes coordinated by the EPC contractors in the first years. Currently, about 30 people are necessary for the operation and 10 people for the maintenance of a 50 MW CSP plant (see Table 11). The tasks for operation and maintenance can be split into four different groups: Plant administration (6 workers needed), operation and control (13), technical inspection of the power block (7), and the solar field operation and maintenance (14). For bigger plants, the O&M cost per installed MW decreases (IEA 2010 Roadmap).

Distribution

The sixth and final phase, the ***Distribution***, involves delivering the electricity from the plant to the consumers. Large utility companies take the responsibility for the distribution. In the United States, these large utilities are obliged to buy or produce a certain amount of solar electricity by the Renewable Standard Portfolios of each U.S. state.

Finance & ownership and political institutions

Two of the cross-cutting activities are absolutely crucial for the realization of a CSP project: ***Finance & Ownership*** and ***Political Institutions***.

Since CSP projects are still not profitable without financial support, the project financing is often the most difficult part of the project development. In Spain for example, feed-in tariffs ensure the payment. Based on the feed-in tariff levels and specifications, private investors, together with the project developers (which can be within the same company), calculate the profitability of a proposed plant. This support mechanism improves the process of making the project bankable because of the long-term guarantees and continuous revenue flows to the owners and consequently to the creditors.

However, if the tariffs are statically set too generously over a longer period of time, the country cannot control the number of plants constructed, as happened in Spain in the PV market. In North Africa so called PPA (power purchase agreements) are often used to assure financing. In a PPA, the state controls the number of plants, and every plant is tendered separately. This leads to individual conditions for every plant constructed, but does not easily promote a dynamic market evolution. In practice, different kinds of ownership structures can be found. There are three common operator models in the context of power plants: Build-Own-Operate (BOO), Build-Own-Transfer (BOT) and Build-Own-Operate-Transfer (BOOT) (Daniel Beckmann 2003).

- In a BOO, the private sector finances, builds, owns, and operates a facility or service permanently. In the original agreement, requirements of the public sector are stated and the regulatory authority takes control.
- The BOOT contract encloses a final transfer of the plant ownership to the government or to another entity at a previously agreed-upon price or the market price.
- Compared to the BOOT contract, a BOT agreement starts the transfer to the government at an earlier point of time (5 years instead of longer periods of 20 to 30 years for BOOT contracts).

Existing financing and ownership structures demonstrate the high level of importance held by political institutions in building CSP plants. Currently, CSP technologies can only be developed with political support. With time, more countries are recognizing this and joining in providing financial support to CSP. For example, Spain has had a feed-in tariff since 2003; some states within the United States support CSP with renewable portfolio standards; Morocco has announced a national solar plan; and India is currently drawing up a feed-in tariff for solar energy.

Research & development

Research & development (R&D) is a cross-cutting issue and a very important aspect for technological progress and fast market entry. To bring the technology forward, project partners must work closely with research institutions. R&D plants play a large role here. Existing R&D plants include the solar tower in Jülich (Germany) and the Plataforma Solar de Almería (PSA) in Spain, where different CSP technologies are tested. In order to reduce the final acceptance period at the end of the construction and commissioning phase of a commercial plant, new methodologies for testing are required. A standardized testing and monitoring procedure for installed solar fields will be an important task for all future projects.

1.2.2 International value chain

Based on the CSP value chain presented above, **Error! Reference source not found.** shows the main international players involved in each phase (either companies or other stakeholders). Some projects are led by large industrial consortia that include new entrants on the CSP market (such as Veolia Environment, CNIM, and Saint Gobain). For a single large CSP investment project, a consortium is formed under an EPC contractor that supplies the components and services for the construction of the plant. After a successful cooperation in a first project, existing relations between the companies are often used to construct new CSP plants. Over the last two years, several mergers and acquisitions have taken place in the CSP industry.

Some important exemplary business activities in the recent years include the following:

- In 2006, Spanish Acciona acquired the majority on US CSP company Solargenix.

- In 2007, MAN Ferrostaal AG and Solar Millennium AG founded the company MAN Solar Millennium GmbH, specializing in project development, financing, and construction of solar thermal power plants. In 2010, this joint venture became part of the company Flagsol GmbH which until then was the engineering subsidy of Solar Millennium (100 percent). Since this merger, Flagsol belongs 75 percent to Solar Millennium and 25 percent to Ferrostaal. In the meantime (in 2009), a 70 percent share of Ferrostaal was sold by the German MAN holding to the Abu-Dhabi-based IPIC.
- In 2008, Sener and Masdar created a joint venture (Torresol) for their common CSP activities.
- In March 2009, German Siemens AG bought a 28 percent share of the Italian company Archimede Solar Energy, a technology company of vacuum receivers for parabolic trough plants. In May 2010, this share was increased to 45 percent.
- In October 2009, German Siemens AG bought 100 percent of the Israeli vacuum receiver manufacturer Solel for US$ 418 million.
- In Feb. 2010, French Areva bought 100 percent of the U.S. technology developer Ausra.
- In May 2010, Alstom invested US$55 million in Brightsource.

This chapter identifies the key players in this chain, including their function and background. The positive attitude of the existing players toward expanding their business activities in the MENA region is an important key to promoting local manufacturing, achieved through the development of their own projects in the region, and the intention to form local subsidiaries, local partnerships, and joint ventures for local manufacturing.

Assessment of key parts in the value chain

The different industries required for each phase in the value chain have specific characteristics that are described here in detail. These include, for example, business models, project experience, company size, technology specialization, etc.

In Table 5 the industrial and market structure for the key components and services are listed. The international industry is used here as an example for local industries to show how they could develop in the future. After a close look at the key components, secondary equipment for CSP is also evaluated according to industry characteristics. Results are important when assessing local capabilities for CSP, because international companies have required long-term experience and have undertaken large investments in R&D and technologies to reach market positions.

Materials (raw and semi-finished)

Since the most used raw materials (steel, concrete, and cement) are consumed for the construction and civil works in large volumes of 50 to 150 tons/MW, it is mostly large players in the local and national construction and steel industries who are mainly involved in supplying the CSP projects and EPC contractors. The assembly of the collectors is supplied by large local industrial companies that have a wide range of products and services. CSP is not the primary business concern of these companies due to the still limited market demand. These supply companies are often active in the building and infrastructure sectors. They also supply the automotive industry, which demands a large volume of these companies' products. Some of the raw materials are specific to the CSP plants, while other materials needed are also in demand for conventional power plants. The latter category includes products such as steel, concrete, and cement, and involves a large number of companies. In contrast, the number of companies on the world market that can supply CSP plants or CSP manufacturers with a very specific raw material (such as thermal oil) is limited.

Figure 15 International CSP value chain with companies/actors for each sector

Table 5 Industry structure and context of component manufacturing and services in the CSP value chain

	Industry Structure	Economics and costs
Project Development	• Small group of companies with technological know-how • Intern. actors have fully integrated activities of concept engineering; often with project development, engineering, financing • Increasing number of local developers in emerging markets like India, South Africa (partly in cooperation with intern. players)	• Activities are mainly labor-intensive engineering and permitting activities
EPC contractors	• Strong market position for construction, energy, transport, and infrastructure projects	• Large infrastructure companies with high turnover
Parabolic Mirrors	• Few, large companies, often from the automotive sector • Large factory output	• Large turnover for a variety of mirror and glass products
Receivers	• Two large players • Factories also in CSP markets Spain and US	• Large investment in know-how and machines required
Metal support structure	• Steel supply can be provided locally • Local and international suppliers can produce the parts	• High share of costs for raw material (steel or aluminum)
	Market structure and trends	**Key competiveness factor**
Project Development	• Very dependant on growth/expectations of individual markets • Activities world-wide	• Central role for CSP projects • Technology know-how • Access to finance
EPC contractors	• Maximum of 20 companies • Most of the companies are active on the markets in Spain and the US	• Existing supplier network
Parabolic Mirrors	• A few companies share the market, all have increased their capacities • High mirror price might decline	• Bending of glass • Manufacturing of long-term stable mirrors with high reflectance • Some players also include the up-stream float glass process
Receivers	• Very dependant on market growth • Low competition today, but new players are about to enter the market (e.g. Archimede (Italy), new players from China)	• High-tech component with specialized production and manufacturing process
Metal support structure	• Increase on the international scale expected • Subcontractors for assembling and materials	• Price competition • Mass production / Automation

	Strengths	Weaknesses	Opportunities	Threats
Project Development	• Reference projects • Technology know-how	• Dependency on political support	• Projects in pipeline	• Price competition with other renewables
EPC contractors	• Reference projects • Well-trained staff • Network of suppliers	• High Cost	• Projects in pipeline • Achieve high cost reduction	• Price competition with other renewables
Parabolic Mirrors	• Strong market position of few players • High margins (high cost reduction potential)	• Cost of factory • Continuous demand required	• New CSP markets • Barriers for market entrance	• Unstable CSP market • Flat mirror technology (Fresnel / Tower)
Receivers	• High margins (high cost reduction potential)	• Dependency on CSP market • High market entrance barriers for new players (know-how & invest)	• High cost reduction potential through competition	• Unstable CSP market • Low market demand • Strong market position of few players (new players to become commercial soon)
Metal support structure	• Experience • New business opportunities for structural steel • Low entrance barriers	• High cost competition	• Increase of efficiency and size	• Unstable CSP market

Cost and logistical advantages are the main drivers in selecting a sub-contractor for the CSP projects in Spain or the United States. Very often the suppliers sell their products on an international level. Spanish CSP plants are built with Turkish steel or Israeli Haifa Chemicals supply salt for the storage systems.

Glass companies whose manufacturing is not centered around CSP mirrors see the potential of a good business opportunity and sell their high-class mirror products to this market. Therefore, investments often are made in markets with existing production capacities and factories. Producing CSP mirrors is constrained by the need for low-iron glass ("white glass", as opposed to regular "green glass"), a glass quality required almost exclusively for this type of use. Solar grade glass can in principle be produced at any float line, provided that appropriate low-iron sand is used as the raw material.

Very high quality sand can be found locally in Michigan; high quality low-iron sand is also available in countries like Belgium and Jordan. Sand is very abundant in the Sahara desert and in the Gulf region but, according to Guardian, it is not suitable for solar glass. Since other applications for white glass are limited, it is a costly product. Transitions from green to white (and back from white to green) take about two weeks each, during which the production of the float line is lost, as it operates on a continuous basis (24/7 non-stop for 15 years); the production of glass during transitions can be recycled, but considerable amounts of energy are wasted in the process. A typical float produces approximately 30,000 square meters of glass per day, i.e., over 10,000 mirrors, which is enough to power 5 MW of CSP (depending upon DNI); thus, making mirrors for a 100 MW CSP plant takes less than three weeks. In other words, a CSP-only float line would only be justified by a yearly market of around 2 GW.

Power block, steam generator, and heat exchangers

Since the power block unit uses many of the same components as conventional thermal power plants, large companies internationally active in converting thermal energy to electricity are also active in the CSP market. Companies like General Electric, Siemens, Alstom, ABB, and MAN Turbo are the most important players for steam turbines, generators, and power control. These high-technology companies also cover the technical side of distribution and connection to the grid. A high level of expertise is required for these components in order to reach continuous output, a large number of operating hours and, in particular, high energy-conversion efficiency. The steam turbine technology is mature, so no new revolutionary technological advancements are expected in this highly competitive and concentrated market, with companies like Siemens, Alstom, and GE controlling the major share of the global market.

Storage system

The company Sener is currently the most experienced player in thermal storage for CSP plants. It is responsible for up to 12 molten salt systems (mainly in Spain) which are either in the operation, construction, or design phase. For example, the storage system used in Andasol 1 consists of two tanks of 14m height and 38.5 m diameter with a concentrate of nitrate molten salts (60 percent $NaNO_3$ + 40 percent KNO_3). This engineering company with 5700 employees has its own very strong R&D division, on which Sener spends 10 percent of its revenues.

Flagsol had developed the molten salt thermal storage concept even before Sener entered this market jointly with Flagsol. Flagsol was responsible for the engineering, procurement, and construction of the molten salt storage of the Andasol 3 power plant (currently under commission).

In general, the molten salt thermal storage is not a technology that can be provided only by one player. The components used are standard components in chemical and energy plants. Therefore, no monopoly/oligopoly is likely. However, this might not be the case with the salt itself as a raw product. One 7.5 hour storage system for a 50 MW_{el} plant needs about 3 percent of the annual salt production of the main supplier (SQM, Chile). Recent salt price increases might be a consequence of increasing demand from the CSP industry.

For example, German Züblin AG is working on a storage concept with concrete as storage material, today at prototype status.

Finance and ownership

The large volume for the finance of CSP plants (4-8 Mio. US$ / MW) is often provided by many different companies, banks, or financial institutions. On the Spanish CSP market several special purpose vehicles have been founded by a project consortium. Andasol 1 was financed in the beginning by the companies Solar Millennium (25 percent) and ACS Cobra (75 percent). In 2009, after the commission of the project, Solar Millennium sold all shares to ACS. Andasol 3 holds a share in the ownership of the special purpose vehicle “Marquesado Solar S.L.” of which RWE AG, Stadtwerke Munich, Rheinenergie, MAN Ferrostaal, and Solar Millennium also share the ownership.

In Algeria, the ISCC plant was financed by a consortium of the engineering and EPC contractor Abener and Sonelgaz (NEAL).

For these first projects, the risk was consequently shared between the project developers and larger investors. The project developers tried to issue a fund to increase their limited financial resources in order to retain these shares of approximately 25 percent.

After finishing the project, the project development company very often sells its share to other owners for the operation. Large development aid institutions have played a very important role in Egypt and Morocco. The Global Environment Facility – together with its implementing agency the World Bank – has been strongly involved in the financing of CSP plants by giving grants to cover the excess costs of CSP.

As in any large investment, debt financing is an important pillar of financing CSP projects, with a share of typically 70-80 percent of the total project volume. Debt financing helps to lower the cost of capital because it is cheaper (approximately 5-7 percent p.a.) than institutional equity financing (approximately 12-15 percent p.a.). Usually, debt financing is realized by long-term bank loans or long-term bonds. The ease or difficulty of realizing debt financing depends on the banks' risk perception of the technologies. Today, parabolic trough technology is the only technology that is considered "bankable" or "proven technology" because of its long-term performance track-record.

In coming years, other CSP technologies will achieve bankability as well, through proof of performance in demonstrators and in commercial installations.

Political institutions

National and international policy guidelines and new energy laws on renewable energies have been an important driver for CSP projects, especially in Spain and the United States. Without governmental financial support for CSP technology, the development of CSP projects would not have been economical and bankable, due to the current higher cost of CSP technology as compared to existing conventional fossil alternatives in competitive and liberalized energy and electricity markets. Promotion by the Spanish ministry (Ministerio de Industria, Turismo y Comercio) and by U.S. federal ministries for energy has been necessary to pave the way for CSP in both countries. In both countries, research activities on all topics related to CSP have been increased. These include efficiency increases, new storage options, higher thermal temperatures, and new plant concepts.

Research & Development

Technology research institutions in the United States, Germany, and Spain have been involved in most commercial technology developments. This technology transfer from institutes to the industry usually happens through the following steps:

- Founding of new companies from institutes' staff
  (e.g., Novatec Biosol, Concentrix Solar or PSE from Fraunhofer ISE; CSP services from the DLR)
- Often, the industry also recruits employees from institutes to build up a high-skilled labor force of engineers and project developers
  (many examples from almost any institute to almost any CSP company)
- Licensed production of components
  (e.g., tower technology by DLR commercialized by Kraftanlagen München)
- Development of materials/components for the industry
  (e.g., absorber coating of Schott developed by Fraunhofer ISE)
- Testing of components for the industry
  (e.g., testing of the Eurotrough collector on Plataforma Solar de Almería by CIEMAT and DLR, receiver testing of Novatec by Fraunhofer ISE)

Furthermore, standardization issues in CSP technology are currently pushed forward on an international level mainly by research institutes (NREL and DLR).

Most activities in CSP started from initiatives in research institutes. All mentioned activities contributed essentially to the development of industrial products and the entire CSP sector. Many leading engineers and decision makers in CSP companies have a background in one of the leading research institutes. The market growth increased the demand for well trained staff to construct, operate, and maintain a CSP power plant.

1.3 Overview of manufacturing processes for the CSP components and systems

This section focuses on the production and assembly steps of the technology. Every CSP product for each company has specific requirements during the manufacturing, production, and assembly processes. In some cases, these steps even vary from project to project; for example, a larger project might justify the use of mass-produced components to be ordered and produced only in large volumes (especially concerning the collector support structure). Using representative examples, this section gives an overview of component production for CSP solar fields. As in section 1.1.1, the focus is set on solar collectors in parabolic trough power plants. However, some general statements on the transferability of the production steps to other technologies are also included in the different sub-sections.

The manufacturing processes described below are structured according to the following four components:

- Civil Works – Site Preparation and Foundations (section 1.3.1)
- Parabolic trough receiver – Production processes (section 1.3.2)
- Bent glass mirrors – Production processes (section 1.3.3)
- Metal structure – Production and assembly (section 1.3.4)

If local manufacturing is to take place in Northern Africa, new production capacities will have to be built up in these countries, because the current capabilities are low or non-existent. The key parameters – component costs and their typical factories – are summarized in Table 6. As civil works, assembly, receivers, mirrors, and mounting structure are by far the most important parts of the plant in terms of investment cost, these manufacturing processes and construction activities are assessed and described in particular detail.

Storage, which represents a high share of the total plant costs (approximately 10 percent of the investment for a 7.5 hour storage), includes a significant cost fraction related to a raw material – the salt itself – that has to be imported from countries with local resources.

The following table provides information about the importance of each plant component in terms of investment intensity as well as initial investments needed for building up production facilities for the individual components.

Table 6 Important parameters of manufacturing process for key CSP components for European industry and European CSP plant

Components	Cost per entity	Typical investment in new factory	Annual output of typical factory	Share of CSP plant on annual output	Jobs created One-year job = Fulltime equivalent for one year	One-year jobs / MW	Share of labor	Energy intensity	Industries Synergies / potential side-markets
Civil Work	-	-	-	-	250-350 one-year jobs per 50 MW	5-7 Jobs/MW	High	Low	High
Installations on the site	-	-	-	-	100 one-year jobs per 50 MW	2 Jobs/MW	High	Low	High
EPC Engineers and Project Managers	€150,000 per Engineer or Project Manager per year	-	-	-	30 – 40 one-year jobs per 50 MW	0.6 – 0.8 Jobs/MW	High	Low	High
Assembling	-	-	-	-	50-100 one-year jobs per 50 MW	1-2 Jobs/MW	High	Low	High
Receiver	€800-1000 (4 m long)	25 Mio Euro	200 MW	12-25 %	140 jobs in factory	0.3 – 0.7 Jobs/MW	Low	Medium	Very low
Mirror *flat* (Float glass)	€6-20 /m²	26 Mio Euro	1 Mio mirrors 200-400 MW	~ 20 %	250 jobs in factory	0.6 – 1.2 Jobs/MW	Medium	High	High
Mirror *parabolic*	€25-40 /m²	30 Mio Euro	1 Mio mirrors 200-400 MW	~ 20 %	300 jobs in factory	0.7 – 1.5 Jobs/MW	Medium	High	Low (if glass production is included then high)
Mounting structure	€45-60/m² €2.00/kg – €2.50/kg	10 Mio Euro	150-200 MW	30-40 %	70 jobs in factory	0.3 – 0.5 Jobs/MW	Medium to High	High	Medium
HTF	€2.70 – 3.20 /kg	Very large	Large	Small	Not identified		Low	Medium	Low
Connection piping							Low	High	Medium
Storage system	$0.65/kg Salt	-	-	-	50 one-year jobs per 50 MW		Low	Medium	Low
Electronic equipment	Not identified	Medium	Medium	Small	Not identified		Medium	Medium	Medium
Reference CSP Plant (50 MW, 7,5 h storage)	7.26 M $ / MW (364 M $ totally) (with 7h storage)	-	Current plants 50 MW to 100 MW	-	500 one-year jobs per 50 MW (only on the plant site)	10 Jobs/MW only on the plant site	High	Low	-

1.3.1 Civil Works – Site Preparation and Foundations

The maximal slope of a site for a parabolic trough plant is 1-3° (NREL, 2009). With excavators, the site is flattened to match the requirements of the collectors. The pylon foundations of the collectors require excavations of about 2 meters' depth on a square of 2.5x2.5 meters (Fichtner, 2009). Pylon foundations are individually designed for end pylons, drive pylons, middle pylons, and shared pylons, as well as in reinforced design for the outer areas of the field, where higher wind loads are expected, see **Error! Reference source not found.**. Sometimes, an additional wind barrier has to be added to avoid large wind loads or sand pollution of the solar field. Additional civil works include all construction for infrastructure like roads to the building site or machine houses, assembling halls, engineering offices, and logistic centers as a feed stock for material and components. These works are basic construction work and not CSP specific; therefore, local companies provide this service for the installation of the plant.

Figure 16 Construction site of parabolic trough solar field at Kuraymat (Egypt) with the foundations of the solar field

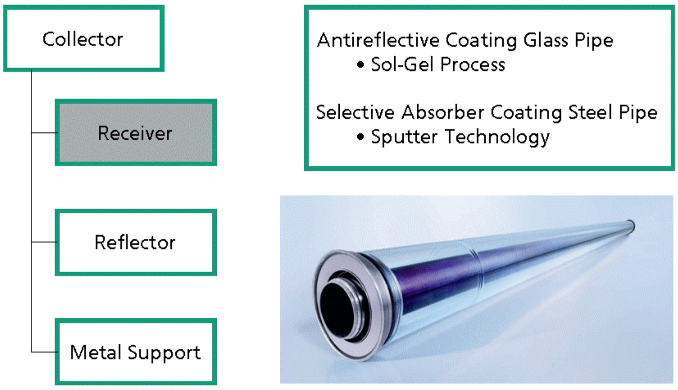
Source: Fichtner, 2009

Ideally the natural, non-leveled land has a slope of less than 1 percent; For PTC and Linear Fresnel collectors 3 percent is still feasible (depending on ground type). Tower and Dish technology are less sensitive to slope and can accept up to 5 percent (NREL, 2009).

1.3.2 Parabolic trough receiver – Production processes

The processes referring to the technical characteristics are presented in **Error! Reference source not found.** and briefly described below. A more detailed description is given in the annex (page 167).

Figure 17 Parabolic Trough Receiver PTR 70 of the company Schott Solar

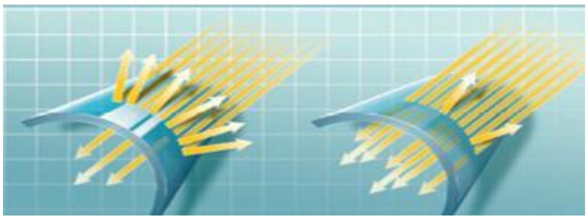


Source: Schott, 2009

Anti-reflective coating on borosilicate glass tube – The Sol-Gel Process

To maximize optical transmissivity of the receiver glass tube, an antireflective layer is deposited on each surface of the tube, see **Error! Reference source not found.**.

Figure 18 Borosilicate glass tube without anti-reflective coating (left) and with anti-reflective coating (right)



Source: TU Ilmenau

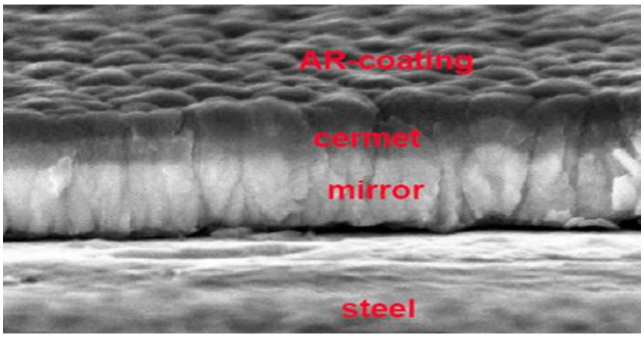
The coatings consist of a varying porous structure that serves as a gradient of the reflective index from its level in air to its level in borosilicate glass. Due to this continuous gradient, the reflection can be reduced to a theoretical minimum. To coat the tube, it is dipped into an acid-modified solution containing silicon dioxide and is pulled out of it at a speed of one centimeter per second (Hel, 2008). The resulting layer has a width of 110 nanometers. The porous structure of the film can be achieved by adding a "porogen" material to the "sol-gel" solution. This compound is removed during a heat treatment after the dipping, generating pores inside the polymeric silica films. The sol-gel dip-coating technology is a widely used method for producing antireflective layers on large area glass and is also applied to solar receivers. The sol-gel process is applicable on a large scale.

The technical challenges are to achieve temperature stability and resistance to natural impacts like dirt or rain.

Selective absorber coating – The Sputter Process

To coat the thin layers of the absorber system, precise layer compositions and precise layer thicknesses are required with high homogeneity on large surfaces. This is achievable with the sputtering technology.

Figure 19 Left: Exemplary sputtered absorber coating (Hildebrandt, 2009) Right: Sputtering machinery at Fraunhofer ISE (ISE, 2010)



Sources: Hildebrandt, 2009, and ISE, 2010

Sputtering is based on a self-maintained noble gas discharge, known as the plasma in an evacuated chamber. First, the gas is ignited (ionized) at low pressure. Then, forced by kinetic energy supplied by electrical fields, the gas ions erode small molecular fractions from the coating material (the target) by collision (Kennedy, 2002). These fractions deposit on the substrate (the absorber), creating the sputtered layers. The different layers are formed by using different materials as sputter targets and different gases as additives to the noble gas (Zelesnik, 2002). For further description of the production techniques please refer to the annex (page 167).

This technology-intensive procedural step is only handled by very few companies, and only two of them, Siemens (formerly Solel) and Schott, have commercial experience applying the sputtering technology to vacuum receivers of parabolic troughs.

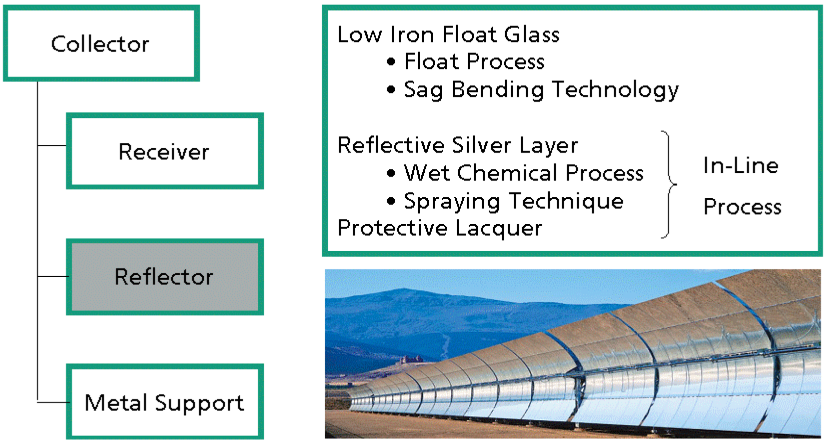
Due to the complexity of the sputtering process, and due to the difficulty in connecting the absorber steel tube to the surrounding borosilicate glass tube (different thermal conductivity of glass and steel normally leads to glass breakage during heating), it seems rather ambitious for MENA companies to enter the market of parabolic trough receiver technology as new entrants with no experience in coating processes. However, in the near future, it might be interesting for companies like Schott and Solel to open up local production facilities as soon as the MENA markets become more important – as they already have in Spain and in the United States.

Most Fresnel and Tower technologies also use selectively coated absorber tubes based on sputtering; the only difference is that they use different materials (both steel and coating material) to match individual requirements (mainly air stability and temperature). Companies offering vacuum receivers cannot automatically produce other coatings (with air stability and for other temperatures) because the development of an application-specific steel-coating system is necessary. The machinery and the production process, however, is in principle the same for all these applications.

1.3.3 Bent glass mirrors – Production processes

The reflector is another core component of the solar collector, as it concentrates the solar irradiation on the receiver. The optical precision is generated by exactly bent glass mirrors that are coated with a reflective silver layer. It has yet to be proven that collector systems using alternative aluminum- or polymer-based reflective materials can achieve the required long-term stability as well as reflectivity performance while still competing with the cost benchmark of the thick glass mirrors. Collectors based on glass mirrors are expected to remain the most important technology line for quite some time. That is why this report focuses on the production of commercially available thick glass mirrors. Further information regarding different mirror types is given in the annex (page 167).

Figure 20 Parabolic Trough mirrors



Source: Flabeg Solar 2010

Production of glass – Float process

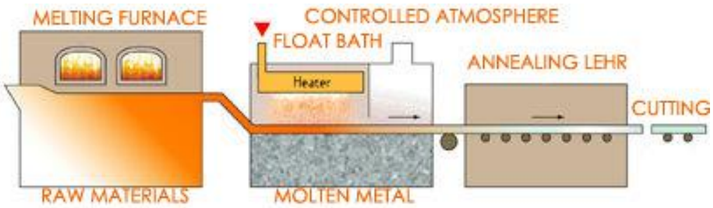
The whole glass production is very energy demanding, mainly due to the float process, and requires large and capital-intensive production facilities. However, the raw materials – which are primarily white silicon sand, old white glass, and soda ash – are available in huge quantities and at low price. The float process is state-of-the-art technology producing large glass sheets in high quantities. The raw materials are fed into an industry-size melting oven, where they are heated to temperatures of 1600°C and thereby converted into molten glass (see Source: Pilkington, 2003).

Figure 21 Gas heater of a float plant to melt the raw materials before the float process

Source: Pilkington, 2003

The molten glass is poured continuously from the furnace onto a shallow bath of molten tin. Due to its inferior density, the glass floats on the tin, spreads out, and forms a level surface because of its surface tension, as oil does on a water surface. The thickness of the glass sheets can be varied by the transportation speed of the glass ribbon and by the flow speed of the molten glass on the tin bath, or by stretching the glass ribbon or compressing it at its edges. **Error! Reference source not found.** and **Error! Reference source not found.** show sketches of the glass production facility.

Figure 22 Sketch of float process: After the melting of the raw materials, the molten glass is poured onto the liquid tin to stretch and form flat surfaces



Source: Glasstech, 2010

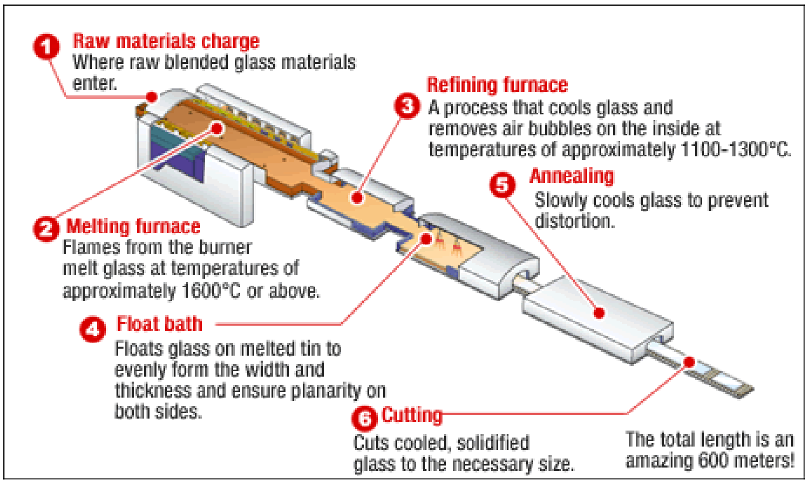
An astonishing 75 percent of the total energy demand is due to the melting of the raw materials. The float glass processes can hardly ever be stopped during the entire lifetime of the plant, which is approximately 10 -15 years. A plant produces around 6,000 kilometers of glass annually, in thicknesses of 0.4-25 mm and in widths of up to 3 meters (Pilkington, 2003).

According to Pilkington, over 380 float lines are in operation worldwide, with a combined output of about 1,000,000 tons of glass annually. In other words, the mirror glass necessary for the Andasol 1 power plant took up the production of about one week of one large float-glass production facility (see **Error! Reference source not found.**).

Most of these float production lines, however, do not produce solar glass, or so-called "white glass"; instead, they produce "green glass," which contains a higher fraction of iron dioxide (and therefore appears greenish at the edges). For most applications (e.g., in housing), the resulting reduction of transmittance of green glass is acceptable, but it is not so for solar applications, such as receiver glass tubes, parabolic mirrors, and the photovoltaic industry. Only recently, an increasing number of companies have been focusing on this new attractive market, mainly driven by the demand of the photovoltaic industry.

Considering the huge and complex manufacturing line (600 m length of float glass line), this process is very investment- and capital-intensive.

Figure 23 Sketch of production facility of in-line float process



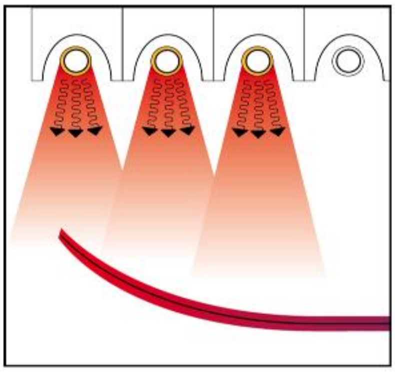
Source: AGC, 2010

Bending of glass

Glass bending is a process which is mainly used by the automotive industry (for car windows). All glass bending processes are thermally driven. There are two principle options for bending glass: the sag bending process and the quench bending process. Both processes are applied by different manufacturers of parabolic trough mirrors.

As parabolic trough power plants require bent reflectors, it is necessary to bend the glass into exact shapes. The best accuracy is provided by the sag-bending technology (Flabeg, 2009). During the sag bending process, the temperature is raised to 650°C (Glaeser, 2001), to reach viscous glass condition. This temperature can be provided either by gas or by electrical heaters. Subsequently, the glass sheet is put into a precise forming bed, where the sheet adopts the parabolic form due to gravity (see **Error! Reference source not found.**).

Figure 24 Precise radiant heater for sag bending



The quench bending process can only be applied to tempered glass. Glass tempering is a process in which the glass is heated up to 700°C and then shock-cooled. This induces inner tensions in the glass, which increases mechanical stiffness and is applied for security reasons (so that breakage will result in small pieces with round edges).

Today, the bending process can be performed by a single machine, allowing for highly automated production. Even the integration into another production line is possible, due to the modularity of the bending process.

Source: Glaston, 2010

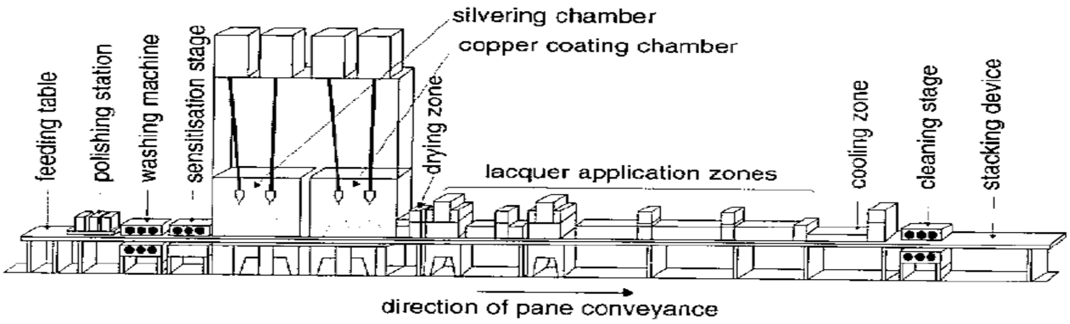
Turning a glass sheet into a mirror – Wet chemical spraying

This process is applied to coat the bent glass sheets with reflective silver and necessary protective layers.

First, the parabolic bent glass sheets have to be cleaned by a polishing and washing machine using only dematerialized water (Glaeser, 2001) to guarantee a perfectly clean glass surface (in nano scale). After that, the sheets have to be silvered, which is achieved through a spraying process.

The solutions containing the silver nitrate and the reducing agents (which are prepared, stored, and applied separately) are pumped to spraying guns to spread the mixture onto the pane surface (Glaeser, 2001). The layer is generated immediately, as soon as the liquids mix and hit the glass surface. It is very important to avoid reducing the silver nitrate solution with the reducing agents before it proceeds from the guns to the flat glass pane; otherwise the mirror surface may contain corns.

Figure 25 Silvering of glass mirrors and application of protective layers



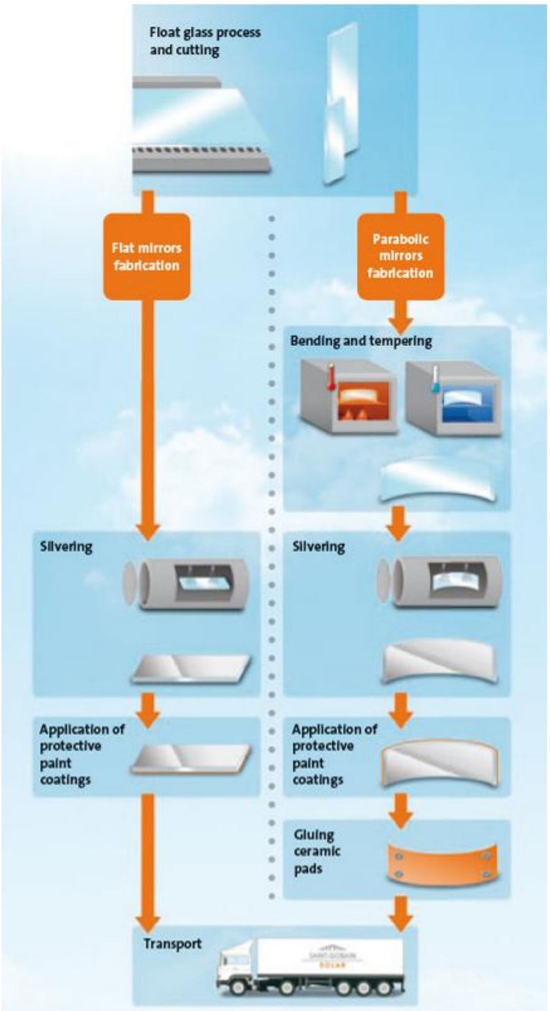
Source: Glaeser, 2001

The next step after the silver layer generation is to deposit a protective copper layer on the reflective coating in a separate chamber. After that, the system is dried by radiant heaters and finally coated with special lacquers to be able to resist the impacts of nature in desert-like areas during the whole life-time of the CSP power plant. The entire coating of silver mirrors is carried out as an in-line process (Glaeser, 2001). In-line silvering plants have a length of approximately 200m. To operate a modern plant, a large amount of demineralized water and a steady energy supply is necessary.

Solar Towers and Linear Fresnel collectors use flat glass mirrors (see *Source:* Saint Gobain, 2010). This means that the bending process (and in some cases also the glass tempering)[20] can be omitted. The pads for the fixation of the mirrors to the trough mirror support structure can also be omitted for flat mirrors. Companies offering bent parabolic mirrors typically also offer flat glass mirrors. The reverse is not true. A company which is able to produce only flat glass mirrors has to invest significant efforts to learn the processes for bending and coating the glass.

[20] The tempering of the glass results in mechanically more stable glass sheets which, on the other hand, break into small glass pieces, in case of breakage (security glass). Both tempered and non-tempered glass is provided by the CSP mirror industry and is used in both trough and Fresnel technologies. (E.g. Flabeg uses non-tempered glass.)

Figure 26 Construction of Solar Glass Mirrors



Source: Saint Gobain, 2010

1.3.4 Metal structure – Production and assembly

After the receiver and the mirrors, the metal support structure is the third core component of the solar collector. There is a large variety of collector structures on the market today; some examples of different structure types are compiled in Table 41 in the annex (page 169). As competition among the CSP collector providers increases and the market conditions toughen, cost-efficient concepts based on mass production and standardized components increase their market share. That is why the involved engineering companies develop concepts based on fewer different parts and faster production assemblies. Today, there is still huge cost-saving potential regarding this component, as the whole assembly and construction process is not nearly as developed as modern automotive equivalents.

The mounting procedures of the different collector systems vary, and details of the structure and the assembly are usually proprietary know-how of the companies. For example, the production and the assembly of the steel structure of the Spanish company Sener (Sener Trough), using stamped cantilever arms (Sener, 2007), are described here, according to their chronological steps:

- Galvanizing process
- Stamping process (cantilever Arms)
- Welding process
- Jig assembly

Galvanizing process

The steel structure is protected against corrosive influences such as humidity from wet cooling, nightly condensation, and high air salinity in coastal areas. To provide protection against these threats, different well-known applications are available. All CSP collector types using steel structures need to apply such a protection against corrosion.

Hot dip galvanization (a metallurgical process) is the most common protection method, coating steel with a thin zinc layer during a dip coating process. During the coating, the metal is put into a conductive liquid, and then an electrical current is connected, see Source: Sener, 2007

Figure 27 Hot dip galvanizing of a whole torque tube

Source: Sener, 2007

Via an electric field, the zinc molecules are transported to the metal and form a protective layer on it. The zinc coating prevents corrosion of the metal by forming a physical barrier. When exposed to the atmosphere, zinc reacts with oxygen to form zinc oxide, which further reacts with water molecules in the air to form zinc hydroxide, and later with carbon dioxide to form zinc carbonate. This thin layer is impermeable, tenacious, and insoluble, protecting the deeper layers from corrosion.

This hot dip galvanization results in a very thin coating that prevents corrosion of the metal support. The advantage of this process is its low cost and ease of application compared to other protective coatings like lacquers.

Stamping: Cantilever arms

Stamping techniques allow manufacturing of a high number of identical pieces able to fulfill resistance and stiffness requirements, as well as increased accuracy requirements. To stamp the cantilever arms and the absorber tube supports from pre-galvanized steel sheets requires a massive stamping machine (Casteneda, 2006). It has to be sufficiently strong to stamp even thick steel sheet accurately. Its adjustment is optimized to reduce material waste. Because of the pre-galvanizing of the steel, no later corrosion protection has to be applied. Repeatability and geometrical accuracy of the stamped pieces is very high, so it is possible to fix the mirrors directly to the metal support during the jig-assembly (see below), eliminating the necessity for further intermediate attachments, which had to be used to fix the mirror to the metal support structure in earlier collector constructions. Figure 28 shows a stamped cantilever arm of the SenerTrough.

Figure 28 Stamped cantilever arm by Sener; the design was developed to reduce material and energy demand

Source: Casteneda, 2006

This mass production achieves cost reduction of 30 percent compared to existing solutions (Casteneda, 2006), and this figure can be improved even further if a growing demand allows for bigger machinery and cheaper purchase prices.

Stamping is not the only approach to mass production of cantilever arms; the same results can be obtained by laser-based or water-jet cutting methods. The HelioTrough collector by Flagsol employed yet another alternative, though still based on cantilever arms and a torque tube. This new concept, which Flagsol developed with their earlier Skal-ET collector, is based on the utilization of mass-produced standardized components (rectangular bars) that can be assembled into arms by robots.

There are also other feasible support structures that are completely different from the cantilever arm concept in combination with a torque tube (see Table 41 in the annex); for example, the SkalET collector installed in the Andasol projects uses a steel framework instead of the stamped arms described above.

Welding process

The well-known welding process is still important in the collector assembly. Older concepts like the Skal-ET relied even more on welding techniques, as the whole torque box was welded. However, due to unavoidable precision faults and thermal stress of the welded components, new concepts try to use alternatives to welding processes (e.g., through plug connections). Use of screws is also avoided where possible.

Collector assembly and Installation

Usually, the collector is assembled on-site in a jig assembly line. This concept uses highly accurate jigs to connect the torque tube, the cantilever arms, and the mirrors (Casteneda, 2006). To guarantee low transport costs, the jigs are located in an assembly hall close to the solar field.

The real manufacturing process of the collectors is managed efficiently: the workers put the different parts on their predetermined positions on the jig, check the geometric verification, and weld, screw, or plug them together, see Source: Sener, 2007

. According to information from the Andasol 2 project where the jig assembly is applied to assemble the Skal-ET collector, four or more collectors (12 meters each) were assembled per hour per jig.

This basic process allows the employment of a fairly low-skilled workforce. Of course a certain introduction phase is necessary, but after that, the construction reaches a high output level.

Figure 29 Sener jig assembly

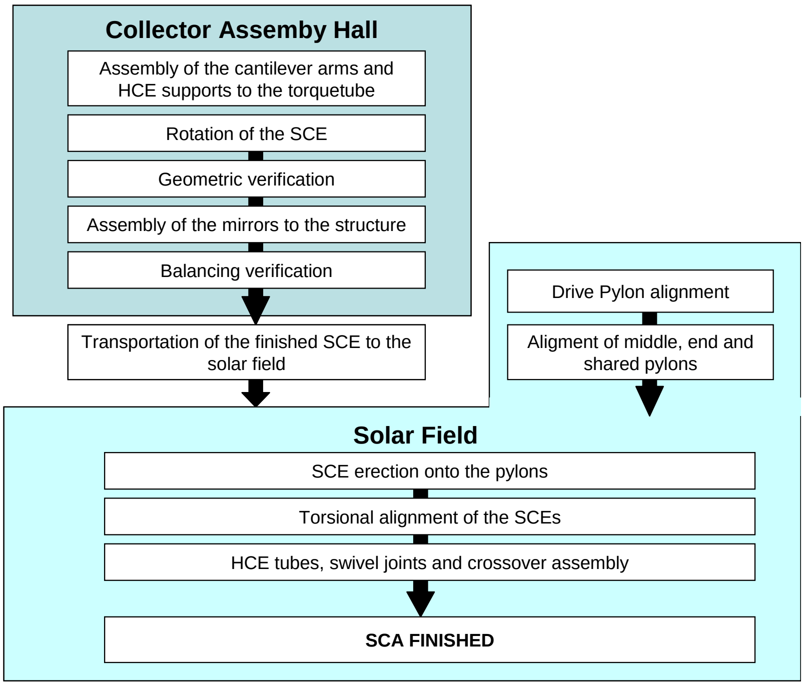
Source: Sener, 2007

In an advanced configuration, the whole process is operated by robots instead of people, to improve constant quality. Using this method, once the cantilever arms are welded to the torque tube, the points to fix the mirrors to the cantilever arms are in the right position without any human error (Casteneda, 2006).

Siemens applies still further automation by introducing robot-based manufacturing, inspired by the vast automation of car production; this reduces the work force but keeps to the jig-assembly model.

Once the collector is completed, it is transported directly to its designated location in the solar field using trucks. In the field, the collectors are installed by a special vehicle or a crane. The correct alignment is ensured via specialized optical equipment.

Figure 30 General assembly process for the solar field, SCE: Solar collection element, HCE: Heat conducting element, SCA: Solar collector assembly



Source: Authors; Casteneda (2006)

After the jig-assembly it is important to coordinate the subsequent logistics to align the collectors in the solar field. This complex process is very prone to bottlenecks, as a strict construction sequence is necessary. Source: Authors; Casteneda (2006 gives a broad overview of the different steps to installing the whole solar field. The solar collector installation process is generally divided into two parts: 1) the single solar collector production in an assembly hall close to the future solar field, and 2) the solar field installation. During the collector assembly, the jig method described above is used. Before the solar field installation, the pylons that support the collector have to be precisely aligned.

After the correct alignment, the solar collectors are fixed with exactness to the pylons and measured once more. Finally, the heat conducting elements (receiver tubes) are installed, and the piping can be connected.

In a nutshell, only a few steps can be done simultaneously; most assembly steps cannot be performed before the preceding activity is complete. That is why it is essential to coordinate the different process steps rigidly, leaving no room for error. As already mentioned above, the structural properties of each collector are very product-specific. Therefore, there must always be an individual assessment – from company to company and even from project to project – to determine the extent to which steel structure mounting principles are applied. At least a minor share will always consist of labor-intensive standard steel/aluminum construction; however, in some cases, a high degree of automation reduces the labor-intensive activities of mounting and assembly.

1.3.5 Complexity assessment and technological barriers

The selection of production processes can be further categorized according to general complexity and investment intensity. This will give a broad overview of which manufacturing process of CSP components can most easily be adapted by local industry or international industry for local manufacturing, and will consequently stand the best chance of being manufactured in MENA countries in the short- and mid-term future.

Today, on-site jig-assembly, antireflective coating, and galvanization seem to be the production activities most likely to be performed in MENA countries. However, it is very difficult to give a clear final judgment, since a production complex is never based on one single process. Nevertheless, this overview is based on recent production technologies. It is therefore likely that this graph will undergo a continual change during the development of a competition-based CSP market.

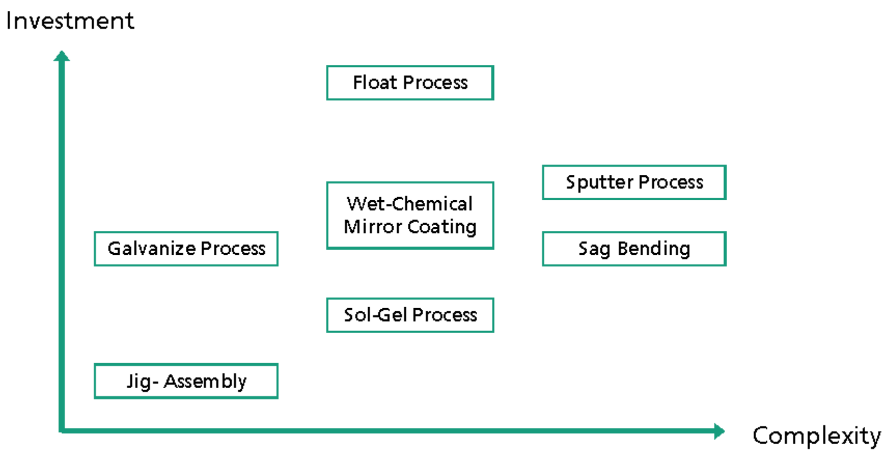
Only recently, the U.S. government has given a loan guarantee (US $1.45 Billion) to Abengoa to realize a 260 MWel CSP power plant in Arizona (Solana). One condition of this grant was to utilize a maximum share of American components. For this reason, Abengoa raised the local share to 70 percent, and a new mirror production facility is planned.

For the first large commercial plant, Andasol 1 in 2006, the share of Spanish supplies was below 50 percent. Now, four years later, the new plants use more than 75 percent local supplies (personal communication Protermosolar).

Similar developments should be supported in MENA countries. Even though their technological level cannot be compared to the United States, some production steps could be performed in the target countries. Early adopters in MENA (e.g., the Kuraymat project in Egypt) already perform the whole jig-assembly close to the solar fields. A next step could be the galvanizing process, and later the mirror production, which are both locally present but not yet in the necessary quality and quantity. Another important step towards including MENA countries is Joint Ventures of CSP companies. For instance, Flabeg erected a whole mirror production in the United States, and every German CSP company has a Spanish and American subsidiary to be regarded as a local, and not as an intruder looking for government subsidies. A good example is Egypt, where almost the entire erection of the CSP power plant was managed by a local company. It is important to include local companies, because local companies usually have good connections to local authorities and know the local specifics.

For each manufacturing process or service, some barriers and bottlenecks may presnt problems for local MENA industry looking to enter the CSP market. These barriers have to be minimized with the presentation of special roadmaps and action plans for each component regarding current MENA potential, analyzed further in chapter 3.

Figure 31 Complexity versus investment-intensity for CSP production processes



Source: Fraunhofer ISE

Table 7 Technical and economic barriers to manufacturing CSP components

Components	Technical Barriers	Financial Barriers	Quality	Market	Suppliers	Level of barriers
Civil Work	Low technical skills required	Investment in large shovels and trucks	Standard quality of civil works, exact works	Successful market players will provide these tasks	Existing supplier structure can be used for materials	**Low**
EPC Engineers and Project Managers	Very highly skilled professionals: engineers and project managers with university degrees		Quality management of total site has to be done	Limited market of experienced engineers	Need to build up own network	**Medium**
Assembly	Logistic and management skills necessary Lean manufacturing, automation	Investment in Assembly-building for each site, investment in training of work force	Accuracy of process, low fault production during continuous large output Low skilled workers	Collector assembly has to be located close to site	Steel parts transported over longer distance Competitive suppliers often also local firms	**Low**
Receiver	Highly specialized coating process with high accuracy technology-intensive procedural step of sputtering	High specific investment for this manufacturing process	High process know-how for continuous high quality	Low market opportunities to sell this product to other industries and sectors	Supplier network not strongly required	**High**
Float glass production (for flat and curved mirrors)	Float glass process is state-of-the-art technology but requires large quantities of material and highly energy intensive Complex manufacturing line High-skilled workforce to run a line	Very capital intensive	Pureness of white glass (raw products)	Large demand is required to build production lines	Supplier network not strongly required	**High**
Mirror *Flat* (Float glass)	Complex manufacturing line High-skilled workforce to run a line	Capital intensive	long-term stability of mirror coatings	High quality flat mirrors have limited further markets Large demand is required to build production lines	Supplier network not strongly required	**High**
Mirror *parabolic*	See flat mirrors Plus: Bending: highly automated production	*See flat mirrors* + bending devices (see Table 6)	*See flat mirrors* High geometric precision of bending process	Large demand is required to build production lines Parab. mirrors can only be used for CSP market	Supplier network not strongly required	**High**
Mounting structure	Structure and the assembly are usually proprietary know-how of the companies Standardization and automation by robots or stamping reduces low skilled workers, but increases process know-how	Automation is capital intensive Cheap steel is competitive advantage	For tracking and mounting: stiffness of system required	Markets with large and cheap steel transformation industries are highly competitive	Raw steel market important	**Low**
HTF	Chemical industry with large productions. However the oil is not highly specific	Very Capital intensive	Standard product, heat resistant	Large chemical companies produce the thermal oil	Not identified	**High**
Connection piping	Large and intensive industrial steel transformation processes Process know-how	Capital intensive production line	High precision and heat resistance	Large quantities	Not identified	**Medium**
Storage system	Civil works and construction is done locally Design and architecture Salt is provided by large suppliers	Not identified	Not identified	Low developed market, few project developers in Spain	Not identified	**Medium**
Electronic equipment	Standard cabling not difficult Many electrical components specialized, but not CSP specific equipment Equipment is not produced for CSP only	Not identified	Not identified	Market demand of other industries necessary	Often supplier networks because of division	**Low**

1.4 Cost analysis for the main CSP components

Today, CSP markets and CSP projects evolve where a political framework ensures some kind of financial incentive. It is virtually impossible to determine the real cost of electricity from CSP, because the cost of electricity equals the electricity tariffs paid; this is the case, at least, in Spain, which is currently the primary world market for CSP. When there is a difference between internal cost and tariff, the actors (e.g., the EPC contractor) adjust their margin. In Spain, the electricity price paid for CSP roughly amounts to at least 27 €ct/kWh, based on a funding system, subsidizing the electricity production (and not the plant installation). Such a feed-in system proves to be the most effective funding scheme when a fast capacity addition is required, because it provides the necessary financial security for investments.

In Spain, many companies have entered the CSP market, including large companies from conventional business sectors such as utilities and construction. This high market response can be considered a sign that CSP pays off well with the Spanish level of remuneration. For the above mentioned SEGS plants, electricity generation costs of 11 to 18 $ct/kWh have been published, but with approximately 30 percent higher solar irradiation (on an annual level) than good Spanish sites. The real cost of CSP today depends on site and suppliers. Some CSP suppliers even claim to have already reached break-even cost with fossil energies, but this has not yet been verified in non-subsidized markets.

This section describes the typical cost structure of a CSP plant. Like the previous sub-sections, this section focuses on data from parabolic trough technology, which is the most commercially advanced. Like any other industry, CSP business actors are not willing to disclose internal information on cost structures in an unlimited way. Still, some commercial cost information has been made available, which is analyzed and referenced in this section. Solar Tower and Fresnel Systems technologies are constructed from the same basic components as the parabolic trough technology. Spanish projects (PS10 and PS20) and the Novatec Fresnel 30 MW plant use the same feed-in tariff regulations for selling the electricity to the market.

Fresnel systems show a similar cost structure, although the cost for the mirrors and steel structure is lower. On the other hand, this cost advantage is counterbalanced – at least in part – by lower plant efficiency caused by lower optical efficiencies and a lower working temperature.

Solar Towers require an extra investment in the tower itself, but also involve lower costs for piping and mirrors in combination with higher possible temperatures. Further evaluation of total costs is made difficult by the small number of existing projects, but the similarity of the production process implies comparable outcomes for local manufacturing, although the simplicity of flat mirrors – both for towers and for Fresnel collectors – should be highlighted again at this point.

Unlike conventional power generation systems, the bulk of the electricity generation costs of CSP plants are dominated by the initial investment, which accounts for approximately 80 percent of the electricity generation cost (Morin, 2009). The remaining 20 percent represents the cost of operation and maintenance of the plant, and of plant insurance.

1.4.1 Total investment for a Parabolic Trough power plant

This chapter presents cost information for a parabolic trough power plant of the Andasol 1 design, i.e., with a rated power of 50 MW_{el} and a storage capacity of 7.5 hours. The cost for each component is depicted in the following table to identify the potential revenues that could be earned if this component or service were executed by a local manufacturing, engineering, or construction company. These revenues will remain local earnings that will benefit the region. The individual cost parameters will be used later to calculate the share of local manufacturing in an ongoing ISCCS project in the region (see section 2.2.3) and to calculate the future economic benefit to be gained if local manufacturing is increased by direct and indirect support.

The cost information refers to a selling price of a turn-key parabolic trough power plant of US$364 million. This price is based on calculations for Spanish CSP plants with volumes of €300 million, but this price was reduced here to €280 million because price reductions are predicted by many experts in interviews and by technical and economic reports. This reduced price is not published officially in Spain because the Spanish feed-in tariff offers attractive revenues for investment costs with volumes of €300 million.

One must note that a plant using storage of this size uses a solar field which is 75 percent larger than a trough power plant without thermal storage. This increases the specific investment of $/kW, which is a number that is often referenced when looking at energy technologies. In CSP, the specific investment is of no relevance, because storage increases the energy production. Storage can therefore reduce the cost of electricity of the plant, which is a much more relevant decision criterion.

Component costs in Table 8 correspond to prices at which an EPC contractor buys the components. Labor in this table only considers labor during construction of the power plant (and not during manufacturing of the components). Most of this is low-skilled labor to be provided by locals.

Table 8 Estimation of the investment cost of an Andasol-like power plant with a rated power of 50 MWel, a thermal storage capacity of 7.5 hours, and a solar field size of 510 thousand m^2.

	Cost for Reference Power Plant in Euro	Cost for Reference Power Plant in US$	Relative Value of plant
Labor Cost Site and Solar Field	**48.0 Mio €**	62.4 Mio $	17.1%
Solar Field	8.7 Mio €	11.3 Mio $	3.1%
Site Preparation and Infrastructure	16.3 Mio €	21.2 Mio $	5.8%
Steel Construction	7.0 Mio €	9.1 Mio $	2.5%
Piping	4.9 Mio €	6.4 Mio $	1.8%
Electric installations and others	11.1 Mio €	14.4 Mio $	4.0%
Equipment Solar Field and HTF System	107.9 Mio €	140.3 Mio $	38.5%
Mirrors	17.8 Mio €	23.1 Mio $	6.4%
Receivers	19.9 Mio €	25.9 Mio $	7.1%
Steel construction	30.0 Mio €	39.0 Mio $	10.7%
Pylons	3.0 Mio €	3.9 Mio $	1.1%
Foundations	6.0 Mio €	7.8 Mio $	2.1%
Trackers (Hydraulics and Electrical Motors)	1.2 Mio €	1.6 Mio $	0.4%
Swivel joints	2.0 Mio €	2.6 Mio $	0.7%
HTF System (Piping, Insulation, Heat Exchangers, Pumps)	15.0 Mio €	19.5 Mio $	5.4%
Heat Transfer Fluid	6.0 Mio €	7.8 Mio $	2.1%
Electronics, Controls, Electrical and Solar Equipment	7.0 Mio €	9.1 Mio $	2.5%
Thermal Storage System	29.5 Mio €	38.4 Mio $	10.5%
Salt	14.3 Mio €	18.6 Mio $	5.1%
Storage Tanks	5.1 Mio €	6.6 Mio $	1.8%
Insulation Materials	0.5 Mio €	0.7 Mio $	0.2%
Foundations	1.8 Mio €	2.3 Mio $	0.6%
Heat Exchangers	3.9 Mio €	5.1 Mio $	1.4%
Pumps	1.2 Mio €	1.6 Mio $	0.4%
Balance of System	2.7 Mio €	3.5 Mio $	1.0%
Conventional Plant Components and Plant System	40.0 Mio €	52.0 Mio $	14.3%
Power Block	16.0 Mio €	20.8 Mio $	5.7%
Balance of Plant	15.9 Mio €	20.7 Mio $	5.7%
Grid Connection	8.1 Mio €	10.5 Mio $	2.9%
Others	54.6 Mio €	71.0 Mio $	19.5%
Project Development	8.1 Mio €	10.5 Mio $	2.9%
Project Management (EPC)	21.6 Mio €	28.1 Mio $	7.7%
Financing	16.8 Mio €	21.8 Mio $	6.0%
Other costs (allowances)	8.1 Mio €	10.5 Mio $	2.9%
Total Cost	**280. Mio €**	**364. Mio $**	**100.0%**

Underlying information sources: Kistner 2009, Nava 2009, Schnatbaum 2009,VoteSolar 2009)

As mentioned above, this table confirms that the components of the solar field (with 550,000 m²) are the most capital-intensive part of the plant (38.5 percent). The price of a collector is mainly determined by the cost of the receiver (7.1 percent), the reflector (6.4 percent), and the metal support structure (10.71 percent). The solar field piping (5.4 percent) and the HTF (2.1 percent) also amount to a considerable investment.

To install these components and build the whole power plant, it is necessary to employ a workforce of around 500 people (Andasol 1), while more advanced concepts rely on fewer workers (see Table 11 for exact numbers). These employees include blue collar workers, logisticians, and construction managers. The total labor costs therefore range around 17 percent.

The blue collar workers assemble the collectors and are responsible for the ground and construction works of general building infrastructure. Consequently they represent the majority of the workforce. Nevertheless, the logisticians have to provide the whole transport system, which has to be resistant to costly bottlenecks. The overall management is provided by experienced specialists to ensure on-time and cost-efficient planning.

If storage is included, 10 percent of total investment is due to this system. However, storage also affects other costs, because a storage plant is usually equipped with a much larger solar field.

Up to 20 percent of cost can be attributed to the category “Others,” which includes project development (2.9 percent), project management (7.7 percent), financing (6 percent), and risk allowances (3 percent). This cost block is strongly project-related and can be changed quickly according to project characteristics.

The following table compiles information on ranges for component costs of parabolic trough power plants. Only key components are shown. Obviously, the prices depend on manufacturer, project size, market situation (e.g., oligopoly), country, and other criteria. Following the table are additional remarks respecting individual sub-systems and components.

Table 9 Cost estimates for individual parabolic trough components

Element	Cost estimate	Unit
Parabolic Mirror (“conventional“ thick glass mirror)	28 – 40	€ per m^2 of collector aperture
Steel structure (material)	50 – 65	€ per m^2 of collector aperture
Vacuum receiver	200 – 300	€ per m receiver length
Thermal oil	3.0 – 7.0	€/ l
Parabolic Trough Collector (incl. installation)	200 – 240	€ per m^2 of collector aperture
Solar Field installed (incl. connection piping, HTF & HTF system)	230 – 290	€ per m^2 of collector aperture

source: authors

note: As in Table 8, component costs in this table correspond to prices at which an EPC contractor would buy the components. The collector and solar field cost correspond to net cost, including labor but excluding costs for engineering, project management, financing, and margins for profit as well as risk.

Metal structure cost

The cost of the metal support structure is a combination of material cost, process cost, design cost, and galvanization cost. For the Andasol 1 project, the total cost of the metal support structure was €30 million. Solarel Energy, a company that produced the steel structure of the Skal-ET (SMI, 2010), published material cost of €1,000/ton (Solarel, 2010). Using these numbers and the total amount of steel in the solar field, 31 percent of the €30 million were spent on the material itself.

The general steel cost composition of similar constructions can be derived from Evers (2000), where 38 percent of the cost of a steel structure accounts for raw steel price. Hence, there price of steel will have some influence on plant cost and on cost of electricity from CSP.

Receiver cost

The essential parts of a state-of-the-art receiver are a coated stainless steel pipe and a borosilicate glass envelope. A standardized borosilicate glass tube (100 - 149 mm) comes to €9.85/kg. The total cost of a 4m long glass tube is around €94 (Doening, 2010). Following the data of SolarMillenium, Archimede Solar, and Schott, the absorber tube is made of stainless steel SS316 (Arc, 2008). Such tubes, with a diameter of around 70mm and a length of 4m, cost about €190 (Doening, 2010). Hence, the combined raw material price of the absorber is €71/meter, disregarding the negligible amounts of material for the absorber and the anti-reflex glass coating as well as the getter material. Process costs for these components are unlikely to justify this high add-on. Hence, this receiver component seems to offer great cost reduction potential once a really competitive market evolves.

1.4.2 Running cost of PTC plants – Operation and maintenance, insurance, and fossil fuel cost

One part of the running cost of the plant is the insurance. The insurance cost is determined by what is to be assured and secured financially. Usually, 0.5-1 percent of the initial plant investment is paid as annual insurance cost.

The larger portion of the running cost is the operation and maintenance (O&M) cost of the plant. Operation and maintenance costs of power plants that have been put into operation since the CSP renaissance in 2007 have not been made publically available. However, a very comprehensive study assessed the detailed structure of the O&M cost and activities of the Californian SEGS plants at Kramer Junction (Cohen, 1999). The following table summarizes the main findings of this study, which aimed at assessing and improving the O&M activities in the Kramer Junction power plants (SEGS III-VII).

Table 10 Summary of total annual costs for parts and material for solar field maintenance

Parts and Materials					
	Unit Cost		SF size = 500,000	m^2	
	$	%replace	m^2/unit	$/$m^2$-yr	$K/yr
Mirrors	100	0.5	2	0.25	125
Receivers	700	3	22	0.963	481.7
Sun Sensor	150	0.5	545	0.001	0.7
LOCs	200	0.5	545	0.002	0.9
Ball joints	2100	0.5	273	0.039	19.3
Hdr. Drive	6000	0.5	545		27.5
Miscellaneous	assumed as 5% of total equipment costs above				33.6
TF Pump Seals	1200	2 per year	500000	0.005	2.4
HTF Makeup	4,221,423	1	500000	0.084	42.2
Water	demineralized water for mirror washing				243.3
Nominal -KJ					**976.5**
With 30% higher material costs and cheap water					**1034.9**
With only cheap water					**810.1**
With only higher material costs					**1196.5**

Note: "KJ" stand for Kramer Junction, the reference plant in California

Source: Cohen, 1999

As can be seen in Table 10, replacement of receivers and mirrors is among the largest cost positions. The reason for this is – in both cases – glass breakage. The receiver glass tube breakage through thermal expansion problems may have been solved since then by adapting the thermal expansion of glass and metal (see section 1.1.3). Glass breakage in the solar field could also be significantly reduced by stiffer collector sub-structures. Another cost position is water for mirror washing (see Sources: Cohen, 1999 and Novatec, 2010).

Figure 32 left: Conventional cleaning methods (Cohen, 1999), right: water-efficient cleaning using a cleaning robot of Fresnel collector by Novatec Biosol (Novatec, 2010)

Sources: Cohen, 1999 and Novatec, 2010

Looking at staffing, the study by Cohen presents different scenarios for nominal (=optimal) O&M procedures and "reduced" O&M activities, both for a developed country and for a developing country (see Table 11).

Table 11 Staffing for solar field operation and maintenance plan, for developed countries (above) and for developing countries (below)

Staffing Developed Countries (e.g. U.S., Europe) For SF size = 500000 m² OH rate								
		Nominal #	Reduced #	Level	Rate, $K/yr Direct	35% Burdened	Annual $K Nominal	Reduced
Solar Field Manager		1	0	Senior	50	67.5	67.5	0.0
Maintenanc	Supervisor	1	1	Skilled	45	60.8	60.8	60.8
2 shifts	Welder	1	1	Skilled	40	54.0	108.0	54.0
(4 10h days	Mech Tech	2	1	Exper'd	35	47.3	189.0	47.3
	I&E Tech	1	1	Skilled	40	54.0	108.0	54.0
Lead Mrror	Wash Supervis	1	1	Skilled	45	60.8	60.8	60.8
1 shift	Equip. Opers.	4	2	Exper'd	35	47.3	189.0	94.5
Field Operator (status)		5	3	Exper'd	30	40.5	202.5	121.5
		20	13			**Total**	985.5	492.8

Staffing Developing Countries							
		Nominal #	Reduced #	Level	Burdened Rate,$K/yr	Annual $K Nominal	Reduced
Solar Field Manager		1	1	Senior	20.3	20.3	20.3
Maintenanc	Supervisor	1	1	Skilled	18.2	18.2	18.2
2 shifts	Welder	2	1	Skilled	15.2	64.8	16.2
(4 10h days	Mech Tech	4	2	Exper'd	14.2	113.4	28.4
	I&E Tech	2	1	Skilled	16.2	64.8	16.2
		4	2	Unskilled	8.5	68.0	17.0
Lead Mrror	Wash Supervis	1		Skilled	18.2	18.2	0.0
1 shift	Equip. Opers.	6	3	Exper'd	14.2	85.1	42.5
Field Operator (status)		10	5	Exper'd	12.2	121.5	60.8
		31	16		**Total**	574.3	219.6

Source: Cohen, 1999

Parabolic trough technology has not yet achieved a significantly higher degree of automation in the operation procedures than what was described by Cohen (1999). However, the technology improvements described above reduced the need for frequent replacement of components. Therefore, the staffing level shown in Table 11 will be reduced by approximately 30 percent in today's trough plants.

In addition to the personnel explicitly dedicated to the operation and maintenance of the solar field, plant personnel for the operation of the power block for the plant administration is needed. A typical 50 MW trough plant requires about 30 employees for plant operation (Dersch, 2009).

Depending on the hybridization of the plant, fuel costs are also part of the running cost. For example, according to Spanish legislation, co-firing of 10-12 percent is allowed. For this, normally natural gas is used.

In the course of the operation and maintenance improvement program described in Cohen (1999), the total O&M cost could be reduced from an initial 4 $ct/kWh to below 2.5 $ct/kWh by improving the O&M procedures (both cost and plant performance). Today's O&M cost should be lower than this, due to improvements in technology and processes (cleaning, glass breakage, and others).

In a nutshell, the O&M strategy has to find an optimum middle ground between a highly efficient solar power production and low operation and maintenance cost, which are normally contrary goals. In most cases, however, working on high plant performance pays off because of the high investment cost share of a CSP plant.

1.4.3 Future cost reduction potential

Cost reduction through research and development

A high number of R&D activities in the field of CSP are underway. An overview of the R&D fields, including recommendations on funding R&D in CSP, is given in Ecostar (2005). Table 12 shows an excerpt of current R&D activities in the field of line-focusing collectors. All technology developments that are shown in Table 12 aim at improving CSP components and sub-systems with respect to cost and/or efficiency.

Table 12 Excerpt of current research and development activities in solar thermal power generation (parabolic trough)

Innovation	State of the Art	Aim	Solutions
New Heat Transfer Fluids	Synthetic Oil	Higher temperatures, cost-reduction, reduce environmental risks	Direct Steam Generation (cheap water & no heat exchangers), molten salt
New Storage Concepts	Molten Salt (Oil)	Cheap storage material, high heat capacity, low freezing point, iso-thermal heat transfer (for evaporation)	Latent heat storage (esp. for DSG), thermocline storage, new storage materials such as concrete, sand or others
New Mirror Materials	Curved Glass Mirrors	cost reduction, high reflectivity	Metallic reflectors, coated polymer film with integrated support
New Collector Concepts	PTC with 5-6 m aperture	Cost reduction, high efficiency, high optical accuracy	Variety of collector substructures, different collector widths (1-10 m); lean Fresnel-Collectors

A recent study, carried out by the European CSP-industry association Estela and by AT Kearney (Estela, 2010), figured out the latest cost reduction potential by interviewing the existing CSP industries regarding technology improvements and effects of economics of scale. The results are shown in the following table. Overall LCOE will decrease by 45 – 60 percent by 2025, according to AT Kearney. Economies of scale, overall plant efficiency increase, and technology improvements are the main drivers for this development. Many components will contribute to these technology improvements by values of 15 to 25 percent.

Table 13 Cost reduction caused by technology improvements, economies of scale (plant size) and efficiency increase of the CSP plant

<table>
<tr><td></td><th colspan="3">Levelized cost of electricity reduction</th><th colspan="3">2025</th></tr>
<tr><td></td><td colspan="3">Total plant LCOE</td><td colspan="3">45-60%</td></tr>
<tr><td></td><td colspan="3">Economies of Scale</td><td colspan="3">21-33%</td></tr>
<tr><td></td><td colspan="3">Efficiency increase</td><td colspan="3">10-15%</td></tr>
<tr><td></td><td colspan="3">Technology Improvements</td><td colspan="3">18-22%</td></tr>
<tr><td>Technology Improvements</td><td>Mirrors parabolic</td><td>Mirrors flat</td><td>Receivers</td><td>Steel structure</td><td>Storage Tank</td><td>Molten salt</td></tr>
<tr><td>2020</td><td>25%</td><td>25%</td><td>25%</td><td>30%</td><td>20%</td><td>15%</td></tr>
</table>

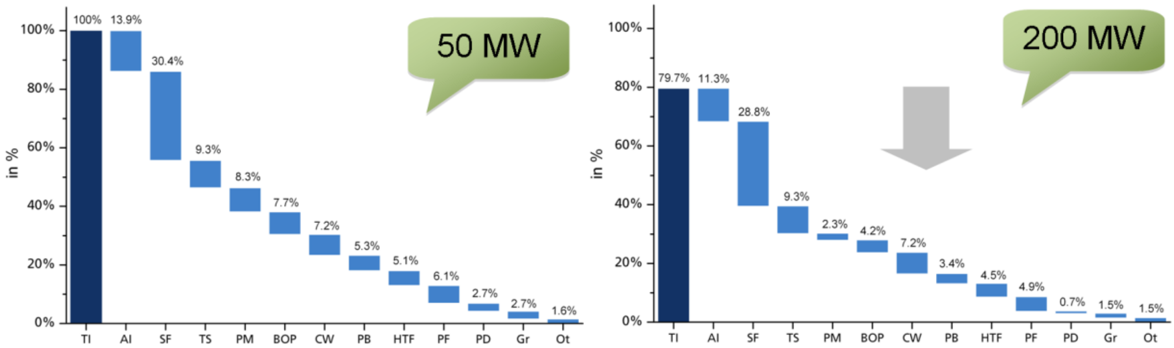
Source: Estela, 2010

Cost reduction through economies of scale – Increasing the plant size

This sub-section goes beyond the assessment of the cost reduction by economies of scale through increased market size on the component level (as in Table 13), and assesses cost reduction potential on the power plant level.

Today, most of the finished and constructed CSP power plants have a capacity of 50 MW. This is mostly due to the Spanish feed-in law RD-661/2007, which restricts the maximal electrical output to 50 MW. In terms of economies of scale, 50 MW is not at all the optimal plant size. Current U.S. project developments all aim at much higher plant capacities around 200 and 250 MW. In Kistner (2009), the effect of plant size on specific plant investment is assessed, see **Error! Reference source not found.**.

Figure 33: Economies of scale: Decrease of component cost with increased plant size.



Abbreviations: Total Investment (TI), Allowances (AI), Solar Field (SF), Thermal Storage (TS), Project Management (PM), Balance of Plant (BOP), Civil Works (CW), Power Block (PB), Heat-Transfer Fluid (HTF), Project Finance (PF), Project Development (PD), Grid Access (Gr), Other (Ot)

Source: Kistner, 2009

The thorough reader of this study might note that the values given in the reference case of **Error! Reference source not found.** (left) correspond well to the data given in the right column of Table 8. The reason for this is that the authors of this study (Kistner, 2009) work for Ferrostaal, who jointly with SolarMillennium, Flagsol, and Duro Felguera act as general contractors for the Andasol 3 power plant.

Kistner came to the conclusion that the specific cost for a parabolic trough power plant with 50 MW and 7.5 h of storage can be cut by 12.1 percent at 100 MW and by 20.3 percent at 200 MW. The study shows that the relative contribution of the different cost shares to the economies of scale is very different. The biggest economy of scale can be realized in Project Management (PM), Balance of Plant (BOP), Power Block (PB), and grid access (Gr). The specific cost can be cut by 20-25 percent in these areas. The specific cost of Project Management drops by 47 percent at double capacity (100 MW) and by 72.3 percent at four times capacity. The specific Project Development cost declines by 33.4 percent and 74.1 percent respectively. Hence, these cost items almost remain constant in absolute numbers, independent of the plant size. Since costs of solar field and storage depend on the plant size, only small changes can be observed regarding the Solar Field, the Heat Transport Fluid, and the storage, as material cost is the dominant cost fraction in these areas.

Similar to Kistner, Acciona came to the conclusion that an augmentation of the capacity from 50 MW to 120 MW would result in specific cost savings of 13 percent overall (Nieto, 2009).

Cost reduction through efficient supplier markets and economies of scope

It is more promising to analyze the capital cost than the enhancement of efficiency in terms of total cost reduction. Short term improvements can be obtained by raising the standard plant size from 50 MW to over 100 MW and reducing the construction period.

Today, CSP markets and projects evolve where a political framework ensures a financial incentive. It is virtually impossible to determine the real cost of electricity from CSP, because cost of electricity equals the electricity tariffs paid. In case there is a difference between internal cost and tariff, actors (e.g., EPC contractors) adjust their margins. In Spain, the electricity price paid for CSP roughly amounts to 31 €ct/kWh. Subsidizing the electricity production – in contrast to subsidizing the plant installation – gives adequate incentives to produce large amounts of electricity over the lifetime of the plant.

In Spain, many companies have entered the CSP market, including large companies from conventional business sectors such as utilities and construction. This high market response can be considered a sign that CSP pays off well with the Spanish level of remuneration. For the above mentioned SEGS plants, electricity generation costs of 11 to 18 $ct/kWh have been published, but with approximately 30 percent higher solar irradiation (on an annual level) than good Spanish sites. The prices of the power purchase agreements that are realized in the U.S. market today are not publically available; according to semi-official information, they are in the same spectrum (11-17 $ct/kWh), but include subsidy schemes (such as state loan guarantees, investment tax credits, or production tax credits).

Today, the real cost of CSP depends on site and supplier. Single CSP suppliers even claim to have already reached break even cost with fossil energies (Novatec, 2010b); however, this has not yet been verified in non-subsidized markets.

Another result of the analysis of the present CSP market is the necessity of a market-driven value chain to allow for more competition. This seems very logical, as current component suppliers like Schott Solar have EBIT-margins around 20 – 25 percent (2008) in CSP. In comparison, in the PV industry, which produces under much more evolved competitive conditions, EBIT-margins are around 6 percent and below. This competition raises the need to differentiate products from competitors' by using more advanced technologies or offering a lower price, which CSP has not yet achieved.

Standardization, combined with mass production, offers large potentials for relevant cost reductions.

Compared with other renewable energies, the installed capacity of CSP is still relatively small. Learning processes in mass production and project management, which are already realized in PV and wind energy, have not been reached. A learning curve that began in the early 1990s was stopped by lack of governmental support.

Following the introduction of the new Spanish feed-in tariffs, a second technology roll-out has started recently. With additional new markets like the United States showing a high competitive pressure, it will be a matter of only a few years before CSP costs will drop considerably. New cost-efficient collector concepts using light designs, a high degree of automation, and a high degree of standardized components will realize this foreseen cost-reduction. Compared to electricity from wind power and photovoltaic, CSP can provide electricity on demand through thermal storage, which will also pay off in the form of higher electricity prices that can be realized through dispatchability. After a market introduction phase a few years from now, CSP technology will no longer depend on subsidies, and will be – at the very least – cost-competitive in the market of peak and intermediate load power, and possibly, in the long run, also with base load power.

1.5 Conclusion of chapter 1

This chapter presents a review of CSP technologies with respect to technology description (section 1.1), description of the industry (section 1.2), analyses of production processes (section 1.3) and cost (section 1.4). The main results can be summarized as follows:

The **CSP market** is mainly driven by the markets in the United States and Spain, but first projects are also under construction or in status of commissioning in North Africa: in Morocco, Algeria, and Egypt. By the middle of 2010, over 800 MW of CSP plants were in operation world-wide; the electricity producing plants have doubled their capacity with new installations since 2007, after the installation of the SEGS plants in California.

Today, parabolic trough technology is commercially the most mature technology, and the only widely bankable CSP technology. Therefore, the focus throughout this study is set on this technology. However, most findings for local manufacturing are also applicable to other CSP technologies, because working principles, materials, and production processes do not significantly vary. Most trough, Fresnel, tower (and partially dish) technologies consist of steel structures, glass mirrors, and absorber tubes using a sputtered selective coating. All systems track the sun, have high optical/geometric accuracy requirements, use high-temperature materials and processes, and have electric generators that need to be coupled to the electric grid. Nevertheless, receiver technologies are quite different between the different CSP concepts, with different degrees of complexity. For example, it could be argued that the receiver technology used in Linear Fresnel technologies is simpler to produce and hence more easily produced locally. However, this requires a more in depth investigation of this key component than possible in this study.

Beyond parabolic trough plants, Fresnel, tower, and dish technologies are about to achieve commercial maturity through the installation of the first fully commercial power plants, and after having installed first prototype power plants (which were in most cases financed by the companies that developed the technologies). Due to considerable advances in all four types of CSP technology, future calls for tenders should not be restricted to one specific technology. In turn, all technologies matching minimum requirements (including experience) should be admitted. Increasing competition will allow innovative and cost-efficient technologies to prove their potential, will bring down the cost of CSP and – maybe the most important point – will help to realize more CSP capacity with a given amount of financing in the MENA region.

This chapter gives in-depth analysis of a selection of important **production processes,** their general manufacturing parameters (e.g., labor and energy intensity), technology complexity, and investment intensity, to give a broad overview of which manufacturing processes of CSP components can be most easily adapted by local industry or international industry for local manufacturing . These products will consequently have the highest chance of being manufactured in MENA countries in the short- and mid-term future.

In the next section, the **cost of CSP** and the contributions from individual components of the CSP value chain were reviewed through an analysis of Spanish CSP plants. A reference plant with 50 MW and storage was evaluated with an investment of US$364 million. The components of the solar field are the most capital-intensive and the largest part of the value chain (38.5 percent). The price of a collector is mainly determined by the cost of the receiver (7.1 percent), the reflector (6.4 percent), and the support structure (10.7 percent). Total labor costs range around 17 percent. Although the components of the solar field are the most capital-intensive and largest part in the value chain, there are opportunities for local manufacturing and services all along the value chain.

Based on the complexity level and the potential for local manufacturing, as well as the share of added value in the CSP value chain, a number of key components and services are identified as the most promising and worthwhile to foster local manufacturing in the MENA region. These key components are support structure, mirrors, and receivers; key services range from assembling and EPC to O&M.

Cost reduction of solar thermal power plants will be important for future success in the MENA region. This will be achieved by:

- an increasing amount of plants being built through sustainable and reliable markets,
- competitive market mechanisms, including all – and especially innovative - CSP technologies, and
- further research and development.

Unlike wind power and photovoltaic, CSP can provide electricity on demand through thermal storage, which will also pay off in the form of higher electricity prices that can be realized through dispatchability. After a market introduction phase a few years from now, CSP technology will no longer depend on subsidies, and will be – at least – cost-competitive in the market of peak and intermediate load power, and possibly in the long run also with base load power.

In order to understand whether **local manufacturing in the MENA region** has a reasonable chance, it was important to conduct a detailed analysis of the CSP value chain; that is, the technologies and services involved, the production processes, and the main industry players behind the technologies. Companies in the value chain show a high potential for participation in future MENA CSP markets and are already involved in the ongoing CSP projects in the MENA region.

The following points summarize the findings of today's status of the CSP industry:

- A growing CSP industry can be identified in Spain, the United States, and also in the MENA market. Effects of new investments in large scale production, increased project capacities, and technology know-how (e.g., Siemens, Abengoa, Acciona, Schott Solar, Solar Millennium, Bright Source, Iberdrola) are observed.
- International companies are strongly concentrated in Spain, the United States, and Germany.
- A growing market has been identified for all phases (raw materials, components, engineering, EPC contracting, operators, owners, investors, and research institutions) across the entire value chain.
- In Spain, many companies from non-energy sectors could start new business activities in the CSP field very quickly.
- Some sectors and companies, like receiver suppliers, are strongly dependent on the CSP market demand and growth. Other firms have built their production and manufacturing capacities on the demand of other markets (CSP is a niche for them).
- Some components (Piping, HTF, electronics, power block) are not produced by companies with large CSP know-how or background, because this equipment is used for many other applications, such as chemical, electronic, and fertilizer (Nitrate salts) industries.
- High technological know-how is required for some components – especially mirrors, receivers, and equipment for the power block – which makes it difficult for new players to enter the market. However, a trend toward more competition, including new players, can be noted in all fields.
- Well-established players for mirrors and receivers opened up new production facilities in the current CSP markets in Spain and the United States at short notice.
- These players will very likely build up production facilities also in the MENA region if the market size becomes large enough (see scenarios in Part II of this report). Sustainability of the CSP market is crucial for this because the specific output of a single component factory is high. Such sustainable markets will have to be facilitated by policy related measures (Trieb, 2010).

Local manufacturing can take place if technical and economic requirements for local and international industry are fulfilled. Most important is a sustainable CSP market, which will have to be facilitated by political measures. Investments for new local production capacities are related to market size, as the specific output of a single component factory is often high.

However, high technological know-how and advanced manufacturing processes are necessary for some key components, such as parabolic mirrors or receivers, which nevertheless offer the highest reward in terms of value added.

Local manufacturing potential in the MENA region may be realized by the following strategies: local construction works, manufacturing of components by local, regional, and international companies, and support by local subsidiaries of international CSP industry.

2 Review of manufacturing capabilities and potential in MENA countries

2.1 Review of the main CSP-related industrial sectors and companies in the MENA region

This study targets the industries in MENA that have the profile to become potential contributors to the CSP value chain in the short or medium term. This work is based on the consultants' experience, on bibliography reviews and on interviews which were carried out during field trips in Morocco, Algeria, Tunisia, Egypt, and Jordan. The list of contacts interviewed is given in annex C of this document.[21]

In a first step, the potential manufacturers of CSP components and second rank suppliers were identified. The most relevant industry sectors were analyzed to understand which companies are positioned on value chain segments where entry barriers do not prevent newcomers. Industry sectors analyzed include:

- glass industry
- steel metallic structure/steel piping
- electrical and electronic equipment industry

A brief summary of the strengths and weaknesses of each of these sectors is also presented in the annexes.
In a second step the potential players in terms of construction works and EPC contractors were covered. In particular the following sectors were screened:

- Construction companies or contractors
- Energy operators and operations & maintenance firms
- Engineering firms and technical consultants

The analysis includes subsidiaries of international corporations that are strongly present in the MENA markets, especially as regards building materials, construction, infrastructure development, and operations. It is aimed at understanding the perception of these players about potential industrial partnerships with local corporations.

2.1.1 MENA Glass and mirror industry

The main output of the MENA glass and mirror industry is food and beverage glass, glassware, building, and automotive glass. The glass product that is of direct interest to CSP is float glass as, given appropriate quality, it can be transformed into flat mirrors (solar tower or linear Fresnel) and bent into parabolic mirrors. Float glass currently produced in MENA countries is used for building, and automotive and household mirrors. No flat or parabolic CSP mirror production has been identified in the countries covered by our study

Float glass production capacities were scarce until recent years but are currently increasing in Algeria and Egypt. However, most of the regional demand is still supplied through imports. Figure 34 gives an overview of the companies that are active in the MENA market and the float glass lines that are currently in service or under construction (starting date in brackets when available). Out of the five countries covered by the CTF ("CTF MENA countries"), only Algeria and Egypt have float glass production capacities (Table 14).

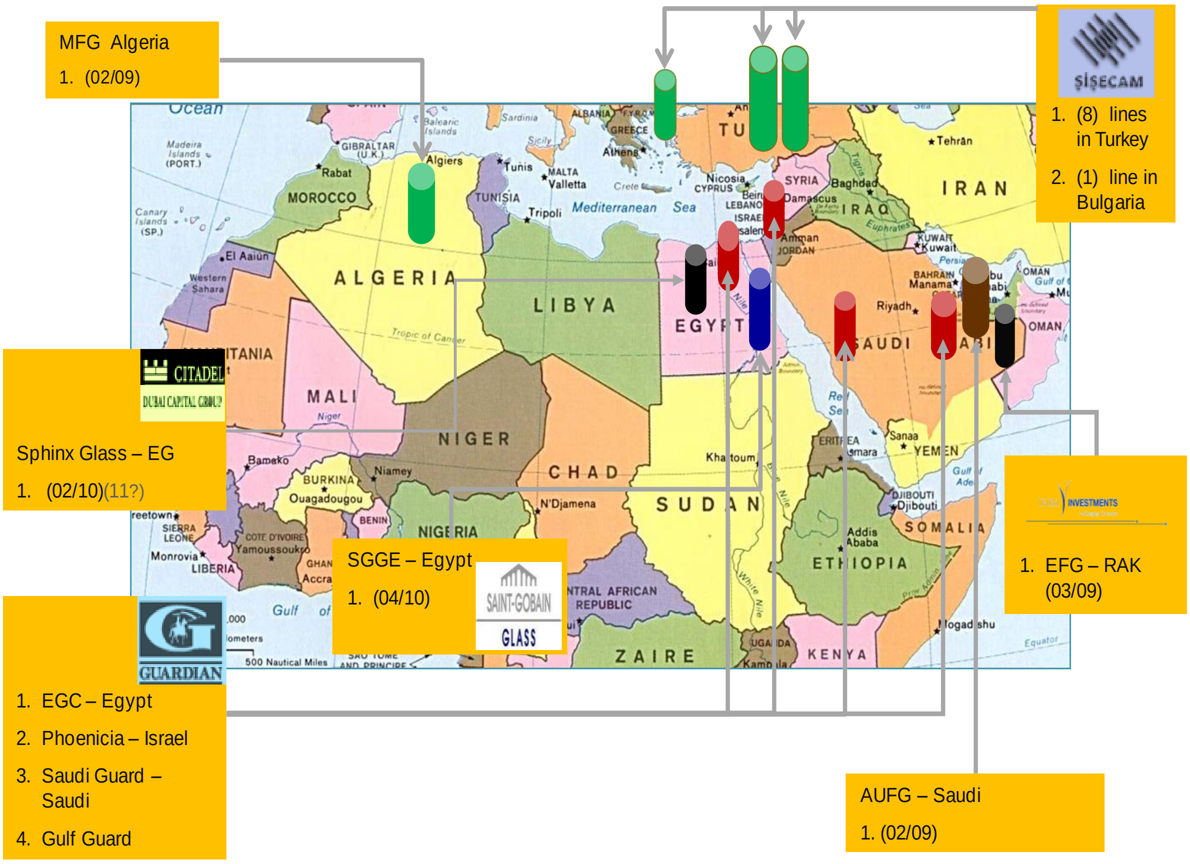
[21] Note that, despite ongoing CSP projects considered in Jordan, the Hashemite Kingdom does not appear as a primary target for international companies related to CSP. This is particularly due to the small size of the local market and to high energy prices. There are also a very limited number of mainstream industrial sectors that could step into CSP components manufacturing in Jordan. As a consequence, the present study displays limited information on this country, especially dealing with its manufacturing capabilities and potential.

Table 14 Float glass production capacities in CTF MENA countries (source: EY, based on interviews)

Name of company	Country	Current output	Shareholders	Production capacities
Egyptian Glass Company	Egypt	Clear glass only Quality grades: Building, Silvering & Auto	JV : 55% Khalafi / 45% Guardian	1 oven of 160 000 tons/year
Sphinx glass co.	Egypt	Glass with thickness varying between 2 mm and up to 19mm in varied sheet sizes up to jumbo size glass panes as large as 6000mm x 3660mm. products	Citadel Group + Dubai Capital Technology transfer agreement with PPG	1 oven of 200 000 tons/year (starting date: Q1 2011)
Saint-Gobain	Egypt	Float glass	In partnership with MM-ID & Ali Moussa	1 oven of 160 000 tons/year to be commissioned in sept. 2010
Mediterranean Float glass/ CEVITAL	Algeria	Float glass	JV with the Chinese CLFG	3 lines of 600, 700 and 900 tons/day

The four float glass producers of CTF MENA countries are the Egyptian Glass Company, Sphinx Glass, Saint-Gobain and Cevital. Note that there are no float glass producers in Tunisia, Morocco and Jordan. In these countries, high energy price combined with low local demand for float glass are strong drawbacks for installing production units. As an example, the local demand in Tunisia is around 25 percent of the production of a profitable float glass plant (for which the minimum output can be estimated at approximately 150,000 tons/year).

Figure 34: Float glass lines implemented in the MENA region



Source: Sphinx Glass

Production of float glass in CTF MENA countries has been generally very low (around 2 tons/1,000 persons, compared to over 7 tons / 1,000 persons in Saudi Arabia for example). Despite this historically low production level, Egypt and Algeria are currently experiencing a serious ramp up in float glass production which is catalyzed by the fact that they are natural gas producers. Egypt's production capacity of float glass was around 160,000 tons per year in 2003, which is at least 40,000 tons short of domestic demand. Egypt had weak export performance across most flat glass products, which was partly due to the shortage of domestic production capacity in basic float glass. Yet, two to three plants of around 200,000 tons/year were under construction in 2010 according to the Egyptian Chamber of Building Materials industries. This adds to the two current float glass production lines with a capacity of around 150,000–200,000 tons each. As a consequence, while all CTF MENA countries are net importers of float glass, recent investments in production lines will make Egypt and Algeria net exporters of float glass. As shown in Table 15, the production of the Egyptian and Algerian glass industry will help meet the increasing local demand while developing exports. Further data on import and export figures and the level of specialization of the glass sector in the CTF MENA countries is provided in the annexes.

Table 15 Annual float glass production in CTF MENA countries, tons/year

Country	2003 production levels	Current demand	Current production	5-year forecast demand	5-year forecast production
Egypt	180,000	250,000	340,000	350,000	> 700,000
Morocco	0	60,000	0	80,000	0
Tunisia	0	40,000	0	60,000	0
Jordan	0	20,000	0	30,000	0
Algeria	Na	70,000	200,000	100,000	400,000

source: EY, based on interviews

Large-scale modern glass manufacturing facilities require either developed domestic markets with large customer bases for their products or access to export markets. For a developing economy, such as Egypt and Algeria, the glass sector is developing to match growing demand from industrial sectors that are significant users of glass, such as: food processing, automotive, pharmaceuticals, electric lighting, and construction. The sector is also export-oriented to supply customers in regional and international markets. In terms of employment, approximately 2,000 people are currently employed by the float glass production industry in Egypt and Algeria. In these markets, despite favorable conditions (local availability of natural gas, materials quality), the emergence of significant float glass production projects has been a lengthy process, partly due to the fact that these projects are very capital-intensive (US$180-200 million) of investment for a float glass plant of 600 tons/day, integrating a high level of automation).

Demand for float glass in Morocco, Tunisia, and Jordan is expected to increase in the next years. This rise of domestic demand might still reach levels required to justify a local float glass production capacity, unless there is a clear business case for exports.

However, it must be stressed that most of the MENA capacities listed above are producing glass with iron content that would not yet be compliant with CSP requirement. Green glass is less expensive than white glass, but green glass mirrors are 5 percent less efficient than white glass. Cost savings would hence need to be about 6 percent for green glass to be cost efficient (because optical effects have a slightly over-proportional effect on performance), which would be about €33/m². Since this represents the cost for the entire mirror, including bending, silvering, and additional coatings, the EPC would not take the option of using green glass mirrors.

Presentation of the glass transformation industry

Not all CTF MENA countries host float glass production capacities, however glass transformation activities exist in all countries; between 10 and 20 mirror lines are currently in operation in CTF MENA countries. The output of most of these production lines is mirrors with an average thickness of ~ 3 mm and with building quality. The main suppliers of these mirror producers are Sphinx Glass, EGC, SGG, and Chinese producers according to Sphinx Glass.

The mirror production capacities identified in CTF MENA countries are presented in

Table 16.

Table 16 Companies with mirror production lines in CTF MENA countries and production capacities

Name of company	Country	Production capacities
Dr. Greiche (1,500 employees)	Egypt	5 kt / year
Khattab Mirrors	Egypt	4 kt / year
United Mirrors	Egypt	3.5 kt / year
Universal Mirrors	Egypt	2.5 kt / year
Hawala Mirrors	Egypt	2.5 kt / year
Loaloa Mirrors	Egypt	2.5 kt / year
El Gammal Mirrors	Egypt	2.5 kt / year
El Sadaawi Mirrors	Egypt	2.5 kt / year
Nabil Salah Mirrors	Egypt	2.5 kt / year
SIALA	Tunisia	6 kt/year
STEMIR, SOVEP, SAVEMI	Tunisia	Not available

source: EY, Sphinx Glass

Some of these companies, for example, SIALA or Dr Greiche, are producing high quality mirrors. In the case of Tunisian-based SIALA, glass used for transformation is imported mainly from Algeria, and to a lesser extent from Egypt and Europe. Transport from Algeria to Tunisia is obviously much easier than from Egypt or Europe as there is no need for heavy packaging (required for maritime transportation).

Even if local MENA glass players have skills in transforming glass and producing high tech mirrors some doubts remain about their capability of producing in coating CSP mirrors with the specifications to endure harsh Saharan conditions like sand storms. At Solar Paces Conference 2010 in France, it was stressed that blowing sand and sand damage to mirrors is going to be a major concern of operations in the MENA region. In fact, DLR has tested monolithic mirrors with paint on the back in a lab simulating Saharan conditions. It was found that in an environment like the Sahara, a monolithic mirror would only last three years.

Manufacturing mirrors that could resist these kinds of conditions, like laminated mirrors where the coating is completely encapsulated between two panes of glass, is more complex than manufacturing conventional CSP mirrors. Few CSP mirrors have patents for the laminated mirror process and product; this adds to the uncertainty for local industries starting production of CSP mirrors for the local stringent market.

Furthermore, mirror bending with CSP specifications would be a challenge for local industries; it remains a difficult process to learn and would need a joint venture, requiring extensive technical assistance and knowledge transfer to be implemented.

As an example, Guardian Industries managed to convert their automotive glass bending assets into CSP bending assets. But they had significant experience in bending glass and even with that experience, development to reach current quality levels required over three years. According to the Guardian Industries an investment of $50 million would be enough to commission the necessary bending equipment. Running that equipment, however, would be difficult without the appropriate knowledge and licenses.

Competitive advantages

The key asset of Egypt and Algeria's glass industry is the combination of:

• Access to raw materials

• Natural gas available locally

• Strategic market location,

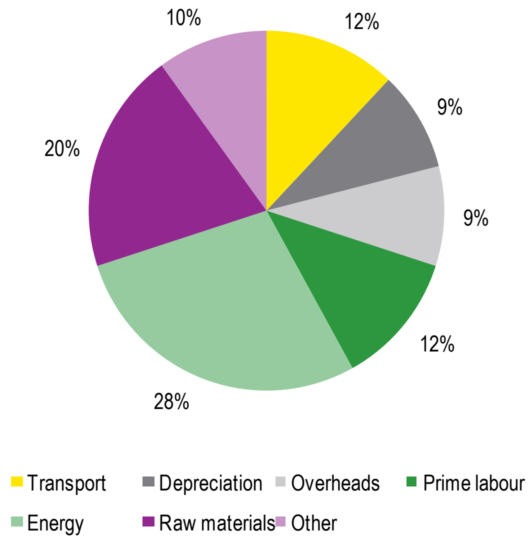
• Access to technology and new products that meet the requirements of domestic and international customers.

The availability of raw materials is not a decisive competitive advantage for Egypt's and Algeria's glass industry. All the input materials available in Egypt and Algeria are international commodities that are readily available to CTF MENA countries' competitors. In the past, Egypt and Algeria have lacked access to technology and new products, but with the development of joint ventures (JVs), know-how and technology are being progressively transferred.

Joint ventures are a key strategic tool, promoting market development, business growth, and risk sharing. There are several examples in CTF MENA countries of glass manufacturers (PPG, CLFG, Guardian, etc.) sharing the risk of large investments in float glass production lines, either with other manufacturers (Cevital for example) or with financial partners (Citadel for example). The development of these partnerships demonstrates the current attractiveness of MENA countries for float glass production. However, low cost producers continue to operate in the region, where a combination of limited regulatory requirements (or no control over their implementation), shortage of reasonably priced quality products, and an emphasis on keeping costs to a minimum maintains demand for low-cost products.

Energy and raw material costs are each as significant as labor in the overall delivered cost. Glass is heavy and comparatively cheap, making distribution costs significant. These typically represent around 15 percent of total costs (figure 35).

Figure 35 Conventional float glass nominal cost



source: Pilkington, 2009

In most cases, transport costs limit the transport of float glass for long distances overland. Typically, 200 km is seen as the average range, and 600 km as the economic limit for most products (which is not a long distance in comparison with the sizes of Algeria and Egypt), although this varies between markets. Potentially it is possible to achieve a very cost-effective transport of float glass, even over long distances, provided that transportation by sea is possible and no long road transport is involved at both ends. This tends to favor float glass production lines with local port access unless a local market is available for the line's output.

Industry outlook

The development of the MENA glass production and transformation industry faces several barriers:

- Limited R&D activity: links between research centers and industry are weak and need to be strengthened through collaborative research and/or clustering approaches.
- Shortage of trained personnel: there is a lack of suitably trained engineers and technicians to operate the existing production lines. For higher quality products, engineering and technological know-how need to be transferred (through knowledge transfer agreements, partnerships, etc.).
- The MENA float glass and mirror industry does not integrate the full value chain. For instance, float glass line equipment is coming from other countries (Europe or Asia mostly). In a number of countries, activities cover only the downstream items; this is typically the case of countries that import float glass in order to transform it locally into mirrors, tainted glass, etc. (Jordan, Morocco and Tunisia).

However, Algeria and Egypt present favorable conditions:

- Natural gas available locally
- Virtually all input materials required to produce glass are available domestically. High quality sand and also high quality limestone are available. Float glass with very low iron content and high solar energy transmittance is available, which is paramount for the production of ultra- clear float glass which is needed for CSP applications.
- Strategic location on the crossroads of three regional markets: Europe, Middle East and Africa.
- Financial strength of players in the MENA market place due to joint ventures and backing by local private equity (Citadel Group for example). Using close strategic partnerships with the main international players allows for example to produce under license high performance glass.
- The well understood opportunity to develop their glass industry (especially float glass), which is proving to be successful.

Glass industry players in MENA could be interested in CSP if the size of the demand is sufficient. According to the stakeholders interviewed, float glass plant implementation is profitable only if its capacity is at least 150,000 tons per year. The size of the regional CSP market has to reach a threshold volume to justify the installation of CSP mirror manufacturing plants, although the size of the export potential is also critical. As an indication, it is estimated that the minimal output for CSP mirror plants would correspond approximately to a year's supply of the equivalent of 400 MW of solar capacity for flat mirrors and 250 MW for parabolic mirrors. Such annual volumes will not be generated by any of the MENA countries in the short to medium term. These aspects are currently under analysis by industry players to establish their investment priorities. In any case, local manufacturing facilities in this sector will not be limited to supplying a national market but will aim at serving a wider regional (MENA) and possibly worldwide CSP market.

The technological gap between conventional float glass produced by MENA players and quality requirements for CSP mirrors remains significant; options to foster technology transfer and to train the local workforce will need to be investigated, possibly in the framework of donor-funded technical assistance.

Despite the lack of float glass production in the other CTF MENA countries (Jordan, Tunisia and Morocco), local industries could position themselves on glass transformation activities in order to manufacture high quality mirrors. For example, SIALA (Tunisia) and Dr Greiche (Egypt) would be ready to consider adjusting their new production capacities to enable CSP mirror production provided a market with a sufficient size. However, they would need technical assistance to identify specifically what adjustment would be needed (coating techniques for example) and the associated costs.

In addition, new entrants seeking to position themselves on CSP-related opportunities in the glass sectors will face the following entry barriers:

- Despite low prices, access to gas needed by float glass plants faces some limitations. In some cases, natural gas produced in Egypt is dedicated in priority to exports rather than to Egyptian industries.
- CTF MENA countries will compete for outside investments in this field and will seek to maintain their first-mover advantage.
- Competition is emerging at regional level either to take new positions (e.g., EUA, Saudi Arabia) or to maintain the competitiveness of existing CSP mirror production facilities (e.g., Saint-Gobain Solar in Portugal, Guardian Industries in Israel).

2.1.2 MENA Electronic and Electrical industry

The electrical equipment industry covers a wide range of components (cables, electric motors, transformers, etc.). This section focuses on the cable industry as well as the other electronic and electrical component industry.

Presentation of the cable industry

One of the main industrial developments in the CTF MENA countries regarding electrical equipment has been cable production for the European automotive and aeronautics sectors. A strong industrial capacity has emerged in Tunisia and Morocco, consisting of both small export-oriented players and a few major cable groups such as Nexans, Leoni or Corning Cable Systems. The Egyptian production capacity is also developing. Today, the MENA region accounts for 6.5 percent of the world's total cable production and Tunisia alone supplies half the European demand for automotive cables, benefitting from local regulations that encourage export-oriented investments by foreign companies. Trade balances and information on the level of specialization of the MENA countries' economies in this sector are given in the annexes.

Although a few cross-border interests have been developed in the region (e.g. the Egyptian group El-Sewedy invests in Sudan and Saudi Arabia), the cable industry in MENA remains fragmented; no large groups have yet emerged with a regional presence comparable with European leaders such as Nexans, Prysmian, or Draka. Another weakness that the industry is not integrated upstream and most raw materials need to be imported.

The cable industry is both highly capital intensive and highly dependent on the price of raw materials whereas labor and energy do not account for a significant share of the total end product cost. As a consequence, there are little cost reduction margins to be obtained by manufacturing cables locally (as opposed to labor intensive assembly activities). However, high transportation cost contributes to the rationale of local production. Quality standards achieved by MENA companies are competitive with European standards.

Presentation of the other electric and electronic components industry

Many international firms have chosen to outsource in the region, in particular in Tunisia where large international companies employ over 45,000 people or in Morocco where manufacturing of electronic components is carried out by approximately 10 firms (e.g., STMicroelectronics) employing over 7,000 people (see examples in box below).

In Algeria, the sector shows high annual growth (from 6 to 10 percent), and export to Europe is expected starting in 2012. Currently, 16 local companies are active in the sector. The region around Sétif (Bordj Bou Arreridj) has become an important industrial pole in the electronic sector. Several international firms have also established their production plants in Algeria.

International electric players producing in the CTF MENA region:

BOSCH, CASCO, CEGELEC, DONCASTER CABLES, DRÄXLMAIER, DELPHI, FRITZ DRIESCHER, HAIER,, HEINRICH KOPP, KASCHKE, KBE ELEKTROTECHNIK, KROMBERG & SCHUBERT, LATÉCOÈRE, LEAR CORPORATION, LEONI, OPTELEC, PHILIPS, RADIALL, SOCOMEC, SOMFY, SUMITOMO, SYLVANIA, VALEO, VOSSLOH SCHWABE, YAZAKI, YURA CORPORATION, ZODIAC, etc.

International electronic players producing in the CTF MENA region:

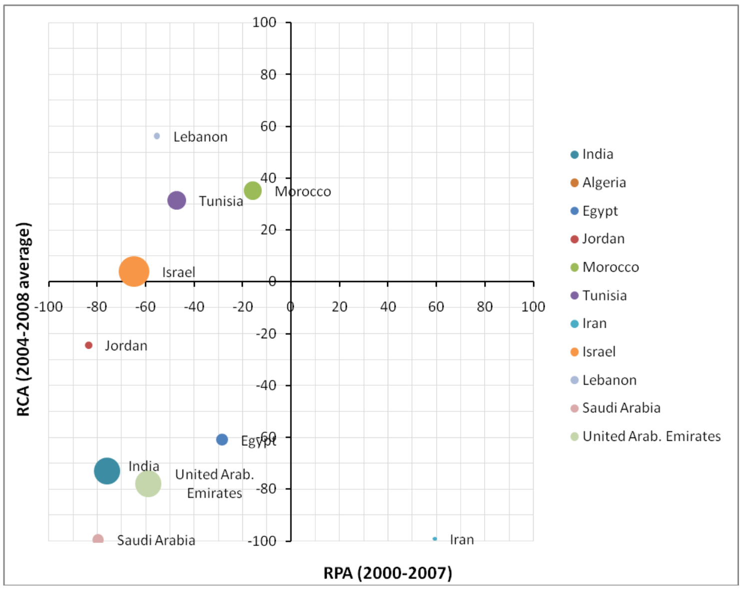
ANJOU ÉLECTRONIQUE, ASTEEL, FITELEC, FUBA PRINTED CIRCUITS, GROUPE ACTIA, GROUPE, COFIDUR, ISOPHON VERTRIEB, JOHNSON CONTROLS, KASCHKE, LACROIX ÉLECTRONIQUE, MENTOR, PHILIPS, PHOENIX, SAFRAN, SIEMENS, ST MICROELECTRONICS, THOMSON, MULTIMEDIA, WECO WESTER EBBINGHAUS, YAMAICHI ELECTRONICS, ZOLNER, etc.

Engineering, design and R&D activities are still limited but are progressively emerging. Local companies have understood the need to develop small product series, with higher added value and technology content, in order to compete with imports from low cost countries (mainly China and South East Asia). Some international European companies have chosen to keep the production of their most technological products (such as specialized cables for the solar industry) in Europe.

This is also reflected by the status of intellectual property rights in this sector. The number of filed patents in MENA in the field of electronics is considerably higher than in all other industrial sectors that have been analyzed. Information on the number of patents held by the CTF countries is provided in the annexes.

Error! Reference source not found. shows a specialization pattern for the electronics industry for several of MENA and non-MENA countries. The specialization pattern combines information from patent analysis (cf. annexes) and foreign trade analysis (cf. annexes). The 'Revealed Competitive Advantage' (RCA) is plotted against the 'Relative Patent Share' (RPA). The export volume is displayed by the size of the data points of the individual countries. Positive values for both indicators indicate that a country is notably active in terms of export and R&D in this sector, compared to other industrial sectors of the economy. Negative values indicate that the respective sector performs below average, considering trade balance and intellectual property. For the electronics industry, however, positive RPA values occur and a relatively high export volume is reached by Morocco and Tunisia, compared to other MENA countries.

Figure 36 Specialization pattern for electronic equipment in MENA countries, Relative Patent Share (RPA) vs. Relative Competitive Advantage (RCA). Sizes of the circles indicate export volumes.



Source: Authors

Industry outlook

The electronic and electrical components industry is developed and dynamic in most of the CTF MENA countries, driven by both increasing local demand and large exports to Europe. According to most people contacted, local industries could probably supply CSP plants with electric and electronic components in the short term, especially cables, tracking systems, balance of the plant and monitoring systems. Most of these components are not specific to CSP or could be rather easily adapted to CSP. Electronic and electrical industry entering the CSP value chain would significantly contribute to an increase of the local share as these components represent over 10 percent of the total value of a CSP plant.

Although local players have mainly acted as subcontractors in the past, they are progressively investing in R&D and starting to develop new products, and the added value of this industry's output is increasing. Added value of the Tunisian electric and electronic industry is increasing by 18 percent a year[22]. The remaining gap between the components currently produced and the electric and electronic components needed for a CSP plant could be easily bridged by current efforts to develop R&D activities. Seizing this opportunity will require strengthening the links between research and industry (for example, by supporting the creation of other industrial poles) and strengthening the business case for the local manufacturing of products that will compete with European and Asian production.

[22] Source: Invest in Tunisia, 2009 (http://www.investintunisia.tn/document/488.pdf)

2.1.3 MENA Steel industry

Presentation of the steel production industry

The main liquid steel production capacities of the region are located in Egypt (9.6 MTPY in 2010), Algeria (2.4 MTPY in 2010), and Morocco (1.25 MTPY in 2010). Only limited capacities are installed in Tunisia (285 KTPY in 2007) and in Jordan (75 KTPY in 2007). In the entire region, local production capacities are much lower than crude steel local demand (as an indication, in 2008 Africa and the Middle East produced 2.6 percent of the world production while using 5.8 percent). All MENA countries rely on imports, mainly from Turkey and Spain.

Table 17 Steel demand and production in CTF MENA countries

Country	2008 demand* ktons/year	2007 production levels ktons/year	2009 production ktons/year
Egypt	8 253	6 224	5 508
Morocco	2 441	512	479
Tunisia	1 301	160	-
Jordan	1 776	150	-
Algeria	5 546	1 278	458

Source: **IISI**

Notes : *Apparent Steel Use, ktons/year=crude steel equivalent

Large investments have been committed during the past few years in order to reduce the supply-demand gap. As a result, CTF MENA countries are now one of the fastest growing regions in terms of steel production. Some steel producers (for example ArcelorMittal with SONASID in Morocco) have invested in several former public companies in CTF MENA countries to upgrade the actual plants and invest in new facilities. Barriers to new entrants in the sector are mainly:

- Capital-intensity of the industry,
- Skilled-labor intensity of the industry. Although several companies benefit from high-tech production lines, there is a lack of sufficiently trained engineers to operate them;
- Uncertainty on price due to monopolistic situations. As an example, the Egyptian market is dominated by Ezz-Dekhela which holds a 61 percent share of the market.

Presentation of the steel structure manufacturing industry

The main output of the MENA structure manufacturing industry is conventional steel products such as reinforcement bars, wire rods, and billets. The industry employs approximately 25 to 30,000 people, and regroups a wide variety of companies, mostly small and medium enterprises. A significant number of companies manufacture high quality metallic structures including National Steel Fabrication (NSF), Al Zamil and El Sewedy in Egypt; Charcomem, Espace Metal, Menasteel, Polymetal and DLM in Morocco; MSGI in Tunisia and several others in Jordan and Algeria. Most of these companies have automated production, quality certification, and high-tech tools and could reportedly supply CSP plants with support structures. Still R&D activities and the status of intellectual property rights in this sector are generally low in the region (cf. patent data in annexes).

However, as for crude steel, all CTF MENA countries are net importers of steel products. The increase of the local production capacity does not yet cover the growing demand from the construction sector, which requires significant imports. Further information on trade balances and the level of specialization of the steel transformation industry on the export of steel structures is provided in the annexes.

Industry outlook

In some MENA countries, the steel industry benefits from the local availability of natural gas and low labor costs, however in return it faces high levels of raw materials imports, as well as monopolistic situations. This leads to uncertainty on prices and presents barriers for new entrants. However, the availability and price of steel would not put at risk the potential of steel structure manufacturing companies to enter the CSP market. Indeed, the volumes of steel needed for CSP plants are not significant compared to volumes needed for building and other applications.

Some local industries already operate high tech production lines and have the skilled workers available that are needed to build CSP metallic structures. A good example is the involvement of NSF in the steel structure supply to Orascom Industries for the Kuraymat project. More generally, CTF MENA countries are currently expanding their industrial sector and are entering a new phase of industrial technology. Demand for flat steel is expected to boost industry performance. However, local players will face competition with foreign companies (mainly Turkish and Spanish).

2.1.4 Other industrial sectors

Piping and insulation

Pipes and insulation systems needed for a CSP plant are not specific and the main companies providing the international market are generally not specialized in CSP pipe manufacturing.

In the MENA region, in addition to Babcock Wanson (an international boiler specialist which has set up one of its three production sites in Morocco) several local producers seem to have the know-how to supply a CSP plant:

- El Nasr Steel which is one of the largest manufacturers and exporters of steel pipes in the Middle East.
- United Company for Manufacture Metal Pipes which has a factory in Cairo.
- Alkarnac which is another manufacturer of metals pipe in Egypt
- The Jordan Pipes Manufacturing Co. which produces water, gas and central heating pipes.

Composite materials

Composite materials are widely used for wind turbines and masts as well as in the aeronautic, automotive, and leisure industries, because of their resilient properties, such as mechanical, weight, and temperature resistance. They could be used to form support structures for CSP plants.

Although the big international players (Toray, Teijin, Owens Corning) are not present in the CTF MENA region, a few locally established enterprises seem to have the necessary know-how to produce such CSP structures:

- Solutions Composites is the leader in the Tunisian and North African market and has a large production site. Its customers come from several sectors: shipyards (they are a major sub-contractor of Zodiac), railway industry, and leisure industry.
- Avionav, established in Tunisia, is a subsidiary of Stormcraft (Italia) producing small planes and helicopters with composites, designed for exportation.
- Aircelle, established in Morocco, one of the leading players in the nacelle and aerostructure market, is developing its expertise in composite materials. The company pursues a policy of innovation by implementing new composite technologies with the design and production of large lightweight structures. It possesses the technical know-how to widen the range of products.

Figure 37 Composite wing for small airplanes produced by Avionav

2.2 Analysis of MENA capabilities and potential for CSP components

2.2.1 Analysis of value- and supply chains for CSP and identification of potential players

In this section an assessment of the current output capacities and capabilities of the local MENA industries is carried out from which a general potential for a local manufacturing of CSP components can be derived. Examples of the project development of ongoing CSP projects in MENA are then analyzed and potential players for a future CSP industry in MENA are identified to evaluate the overall potential of CSP manufacturing in MENA.

Potential of local industries to integrate the CSP value chain

Table 18 MENA industries gaps and competitive advantages regarding CSP requirements

MENA industry\capacity	Investment potential and financial strength	Current output quality	R&D potential	Cost reduction / international competitors
Glass and mirror industry	++ JV and international partnerships already developed	-/+ Conventional glass and mirrors (most of output is green glass)	-/+ Low local R&D but possible technology transfer	++ Availability of natural gas in Egypt and Algeria
Importance of criteria regarding CSP requirements	Important as it requires large and capital intensive production facilities	Need for low fraction iron dioxide, precision of bending and quality of coating	Not much R&D needed if technology transfer takes place Further R&D needed for "Sahara conditions " resistant mirrors	Important as energy is a large share of the total CSP mirror cost
Electronic and Electrical industry	++ Large local and international firms present in MENA	+ Supplying international clients	+ Already in place to comply with international new requirements	+ Impact of lower transport cost on total cost
Importance of criteria regarding CSP requirements	Not much investment needed to provide CSP compliant electronic and electric components	Na	Needed to meet potentially specific CSP requirements	Needed as not many other opportunities to differentiate from competitors
Raw material and structure manufacturing	+ Large companies in value chain	--/++ Large discrepancies between stakeholders	+ Some companies used to develop new structures for particular needs	+ Low labor cost
Importance of criteria regarding CSP requirements	Investments needed to develop new designs and production line	High resistance and stiffness as well as accuracy needed	R&D needed to design mounting structure at the beginning and then need for mass industrialization	Importance of labor cost in total cost (if not highly automated)

The quality of the steel and glass industries' output is variable. On the one hand some companies are producing very basic hand welded steel structures or green glass with high iron content. This kind of float glass is used for automotive or building industries but would not be suitable for CSP mirrors. On the other hand, several companies, operating automated production lines and benefiting from international certification and knowledge transfer agreements, would be in a position to meet the quality requirements of CSP industry.

As discussed in the previous section and highlighted in table 18, many local industries already benefit from strong partnerships with international stakeholders. Some of these are looking into developing new activities, and CSP is considered as a potential opportunity.

However, the awareness of CSP technologies is low among local industries and mainly relies on the curiosity of some individuals. Furthermore, some companies are focusing on other technologies such as wind and PV and do not see CSP as a priority for diversifying their businesses.

Local availability of natural gas and low labor costs are competitive advantages for some industries like glass production and transformation and steel structure manufacturing, and could reduce costs for a CSP system. The lower transport costs of local suppliers could also contribute to the business case for local production of some low added value components like cables, pipes or raw materials (cement, concrete, etc.). However, transport costs remain a small share of the total CSP plant costs and will not be a main driver for cost reduction.

Other local industries have developed due to a skilled workforce and regulatory frameworks that incentivize foreign investments, as in Tunisia which has developed flourishing cable, electric, and electronic industries. These industries have managed to expand thanks to the development of partnerships and to the supply of international clients with high quality products, meeting specific needs and quality standards.

The current R&D capacities of local industries are limited, and depend on the company's business model. For instance, a complex structure manufacturer is used to dealing with "one shot" orders, which need a phase of design and development. On the other hand, the glass industry produces mostly standard types of float glass. This is also the case for glass transformers, like Dr Greiche, the R&D of which relies only on five people (out of hundreds of employees). For the moment very few collaborative research projects with public bodies have emerged, although the establishment of technology platforms in most CTF MENA countries should encourage more collaboration. Most stakeholders interviewed consider that the availability of a skilled workforce is not a problem. Skilled workers can be acquired, and generally on-the-job and cross-training is done within the company.

The gaps identified in this study might be addressed through various measures, including private or public international cooperation, investment in R&D, and the development of centers of excellence. One short term action that would increase interest from the industrial sector would be to provide more visibility of the CSP projects pipeline and more precision about the potential of the CSP market. This could be partly addressed by the decision of MENA countries to better communicate about CSP development road maps, including calls for tender. Other measures, such as including requirements for a target level of local content in calls for tenders will be critical.

If the incentives and capacity building detailed in the following sections are put in place, CTF MENA stakeholders consider that cables/electronics could potentially be supplied by local industries. The steel structure could be manufactured locally as is already done for the Kuraymat project. The mirrors could be manufactured in the mid-term, however the bending process requires new production lines and additional know-how, which currently does not exist in CTF MENA industries (e.g., the coating process for bended mirrors, which needs a special spray technique). Conventional CSP mirrors might not be suitable for harsh Saharan weather conditions (sand storms, very high temperatures, etc.); R&D that can only be carried out through joint ventures with extensive background in mirrors bending and coating will be needed.

2.2.2 Illustrative industrial development in the MENA region: aeronautics industry in Morocco

The potential of industries to develop CSP activities is confirmed by some success stories in the MENA region; the development of the aeronautical industry in Morocco is one example.

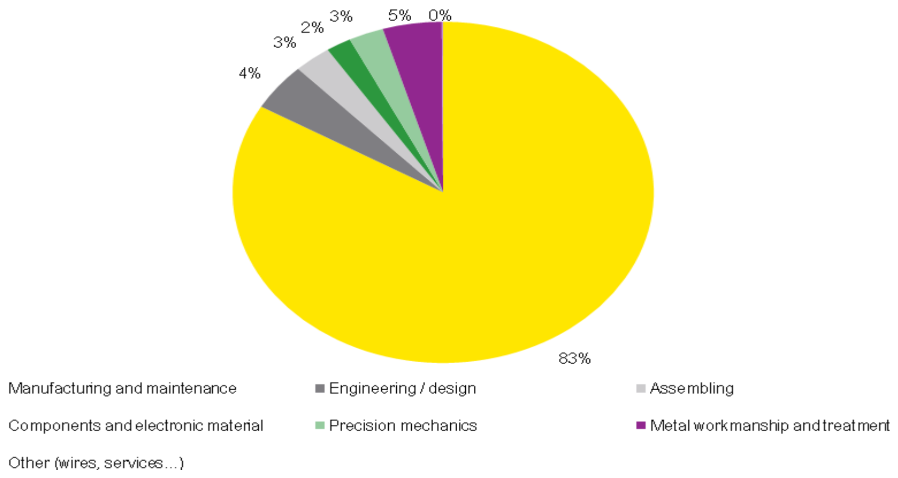
Historical background

The aviation industry in Morocco can be dated to 1994 with the inauguration of the "Aéropôle" located next to the Casablanca airport. It was the first Moroccan cluster in aeronautics and was created through a state initiative. This area of 85 ha—which became operational in 1996—is dedicated to innovation, incubation, and outsourcing of material and components related to aeronautics. In 1999, one of the first actors was created by a joint venture between Royal Air Maroc and Snecma Services (SAFRAN). Snecma Morocco Engine Services (SMES) specializes in the maintenance and repair of civil airplane engines. In 2000, a school located in the "Aéropôle" called "Académie Internationale Mohammed VI de l'Aviation Civile" was created to help provide the sector with qualified workers. In the early 2000s, several equipment manufacturers and their suppliers set up business in Morocco, which led to the creation of Matis (JV Ram, Safran and Boeing), Sermp (Le Piston Français), Sefcam, Asi, Assystem. These companies, mostly French subsidiaries, helped Morocco turn its aeronautic industry from maintenance toward production.

In 2005, aeronautics is designated in the national "Plan d' Emergence" among the eight strategic sectors for the economic development of Morocco. At the beginning of Emergence, 17 companies settled in the "Aéropôle." A sectoral federation called the GIMAS (Le Groupement des Industries Marocaines Aéronautiques et Spatiales) was created in 2004.

Although the industry developed in Casablanca, cities such as Tangiers (in the "Tanger Free Zone"), Rabat and Marrakech recently began to enter into this field.

Figure 38 Breakdown of activity types for aeronautics industry in Morocco



source: sectoral study by the FIMME, 2005

General description

Most of the companies operating in this sector are foreign capital enterprises. Many are subsidiaries of foreign groups, such as EADS, SAFRAN and DAHER, whose only client is their parent company. These companies tend to be small and there is little competition or commercial relationship between them. They operate in the outsourcing of elementary operations that can be classified under seven types of activities.

Nevertheless, with more than 90 players today,[23] the industry is making its way toward greater technological content and more added value. This results in the increase of services and engineering/design activities as well as R&D. The industry's clients are mostly airlines but also aircraft and engine manufacturers as well as subsystems designers and manufacturers mainly located in France and Morocco.

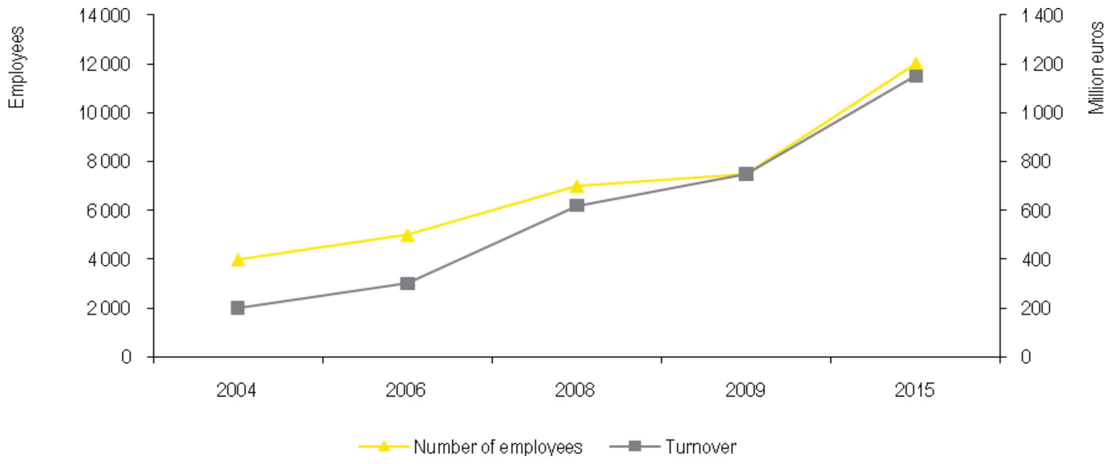
In 2009, the industry reached a turnover of €750 million (more than 70 percent of which comes from exports) with an average growth of 25 percent during the last five years and employing about 7,500 workers. Most of these are factory workers or technicians. The proportion of engineers is usually low (about 5%)[24] with the exception of companies, such as Teuchos, that are focused on engineering and design, and where up to 60 percent of the workforce are engineers (cf. **Error! Reference source not found.**).[4] Currently, the sector benefited from €350 million of investment. By 2015, the sector is expected to create up to 15,000 new jobs and reach an additional €400 million turnover (**Error! Reference source not found.**).[25]

[23] According to GIMAS (Le Groupement des Industries Marocaines Aéronautiques et Spatiales).

[24] Estimation made by ESCAE MBA students in their research paper conducted in 2007 under the title "
Dynamique des relations verticales et clustering : Quelle strategie pour une sous-traitance aeronautique marocaine competitive ?"

[25] Forecasts from the Moroccan daily Newspaper 'Le matin': http://www.lematin.ma/Actualite/Supplement/Article.asp?origine=sej&idr=639&id=116183

Figure 39 Evolution and projection of employment and turnover in aeronautics industry in Morocco



source: EY, GIMAS, Le Matin, ISCAE

Key success factors and strategic issues

In addition to the general trend of low costs and outsourcing of non strategic activities, Morocco benefited from several key factors that contributed to the success of its aeronautics sector. These include the country's geographical and cultural proximity to Europe, its economic and political stability, and its economic position in Africa with the second largest air fleet after South Africa. Free trade agreements with Europe and the United States were also important.

The Aéropôle and the Emergence plan were important state-sponsored initiatives for the development of this sector. They resulted in significant tax relief with total exemption during the first five years, with subsequent deductions of 17.5 percent as well as financial aids for land cost, construction, and equipment. The Aéropôle is located in an area of Casablanca that is at the heart of an important labor pool, offering a workforce at lower costs and more flexible work legislation, as well as specialized engineers from top schools in Morocco (EMI, RAM Academy) or in France (Supaéro, ENAC). Moreover, the Aérôpole was designed to allow quick and easy set up of operational units: companies can rent parcels at a low price for building their own factories or rent "ready to produce" modular industrial spaces equipped with utilities (electricity, water, compressed air and computer network) allowing them to install their machines in 24 hours. There are also "ready for services" buildings offering modular and cabled offices for service companies. The Aéropôle also offers general services such as cleaning, security, training rooms, meeting rooms, and copy centers. The strategic location next to Casablanca's airport also allows quick delivery by plane.

Finally, the presence of major foreign groups' subsidiaries such as EADS, Boeing and SAFRAN and the success of the first actors and joint ventures acted as a virtuous circle by attracting other companies.

Some of the factors that contributed to the success of the Aeronautics industry in Morocco took time to develop. The first and most important gap to address at the start was the training of professionals. The training of technicians and workers is usually provided by external companies, but when the process is complex, they can be trained directly by the parent company or the client. In 2000, the "Académie Internationale Mohammed VI de l'Aviation Civile" was created by the ONDA (a state institution for the management of Morocco's airports), joined in 2009 by the "Institut des Métiers de l'Aéronautique" created by the GIMAS (sectoral federation). Nevertheless, companies still play a large role in the training of their own workers. For example, Nexans created its third industrial site dedicated to aeronautics wires in Morocco by signing a technology transfer contract with Nexans Maroc, that allowed the subsidiary's. experience in the manufacture of car wires to be converted to the aeronautics industry.

The lack of relationship and communication between the different companies acting in this industry created another barrier to growth. In the past, most companies were addressing their parent companies' needs instead of serving as a supply source for other local companies, which impeded vertical integration in the industry. This was partially addressed through the creation of the GIMAS in 2004 which is in charge of creating a federation for these companies. Institutional communication was improved with the participation of Morocco since 2007 in the French air show "Le Bourget" and the creation of the Moroccan air show "AeroExpo" in 2008. The industry is also promoted by the CRI ("Centres Régionaux d'Investissement") and the CFCIM ("Chambre Française de Commerce et d'Industrie du Maroc"). There are still some challenges to tackle, however, including the development of R&D, the further development of support services (supply, logistics and quality support), the structuring of commercial actions, and the development of local supply sources for materials and components.

Other supporting activities such as bank financing, administration reactivity, public transportation, and reliable electricity supply could help this field be even better.

Learning from the aeronautics experience for the development of CSP manufacturing in Morocco

To make the link with the development of a CSP industry in Morocco, Table 19 and Table 20 show an analysis of the key factors and challenges for Aeronautics that are relevant for CSP:

Table 19 Comparative analysis of key success factors (Source: EY)

Challenges	Importance of the factors for the successful industrial development		Comments
	Aeronautics	CSP	
Geographical and cultural proximity to Europe	●	◑	Market for CSP components is mainly in MENA region, Africa and USA whereas market for aeronautics components manufactured in Morocco is mainly European.
Economic and political stability	●	●	This is a factor of major importance for any investment decision.
Proximity to regional MENA/Africa markets	◑	◕	CSP market is MENA whereas aeronautics market is Europe.
Free trade agreement with Europe and the US	●	◑	See comments above
The state's support (political support, tax reliefs, grants, etc.)	●	●	The state's support has been determinant in the case of aeronautics' industrial development. Considering the high level of investments needed for development of CSP, state's support might be as determinant.
Cheap labor costs and flexible work legislation	●	◑	CSP is less labor intensive than aeronautics and should rely on more skilled staff.
Strategic location (next to an airport or in a logistics zone)	●	◕	CSP will need good logistics infrastructure (ports, roads…) in order to reach MENA and world market. Nevertheless, it should be less critical than aeronautics that requires quick delivery from subsidiaries to parent companies.
Network development	◔	●	CSP makes the junction between several industries that are not used to cooperate. Then, the creation and development of a network between these companies and the integration of their technical skills is critical. Moreover, CSP needs to leverage its network in order to get known.
Trained workforce	●	●	For both industries, there were/are no competencies before the first training from foreign companies/experts.

Table 20 Comparative analysis of key challenges (Source: EY)

Challenges	Importance of the remaining challenges		Comments
	Aeronautics	**CSP**	
Lack of bank financing / fund raising	◔	●	CSP development might be more capital intensive than aeronautics. Therefore, state's funding might not be sufficient.
Administration burden	◑	◑	Aeronautics experience showed that administrative constraints are not insurmountable
Reliable energy supply for industries	◕	●	CSP industry is energy intensive
R&D and engineering	◕	●	R&D is an important challenge for aeronautics to continue going toward a high-tech industry. It should be at least as critical for CSP suppliers that will have to produce CSP-quality components.

○ ➔ ◔ ➔ ◑ ➔ ◕ ➔ ●

Neutral — Decisive

2.2.3 Illustrative business cases of current CSP projects

ISCCS power plant in Kuraymat (Egypt)

Project Overview

The Integrated Solar Combined Cycle Power Plant (ISCC) Kuraymat is a hybrid power plant with a total capacity of 150 MW that uses both solar energy and natural gas to generate electricity. It is located about 90 kilometers south of Cairo, Egypt on the eastern side of the Nile River. In 1999 the World Bank decided to sponsor four ISCC projects (in Egypt, Morocco, India and Mexico) by a grant of US$50 million each. In 2001 Fichtner Solar started with the first layouts of the plant in Kuraymat, and construction has been underway since January 2008. The plant was divided into two lots: the Solar Island, for which Orascom is the EPC contractor (together with Fichtner Solar and Flagsol as subcontractors) and the Combined Cycle Island, for which Iberdrola was chosen as EPC contractor. The BOOT (Build-Own-Operate-Transfer) project was expected to be finished by the end of 2010 (originally planned for 2009). The ISCC Kuraymat is the first of its kind with the projects in Algeria and Morocco. The solar field thermal power output is estimated at 50 MJ/s which corresponds to estimated electric power of 20 to 25 MWe at reference conditions.

Table 21 Technical data of Kuraymat ISCC plant

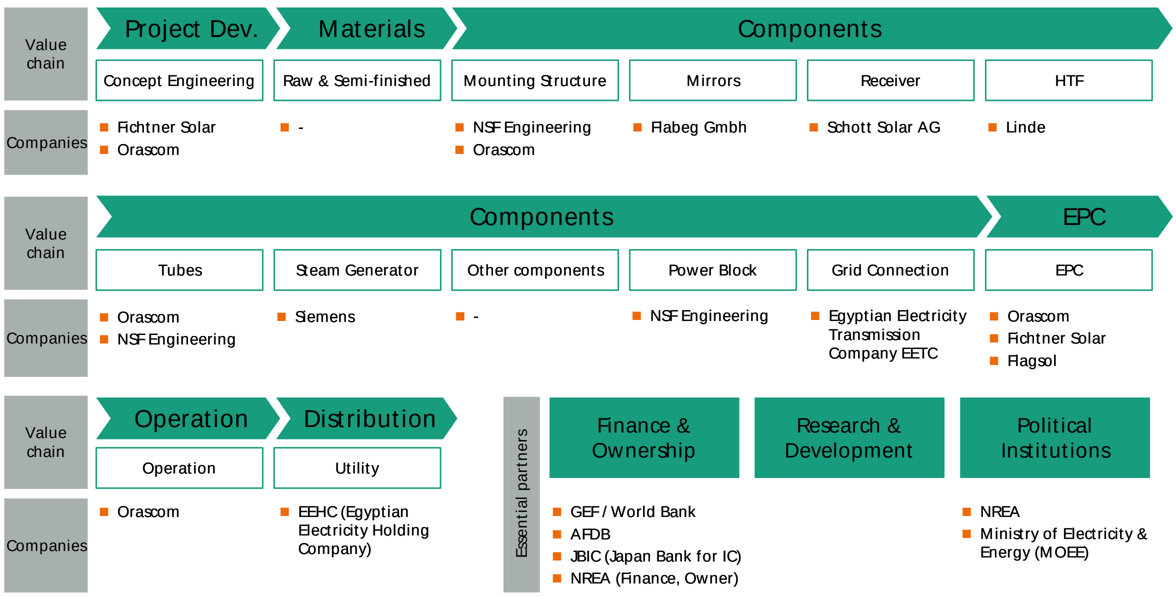
Technical Data	Value	Unit
Solar Field total Area (mirror surface) (Source: Flabeg)	148169	m²
Number of mirrors (Source: Flabeg)	55502	N°
Total length of the rows	23600	m
Number of Collector-units (~ 12 m long, 6 m wide) (Source: Solar Millennium)	2000	N°
Receivers	5900	N°
Number of Loops	40	N°
Hot Leg HFT Temperature	393	°C
Cold Leg HFT Temperature	293	°C
Gas Turbine Generator	74,4	MWe
Steam Turbine Generator	59,5	MWe
Solar Field Design Thermal Power at Reference Conditions	50	MJ/s
Output solar field (electric power) (Source: Flabeg)	20 - 25	MWe
Installed power specific investment costs	4.935	US$/kW

Sources: Fichtner Solar, Flabeg, Solar Millennium, Fraunhofer ISE

Value chain for Kuraymat

The Kuraymat project is financed by the Egyptian New and Renewable Energy Authority (NREA), the Global Environmental Facility (GEF) of the World Bank and the Japan Bank for International Cooperation (JBIC). The GEF has granted a US$50 million subsidy for the solar field due to the project's exemplary status. The remaining foreign currency portion is financed by JBIC and the local currency portion of the investment by NREA. About 60 percent of the value for the solar field is generated locally. Civil works, the mounting structure, the tubes, electrical cables, grid connection, the engineering, procurement, and construction responsibility (engineering strongly supported by Fichtner Solar and Flagsol), the operation and utility is all done by local industry. However some of the key components are still provided by international industry (e.g., the mirrors, receiver, heat transfer fluid, and steam generator).

Figure 40 Value Chain for the ISCC plant in Kuraymat, Egypt with involved companies



Key Findings from interviews and project experience

The Kuraymat ISCC plant might become a reference project for pure CSP plants in the region. Despite unfavorable conditions for CSP approximately 60 percent local value generation for the solar field shows that local industry is already capable of realizing CSP projects. The project development for the solar field was done by international companies. But this is one of the first CSP projects in North Africa and international industry already has experience with the development of CSP plants; it is likely that local engineering offices and EPC contractors will be able to transfer their experiences to future projects. In Kuraymat the EPC contractor Orascom was strongly supported by Fichtner Solar and Flagsol with the conceptual design, engineering, and technical advisory of the assembly. However, materials were purchased partly from local sides: the windbreakers were constructed from locally manufactured bricks; the cables, steel for the mounting structure, and tubes (performed by NSF) were also locally produced; the SKAL-ET collector was assembled by Orascom close to the site from a pre-fabricated low cost steel structure; and local sub suppliers delivered the pre-fabricated welded steel parts of torque box frames and plates, cantilever arms, and HCE supports.

Figure 41 **Installation of mirror collector at Kuraymat site**

source: Solar Millennium

The site conditions at the Kuraymat plant are not ideal for a solar field. The chosen field area is rocky so the civil works became much more complicated and expensive than expected. Because of high wind loads, windbreakers had to be built and the collectors reinforced. Strongly varying temperatures made it necessary to add a freeze protection unit with a natural gas fired freeze protection heater and freeze protection pumps for the HTF.

The project suffered from different cost and scheduling issues. Since two different tenders for the solar field and power block of the combined cycle were contracted, coordination problems occurred. Also a relatively low solar share does not increase the efficiency significantly: a large solar field with smaller gas back-up would raise the economical parameters of the plant. Furthermore the final price that was tendered for the solar field was comparatively high.

Conclusion for future CSP plants in Egypt

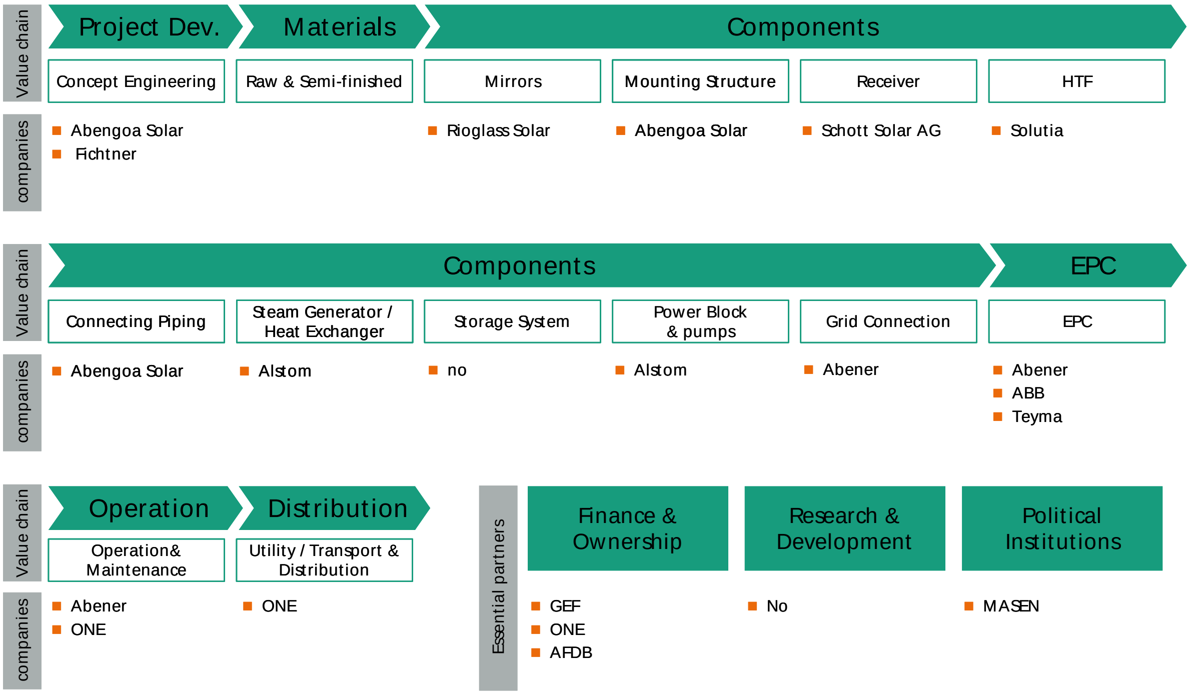
The Kuraymat ISCC plant proves that international know-how and technical support in project engineering combined with local know-how, raw material supply, and locally manufactured components is feasible and serves as a model for future projects. With a value generation of about 60 percent for the solar field already in 2010, the local economy will see significant benefits from this investment in renewable technology. Currently, local industries confirm that they suffer from a lack of engineering experts. For these projects to be successful, local industries and the country as a whole will need to invest further in R&D and education. But because CSP is not a highly specific technology and Egypt already has industries that produce some of the necessary components, actions to support CSP industries will have synergies with other industry sectors (steel, glass, cables, and engineering in general).

The critical aspects of the tender procedure and design of ISCCS plants should be assessed further. A larger solar share would be a good alternative to provide pure solar power to the Egyptian electricity consumer in the future.

ISCCS power plant in Aïn Beni Mathar, Morocco

The ISCCS plant in Ain Beni Mathar, Morocco, is currently being constructed by Abener in cooperation with Abengoa Solar. It will have a total capacity of 470 MW of which 20 MW will use thermal energy from a solar field. The largest share will be generated by a conventional combined cycle system. The solar field counts on a reflecting surface of more than 180,000 m² and has a capacity to generate a power of 20 megawatts. Abener Energia won the bidding of ONE and GEF for the EPC contract for the construction. Abener provides global, innovative, and sustainable solutions, which have been applied to the design, construction and operation for energy and industrial plants. The equipment and components are mainly imported from European countries like Spain, France, and Turkey. The civil works and construction are done by international firms that use a few subcontractors to provide basic and elementary ground breaking with local work force and their own machines. The construction of the total plant was expected to be completed by the end of 2010 by linking the solar field and the conventional bower block. Figure 42 shows the main companies involved in the production of components and equipment and the construction of the plant at the site which lies 80 kilometers outside the city of Oujda in East-Morocco.

Figure 42 Value chain for ISCCS power plant in Ain Beni Mathar



Source: Authors

Main lessons from this project:

An examination of the first CSP project as an Integrated Combined Cycle System in Morocco reveals some important lessons learned. Future CSP projects will not have completely the same project structure and an EPC contractor will be involved. But some aspects of this project reflect the general situation of manufacturing, construction, and project finance in Morocco:

- All main components and equipment are imported for the Aïn Beni Mathar project from international market players.
- International EPC contractor Abener was expected to commission the project successfully by the end of 2010 (duration of construction will be 3 years)
- Abengoa and Abener observed small cost differences for metal mounting structures in Morocco because of the small margin between imports and local manufacturers (no advantage for local components)
- Abengoa and Abener lacked significant international experience in CSP, which made contracting with local companies more complex
- There were doubts about the ability of local industry to supply in quantity and in a timely fashion and it was considered a lower risk to buy from large international suppliers)
- Problems of finding well trained and highly skilled workers
- Problems of local products and steel construction: mainly quality and price

- ► Issues related to intra-Morocco logistics: importing components from abroad seemed easier than shipping by road from economic hubs (Casablanca for example) to Ain Beni Mathar.
- ► Available in Morocco: Large machines (all types)
- ► Administration and bureaucracy: Lower speed of implementation of project
- ► Reasons for imports: No import taxes (price advantages to local products/price difference 6-10 percent)
- ► O&M has to be done by international experienced company to sustain the performance of plant

Conclusion for future CSP plants in Morocco:

Strongly supported by international donors, the first CSP project in Morocco will produce electricity for the Moroccan market by the end of 2010. This pilot project will increase knowledge, experience with operation and maintenance, and acceptance for CSP projects in Morocco. But local manufacturing outcomes have not proved positive:

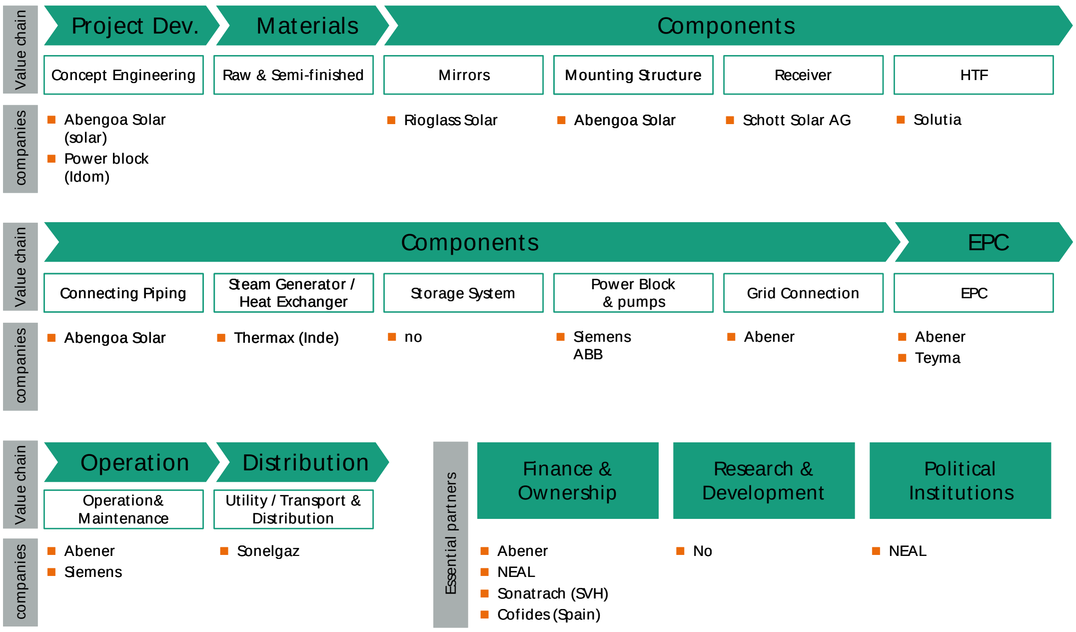
- ► Low participation of local industry in this initial project may lead to low levels of technology transfer and little learning
- ► Many international component suppliers have made first steps into the MENA market by selling their components in Morocco, but cost advantages for local components and services could not be identified

ISCCS power plant in Hassi R'mel (Algeria)

This project is being promoted by Solar Power Plant One (SPP1), an Abener and NEAL joint venture formed for this purpose, which will operate and exploit the plant for a period of 25 years. The Algerian state society, Sonatrach, will buy all the power produced under a Build own operate (BOO) contract with Abener. The project company is owned by four shareholders: Abener (51 percent), Neal (20 percent), Sonatrach (14 percent) and Cofides (15 percent). The lead bank for this project was the Algerian bank BEA, Banque Extérieure d'Algérie. The total investment was issued for 315 Mio Euro to Abener.

The plant will be composed of a 25 MW (183,860 m²) solar field of parabolic trough technology that will provide complementary thermal energy to a 150 MW combined cycle. The concept includes a dry cooling system that uses only 10 percent of a water-cooled system. The leading role of Abener as EPC-contractor and Abengoa Solar as central for the solar field development is shown in **Error! Reference source not found.**.

Figure 43 Value chain for the ISCCS power plant in Hassi R`mel *(Source: Authors)*



Main lessons from this project:

The first project in Algeria was built because there was strong political will for a CSP plant in Hassi R´mel to be built in a total project time of 33 months. The next series of three solar thermal plants in Algeria can profit from the technological experience gained in this first project.

- ► Engineering company Abener is responsible for the EPC of the total ISCCS plant; Abengoa´s subsidiary is the main supplier for the components and engineering of the solar field
- ► Ninety percent of equipment and components are imported
- ► Solar field is 30-40% of total project cost, engineering 10-15% of total project cost
- ► No local manufacturing was used for the solar field
- ► Civil work at Algerian site ranges up to 30 percent higher than in Spain
- ► Abener expects to use locally produced steel mounting system for future projects
- ► Limited know-how for project development of (conventional) power plants exists in Algeria; EPC contractor always international company
- ► Local company Sarpi provides electronic equipment for the plant
- ► The main O&M is done by Abener but an Algerian engineering company (Algesco) will provide turbine maintenance during operation

Conclusion for future CSP plants in Algeria:

- Low developed private industrial sector reduces the capabilities of Algerian industry to react efficiently and quickly to market demand and project needs
- Turnkey projects preferred in Algeria because of limited experience with power technologies

The share of local involvement in the project is very low. The Algerian industry could play a limited role in local manufacturing, but even components and services with a lower technology level have been provided by international companies.

Conclusion on feedback from MENA ISCCS

The local share has been very limited for Hassi R'Mel and Aïn Beni Mathar as most components have been imported by the EPC contractors. This can be explained by the fact that the first aim was not to develop the local CSP related industry but to deliver a functional ISCCS within tight deadlines. On the other hand, the Kuraymat ISCCS achieved 60 percent local production. The key to that success was the involvement of a local EPC contractor, Orascom Industries, and the support of Fichtner Solar and Flagsol for the conceptual design, engineering, and the technical advisory of the assembly. As Orascom is an Egyptian company, it was easier to involve local subcontractors, like NSF for the steel structure. The local companies involved in the Kuraymat project gained know-how and should be able to use it for future projects.

A promising approach to develop local CSP components production would be to combine the following elements:

- ► International cooperation to facilitate knowledge transfer
- ► Involvement of a local EPC contractor to facilitate the involvement of local companies
- ► Funds to compensate companies for the potential extra costs related to using local components. Although it can be more cost- and time-efficient to import components, making the effort to involve local companies in a first project, even at additional cost, can be a profitable investment as these local companies will gain experience for involvement in future projects.

2.2.4 Potential involvement of international players in local production

International companies and partners are already involved in recent CSP projects in the MENA region. In the future, local manufacturing capacities by international companies will be a key to increasing manufacturing at the local level. Several expert interviews with international European market leaders in Spain, France, and Germany were conducted to identify the position of industry with regards to the MENA market. Strategies to enter the market or to build up local production factories were discussed. This section is divided into four topics: expectations on market development, experts' experiences in MENA, the potential for local manufacturing by international industry, and reasonable support mechanisms.

Expectations of CSP market development worldwide and in North Africa

In the short and medium term, the largest markets will be in the United States and Spain. While Asia (China and India) will increase their solar markets significantly in the near future, expectations for the MENA region are limited to a slow growth but could increase later if support mechanisms are installed. One important factor will be the cost disadvantages of CSP compared to fossil fuels in countries where local resources like gas or oil are available (Algeria, Egypt). Morocco is seen as the most important and fast growing CSP market in the region.

Experiences in the region

The CSP regional market is subject to economic, political, and legal factors. Positive and negative experiences strongly influence further business decisions on the part of international companies. Almost all the companies interviewed have conducted business in the region. EPC companies like Acciona, ACS Cobra or Ferrostaal have extended experience working in MENA from previous business activities. For future projects, engineering companies like Fichtner and Flagsol can make use of the experience gained at the ISCCS plants in Morocco and Egypt. The problems associated with doing business in the region are perceived in different ways by different companies working in different regions. Companies with longer experience in MENA describe fewer problems because they have found stable local partners for their activities; local partners and political support are important factors to success in these markets. In terms of regional variation, Egypt is seen as highly attractive due to its technical expertise and qualified work force. Problems of criminality and corruption were raised in interviews about Algeria.

Table 22 Barriers and problems expressed by the CSP industry

Often mentioned problems in countries of North Africa	
Payment of bills	Security concerns
Political risks	Qualification and education of work force
Corruption	Problem of time scheduling

Political risks are critical for international industry. The industry ranks them among the most severe problems in North Africa. Political risks lead to several barriers to productivity: direct investments are limited and very expensive because of countries' high risk ratings, and the full potential for local value generation is not tapped. The CSP market can only reach its potential with a foreseeable market development and lower debt costs. Companies are seeking long-term guaranties and long-term investment in the solar market. One company also recommended the creation of an arbitration court with international standards to secure payments for supplied components and long-term contracts.

Security concerns are important for international firms. Companies often incur extra expenses for on-site security staff, if they send their employees into the countries of North Africa.

Customs duties hinder business activities in the CSP market. For an integrated MENA market, intra-MENA countries' logistics might be a relevant aspect if barriers of international trade come into the focus.

Education and qualifications of the workforce are lower in North Africa, but this is not seen as a primary problem for international companies because training on the job is possible. Wages for local staff are 1/3 to 1/4 lower than in Europe, which helps offset lower education and efficiency. However for expert tasks the international companies still use their regular employees from Europe.

In summary, the interviews indicated a different rating of risk and problems in different countries. Stable frameworks in combination with strong local business partners could facilitate growth. Further regulatory and legal support would help international companies build up local subsidies and joint ventures and consequently new factories and production capabilities.

Potential for local subsidies and local manufacturing by international companies

EPC companies and project developers already active in the region have local offices close to CSP projects and their customers. The companies employ local and international workers for projects. As with conventional power plants, CSP companies expect a large share of project development, management, and engineering will come from international companies with knowledge and experience in these kinds of projects.

Schott Solar sees some critical issues for high technology receiver production in North Africa. Complex and expensive production facilities require a sophisticated technology framework for operation and maintenance. In Spain a local content clause was the main driver to move a factory to Spain. According to Schott Solar local manufacturing of receivers is problematic, but may be feasible in the long-term.

Mirror production requires a large local market to be economically viable. CSP developers explain that the metal support structure could be easily produced in MENA if licenses for the design and assembling are obtained by local companies in the steel transformation industry. Other installation works could also be done locally in the near future.

Table 23 Industry view on potential of local manufacturing

Component	Local manufacturing possible?	Services and power block	Local manufacturing possible?
Mirrors	Yes, large market	Civil works	Yes, up to 100%
Receivers	Yes, long-term	Assembling	Yes, up to 100%
Metal structure	Yes, today	Installation works (solar field)	Partly, up to 80%
Pylons	Yes, today	Power block	No
Trackers	Partly	Grid connection	Yes, up to 100%
Swivel joints	Partly	Project development	Partly, up to 25%
HFT systems	No, except pipes	EPC	Partly, up to 75%
Storage system	Only small share	Financing	Partly

As a whole, the CSP industry reiterates that *"if the local market is large and stable enough, we will produce locally."* As the average factory for mirrors as well as for receivers has an output of 200–400 MW per year this is the absolute minimum market size required to motivate companies to invest in local plants. The industry underlines the importance of a stable and growing market. If the industry is not convinced that a local market will demand a more or less stable amount of components per year, companies will not invest in local factories. Table 24 shows the output of a typical factory for core CSP components and corresponding jobs and factory investment costs.

Table 24 Component specific parameter for typical factories

	Components of the value chain	Annual output of a typical factory (MW/year)	Investment per factory (in Million €)	Jobs per factory (Jobs per year	Specific Jobs (Jobs/MW)
Components	Receiver	200–400 MW	€40	140 Jobs	0.3–0.7
	Mirrors	200–400 MW.	€30	300 Jobs	0.7–1.5
	Steel structure	50–200 MW.	€10	70 Jobs	0.3–0.5
	HTF	Very high	-	-	-

Support actions for a predictable and stable market

In interviews companies were asked which support mechanism would improve the situation of CSP in the MENA region.

Three central answers emerged to this question:

► Long-term security for planning and financing by feed-in tariffs

► Improvement of the legal situation for orders and projects in MENA region

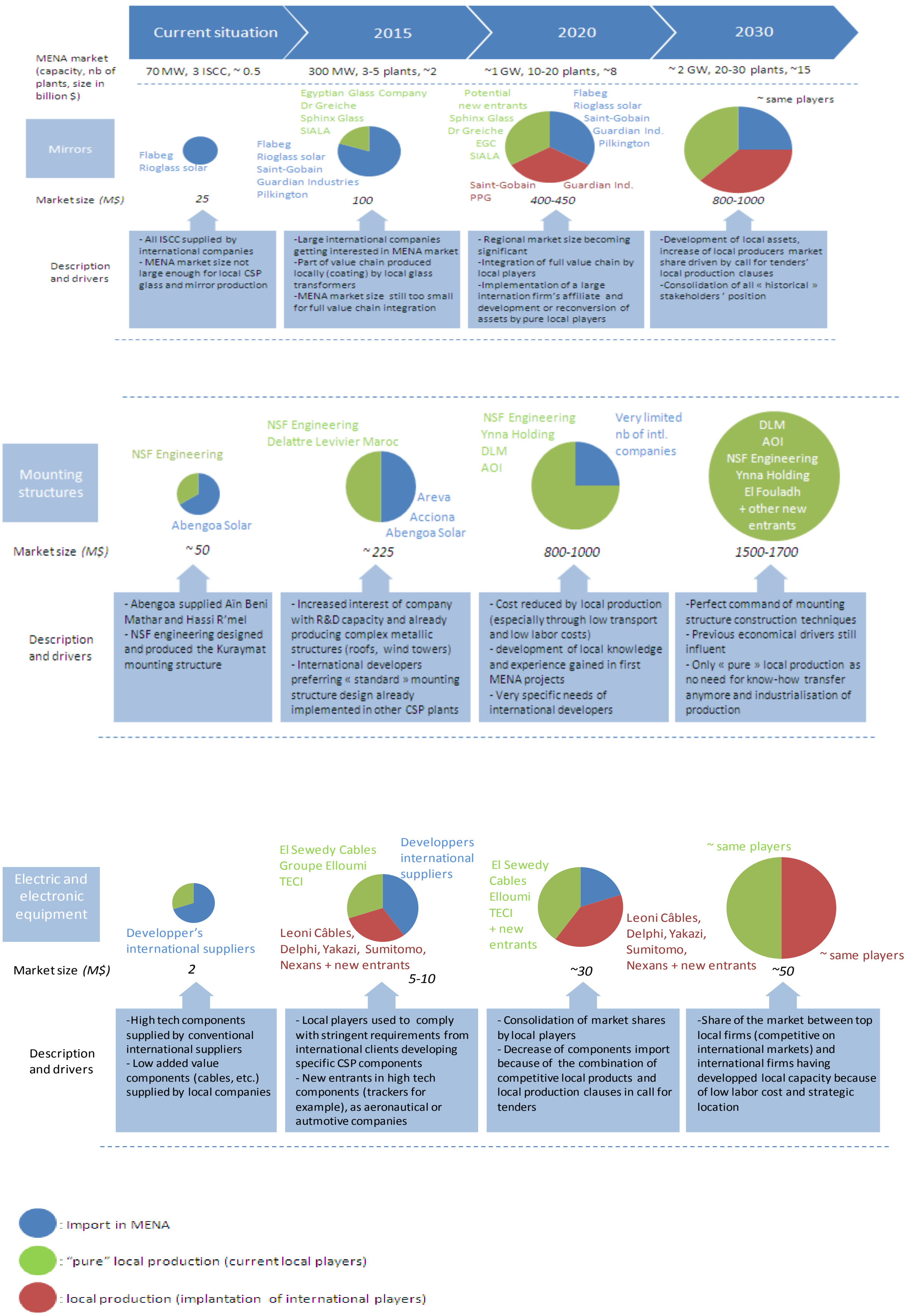
► Guarantees from European countries or international financial organizations to reduce country specific risk and financial costs

A sustainable market is difficult to achieve with grants that are for only a limited number of projects in the region; a feed-in tariff would give the industry a long-term planning scenario. If a long-term perspective is missing, international companies have a limited interest in investing in the region. Some interview partners recommended PPAs with a long-term perspective of tender procedures with a constant annual installation volume over 5 to 10 years. Investment decisions depend more on the existence of a predictable and stable market than on secondary factors like skilled workers or business networks.

2.2.5 Mapping of potential CSP MENA players

This section maps the potential CSP industries in the CTF MENA region in regard to the size of the components market and three terms, 2015, 2020 and 2030.

Figure 44 Mapping of potential CSP industries and their respective markets ()



Source: EY, based on the scenarios presented in section 2.1.2 without exports

The mapping of players for CSP components other than mirrors, mounting structures, and electric/electronic components should be less dynamic. On the one hand, components that are not specific to CSP (cables, balance of plant, etc.) will be supplied by players that are currently active on conventional markets. Market shares should evolve according to traditional market drivers like MENA industries competitiveness, change rate, availability of low cost materials, etc. On the other hand, high tech components that are specific to CSP (HTF, receivers) will continue to be supplied by a very limited number of international companies; the mapping for these components should not change completely.

2.2.6 Illustrative business cases of current or potential CSP MENA players

CSP mirrors

Sphinx Glass

MENA Glass, through its fully-owned subsidiary Sphinx Glass, is a company established by Citadel Capital and a group of leading regional investors to pursue investments in the promising MENA glass industry, with an initial capital of $120 million. Sphinx Glass' greenfield plant is located in Sadat City, 70 km north of Cairo, and has licensed world-class production technologies from PPG Ind. Inc. The new state-of-the-art facility has a production capacity of 600 tons/day and sells to both local and export markets. Two hundred new jobs will be created initially. The construction phase has employed some 2,000 workers.

The new plant is producing high quality clear, colored, and reflective float glass for use in both the automotive and construction industries. Glass sizes vary in thickness between 2-19 mm.

Hisham El-Khazindar, Managing Director and Co-Founder of Citadel Capital, sees strong competitive advantages in Egypt in the global glass industry with a large supply of high-quality raw materials, local availability of natural gas, low labor costs and a geographic location that easily supports exports. The country is perfectly suited to become an important manufacturer and exporter of both float and container glass.

Saint-Gobain

The Saint-Gobain and Şişecam groups have agreed to jointly develop their flat glass (float) activities in Egypt and Russia, by carrying out two projects together. Şişecam will take a minority stake in Saint-Gobain Glass's investment project to build its first float glass production line in Egypt, alongside Saint-Gobain's local partner, MMID.

In addition, a joint venture will be set up between Saint-Gobain and Şişecam for the construction of a float line in Russia, in the Republic of Tatarstan. A feasibility study for this investment was recently announced by Trakya Cam, a company of the Şişecam Group. Output from this plant will be sold in the building and automotive markets.

Guardian industries

Guardian Industries (GI) operates four float glass plants in Egypt, Saudi Arabia, EUA, and Israel. The plants are "high tech and modern". The group has taken over 62 percent of the stakes of the Egyptian Glass Company (EGC), a former state-owned company, from the Egypt Kuwait Holding Co. With the same infrastructure, the company managed to increase the daily output from 400 to 500 tons. Float glass in Egypt is much cheaper than in the US (US: US$350-400/ton, Egypt: US$200/ton). However, GI has expressed concerns in interviews for the poor condition of infrastructure in the country and in the region as a whole.

In the context of CSP, Guardian Industry is producing flat monolithic, bent monolithic, flat laminated and bent laminated mirrors in the United States and in Israel. Laminated mirrors have been developed for higher reflectivity and increased durability. Guardian industry is already experienced in CSP mirror manufacturing with annual production figures of 7.4 million square meters bent, 9.2 million square meters laminated, 20.4 million square meters mirrored

Among other projects, Guardian Industries has already supplied the following solar fields:

- Acciona (Parabolic) La Riska
- Acciona (Parabolic) Palma Del Rio
- Acciona (Parabolic) Majadas
- Novatec Biosol (Flat Linear Fresnel) Puerto Erado 2

GI has altered the bending furnaces used for automotive glass dramatically in order to step into the CSP industry. The conversion took over four years as bending parabolas requires a high degree of accuracy.

GI considers that there are different ways to develop local integration for CSP mirror construction. For example, mirrors that are already bent could be sent to CTF MENA countries. Local industries could then undertake the high added value step of silvering and treating the glass.

Guardian Industries would be ready to manufacture CSP mirrors in CTF MENA countries if the market was there. At the beginning, local MENA companies could take on only some steps of the manufacturing process and then eventually integrate the full CSP mirror value chain. The local production of CSP components could be initiated by the development of JVs with public authorities.

CEVITAL

An industrial glass complex that will be among the largest in the world is being developed by Cevital. Three production lines will be implemented as follows: the first line of 600 tons/day will come into production by the end of 2010, a second line of 700 tons/day and a third line of 900 tons/day will then be added. According to Cevital's chairman, the total cost of the project investment is US$181 million funded by 75 percent equity and 25 percent bank credits. The complex will create over 2,500 direct jobs on the site of Larbaa. The first line will employ 375 staff including 15 expatriates, the 2nd and 3rd lines will add 300 jobs each.

Sand and feldspar necessary for production will be supplied to the site from two large quarries, in Algeria.

According to Cevital's chairman, the plant will be highly competitive on world markets due to low Algerian energy costs.

Cevital has built a partnership with the Chinese company CLFG. CLFG is a major player in the float glass Industry in the world with 10 production centers in China. In this contract, CLFG operates in four areas: engineering, technology (licensed and know how), and assistance in the acquisition of production equipment and production management.

SIALA (Tunisia)

SIALA is producing 6,000 tons/year of mirrors, its activity is limited to glass transformation. SIALA could be interested in CSP mirrors as a way to diversify their industry.

An oven for toughened/tempered glass will be built in the next months. It will produce mirrors of a thickness of 4 millimeters. This is too thick for CSP, but SIALA might reconsider their position and assess the additional cost needed to produce thinner mirrors that would be compliant with CSP specifications.

Dr Greiche Glass

Products of the company are mostly flat glass for buildings, automotive glass, and mirrors. The company has a clear interest in manufacturing mirrors for CSP and is currently involved in providing mirrors for a pilot/demo plant with Cairo University (~60 square meters of slightly bended mirrors). The company is interested in extending its current business into CSP.

The main condition for becoming more heavily involved in CSP technology is growth of the market. Suppliers of glass manufacturing machines are the same for CSP glass as for ordinary glass. The minimum market size to develop a new factory to locally manufacture CSP mirrors in Egypt is one million square meters per year. White glass as the main input material is currently not produced in Egypt. The minimum market size to open a factory for white glass is 20,000 tons/year.

The main barrier for local manufacturing at the moment is that the market does not exist. Dr. Greiche Glass is willing to take some risk, but before making investments in CSP they want to see a clear government policy and projected trajectory on CSP's role in energy production for the country.

Raw material suppliers and mounting structure manufacturers

SONASID

Created by the Moroccan state in 1974 to develop a fully-integrated steel company, in 1996 SONASID introduced 35 percent of its capital in the Casablanca stock exchange. In 1997, the state sold 62 percent of the capital to a consortium of investors and industrials including Arcelor.

SONASID's controls 75 percent share of the Moroccan market. Some subsidiaries are specialized in downstream activities (for example, Longometal Armatures, specialized in the construction and installation of metal armatures). SONASID has been an active founder of the professional association, the ASM (Association des Sidérurgistes Marocains"), and employs 930 persons.

A broad estimate of the need for steel for the Plan Solaire Marocain shows that this demand could easily be satisfied by local steel production:

- With a projected estimate of 10,000 to 15,000 tons of steel for a 50 MW CSP plant, by 2020 the demand could reach 40,000 to 60,000 tons in 10 years.
- The actual long product production capacity in Morocco reaches 2.2 million tons per year.

EzzSteel

After being a leading importer and distributor of steel products from the 1970s to the 1990s, the Ezz family launched its long steel production in 1996. Today, Ezzsteel is the largest independent producer of steel in the MENA region and the market leader in Egypt.

Its four plants (Alexandria, Suez, Sadat City, 10th of Ramadan City) produce long products, principally rebars and wire rods, and also flat products, which consist of hot roll coil, for use in a wide range of applications.

Ezzsteel's total production capacity is 5.8 million tons per year (3.5 MTPY of long products and 2.3 MTPY of flat products). It employs 6,300 workers and the turnover reached $2 billion in 2009 ($288 million of which was export sales).The EU is Ezzsteel's largest export market accounting for 59 percent of total exports. The MENA region countries account for 15 percent.

Today, Ezzsteel exclusively produces reinforcement bars and wire rods. Diversification is not in the agenda, which implies that the region's largest producer would not be directly involved in the CSP value chain.

DLM (Delattre Levivier Maroc)

Delattre Levivier Maroc (DLM), the leading heavy steel construction company, and boiler making and pipe work specialists, has been a presence for 50 years on Morocco's national market and on international markets and has 1,300 employees. Thanks to its long experience, technical expertise, cutting-edge industrial tool, and the expertise of its teams, DLM has won the trust of the largest operators and engineering offices in a wide range of sectors (Mines and Chemicals, Oil and Gas, Infrastructures, Cement and Energy).

DLM is currently concentrating on three new axes of development: export, with increasing presence in Africa and the Middle East; wind power, with construction of a new production line; and offshore oil. DLM has shown ability to adapt to new markets (e.g., wind masts, offshore platforms).

NSF (National Steel Fabrication)

NSF was established in 1995, with a single production facility in Egypt and a total annual production capacity of 36,000 tons. They now own and operate four major facilities in Egypt and Algeria with a total combined production capacity of 120,000 tons annually. NSF's plants cover a total area of 1 million square meters.

NSF is involved in the production of specialist pressure vessels and boilers, as well as steel structure components for projects including bridges and military airports. They were involved in the Kuraymat ISCCS project by supplying and erecting the steel structure (around 3,200 tons of steel). Their scope of work was the following:

- Preparations of shop drawings as per specifications and data sheets
- Supply of carbon steel materials
- Pre-fabrication of steel work at NSF for site assembly
- Hot dipped galvanization for all steel parts
- Supply of Huck bolts
- Erection of steel elements

NSF's production facilities include the latest CNC machines, laser cutting equipment and highly automated robots. In addition, NSF production is executed in line with ASME, AISC, BS, DIN and Euro norm quality certificates.

Electric and electronic components manufacturers

Chakira cables (Elloumi group)

Chakira is one of the main cable manufacturers in Tunisia and in the MENA region. Chakira does not see any issue in supplying CSP plant with cables produced locally.

Chakira is looking forward to diversify its production and is already producing PV cables. The company would be ready to invest for CSP cables as they know that they would get financial and technical support from the Ministry of Industry. Indeed, the Ministry has set up a fund aiming at supporting innovation in Tunisia.

For information, the Elloumi Group entails an entity which is specialized in electric installations. This entity has performed the electric network of the first wind farm in Tunisia. Furthermore a subsidiary of Elloumi group is doing R&D electric vehicles (cables enabling high speed charge of vehicles).

Arab British Dynamics, affiliate of the Arab Organization of Industrialization (AOI)

The Arab British Dynamics is state-owned and was established in 1978 as a joint venture of AOI and British Aerospace for design of defense systems. Since 1998 it is completely owned by the AOI.

Their main products are defense products (wireless communication systems, rocket systems), aircraft harnesses and cables for navigation systems, gas- and oil burners, gas taps, medical equipment (e.g. hospital beds). Production lines are Computer Numerically Controlled (CNC) and are certified ISO standard 9000 & 14001 and awarded by national standard certificates. AOI believes a production of CSP mounting structures is possible but is not yet well informed about it.

AOI might have the capabilities to enter into manufacturing of CSP components but currently the awareness about the technology is low and the focus is on other technologies (mainly PV).

AOI-Electronics Factory

AOI-Electronics Factory is also an affiliate of AOI and produces communication systems (military) and consumer electronics (LCD television screens, speakers, etc.). The company is interested in renewable energies and already did the design of a wind turbine control unit (but manufactured only 2 pieces in total).

El Sewedy Power

El Sewedy's companies are active in a large variety of sectors: cables, electrical products, communications, transformers, meters, steel structures, wind turbines, EPC. El Sewedy is exporting to over 100 countries and operates 30 manufacturing plants in 16 countries. It is the 4th largest cable manufacturer worldwide. El Sewedy Power owns the biggest galvanization factory in the world.

El Sewedy Power holds a 90% share in Spanish wind manufacturer M Torres and manufactures wind turbines and blades. Currently the company negotiates with the government the erection and support of a 300 MW wind park in Egypt. The deal is that El Sewedy Power gets the contract but produces the turbines 100% locally.

2.2.7 Competitive advantages and weaknesses of CSP value chains in MENA

The readiness of economies to adopt new technologies and to implement innovation activities in the future is a crucial factor for sustainable development. To allow for the design of a suitable action plan for the promotion of CSP component manufacturing within the MENA Region it is important to assess the innovative capability and the competitiveness of country economies. A general SWOT analysis of the CSP value chains in the MENA market can help point out the competitive market positioning of company players in the value chain (see Table 26). It is based mainly on the findings from expert interviews during the field study. By analyzing the strengths and weaknesses this assessment focuses on the barriers that must be faced by MENA market players in order to penetrate the CSP value chain, and on first directions for addressing these difficulties. The analysis is supplemented by information on the general conditions of the research system, the technological capability, the conditions for technology diffusion, and the general investment climate in the countries.

Information on aspects of general competitiveness and investment friendliness of 133 countries is aggregated in the Global Competitiveness Report (GCR) by the World Economic Forum (World Competitiveness Report 2009). The Report compiles data on 113 variables and provides a ranking based on the Global Competitiveness Index (GCI). The GCI is split into three categories: basic requirements, efficiency enhancers, and innovation and sophistication factors, which are split into several sub-categories. A selection of data in these sub-categories is used in this report to conduct a cross-country comparison of the CTF countries (Table 25). The CTF MENA countries are related to the remaining MENA countries (non-CTF countries[26]) and a relative comparison to other countries is provided by the international ranking in the GCR. To allow for a simplified overview, an average value for the non-CTF MENA countries is calculated (Table 25, right column).

---

[26] This group consists of ten countries: Bahrain, Israel, Kuwait, Libya, Mauritania, Oman, Qatar, Saudi Arabia, Syria, United Arab. Emirates. Data for Djibouti, Iraq, Iran, Lebanon, Sudan and Yemen is not provided in the GCR.

Table 25 Selection of scores in GCR-sub-categories illustrating the general competitiveness of the 5 MENA countries.

	Algeria		Egypt		Jordan		Morocco		Tunisia		CTF Average	Non-CTF Average
	Eval.	Int. Rank	Eval.	Int. Rank	Eval.	Int. Rank	Eval.	Int. Rank	Eval.	Int. Rank		
Basic Requirements												
Public Institutions	3.12	109	3.98	57	4.94	23	3.85	61	5.02	22	**4.18**	**4.36**
Infrastructure	2.91	99	4.07	55	4.45	42	3.62	70	4.62	37	**3.93**	**4.24**
Macroeconomic Stability	6.39	2	3.46	120	3.97	105	5.24	32	4.77	55	**4.77**	**5.41**
Efficiency Enhancers												
Higher Education and Training	3.30	102	3.62	88	4.45	42	3.40	99	4.70	32	**3.89**	**4.01**
Labor Market Efficiency	3.45	127	3.46	126	3.97	106	3.42	129	4.07	98	**3.67**	**4.36**
Financial Market Sophistication	2.79	132	4.01	84	4.45	52	3.81	96	3.97	87	**3.80**	**4.19**
Technological Readiness	2.56	123	3.35	82	3.75	61	3.41	76	3.82	55	**3.38**	**4.02**
Innovation and Sophistication Factors												
Business Sophistication	3.13	128	3.98	72	4.30	49	3.83	78	4.24	54	**3.90**	**4.16**
Innovation	2.64	114	3.03	74	3.27	59	2.88	96	3.64	38	**3.09**	**3.37**
GCI (total score)	**3.95**	**83**	**4.04**	**70**	**4.30**	**50**	**4.03**	**73**	**4.50**	**40**	**4.16**	**4.39**

Note: Indicators range between 1 (= weak position) and 7 (=strong position). Light red: below CTF country average; light green: above CTF country average; green: above remaining MENA countries average. International rank ranges from 1 to 133 (source: GCR homepage. Column 7 and 8: own calculation).

In average terms, the non-CTF MENA countries show slightly higher scores in all presented sub-categories compared to the CTF countries, but as the MENA economies are heterogeneous in their development and represent a wide range in an international comparison, a more differentiated outline for the remaining MENA countries, regarding single sub-indicators of special interest, is necessary.

The basic requirements for the development of an economy are, efficiently functioning institutions, a well developed and maintained infrastructure, and macroeconomic stability. These characteristics manifest themselves in a precise definition and strong protection of property rights and intellectual property, righteousness and independence of the political and legal system, and the existence of overall corporate ethics. The infrastructure encompasses not only the development and quality of roads, railroads, air- and waterways but also electricity and telephone lines.

Concerning these fundamentals of economic development, the five CTF MENA countries mostly lie in the middle of the scale, indicating that they meet the basic requirements relatively well in most fields. However, some countries, Tunisia and Jordan in particular, have above-average rankings, and Algeria surpasses all examined MENA countries in macroeconomic stability, achieving the second highest ranking worldwide[27]. Nevertheless, the rankings for infrastructure and public institutions in Algeria reflect some deficits in these fields.

27 Due to revenues from oil and gas exports

On a more advanced stage of economical development, the efficiency of economical processes gains importance. At this point, decisive factors for the competitiveness of economies are, for example, the status of higher education (measured by the number of graduates, overall quality of the educational system, availability of specialized research services and extent of staff training in companies), the development and size of goods, labor and financial markets,[28] as well as the ability to access and to adapt to new technological advancements. This can be expressed by the level of availability of modern communication systems (e.g. number of broadband internet & mobile telephone subscribers), the general disposability of latest technologies, or the legislation related to information technologies (e.g. consumer protection, use of digital signatures).

Here the MENA countries again appear mostly in the medium range of the scale as well as in the international ranking with strengths indicated in the fields of higher education (in particular in Jordan and Tunisia) and financial market sophistication (in particular in Jordan and Egypt). Deficits are indicated concerning the development of the technological readiness and the financial markets in Algeria, which might be of particular relevance with regard to financing of CSP projects and potential industrial investments in the area of CSP manufacturing.

Finally, to be internationally competitive, economies must develop a sophisticated, innovation-driven approach which allows for the enlargement of intellectual property rights and the design of their own, unique products. This is expressed, by a large number and a high diversity of local suppliers, well developed industrial clusters and –networks, and the application of precise and efficient production technologies. The innovative capacity is reflected in the quality of research institutions, the extent of collaboration between industry and research facilities, the number of recorded utility patents, and the general availability of scientists and engineers.

On this high level of economic development the CSP MENA countries rank mostly in the lower range of the scale. Nevertheless, Tunisia, Jordan and Egypt achieve above-average scores with regard to business sophistication, indicating significant potential for the development of business in these countries. The innovative potential of MENA countries could be improved through the promotion of research facilities and the development of intellectual property rights.

---

28 Status of financial markets is characterized e.g. by the development of local equity markets, access to loans and venture capital, state of investor protection, soundness of banks and restrictions on capital flows

Table 26 SWOT analysis of local manufacturing of CSP components in MENA region[29]

Strengths	Weaknesses
• Low labor cost (especially for low-skilled workers) • One of the highest solar potentials in the world (desert areas) • Strong GDP growth over the 5 past years in all MENA countries • High growth in the electricity demand will require large investments in new capacities • Strong industrial sector in Egypt • Particular proximity of Spain and Morocco • Existing float glass sector in Algeria • Large export industry in Tunisia and Morocco with long experience with Europe (e.g. automotive industry and aeronautics to a lesser extent) • First CSP/ISCCS plants in three MENA countries constructed by 2010	• Insufficient market size for creation of local manufacturing • Administrational and legal barriers • Lack of financial markets for new financing • Higher wages for international experts/engineers • Higher capital costs • Energy highly subsidized at 75% (although subsidies are decreasing) / Egypt is a net exporter of crude oil and natural gas. • No fiscal, institutional and legislative framework for RE development (laws for renewable energies under development for long periods) • Despite numerous regulations, implementation and enforcement of environmental regulation is often deficient • Need for strong network, business and political connections • Lack of specialized training programs for RE • Partly insufficiently developed infrastructure

Opportunities	Threats
• Further cost reduction of all components • Attractiveness to external investors by large market demand • Solar energy: premises of an Egyptian Solar Plan or Morocco with 2 GW • Wind energy: 400 MW of wind capacity / year until 2020 to be developed by the private sector (bid-procedure) • Political will to develop a local renewable energy technologies industry • Possibility of technology transfer/spillover effects from foreign stakeholders in MENA • Export potential (priority given to export industries by GoE)	• Training of workforce and availability of skilled workers not sufficient • Technical capacities of local engineering firms • Lack of informational awareness of management on opportunities in the CSP sector, etc. • Access to financing for new production capacities, etc. • Presence of public actors in clean-techs value chain (ex.: Arab Organization for Industrialization (AOI) in turbine blades manufacturing) • Competition with foreign stakeholders: e.g. historical presence of German players and strong interest of USA in the Egyptian market • Higher manufacturing costs compared to international players • Higher transport losses/costs due to insufficient infrastructure • Competition with other emerging countries

[29] An analysis of the strengths and weaknesses on a country basis is provided in the annex (cf. page 170 onwards).

2.3 Conclusion of chapter 2

Industry capabilities for CSP components and services

Several industrial sectors that have the potential to integrate the CSP value chain in the MENA region are dynamic and competitive at regional and sometimes international scales. The glass industry, particularly in Egypt and Algeria, has been a regional leader for a long time and continues to increase its production capacity. The cable, electrical and electronic industry can also claim the same position, especially in Tunisia and in Morocco. The success of these industries is facilitated by the development of joint ventures between large international companies and local firms but also by the local implementation of subsidiaries of international players.

Inititally, the development of MENA CTF industries was driven by the low cost for labor and energy (in particular for Algeria and Egypt) and also by the geographic proximity to Europe; a delivery to Europe within 48 to 72 hours is possible. This is a key factor for short production cycles with variable specifications, for example components, cables and wiring for the automotive sector. In order to position themselves on the CSP market, MENA CTF industries face several challenges, mainly adapting their industrial capacity to a higher technology content. The landscape is already changing; the situation of pure subcontracting is now shifting toward more local R&D and the production of high tech components. MENA CTF countries are aiming to be considered as "centers of excellence" instead of low-cost and low-skilled workshops. The shift toward higher technology will require increased international cooperation. For example, Guardian Industries has taken over the Egyptian Glass Company, while a technology transfer agreement has been signed between PPG and Sphinx Glass.

Although cooperation between western countries and CTF MENA is thriving, cooperation between industries in MENA countries is relatively low. Initiatives have been undertaken to develop intra MENA cooperation (for example in the aeronautics industry) but have never been very successful. Shared research and technology development between public bodies (universities, etc.) and corporations could be strongly enhanced, for instance, by developing technology platforms and clusters. Horizontal cooperation could be better utilized to support regional centers of excellence.

Many companies discussed in this study still have a limited understanding of the market potential offered by CSP. Raising the awareness and interest of these potential players will require a clarification of the market for CSP in the MENA region and beyond; the identification of future demand volumes will be critical in the investment decision process. Specifying the market shares achievable for local industries will also be useful for regional corporate strategies. Furthermore, an investigation of the possibilities of flexible production lines might contribute to mitigating the risks related to entry into the CSP market; for example, steel structure manufacturers can adapt their production tools to different products with little effort.

In spite of the obstacles to participation of local MENA industries, expert interviews with MENA companies and with the existing CSP industry revealed potential for the local manufacturing of CSP components. The participation of local firms in the provision of construction and engineering services for new CSP plants in the MENA region were identified as an activity with promising growth in the future.

Key findings of this chapter are:

- Successfully constructed ISCCS projects have increased CSP experience and expertise in MENA (Algeria, Egypt, and Morocco).
- Some components and parts for the collector steel structure have been supplied by the local steel manufacturing industry (Algeria, Egypt, and Morocco).
- Workforce has been trained on the job; engineering capacities have also experienced some progress.
- Specialization in each country would be beneficial, because local demand will probably be relatively low in the short to medium term.
- Several parts of the piping system in the solar field—for the (inter)connection of collectors and power block—can already be produced locally by regional suppliers.
- The development of a CSP mirror industry in MENA is a promising direction for future local involvement. .
- The involvement of international companies will play an important role in the mid-term development of a CSP industry in MENA countries because it will facilitate the creation of local production.
- Minimum factory outputs have to be taken into consideration when local manufacturing of special components is envisaged (parabolic mirrors, receivers, salt, thermal oil).

The main drivers for a development local manufacturing of CSP components in the MENA Region are similar to markets in Spain or the United States and include the following issues:

- attractiveness of local markets
- technology transfer for capacity building

- technological expertise, including precision of processes and lifetime stability
- training and education of workforce, including structure and skills of the workforce
- large financial investments in production capacities
- competitive location factors including attractive costs for local manufacturing, availability of required raw materials, and infrastructure and logistic networks
- improvement of quality standards
- improvement of regulatory framework with financial and legal issues

Depending on the specific component under consideration the importance of each of these conditions may vary (Table 27).

Table 27 Required conditions for enhancing local manufacturing of CSP components

Component	Attractiveness of local markets, local demand	Technological Know-how	Training Education	Financial investment	Competitive location factors	Improvement of quality and assurances standards	Investment regulatory framework
Civil Work					x	x	
Installations			X			x	
EPC Engineers		x	X			x	
Assembling		x				x	
Receiver	x	x	X	x	x	x	x
Mirrors Flat & Parabolic	x	x	X	x	x	x	x
Mounting structure				x	x	x	
HTF	x	x			x		
Connection piping	x	x	X	x	x	x	
Storage system		x	X			x	
Electronic equipment	x	x	X		x	x	

It has to be stressed that the increase in CSP performance with stepped-up MENA investment could also translate into a boost for strong competitors in technology supply, China or India for example, as has occurred with Chinese PV modules or, to a lesser extent, with Turkish Solar Water Heaters. This could then jeopardize the emergence of local CSP related industries in the MENA region.

To face international competition, particularly with China or India, MENA countries would need to strengthen and develop their competitive advantages:

- Rapid delivery and low transport costs, would be strong assets as shipping from India or China would take several days. However, although rapid delivery has been a decisive asset for the MENA automotive industry, it might be less crucial for CSP as logistics are less tight.
- Enhanced R&D would help to improve CSP components, drive their cost down, and increase their quality, compared to the competition.
- MENA industries could tailor their CSP component production to local environmental conditions (desertic conditions) whereas non MENA countries would lack this specialization.

Eventually, the development of local production clauses in CSP call for tenders that are compliant with international free trade agreements would help to limit competition with international low-cost competitors, but this will require careful consideration of possible negative impacts on learning curves due to a lack of competition.

Summary of outlook on local component manufacturing

First step: Construction and Civil works

In the short-term, all construction work at the plant site including basic infrastructure, installation of the solar field, and construction of the power block and storage system could be accomplished by local companies. These activities account for roughly 17 percent of the total CSP investment or approximately US$1 million per MW (cf. Table 8). Large companies from the construction sector play the most important role in this area of basic construction. In Spain and the United States, on-site construction and assembly is contracted by the local construction and infrastructure industry, and basic construction (civil and infrastructure works, plant engineering) is the first step in which local firms are involved in building the plant. Experience from the ongoing CSP projects in Egypt and Morocco support this finding.

Engineering and EPC companies in the CSP industry are limited. In the world market, only a few companies already have the expertise to construct large CSP projects. New firms are now entering this market, but the demand for these services is concentrated in Spain and the United States. In the MENA Region companies in the CSP engineering and project managing sector still need to be established. The Egyptian company Orascom is a good example of a successful venture in this sector; its activities go beyond the provision of labor and it has even become the EPC contractor for a CSP project. Orascom uses a large number of local staff for construction on the plant site. For the initial CSP projects some of the EPC and labor tasks were carried out by external (international) companies and workforce.

The ability of local industry to provide EPC services in MENA varies by country. Egypt now leads in this area, but Egypt required the expertise and management support of an international company to reach this position. In other MENA countries the short-time focus should be set on developing EPC capabilities to reach the same level.

Second step: Mounting structure

The mounting structure can be supplied locally if the local companies can adapt manufacturing processes to produce steel or aluminum components with the required high accuracy. Generally it has been found that companies in MENA are very competitive in the field of steel structures on a global scale. Required quality levels require an adaption of automatic production lines with typical machines and equipment.

Third step: CSP-specific components with higher complexity

In the short to medium term, the local industry is generally capable of adapting production capacities to produce high quality mirrors (glass bending, glass coating and possibly float glass process) to a high technical standard as required for parabolic trough plants. This might require international co-operation for specific manufacturing steps in the short term. Later, local manufacturing of components could include, in addition to high-quality mirrors, receivers, electronic equipment, insulation and skills for project engineering and project management (see assessment of ongoing ISCCS construction).

The success of this process will be dependent on the attraction and integration of international firms. As it might be difficult for local firms to enter the CSP manufacturing market of specific components immediately, it will be economically beneficial for international CSP companies to increase their manufacturing and production capacities in the MENA region to supply new CSP plants with locally produced equipment and components. In that case, international companies invest in the region with a long-term objective and strategy, creating jobs and wealth locally.

Particularly for receiver (absorber) production, the most promising option will be for international companies to move closer to a strongly increasing market. This happened in the Spanish market where international firms (Solel and Schott Solar), which had previously shipped components from plants in Israel and Germany, formed new production capacities in Spain to be closer to the CSP market.

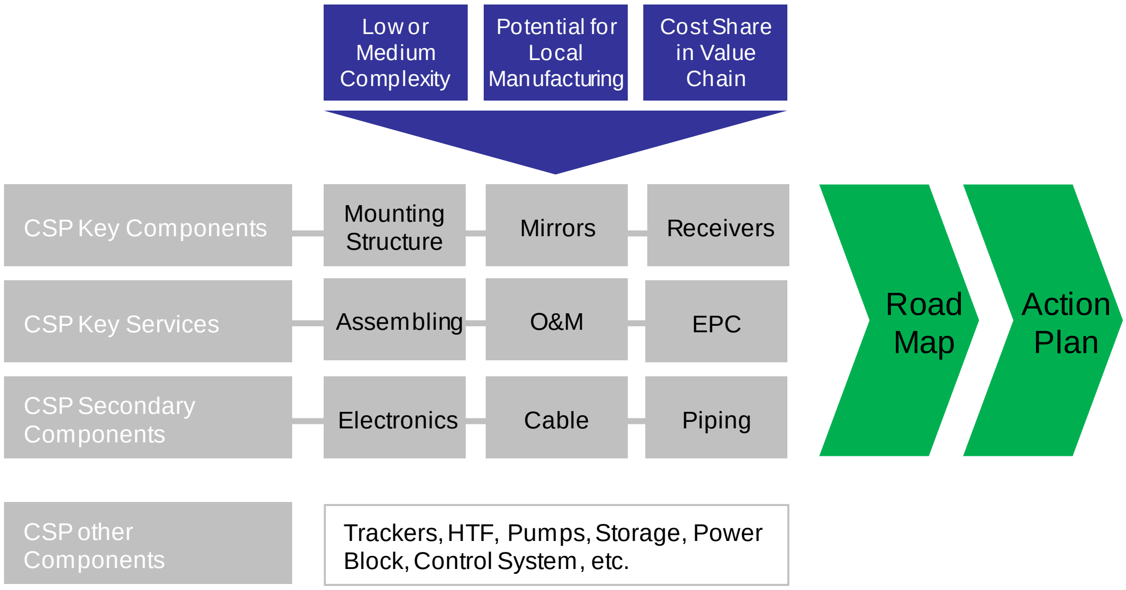
Components with potential in the MENA region

Based on the complexity level and the potential for local manufacturing (cf. section 1.3) as well as the share of added value in the CSP value chain (cf. section 1.2), a number of key components and services can be identified which are most promising to foster for local manufacture in the MENA region (figure 45). Key components are mounting structures, mirrors, and receivers, and key services range from assembling and EPC to O&M.

Secondary components can also be identified, for which some MENA countries have already developed production capabilities and which might thus contribute to an enhanced local supply of future CSP projects, although their share in the overall value chain might be of minor importance (see **Error! Reference source not found.**). Electronics, cables and piping belong to this group.

For these key components and services in the CSP value chain, roadmaps and an action plan are developed in the next chapter.

Figure 45 Key components and services for CSP



Part II: Action plan and economic benefits

3 Outline of an action plan to develop the region's potential in CSP component manufacturing

3.1 Potential roadmaps for the development of local manufacturing of CSP components in the MENA region

Introduction

Based on the assessment and identification of existing and potential domestic and foreign players (manufacturing companies, financial investors, etc.) carried out in the previous steps, this section will focus on the potential routes to develop local manufacturing capabilities. The aim of the roadmaps is to show, based on the current situation, possible technological and entrepreneurial developments in the regional manufacturing of each component in the short, medium and long term and to name overall, long-term objectives in these fields. The underlying essential preconditions for all components include a reliable CSP market growth and a stable political framework.

Detailed roadmaps are developed for **key components** and **key services** which have the potentially highest share in the CSP value chain (as identified in section 0 of this report, cf. **Error! Reference source not found.**). The highest value added for the region can be expected from these components.

Furthermore, other components will be taken into account for which the countries have already developed competitive advantages, e.g. production of electric cables in Tunisia or Egypt. These **secondary components** may not have a major share of the value added, but can still contribute significantly in absolute terms also due to possible exports.

The roadmaps are separated into technological developments (e.g. changes in production lines, production skills and production capacities), business developments (in terms of cooperation agreements, R&D activities and other entrepreneurial decisions) and the underlying market and policy development, all of which make up the basis for industrial development. For each of these levels, the most important milestones and critical steps are presented and interrelations between the different levels are indicated (dotted arrows). The related measures needed to overcome critical steps and reach the milestones are subsequently discussed in the action plan (cf. section 3.3).

The timeframe of the roadmaps covers possible short-term developments which could be realized within the next 2-5 years, mid-term developments in 6-10 years and long-term developments which might be realizable after 2020.

However, especially the long-term targets are strongly dependent on the development of the CSP market as described in the different scenarios presented in section 3.2. Some technological milestones might only be reached assuming a strong growth of the CSP market.

Roadmap for the production of CSP mirrors in the MENA region

Figure 46 presents potential development paths for producing CSP mirrors in the MENA region. The basic conditions are promising, because the glass industry is already present in this region and raw materials are easily available (cf. section 2.2). A key condition for the production of mirrors for CSP technologies, however, is the availability of production lines for high quality white glass. There are no such production lines at present in MENA countries. Short-term actions on company level could be either the creation of such production lines by international players, or the formation of joint ventures between local players and international companies for such a purpose. The economic viability of creating a white glass production line will strongly depend on the market demand for such glass in MENA countries. As a second step, new production lines for linear or bent mirrors need to be established. Again, this could be accomplished through joint ventures with international companies experienced in mirror production for CSP plants (for companies see section 1.2) or by setting up new mirror production lines of MENA companies (for companies see section 2.1.1) possibly accompanied by acquiring licenses for this technology. From a MENA country's perspective, a joint venture is more favorable than direct investments of international companies since this is usually linked with a more intensive know-how transfer, which may lead to a more independent evolvement of the industry. Depending how the CSP market develops in MENA and globally, this would also facilitate the establishment of independent CSP mirror companies in the MENA region in the medium and long term.

From a technology viewpoint, the first step for existing glass companies in the MENA region which are interested in adapting production to produce glass for CSP applications is to develop new, or enhance their present, capacities of float glass production in the short-term to be able to supply glass for CSP plants. At the moment, float glass production lines exist only in Algeria and Egypt and the major share of the regional demand for conventional glass is covered by imports. In addition, most of the float glass plants today produce green glass, which is not suited for solar applications (cf. sections 1.3.2 and 1.3.3). Consequently, in order to achieve the standards needed for high quality white glass, it is necessary to adapt the glass production lines. A substantial amount of capital is needed for both measures since production lines are highly automated and the processes are very energy-intensive (cf. section 1.3.3). Here, the different countries should coordinate and exploit locational advantages. Glass plants for CSP applications could, for example, be set up in countries already operating conventional plants which only need to adapt production lines (Algeria and Egypt), or in those countries where energy prices are particularly low (e.g. Algeria), so that production might be more profitable than elsewhere. Plants in those countries could then supply the whole region. Independent of this, the mirror fabrication (coating- and, if necessary, bending process) could be done in countries which are already experienced and specialized in mirror production (e.g. Egypt, cf. Figure 81) and thus have the basic know-how and a skilled workforce at their disposal.

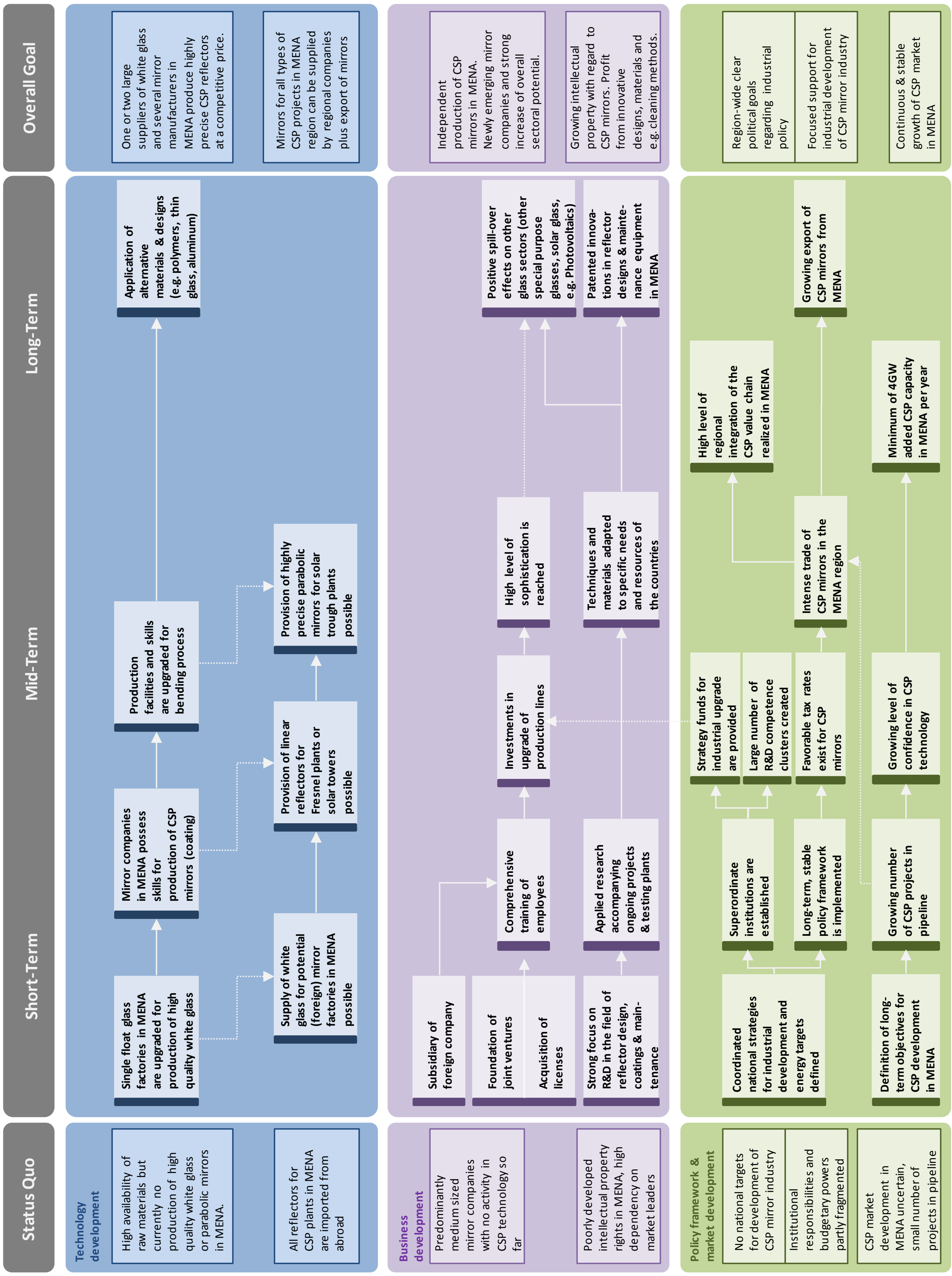
Based on these measures, further steps can be taken in the mid-term towards producing flat and parabolic mirrors for CSP plants. Flat mirrors for Linear Fresnel and Solar Tower power plants are easier to produce because they do not require a bending process. This energy-intensive and sophisticated step is only necessary for the curved mirrors of parabolic trough plants and the degree of precision here has a decisive influence on the later effectiveness of the whole plant. Upgrading conventional mirror production lines to produce such precisely bent CSP mirrors requires a considerable amount of capital. It should therefore be considered that the decision about which mirrors should be produced in the MENA region depends on which technology has the main proportion of CSP plants in this region. The ISCC plants that are currently under construction all apply the parabolic trough technology, which has proven its reliability in the Mojave Desert in California for more than 25 years. But other plants in the pipeline in this region (e.g. JOAN1 in Jordan with a capacity of 100 MW) also rely on the younger Linear Fresnel technology.

Besides the necessary capital to set up highly automated plants for the coating- and bending processes, a comprehensive transfer of know-how is necessary. Particularly the bending of CSP mirrors with the necessary precision and scale is currently handled by only a few companies. Knowledge transfer can be achieved, for example, by acquiring licenses for CSP mirror production within the framework of a joint venture. Experienced companies can also contribute their experience in the adaptation of CSP mirrors to the special environmental conditions in coastal regions, where the mix of salt spray and sand dust in the air complicates mirror cleaning and reduces the effectiveness of the CSP plants. R&D efforts in this sector might be undertaken in cooperation with international companies and research institutions but might also be realized independently by the MENA countries themselves. In Egypt at the Cairo University, Faculty of Engineering, for example, first research activities have started to improve and adapt different CSP components to local conditions. In this context also a pilot plant is planned to conduct further experiments. Also single companies took first steps towards developing the know-how for the production of CSP mirrors by themselves, for example Dr. Greiche glass in Egypt.

Assuming a very favorable market development and the strong promotion of applied research in the field of CSP in the MENA region, it is thus conceivable that this region could develop its own technology for products specifically tailored to the conditions here. Also future technical advances, such as reflectors made of alternative materials like polymers or aluminum as well as front-surface or thin glass mirrors could possibly be developed further and customized to the needs of the MENA countries in the long term. However, these are currently research topics in countries with experienced research institutes and CSP industries like Spain, the United States or Germany.

To sum up, if CSP plants are constructed in the MENA region in the not too distant future, there is a good potential that mirrors can be sourced from domestic companies if the above mentioned financial and knowledge barriers can be overcome. Assuming a growing level of regional integration and a reduction of trade barriers within the MENA region, also substantial economic benefits can be expected from an export of CSP mirrors.

Figure 46 Potential roadmap for the production of CSP-mirrors in the MENA region.



Roadmap for the production of CSP mounting structures in the MENA region

Similar to mirror production, the manufacturing of complete CSP mounting structures or parts of them also has good potential in the MENA countries due to their overall low energy and labor costs. Also current steel production in CTF MENA countries is far above the volume needed to develop CSP plants. Figure 47 displays a potential roadmap for the production of CSP mounting structures in the MENA region. Since local companies have already delivered mounting structures for the ISCC plants in Egypt (and to a lesser extent in Morocco), a local provision of complete mounting structures for future CSP projects should be possible, even in the short-term perspective. The highest steel production capacities are currently located in Algeria, Egypt and Morocco. The latter have increased their capacities in the last year or plan to increase steel production in the next year, so that the amount of raw material should not be a bottleneck (cf. section 2.1.3 for production capacities). However, it should be mentioned that, overall, most MENA countries are still net importers of steel and that domestic steel faces competition with steel from other countries, e.g. Spain and Turkey. Moreover, experiences at the ISCC plant in Beni Mathar also revealed quality issues with the steel structures sourced from MENA.

Moreover, another crucial requirement for CSP mounting structures is the high precision of metal transformation and the assembly of the individual parts to warrant a safe and precise anchorage of the reflectors. This involves not only an experienced and well trained workforce, but also technological know-how in terms of cutting, coating and assembling metallic materials.

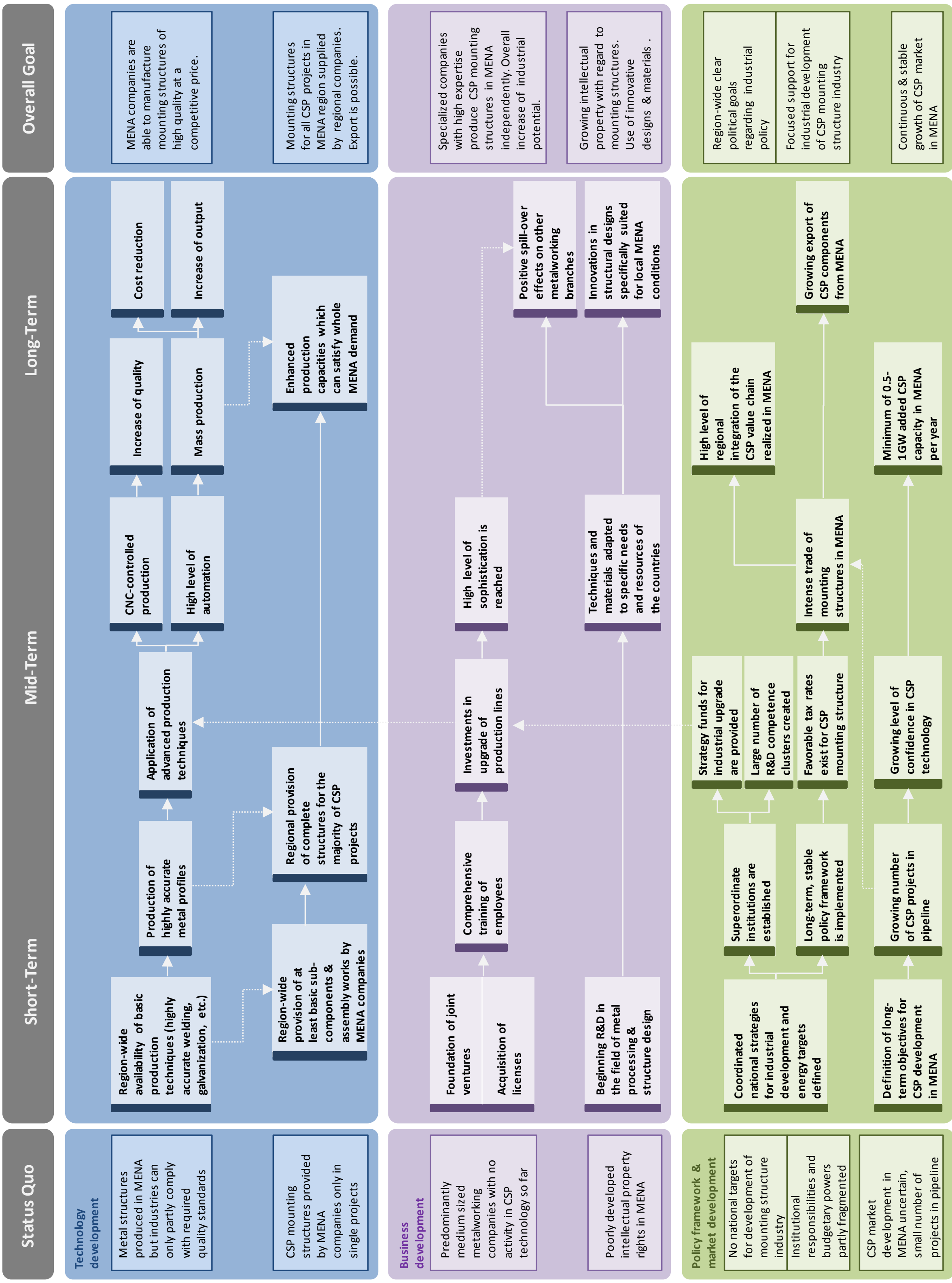
Therefore, in the short-term, joint ventures or other forms of collaboration with experienced companies might be useful to overcome this hurdle. To achieve the required precision and quality standards in production, production know-how must be acquired. Staff have to be trained, e.g. in highly accurate welding skills to assemble the structures. Furthermore, there are different types of collectors (cf. section 1.1.3) each with specific processes in metal transformation, welding and assembly. Also, galvanization is indispensible to protect the structures against humidity from wet cooling, nightly condensation and/or high air salinity in coastal areas. However, both welding and galvanization are well established processes and potential quality issues should be manageable.

If there is an extension of installed CSP capacity in the MENA region, it should be possible in the short term for MENA companies to provide and assemble the complete mounting structure. Depending on the CSP market development and the available investment volumes, there are different routes the production of mounting structures could take. Labor-intensive, non-automated production might make sense because of the advantage of region-wide low labor costs and this would have extensive employment co-benefits. However, comprehensive training is still necessary to meet the required quality standards, obtain greater experience and achieve a higher output. Under the conditions of strong market growth, larger investment volumes might be available to deploy laser-cutting and other innovative manufacturing technologies as well as a higher level of automation in production. This could lead to a further increase in quality and substantial cost reductions. For example, installing machines for the automated stamping of parts for trough structures is one way to significantly reduce the production costs. A further step in the mid-term, especially for the welding process, could be the introduction of CNC-controlled machines which involves construction lines similar to, e.g. those used in the automotive industry.

Assuming an extensive expansion of CSP capacity in the MENA region and a strong promotion of regional R&D activities in this field, the countries could, in the long term, also develop their own mounting structures with technical advancements and the use of alternative materials specifically adapted to the respective conditions and available resources. Larger troughs and alternative materials like aluminum are examples for R&D projects in experienced CSP countries that could also be pursued in MENA which might lead to specialized techniques and a higher level of intellectual property rights in MENA. Regional R&D efforts might be either taken in co-operation with international players, e.g. with an initial procurement of production licenses, or the necessary know-how might be developed independently from the start. Some large companies in the MENA region apparently already possess the innovative potential and the necessary practice to successfully develop such new business areas by themselves (e.g. Orascom, El Sewedy, Al Babtain, TECI and others).

In conclusion, depending on market development and the support for CSP in the MENA region, the MENA countries have different options for CSP mounting structures which involve different requirements with regard to effort and capital intensity. Overall, there is a realistic potential to provide and assemble complete mounting structures in the short- and medium-term. Exporting mounting structures from MENA might even be realizable if the relevant production quantities are achieved.

Figure 47 Potential roadmap for the production of CSP-mounting structures in the MENA region



Roadmap for the production of CSP receiver tubes in the MENA region

Based on the analyses in the preceding chapters, providing the receivers (absorber tubes) for solar trough technology in the MENA region is theoretically feasible, but development possibilities are limited. This is due to the highly sophisticated production processes involved (cf. section 1.1.3) and the fact that the market is currently dominated by only two large companies, namely Schott and Siemens (cf. section 1.2.2). None of the MENA countries holds intellectual property rights in this field or has experience in producing this component. Consequently, the possible developments shown in the roadmap in Figure 48 are limited.

In the short- or medium-term, the only realistic option to establish manufacturing capabilities in MENA is if the two current major suppliers, Schott and Siemens, were to set up subsidiaries in the region.

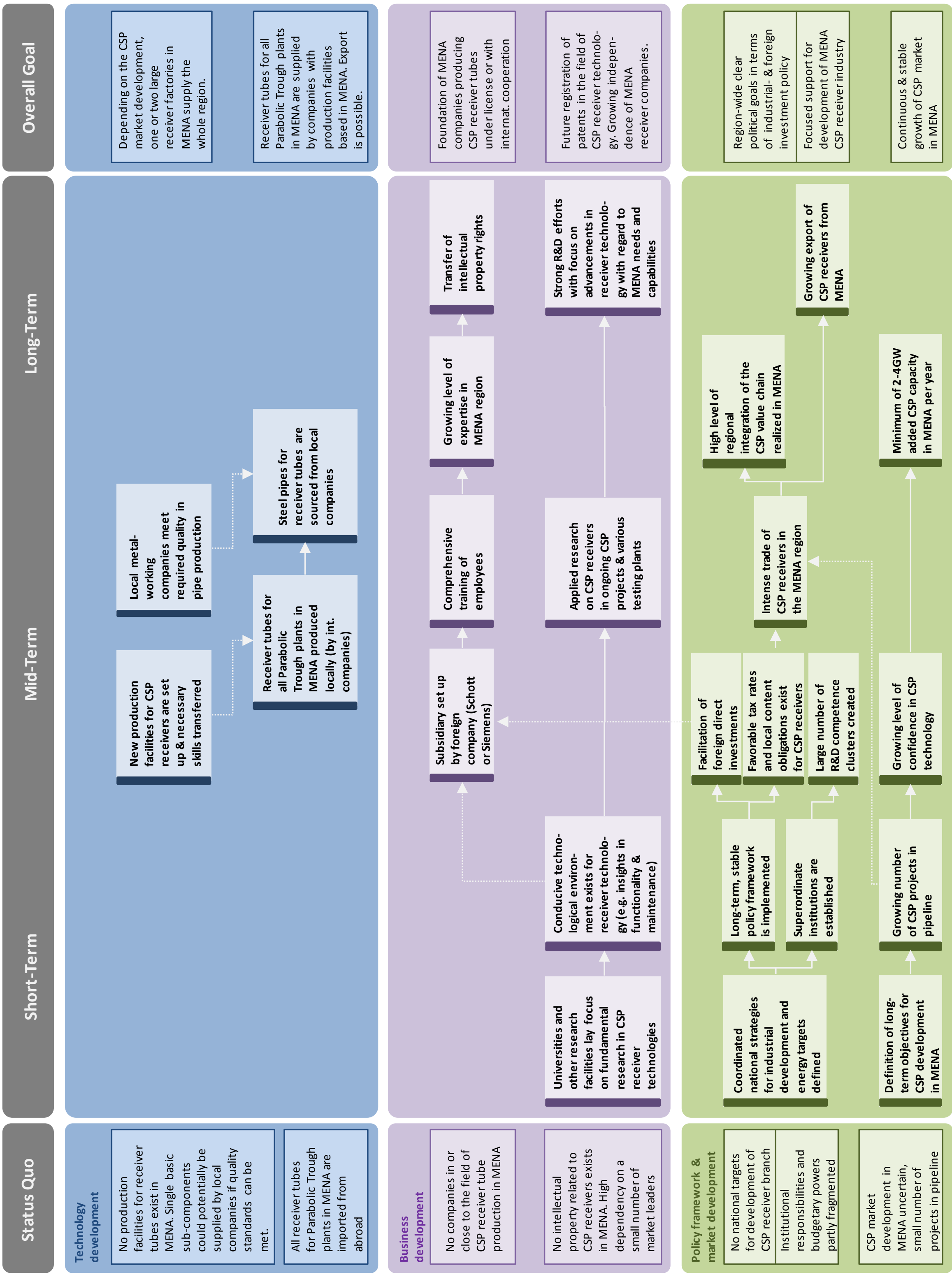
Experiences with other markets in Spain and the USA show that such production facilities only develop if there is significant growth of the respective local CSP market and a strong government focus on enhancing local content in CSP projects. Otherwise it is more profitable for suppliers to produce the receivers in their home countries (Germany for Schott, Israel for Siemens).

In the mid-term, some sub-components, like the steel pipes of the receivers, could be supplied and assembled locally, but it is questionable whether local suppliers would be able to deal with the quality issues without prior knowledge transfer from the existing market leaders. It is considered unlikely that receiver manufacturers will develop independently in the MENA region or that this region will produce its own receiver design due to the lack of experience and intellectual property in this highly advanced field.

A strong focus on early R&D activities related to receiver technologies is therefore necessary to pave the way to future development of intellectual property in this field. Research activities in this field will require strong co-operation with international companies and experienced research facilities, at least in the initial phases of the development. Initially, the according research facilities, e.g. in universities and technology clusters, must be created and a basic understanding of the technology must be developed in the region.

This fundamental research would also help to create a favorable environment for foreign subsidiaries, since a basic understanding of the technology in the recipient country facilitates production, e.g. through a better availability of maintenance personnel and engineers.

Figure 48 Potential roadmap for the production of CSP receiver tubes in the MENA region



Roadmaps for the production of secondary components for CSP in the MENA region

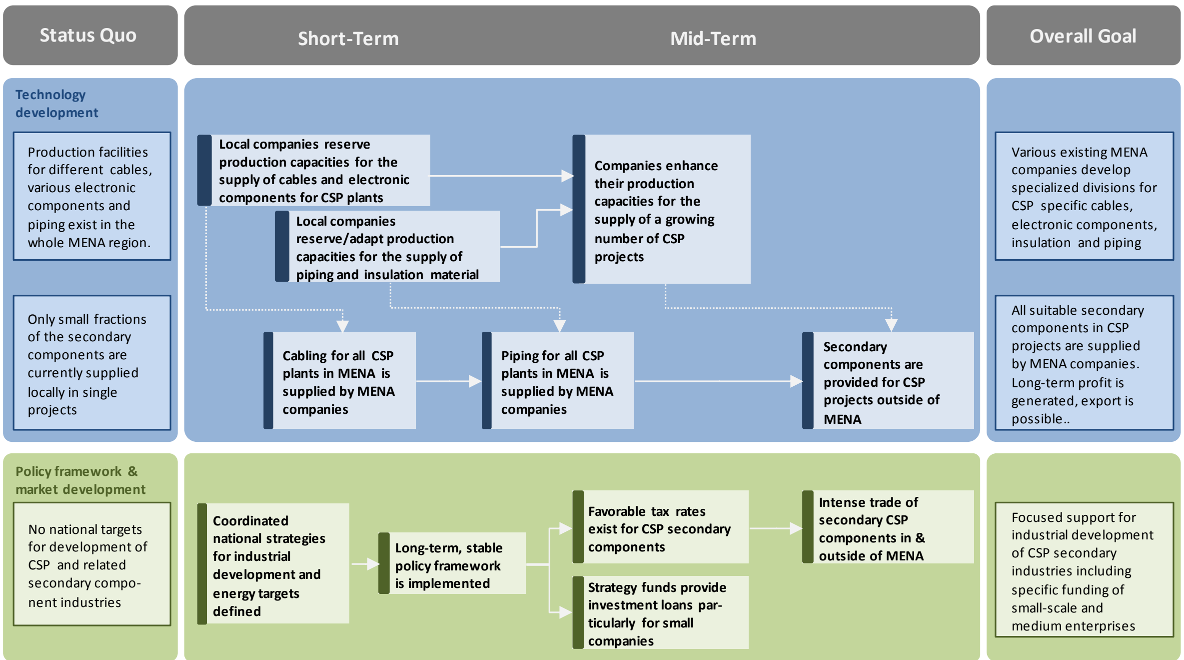
As identified in section 2.2 there are some minor components of CSP plants which might easily be supplied by local MENA companies because the countries have already developed production facilities and technological know-how in the respective fields. Two examples of such secondary components are electric cables and metal pipes which are already partly being supplied to ongoing projects in the MENA region.

The fact that there are no big technology steps expected in these "secondary industries" is reflected in the reduced roadmap. It can be presumed that only smaller adjustments to production lines and technical skills are necessary to supply CSP components, although production upgrades might be necessary to supply larger volumes if the market grew strongly or for export.

Chakira cable from Tunisia, to name one example, is already producing cables for PV-plants and sees no problem in providing them for CSP plants as well (cf. 2.1.2). The cable industry in MENA is fragmented with no multinational player, which means that MENA companies have the potential to become a supplier for CSP plants in their respective country. However, there is no real cost advantage for the companies due to the lower labor and energy costs because the raw material costs constitute the main cost fraction of cables so they will face competition from other international players. However, after successfully providing cables for plants in their home countries, MENA-based cable companies could become competitors on the international market in the short and medium term and could use CSP as a first step for exports.

The provision of piping could develop in a similar way, albeit with a time lag due to the higher complexity of the piping and the insulation material. Hurdles to overcome from a technical point of view are the high precision and special heat resistance required for the steel-pipes. In addition, capital-intensive production lines have to be built. At the moment, the connection piping in ongoing CSP projects is supplied by big multinational companies (cf. section 1.2.2). The piping itself consists of a steel tube, a surrounding insulation and sheets that protect the insulation. First plants in MENA countries could be supplied by specialized steel and insulation manufacturers and after that exporting to other countries is also possible in the mid-term.

Figure 49 Potential roadmap for the provision of secondary components (piping & cables) for CSP plants in the MENA region



Roadmap for EPC and services in CSP projects in the MENA region

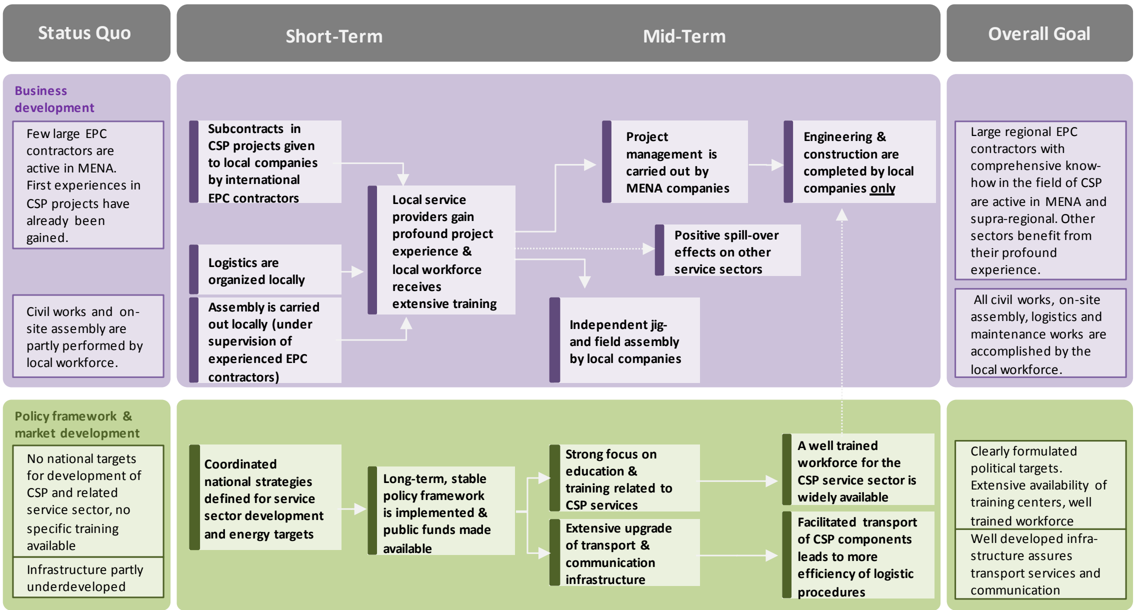
The services associated with the construction of CSP plants also represent an important factor for local value creation. In the following, a roadmap is described for the field of EPC (Figure 50). Currently, several companies in the MENA region are gaining first experiences with

CSP projects as subcontractors or receiving substantial support from international companies experienced in CSP. For example, in Kuraymat, the EPC contractor for the solar field, Orascom, has been strongly supported by Fichtner Solar and Flagsol concerning the conceptual design, engineering and technical advice on assembling the solar part of the ISCC plant (cf. section 2.2.6)

With training and qualification, jig and field assembly could be done independently by local companies in the mid-term. Logistics are also already organized locally or could be in the short term in each country.

With the further expansion of CSP plants in MENA and as more experience is gained, service subcontracts could also be offered by local companies. In the mid-term, the whole project management at construction sites could be done by MENA companies with general contracting by locals as a further step. This could lead, along with a further expansion of CSP capacities, to engineering and construction being managed by MENA companies only. In the case of strong market growth, large regional EPC contractors would have the opportunity to gather comprehensive CSP know-how and could manage a growing number of CSP projects in MENA or even act as bidders for projects outside MENA.

Figure 50 Potential roadmap for EPC and services in CSP-projects in the MENA region



3.2 Definition of scenarios

The action plan, with a time horizon until 2020, is developed based on three scenarios (see Figure 51). It is assumed that the volume of the installed CSP capacity within the MENA region (home market volume) is a main precondition for local manufacturing to take place. This assumption is based on experiences made in the wind turbine industry (Lund 2008) (Lewis & Wiser 2007). The home market volume and the potential amount of export (external market volume) are regarded as indicators to develop an optimal support scheme. **However, it is not subject of this study under which circumstances the market volume of the four assumed scenarios is reached (e.g. by energy policy measures like feed-in tariffs) and it is assumed that the home market is free of any fragmentation like adverse trade regulations within the MENA countries.** We will nevertheless briefly motivate the scenario development in this section by looking at similar developments in the markets for wind and solar PV.

The scenarios chosen here represent critical levels of market development for local manufacturing. Concerning the market volume, it is assumed that the newly installed CSP capacity in the CTF MENA countries is distributed equally over the years and that the market will continue to grow after 2020. The market volume is described for the five countries investigated in detail in this study. **For the MENA region has a whole it can be assumed that the market volume could be doubled as compared to the figures provided in the scenarios.**

The three scenarios proposed are the following:

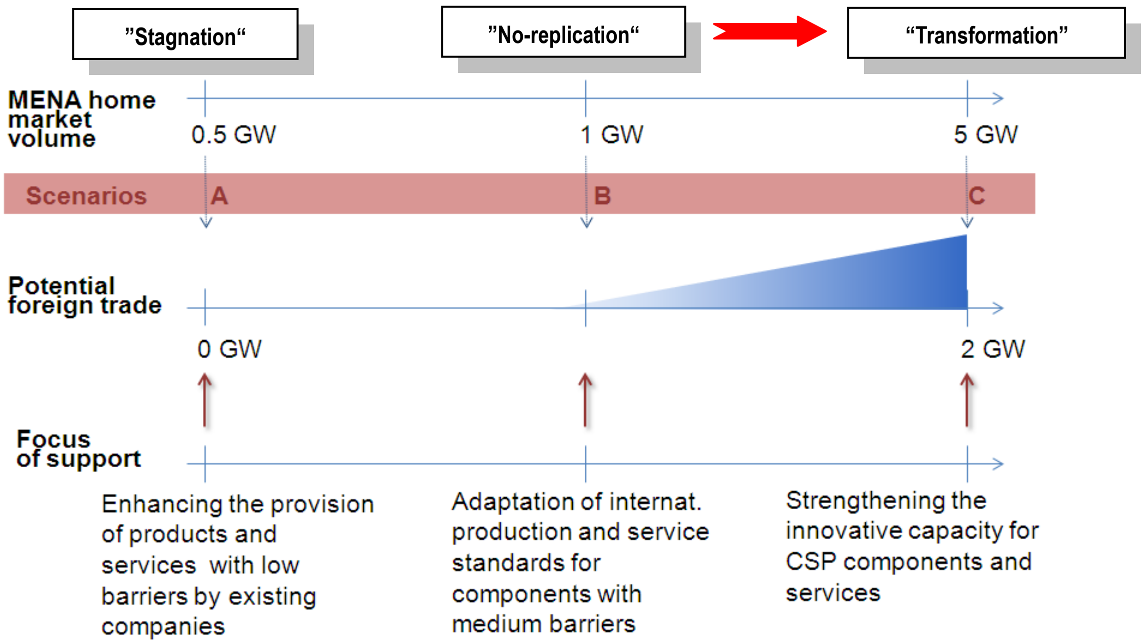
Scenario A – "Stagnation": The home market volume of the five countries amounts to 0.5 GW: Strong obstacles to local manufacturing of CSP components remain on the country markets. Therefore, most components, particularly those whose production requires high investment costs, remain imported from other more advanced markets. In this case, support should focus on enhancing the manufacturing of low-tech products and basic services for which the market barriers are relatively small. This scenario implies an incomplete realisation of the CSP scale-up initiative.

Scenario B – "No-replication": The home market volume of the five countries amounts to 1 GW in 2020 based on the target of the MENA CSP IP. As a result of the success of the CTF's CSP scale-up initiative and national initiatives, the market offers opportunities for the development of local manufacturing of CSP components and provision of CSP services. This scenario aims at an adaptation of international production standards and -techniques in existing industries and leads to a region-wide supply of suitable CSP components produced locally in the MENA region. The base level of 1 GW, which would mainly be determined by the CTF alone, does not include any additional CSP development triggered beyond the initiative in a narrow sense. This base level constitutes therefore the foundation on which more comprehensive policies can spur a larger CSP development in the region. The CSP scale-up initiative is intended to spur as much additional policy development as possible to cover the space towards scenario C. So it is by no means a reference development but represents the minimum development if only the CSP scale-up initiative alone would deliver. This is indicated by the red arrow in Figure 51 between scenario B and C.

Scenario C – "Transformation": The home market volume of the five countries amounts to 5 GW and the export of components reaches a volume corresponding to 2 GW installed CSP capacity: National CSP promotion plans have been developed quickly, international initiatives are strongly represented and / or private investors are notably active in the region. Policy actions should support innovations and the development of intellectual property rights in the field of CSP components. A strong export orientation should be motivated to take advantage of the proximity to other emerging markets. The "Transformation" scenario may materialise under very favourable conditions only and a more realistic level of installed power may be found somewhere between the "No-replication" scenario and the "Transformation" scenario. It was, however, the purpose here, to span up a range rather than to come up with a precise view on how many GW out of the 5+2 GW underlying the "Transformation" scenario will be realised by 2020.

Figure 51 depicts the assumed interrelations between the home market size, the possible export volume and the consequential focus of support for local industries which stands in the centre of this analysis.

Figure 51 Assumed interrelations between MENA home market size, possible export volume and consequential focus of support for local industries (source: own design).



The basic underlying assumption is that local industries, as long as they are able to provide CSP components, should be given priority in support over the attraction of international players. The focus of support in the three scenarios is based on the one hand on the extent of barriers for the existing local industries to participate in the promotion of CSP components and -services and, on the other hand, on the expected total market volume which determines the size of the expected long-term profits.

Table 28 motivates the CSP market size chosen here for the five MENA countries by comparing the average annual growth rates of the cumulatively installed CSP capacities in the three scenarios with the rates for wind energy, solar PV and the expected annual average growth of the world-wide installed CSP plants.

Scenario A represents an annual growth of 24 % between 2010 and 2020, while scenario B reaches 32 % and scenario C 61 % annual growth. Historically, for wind energy one observes levels in a similar range in terms of total installed capacity. Countries with initial booming markets and/or strong policies reach levels exceeding 60 % annual growth while countries facing more barriers and a less favourable policy environment may on average achieve 20-30 % annual growth. Mature markets, such as Germany, Spain and Denmark after 2000 achieve less important growth rates. Egypt and Morocco have achieved 29-36 % in the period 2003-2009. It is not excluded that a country can exceed the level of 60 % in a particularly booming period as illustrated with the example of Turkey for wind energy with a growth rate exceeding 150 % between 2005 and 2009. However, this may also be the sign of an overheated growth. This example shows, however, that a development beyond the scenario C is possible in the countries considered but requires well coordnated policies at different levels. In particular, it has to be assured that the R&D system as well as the education system can deliver with a sufficient large number of well-trained üersons

Looking at the PV development confirms further the choice of the growth rates. Germany which has a very strong policy for PV reaches levels of 60 % annual growth, while the US and Japan with less powerful policies are in the range 20-30 %.

The world-wide cumulative CSP installations have grown in the period 2007 to mid 2010 by around 40 % annually while the expected growth for the period 2007 to 2015 would be close to 60 % if all the plants described in section 1.1.4 will come on-line.

Table 28 Average annual growth in cumulative installed capacities for wind energy, PV and CSP

Wind Power	1991/2000	2000/2009	Exact period
Germany	56%	17%	
Spain	90%	27%	
Denmark	22%	4%	
USA	-	63%	2003/2009
China	-	60%	
India	-	28%	
Brazil	-	66%	2003/2009
Egypt	-	36%	2003/2009
Morocco	-	29%	2003/2009
Turkey	-	155%	2005/2009
Solar PV	**2000/1991**	**2009/2000**	
Germany	57%	64%	
USA		28%	
Japan		18%	2004/2009
CSP			
World		41%	2007/mid-2010
World		59%	2007/2015
Scenario A		24%	2010/2020
Scenario B		32%	2010/2020
Scenario C		61%	2010/2020

Source: Fraunhofer ISI based on various sources

The second motivation for the three scenarios chosen is provided by taking an optimistic view of CSP developement as given by the Greenpeace (2009) scenarios (Table 29) as well as a more pessimistic view provided by Emerging Energy Research (2010) (

Figure 52).

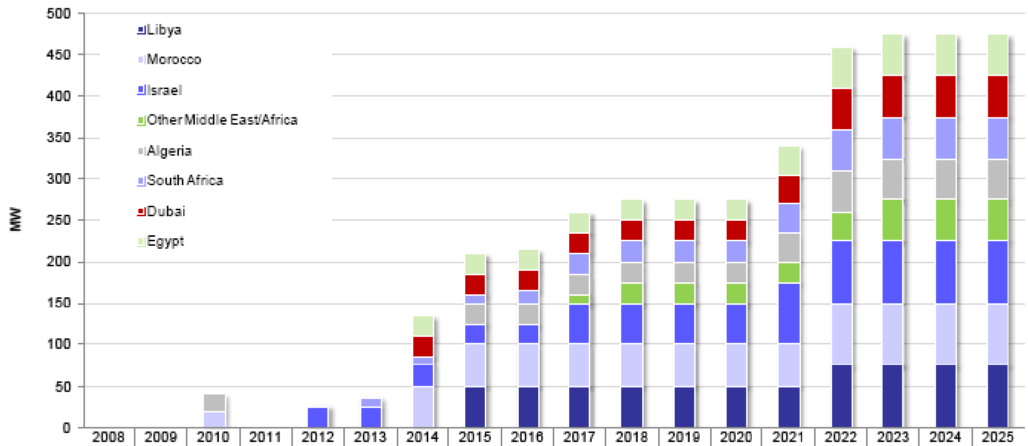
Table 29 Outlook for cumulative installed capacity of CSP per region in 2020

	EUROPE (EU 27)	TRANSITION ECONOMIES	NORTH AMERICA	LATIN AMERICA	DEVEL ASIA	INDIA	CHINA	MIDDLE EAST	AFRICA	OECD PACIFIC
Advanced										
2020 (MW)	11,290	474	29,598	2,298	2,441	3,179	8,650	15,949	4,764	9,000
Moderate										
2020 (MW)	6,883	328	25,530	2,198	2,575	2,760	8,334	9,094	3,968	2,848
Reference										
2020 (MW)	3,065	100	1,724	121	0	30	30	612	1,113	475

Source: Greenpeace (2009)

The figures from Greenpeace suggest that in the Middle East + Africa region (which also includes South Africa) in the advanced scenario around 20.7 GW are possible. This scenario could imply for the five countries considered here a figure of roughly 10 GW in 2020. This is somewhat higher than the 5+2 GW "Transformation" scenario, however indicates that this scenario presents a reasonable scope for what coherent and ambitious policies could reach. In particular, the Greenpeace "advanced" scenario implies more than 7200 MW in 2015 which could be hard to reach given the time scales to set up plants which are typically 3-4 years at present. Therefore scenario C can be considered a cautiously optimistic scenario. The base case projections from Emerging Energy Research (2010) are much more cautious with around 1600 MW for the group of countries considered, comparable to the Greenpeace reference case.

Figure 52 Middle East /Africa CSP additions 2008-2025 (base case)



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Egypt							25	25	25	25	25	25	25	35	50	50	50	50
Dubai							25	25	25	25	25	25	25	35	50	50	50	50
South Africa						10	10	10	15	25	25	25	25	35	50	50	50	50
Algeria			20					25	25	25	25	25	25	35	50	50	50	50
Other Middle East/Africa										10	25	25	25	25	35	50	50	50
Israel					25	25	25	25	25	50	50	50	50	75	75	75	75	75
Morocco			20				50	50	50	50	50	50	50	50	75	75	75	75
Libya								50	50	50	50	50	50	50	75	75	75	75

Source: Emerging Energy Research (2010)

It is important to compare the scenario settings here with the production thresholds established in Table 24. We saw that typical thresholds for key components are in the range of 200-400 MW per annum for mirrors or receivers and 50-200 MW per annum for mounting structures. This implies that the total MENA market should reach in ten years up to 2020 a level of total installed CSP capacity of 2-4 GW in the first case and 0.5-2 GW in the second case. Assuming half to be installed in the five countries considered here the thresholds are 1-2 GW needed for the 5 countries if mirrors or receivers are considered for local production, and 0.25-1 GW in the case of mounting structures, hence, in between scenario B and C. This shows that the "No-replication" scenario is at the lower level to fulfill those thresholds and that the CTF effort must at least trigger a doubling of the CSP installations in these five countries.

3.3 Recommendations actions on different levels to enhance the local CSP manufacturing capabilities

The comprehensive review of the structure, capabilities, and innovative potential of the existing industries (cf. section 2.1) and the analysis of current CSP projects in the MENA region (cf. section 2.2) clearly revealed some substantial obstacles for the development of an integrated CSP value chain in the MENA countries. Based on the identification of these potential barriers to local manufacturing of CSP components, a variety of measures is derived to overcome these barriers and to allow for a maximum of long-term value creation for the MENA countries. The proposed actions refer to two different levels of recommendation:

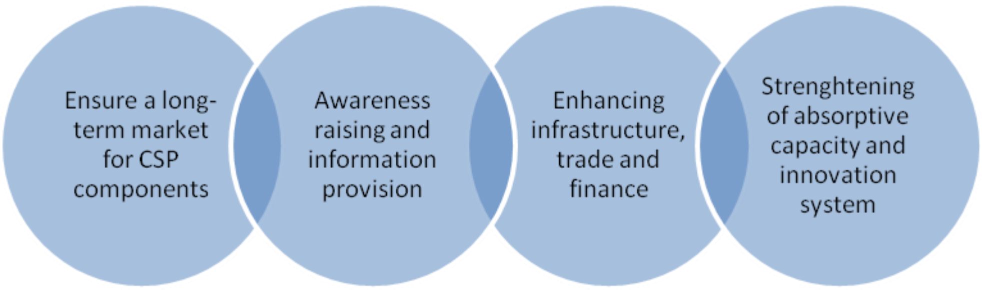
- **General recommendations** that are applicable **on a regional level** and are meant to create a more favorable framework for industrial innovation and
- **Component specific** recommendations which are specifically targeted at the promotion of individual parts of the CSP value chain (products and services).

Both levels of recommendation need to follow a long-term design of the respective measures to lower uncertainties for investors.

3.3.1 Recommendations at regional level

Figure 53 depicts the main pillars to facilitate the development of a CSP scale-up in the MENA region. These four aspects represent the major preconditions for the development of a sustainable CSP-industry.

Figure 53 Main pillars to facilitate the deployment of local CSP manufacturing and service provision in the MENA region. Source: own design.



Ensure a long-term market for CSP-components

CSP market development is one of the major variables for developing CSP manufacturing in the MENA region. Most interview partners (in the MENA region and Europe) stated they would only extend CSP manufacturing activities in the MENA region if the market developed sufficiently and governments expressed a clear interest in developing this technology. Therefore, clear signals in terms of energy policies have to be sent to reduce uncertainties and accelerate direct investments. Even though all the CTF countries have set renewable energy targets, there are still deficiencies in the **formulation of clear and binding political goals**, the creation of the necessary legal framework and specific support instruments for the CSP technology in particular on national and regional level (cf. also case studies on development of the wind energy industry in India and the CSP industry in Spain and the USA, pages 201 and 206 onwards). Among other things, clearly defined intermediate steps are required to achieve the set goals and objectives.

Introducing **local (domestic) content clauses** in CSP tenders and other support instruments is another direct political way to foster the long-term demand for CSP components (both key and secondary components). Specifying a share of goods and services that has to be provided locally could stimulate the local CSP component industry30. These obligatory content shares should be relatively low to start with and then rose as technology and management capabilities increase over time. A too high share in local content at the beginning might raise the project costs and thus hinder market deployment. To further stimulate the regional integration of CSP manufacturing, content

[30] For example in the Spanish wind industry the creation of the company Gamesa can be partly traced back to the local content requirement (Lewis and Wiser 2007).

clause could also be applied regionally, so that components which cannot be delivered by the country in which a CSP plant is built could still be supplied by other regional providers.

An example of strong regional efforts in the field of renewable energy legislation and R&D in the MENA region is the **Regional Center for Renewable Energy and Energy Efficiency (RCREE)**. The founding members are Egypt, Morocco, Algeria, Jordan, Tunisia, Lebanon, Libya, Palestine, Syria and Yemen. Germany, Denmark and the EU are the development partners who assist with financial support. The center was initially founded to develop and disseminate energy policies and energy-related R&D policies to promote technology research in the region. Other, self-imposed tasks include the support of pilot projects, training courses and the integration and promotion of regional industry as well as exchanges with actors outside the region. The RCREE's current focus is on renewable energy legislation enforcement but it could be further utilized and serve as a central hub for research activities, information distribution and coordination of further legislation efforts in the MENA region.

In particular the **employment of regional/local EPC contractors** might play an important role in enhancing the local share of manufacturing in MENA CSP projects. Local EPC contractors will make more extensive use of local suppliers and subcontractors (cf. analysis of current CSP projects described in section 2.2.3) since they have better access to the countries' supplier networks and are more familiar with the terms and conditions of doing business in the region. Therefore, in bidding procedures for CSP projects, such offers should be preferred which include involvement of local EPC contractors. Even if these service providers might not yet possess comprehensive experience with CSP or energy projects in general, this would strongly foster the development of local CSP know-how.

Additionally, to ensure regional and international quality requirements and to strengthen the competitiveness of future MENA CSP industries, implementing **quality assurance standards** for CSP components should be considered in the medium to long term.

Several countries, e.g. China, have successfully used **local content requirements** to upgrade the local manufacturing of renewable energy components. In 2005, the Chinese National Development and Reform Commission (NDRC) stipulated that new wind farms have to meet a 70% local content requirement on value added. Previously, local content requirements were gradually increased from 20% (introduced by the Ride the Wind Program in 1996). This led to a rise in domestic demand and to international wind equipment companies establishing manufacturing facilities in China, increasing the wind industrial FDIs and the value chain. One disadvantage is that the domestic wind turbine technology is still immature, requiring intensive maintenance and lowering load hours (Dewey & LeBoeuf LLP 2010) (Walz unp). This needs to be kept in mind for applications in the MENA region to avoid price increases, but overall this instrument could strongly promote regional industry participation. In China, local content clauses are removed once internationally competitive local industries have been established.

Egypt also makes efforts to reach a higher local content in newly established wind parks. **In tenders / bidding procedures**, **projects with a large share of locally produced components are prioritized**. This approach could also be introduced for CSP projects.

An early **competitive positioning of the MENA countries among the emerging economies worldwide** is required since a strong CSP market growth in the MENA region might as well lead to a competition of uprising MENA CSP component producers with potential future CSP manufacturing industries in other emerging countries, such as China and India. These countries are already strong in the field of manufacturing of renewable energy technologies (a.o. solar heaters, photovoltaic cells and wind turbines, cf. case study on wind turbine industry in India page 201 and textbox about Chinese wind industry above) and might as well develop expertise with regard to the CSP technology.

However, it is rather unlikely that CSP manufacturing industries in these countries will evolve exclusively based on export opportunities to the MENA region. In India as well as in China a strong home market demand, fostered by measures like e.g. tax- and investment incentives and local content requirements, led to the development of competitive manufacturing industries for renewable energy technologies with the notable exception of PV in China which had, however, a strong basis in the China's capabilities in the microelectronics field. In addition, China is developing the home market for PV at present.

Nevertheless, it can not be excluded that also in China and India markets for the CSP technology will arise in the future and that the countries will seize the opportunity of exporting CSP components to the MENA region, thereby competing with local suppliers. Thus it is even more significant for the MENA countries to benefit from an early commitment to the development of a regional CSP industry to be able to profit from competitive advantages like e.g. low transport costs, the proximity to the European market and the design of technologies specifically adapted to MENA conditions. In this respect it is of particular importance that the MENA countries take the lead in CSP related R&D activities and focus on a strong regional integration and a removal of inter-MENA trade barriers (see below) to strengthen their competitive position among emerging economies worldwide.

Awareness rising and information provision

Based on the interview findings, most potential companies have a low level of awareness and little information concerning CSP technology and are rather pessimistic about its future development due to technical, institutional and cost uncertainties. Besides awareness raising and information distribution on a company level, policy makers will also have to be addressed to draw more attention to the subject. To overcome informational gaps and create a higher level of certainty for potential investors, first of all **clearly framed national targets** and estimations of future CSP project development should be defined and communicated by the governments, e.g. in the public media. Awareness actions aimed at policy makers and high level technical officers with specific seminars and stages in operational plants could also be appropriate to enhance the interest and knowledge in the public sector.

Further on, a **regional co-operation** between the single countries of the MENA region must be strongly encouraged. Besides others, this can be achieved by broadly communicating on the one hand the large potential of a CSP industry in MENA but on the other hand the significance of reaching the respective critical output volumes (threshold values) in the factories to allow for a profitable production. Strong emphasis must be laid on pointing out locational and competitive advantages of the different countries (cf. section 2.2.7) and the diverse requirements for the production of individual CSP components. (e.g.; with regard to required capital investments, demands on infrastructure, energy demand and required skills for production processes, etc.).

The creation of a **regional CSP association** dealing with issues such as CSP market development, manufacturing options and the latest technology advancements could, at this point, be an important support measure to scale up awareness and to exchange information between the different parties concerned. For example, such an association could interact with CSP associations in other parts of the world, create an internet platform, publish regular newsletters, set up information centers as well as organize regional and international conferences and workshops involving the local industries and service providers. This might motivate industrial players to enter the CSP-value chain and it helps to establish first business contacts between regional and international players. Such events could address small and medium-sized companies, in particular, which might benefit from being involved in the provision of secondary components and minor services. Additionally, training courses could be offered to interested parties to provide insights into the technical requirements and complexity of the various production processes. In Europe, for example, the CSP associations *"Protermosolar" (Spain) and the "European Solar Thermal Electricity Association"* played an important role in the development of local CSP industries (cf. case study on page 206).

Within this framework, links to industrial federations, chambers, international institutions and other existing networks should also be encouraged and fostered.

Positive examples of political institutions in MENA, which are already **involved in the upgrade of CSP industrial potential**, are the Industrial Modernization Center (IMC) in Egypt and the Moroccan Agency for Solar Energy (MASEN). MASEN is the first institution in the region which combines the promotion of solar energy with the aim of industrial development.

Enhancing infrastructure, trade and finance

Besides direct, sector-specific policies, the success of industrial policy schemes also depends on policies which influence the overall framework conditions within the country, for example infrastructure, trade and financial market regulations. Potential obstacles have been identified in the physical as well as the institutional **infrastructure** of the MENA countries (cf. section 2.2.7). Concerning the transportation and trade of raw materials, intermediate products and finished components, improving logistic networks, road and railway connections is a crucial aspect. Maritime links between the countries in the region also need to be enhanced to accelerate regional integration (WB 2010). With regard to the institutional infrastructure, it is important to have better administrative and legislative support to simplify business processes for local manufactures.

Currently, trade regimes in the MENA region are still rather protectionist despite efforts like the Greater Arab Free Trade Area (GAFTA) under the Arab League. Tariff rates and especially non-tariff barriers (e.g. technical norms) have to be lowered to enhance and accelerate trade (World Bank 2008a). In the CSP technology context, a **regional free trade arrangement** for trading renewable energy components or primary/intermediate products for renewable energy components could contribute significantly to better market integration, accelerate the development of a stable and sizable CSP market and enlarge the regional content in future CSP projects. This could be of particular importance with regard to the competition of the MENA countries with other emerging economies which might develop expertise in the production of CSP components in the future (e.g. India or China): These countries might be favored in trading if high inter-MENA trade barrires exist. Non-tariff barriers might have to be particularly addressed. A free trade agreement is also seen as a crucial pre-condition for successful market development within the scenarios (see above).

Finally, the provision of financial resources in the form of soft loans and **tax incentives** for local companies and investors should be facilitated to increase the profit margin and reduce the time until investments, e.g. in new production lines, pay off. Possible incentives with regard to business related taxes are listed in

Table 30.

Table 30 Potential tax incentives to foster CSP related industrial development

Tax	Potential incentives
Corporate tax	Reduced corporate tax or tax exemptions for manufacturers of RE- technologies. E.g.: • Tax exemption for revenues from CSP component exports • Complete exemption for a certain period after starting CSP business • Permanently reduced rates for producers of CSP-technology
Property tax & land registration tax	Exemption from land registration tax and property tax for manufacturer of RE- technologies.
VAT	Facilitated VAT refund on business related activities for foreign companies producing CSP-technology in MENA.
Capital allowances	Enhanced capital allowances for investments related to production of renewable energy technologies. For example on: • Purchase of production equipment • Renovation/upgrade expenses • R&D spending • Training activities for employees • Marketing & networking activities Allowances might be graduated, e.g. starting with 100% in the first year.
Customs duty	Exemption from/refund of customs duty e.g. for: • Equipment for production of RE-technologies • Materials and sub-components of RE-technologies which are re-exported as finished products

As described in the case studies for the aeronautics industry in Morocco (page 87) and the wind turbine industry in India (page 201), the introduction of long-term guaranteed tax holidays or attractive tax deductions is a significant factor for local manufacturing by national as well as international companies. A general reduction or periodic exemption from corporate tax, property tax and land registration tax and enhanced capital allowances for producers of CSP components (or renewable energy technologies in general) would make this business generally more attractive. However, a refund of customs duties for imported raw materials or sub-components for CSP technologies with export of the finished component, might make a production more attractive, particularly for CSP industries which rely on certain imports especially in the starting phase of the business (e.g. heat transfer fluid, parts of the CSP receivers or special production equipment) and for CSP companies that want to make extensive use of export opportunities.

Although some of these incentives have already been introduced in the MENA countries they are not specifically targeted at CSP, or other renewable energy technologies (Table 55 in the annex provides an overview of some business related taxes in the 5 CTF MENA countries).

Providing **low interest loans and grants** specifically for the local manufacturing of renewable energy components might help local companies raise funds for production lines or company startups. **Strategy funds** could, for example, be specifically designated for upgrading existing glass production lines and assessing the required changes as well as for supporting company startups or technology transfer, e.g. in CSP mirror manufacturing. Here, easier procurement of land and connection to power and water supplies could be an additional incentive for companies planning to open a CSP-related business in MENA. Funds for such national financial support schemes as well as for R&D activities in this field could also be generated by revenues from the “Certified Emission Reductions” of other renewable energy projects (Khalil et al. 2010).

Examples of past industrial upgrade programs in MENA:

Tunisia initiated a comprehensive industrial modernization program in 1995, aimed at supporting eligible enterprises in upgrading their technological capabilities, strengthening their financial structures and enhancing their overall competitiveness. The companies received financial support from the 'Industrial Competitiveness Development Fund' (FODEC) to cover expenditures for feasibility studies and other diagnostic procedures, investments in equipment, acquisition of technology and quality management skills and application of new technologies. Besides measures directly aimed at single companies, the program also focused on strengthening national support institutions, e.g. technology centers and vocational training facilities. Its success was visible in noticeable sales and export increases and positive employment effects, particularly in managerial positions.

A similar program launched in **Algeria** ('Structural Adjustment Programme') also addressed the restructuring of the industrial sector to achieve greater economic competitiveness. The 'Fund for promotion of industrial competitiveness' was created, which provides financial aid for enterprises aspiring to improve their manufacturing capabilities. Financial aid is provided for strategic diagnosis and formulating upgrade plans. Besides this company-focused support, the aim was to enhance the overall economic performance by providing funds, e.g. for training activities, promoting exports and specific R&D activities.

In **Egypt,** the 'Industrial modernization Bureau' (IMB) offers grants for industrial upgrades with capital from the 'Fund for Improving Competitiveness'.

Similar programs have also been implemented in **Morocco**. Here, there was a particular focus on dismantling tariff barriers (UNIDO 2003a) as well as the support measures mentioned above. Removing import duties on specific goods, spare-parts or raw materials is an important way to stimulate a strategic industrial sector and should be pursued.

These industrial upgrading programs generally cover a large variety of sectors (e.g. chemical, building, textile, engineering and agro-food industries) and do not target specific fields, but they could serve as the basis for designing programs and funds for targeted support of the manufacturing sector for renewable energy technologies.

A favorable framework should be created to attract those foreign investments in strategic industrial fields with a maximum value added for the local economy, which involve technology spillovers, innovation processes and the demand for R&D. Simplifying bureaucracy could help where complex application procedures slow down innovation processes or hinder foreign investments. Enhanced protection of intellectual property rights might also be necessary.

Strengthening of the absorptive capacity and the innovation system

Examples of industrial catch-up processes in emerging countries (e.g. Korea and Taiwan, described, e.g. by (Mazzoleni 2007)) clearly pinpoint the essential role of supporting academic research and R&D activities. Public support for the formation of research facilities, particularly focused on industrial development, leads to new processing techniques, boosts national intellectual property through patent registration and promotes dissemination of technological know-how in the respective industrial sectors. Efficient R&D activities require highly specialized R&D funding. The focus should be on future strategic sectors or technologies like CSP. Other under-utilized funds could be terminated or transferred into more specific ones to improve the overall efficiency of government spending (World Bank 2010).

Later, a larger number of technology parks/clusters and regional innovation platforms should be created to foster regional cooperation and enhance the innovative capacity of industrial sectors. This would help small and medium-sized firms in particular to overcome innovation barriers and access the latest technology advancements. To foster such competence clusters, building sites in dedicated areas could be offered to institutions in the respective field at a favorable price.

In the MENA region the Sinai **Technology Valley** in Egypt and the **Technology Park** of Borj Cedria in Tunisia can serve as examples for technology clusters with focus on renewable energy technologies.

The promotion of higher level education and improving the quality of education are further crucial aspects of strengthening the innovation system of a country willing to develop its industrial capacities. To avoid unemployment among the higher educated workforce, it is crucial to tailor educational programs to the needs of the respective emerging industrial sectors: If labor-intensive industries are involved, it might be preferable to focus on vocational education schemes or "on the job training"; if industries need highly advanced technologies, new study courses/faculties at universities should be created to ensure the availability of expert engineers. Maximum efficiency in promotional programs can only be achieved with a common approach and a clear national focus in policies concerning industrial development, education and research promotion.

An example for a highly specific educational program related to renewable energy technologies is the study course "Renewable Energy and Energy Efficiency for the MENA region" (REMENA) at the faculty for engineering at Cairo University. This master program in cooperation with Kassel University (Germany) offers students from MENA countries and Germany the opportunity to acquire competences in the field of renewable energy and energy efficiency. The study course includes, besides general modules on renewable energy issues, classes on solar thermal systems and power generation. With a stronger regional focus on developing CSP technologies, programs like this could be extended and more emphasis placed on solar thermal applications.

Generally, providing students with more practical experience, e.g. by combining studies at universities with vocational training in companies, might also help to address the needs of emerging industries more specifically and provide suitably skilled and specialized graduates for every sector. Funds could also be used to implement or upgrade the required training institutions and in-house trainings. 'Train the trainers' programs are also an option.

In Egypt, several **capacity building programs** in the field of energy efficiency have already been implemented. Main institutions were the Organization of Energy Planning (OEP) and the Energy Conservation and Environment Project (ECEP). The training courses usually lasted two or three days and covered specific technology subjects. Up to now, more than 8000 persons have been trained by the two institutions. Most of the trainees are engineers from different industrial companies. Besides strictly technology-related topics, the programs also covered subjects like project management and the preparation of feasibility studies.

Other institutions offering training courses in energy efficiency technologies in Egypt include the Energy Efficiency and Greenhouse Gas Reduction Project (EEIGGR), the Energy Research Center in Cairo University, the Tabbin Institute for Metallurgical Studies (TIMS), the New and Renewable Energy Authority (NREA) and the Institute of Graduated Studies and Research and Syndicate of Engineers (ERC 2010).

A general training infrastructure seems to already exist in Egypt, which could be used for a potential capacity upgrade in the field of renewable energy and extended to cover CSP-specific requirements.

3.3.2 Component specific recommendations

A coherent, direct, supply-side-oriented industrial strategy is needed which should be embedded in the overall market enhancement scheme described in the previous section. The component-specific action plan focuses on key components with significant shares in the value chain (cf. section 1.3). These comprise key CSP products and services. The latter encompass all the services related to the construction, operation and maintenance of a CSP plant.

For the key components and services, different promotional measures are discussed and rated with regard to overcoming the most critical steps for their deployment (see Table 31 and Table 32). Depending on the expected market growth (scenarios), specific recommendations are given with respect to different possible cooperative business relationships.

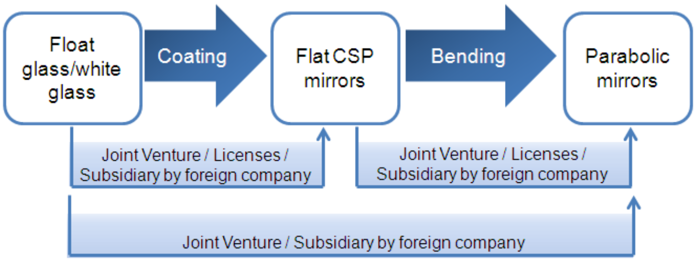
Cooperative agreements are particularly important as they enable CSP industries in the MENA region to absorb technology- and management know-how via technology transfer. Technology transfer is understood as the reception and utilization by one country of technology development in another (Graham 1982). There is a wide range of cooperative arrangements in international business. Considering the extent of inter-organizational dependence, cooperative agreements can vary from technical training or start-up assistance agreements of a short duration, through patent licensing and know-how licensing to equity joint ventures between firms (Contractor & Lorange 2002). For the purpose of this study, the wide range of cooperative agreements is simplified and limited to licensing and joint ventures. A local company remains strongly independent if only a license is procured. Nevertheless, licensing should be associated with extensive know-how transfer rather than simply a patent transfer. A joint venture may be based on a rather unequal cooperative arrangement between a local and an international company. This unevenly distributed cooperation agreement results, on the one hand, in a loss of independence for the local company (recipient), but, on the other hand, it offers the advantage of a potentially high knowledge transfer from the international company (transferor). Thus, the production of goods and services within the recipient country or region becomes feasible, which may have otherwise not been possible without the cooperation. For components with high barriers, and whose provision by independent local players or joint ventures is not possible in the foreseeable future, subsidiaries of international companies should be fostered. The local economy can still benefit here from job creation and tax revenues although the spillover effects of technology transfer may be lower[31].

[31] Knowledge transfer might be smaller due to nondisclosure arrangements.

Figure 54, Figure 55 and Figure 56 depict simplified schemes of the most relevant technology milestones and critical production steps for three key components: mirrors, mounting structure and receiver tubes. The cooperative agreements of licensing and joint ventures as well as subsidiaries of international companies are potential routes to the next reachable milestones.

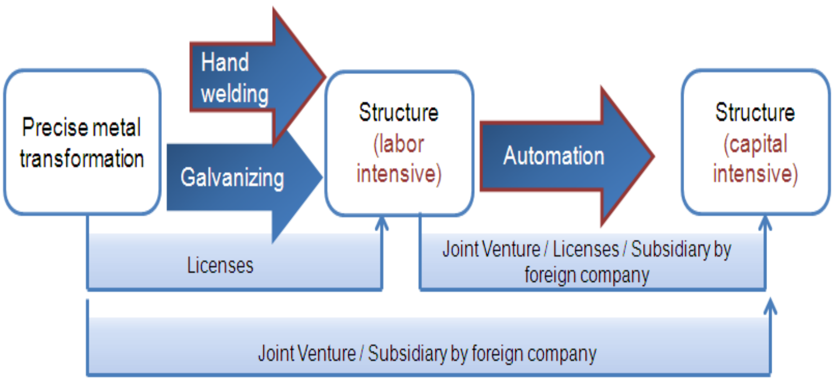
In the case of CSP mirrors, all three routes are possible to realize flat CSP mirror production based on existing float glass production. However, in case of mere acquisition of licenses without additional support (knowledge transfer) by experienced companies, the realization of a MENA parabolic mirror production might take a longer time since extensive technological learning is required. A shortcut straight to parabolic mirror production could be taken by the opening of a subsidiary by an already established company or the formation of a joint venture between regional and experienced international players.

Figure 54 Schematic illustration of potential cooperative forms to overcome critical steps and reach the technological milestones for the production of CSP mirrors. Source: own design



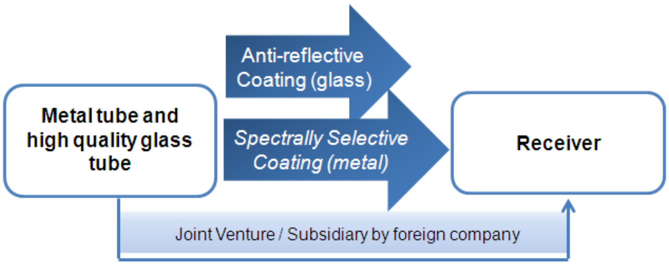
Concerning the production of CSP mounting structures in MENA, there are different approaches possible. In case of a labor-intensive, non-automated production, the foundation of a joint venture or the establishment of a local subsidiary by a foreign company seems improbable. Foreign players are more likely to enter the automated, capital-intensive manufacturing sector, as international production is already moving in this direction. Nevertheless, labor-intensive production might be reasonable and feasible for MENA companies in the short- to medium-term. Advantages due to lower labor costs may facilitate local production.

Figure 55 Schematic illustration of potential cooperative forms to overcome critical steps and reach the technological milestones for the production of CSP mounting structures. Source: own design



Based on the interviews with potential companies and industry experts, a production of high-tech CSP receivers under license is probably not feasible due to the high complexity of the production processes and the resulting strong industrial barriers. Furthermore, a transfer of licenses can be considered unlikely since the receiver tube market is dominated by only two large suppliers (Schott & Siemens). Consequently, the technological know-how for managing the critical steps in production would need to be transferred by a joint venture or by establishing a subsidiary of an experienced receiver company in MENA.

Figure 56 Schematic illustration of potential cooperative forms to overcome critical steps and reach the technological milestones for the production of CSP receiver tubes. Source: own design



This general presentation of the possibilities for developing the key CSP industries in the MENA countries under different cooperation agreements is followed by an analysis of how the different market growth scenarios influence the choice of collaborative form and the focus of the support measures that can be applied to each component.

Scenario A: "Stagnation"

Under the conditions of a weak CSP market in MENA, it is not likely that local companies will **manufacture CSP mirrors** by acquiring licenses. Due to the existing high industrial barriers in the region (cf. Table 18 and Table 22), investments in acquiring licenses and upgrading production facilities would not pay off. The same applies to joint ventures as the regional market is too small and local R&D efforts insufficient to create the required technological environment, so that the conditions for entering the market are unfavorable for international companies. An example can be given regarding the company "Dr. Greiche Glass" in Egypt. An adaptation of the current production line to the production of curved CSP mirrors would involve the construction of a new factory. This would only pay off if sales of about one million m^2 of mirrors per year could be achieved. Consequently, this market value forms a threshold for the glass industry participating in CSP mirror production.

As the example of El Kuraymat (cf. section 2.2.3) showed, the provision of CSP **mounting structures by regional companies** is already feasible in the MENA region if licenses are available. Interviews revealed that several companies in MENA are interested in expanding their production lines to the manufacture of mounting structures. Because of the already high diversification of suppliers in this field (cf. section 1.2.2), licensing agreements seem a suitable option. Licensing agreements might be sufficient for labor-intensive manufacturing if adequate training measures are applied. However, capital-intensive, automated production may not be feasible yet as, in analogy to CSP mirrors, the market is not large enough to guarantee a long-term profit for the companies.

Receiver manufacturing under the "Stagnation" scenario can be considered to have an extremely low potential as, on the one hand, a sufficient production potential by local industries could not be identified in this study and, on the other, European companies clearly stated they would only enter the market if the MENA market volume were sufficiently large.

Scenario B: "No-replication"

One million m^2 CSP-mirrors per year, the threshold for a **CSP mirror factory** in MENA, corresponds roughly to the installation of one 100 MW plant per year (cf. section 1.1.3). Based on this figure, the "No-replication" scenario could already ensure the required demand if a single company covered the majority of CSP projects in the CTF MENA countries. The potential benefits of a growing CSP MENA market could be exploited by regional companies by acquiring licenses from market leaders like Flabeg, Guardian, Saint Gobain or Pilkington, although it is questionable whether market leaders would be willing to sell licenses. Countries with a more advanced glass and mirror industry (e.g. Egypt or Tunisia, cf. section 2.1.1) may even develop their own production know-how for the reflectors with some technical assistance by, e.g. machine suppliers and R&D support by research institutes and universities. A good example might be the Egyptian company "Dr. Greiche Glass," which is currently developing the capability of bent mirror production to supply a small research and test CSP plant of the Cairo University. The company developed its own mirror design with a mirror surface of 2.25 m^2 and a bending depth of 2cm. Even though only a small batch of 24 pieces is going to be produced for the test facility, this might be an important step for the company to gain first-hand experience with this technology.

Under the conditions of reliable market growth, a more automated production might develop for **mounting structures** for which much higher capital investments, a skilled workforce and greater R&D efforts are necessary. These could stem from single major suppliers, but assistance for small or medium-sized enterprises might be particularly important. Furthermore, joint venture agreements might be a way to achieve a quick alignment with international standards in production.

Therefore support for the CSP mirror and mounting structure branch should focus on matching regional and international players in CSP mirror production to encourage licensing and joint venture agreements. Joint ventures could be supported by international networks and exchange platforms as well as tax exemptions on joint venture agreements. To further support CSP technology advancements in the region, the promotion of stronger links between industry and research facilities should be incentivized, public spending on innovative CSP designs and new materials increased, and further incentives set to stimulate private R&D spending. One short-term focus of R&D activities could be the design of mirror and structure surfaces which are better adapted to sandstorms. In this scenario, knowledge transfer and the associated economic benefits could be much higher than in the case of a subsidiary of an international company.

In this scenario, a production of **CSP receiver tubes** in the MENA region is improbable, since the market volume is not sufficient for local companies to reap the benefits of acquiring licenses or upgrading production lines. License transfers are also unlikely because the market is currently dominated by only two large suppliers. In addition, the establishment of a foreign subsidiary of a receiver company in MENA will probably not take place without considerable growth of the regional market, but international companies could still be encouraged by providing support for bureaucratic processes and assistance in searching for qualified workers; tax deductions (cf. previous section) might also be an incentive.

Scenario C: "Transformation"

With a total trade volume of 7 GW, fast knowledge transfer to regional companies should remain the dominant strategy, so that these can quickly catch up with other international companies. Furthermore, strong R&D efforts should be pursued to support innovative technology designs and use of alternative materials in order to develop a first-mover advantage. Investments in the education and training of engineers and other high-skilled workforce will be particularly necessary under this scenario. Generally, it should be assumed that local manufacturing of the mounting structure and mirrors is fully feasible under this scenario so the emphasis should be on developing own designs, integrating the regional market and exploiting export opportunities to other world regions.

The following section discusses the critical steps for the local provision of each key component and evaluates the importance of support measures to overcome the most challenging obstacles.

Action plan to facilitate the manufacturing of the identified core CSP products

Regarding the solar field components, significant value shares of 10.7%, 6.4% and 7.1% have been identified for the mounting structure, CSP mirrors (parabolic) and the receiver, respectively[32] (cf. summary in Table 6). Moreover, the analysis classified synergies with other industries and/or side-market potentials as of medium to high importance for CSP mirrors and the mounting structure (cf. Table 6). Thus, favorable spillover effects can be expected if these industries develop. For example, in the case of CSP mirror production in the MENA region, white glass production might be established in some countries, or the quality of glass production in general might be improved as a 'by-product'. Therefore industries working with white glass, e.g. the window industry or even a potential PV-industry, would be strengthened and glass imports from abroad could be significantly reduced.

For the production of receivers, however, very limited complementarities to other industry sectors in MENA were identified (cf. Table 6). Furthermore, due to the complexity of the essential production steps of spectrally selective coating the steel tube and anti-reflective coating the glass tube (cf. description of the production process in section 1.3.2), all the measures depicted in Table 31 are very important to overcome major critical production steps, but as there is currently no feasible production potential for local manufacturing facilities, the first sub-section below focuses on manufacturing CSP mirrors and the mounting structure. Nevertheless, the recommendations given can also be applied to receivers. Due to the similarities of the actions identified for the mounting structure and the mirrors, these two components are treated together.

Measures to overcome critical steps

As already pointed out when deriving the roadmap for CSP mirrors, the conditions for the **production of glass and mirrors** are quite favorable in the MENA region since the raw materials (e.g. high quality sand and limestone) are widely available and transport distances from the production facility to the plant should be fairly short because of mirror weight and size (typically 15% of total costs are transport costs; cf. **Error! Reference source not found.**). Furthermore, the production of CSP mirrors is quite energy-intensive, so that countries with low energy costs, like Egypt and Algeria, have a considerable competitive advantage.

Mounting structure manufacturing has relatively high similarities to CSP mirror production in the MENA region concerning energy costs, labor costs, the availability and quality of raw materials and transport costs.

Table 31 shows the identified critical steps to reach CSP mirror- and mounting structure production and estimates the importance of related support measures. In the following, each measure is briefly discussed, focusing on the current parabolic collector technology. However, for other CSP collector designs, the importance of measures may differ in some cases, e.g. for the less complex CSP tower heliostats.

[32] for a representative 50 MW parabolic trough plant with 7h storage capacity

Assessing the feasibility of production line upgrade

A particularly important short-term measure is to provide external know-how to assess the technical feasibility of firms to upgrade their production lines to CSP mirrors and the mounting structure. This could, for example, be achieved by providing financial resources (e.g. from a strategy fund) to commission an external consultant or by nominating national/regional consortia of such experts funded by the governments.

Regarding **CSP mirrors**, this measure is particularly significant for adjusting production lines to float glass/white glass and for the process steps of coating and, in the case of parabolic mirrors, bending. Current producers of float glass are found in Egypt and Algeria; high-tech mirror production is located in Tunisia with the company SIALA, or in Egypt with "Dr. Greiche Glass" and Smart Glass, who have already showed interest in producing CSP mirrors by implementing or adapting the required process steps of coating and bending.

In the case of the **CSP mounting structure**, the most critical steps were identified as adjusting production lines to highly precise metal transformation and achieving a more automated production. Experiences with galvanization already exist in the MENA region (e.g. El Sewedy Power in Egypt has one of the largest galvanization factories worldwide).

The steel transformation industry was identified mostly in Egypt and Algeria as well as Morocco to a smaller extent. Some large global players are operating in the field of steel structures in MENA, e.g. Egypt.

Provision of financial resources

High quality white glass is the main input for **CSP mirror** production. The float glass/white glass processing industry is very capital-intensive as there is a high degree of automation. Thus, upgrading production to white glass requires considerable investments. These investments are typically pursued by a relatively small number of international companies who make decisions based on the size of the regional markets. These companies typically possess the necessary financial resources for the investment needed. For the other steps in the matrix, adequate financing is important to very important.

Overall, the financial resources needed to enhance **mounting structure** production are lower than for mirror production. Analogue to the float glass processing industry, the metal transforming industry including the galvanization process might be largely independent of financial resources because of enterprise scale.

Potential measures to integrate investment support mechanisms for upgrading include soft loans to companies, or offering a subsidy if companies decide to upgrade production facilities, e.g. a certain percentage of the investments needed. For such subsidies, a fund could be implemented which invokes certain criteria concerning the suitability for CSP technologies. Tax credits or deductions for investments in production lines or R&D expenditures (as discussed in the previous section, cf.

Table 30) could further stimulate current glass and mirror as well as steel transforming companies to extend their efforts. If necessary, suitable institutions should be set up to coordinate applications for such financial support.

Training of low-skilled workforce

Capacity building programs are a very important measure to ensure the high quality of the components for CSP plants. This is particularly true for mirrors as even tiny changes in alignment have a high impact on the efficiency of the whole plant. Training courses for low-skilled workers could significantly reduce this risk assuming the presence of suitable machinery. Training courses of several weeks could already transfer the basic knowledge about single process steps in mirror and mounting structure manufacturing and could be offered within technical assistance agreements with companies deciding to upgrade production on their own. The training requirements for the mounting structure might be lower for single production steps as they are much less complex.

Table 31 Importance of measures to overcome critical steps in the CSP mirror and mounting structure production. Light blue: minor influence, blue: important influence, dark blue: very important influence (Source: own design).

Measures / Critical steps	Assessing the feasibility of production line upgrades	Provision of financial resources	Training of low-skilled workforce	Education & training of high-skilled workforce	R&D enhancement
CSP Mirrors					
Adjustment of production lines to white glass	dark blue	light blue	blue	blue	light blue
Coating (protection & silvering)	dark blue	blue	dark blue	dark blue	blue
Bending (parabolic trough)	dark blue	blue	dark blue	dark blue	blue
Quality of product	light blue	blue	dark blue	dark blue	blue
Adaptation of mirror design and materials	light blue	dark blue	light blue	dark blue	dark blue
Own mirror design and new materials	light blue	dark blue	light blue	dark blue	dark blue
Mounting Structure					
Adjustment of metal transformation facilities	dark blue	light blue	blue	blue	light blue
Galvanization	light blue	light blue	light blue	light blue	blue
Hand welding	light blue	light blue	dark blue	blue	light blue
Automation (CNC for welding and e.g. stamping)	dark blue	dark blue	blue	dark blue	blue
Quality of product	light blue	blue	dark blue	dark blue	dark blue
Adaptation of structure design and materials	light blue	blue	light blue	dark blue	blue
Own technology design	light blue	dark blue	light blue	dark blue	dark blue

Education and training of high-skilled workforce

Universities should be encouraged to teach CSP technology-based courses to educate a potential workforce, particularly engineers and other highly skilled workers needed for the CSP branch. In general, the interview partners perceived few problems in the availability of a skilled workforce, but nevertheless specific CSP training will still be needed. CSP technology could offer a big opportunity for most CTF countries as a highly educated workforce is not being sufficiently absorbed by their markets because of rather low-skill-oriented industries (World Bank 2010). Furthermore, teaching courses should be offered by the companies in cooperation with universities, research institutes or other CSP experts to impart in-depth knowledge of the technology. Within the enerMENA project of the DLR (German Aerospace Center), training courses are already being offered, but the focus tends to be on project developers, plant manufacturers and operators to foster CSP market development and the program is due to end in December 2011. Another option is to build capacity by educating students and thus the future workforce abroad. This route is being taken by the Renewable Energy and Energy Efficiency for the MENA region (REMENA) master program, a cooperation of Cairo University and Kassel University (Germany) and financially supported by the Federal Ministry for Economic Cooperation and Development. Egyptian and German students are participating, although the number in the first round has been rather small. Co operations of this kind should be further accelerated in cooperation with other universities in the region and the CSP technology focus could be intensified.

Educating and training a high-skilled workforce is identified as important to very important for all the critical steps in CSP mirror and mounting structure production apart from the galvanization process. But in contrast to training low-skilled workers, this measure is much more capital and time intensive. Furthermore, if the workforce is highly qualified, wages will also have to be adjusted to prevent the emigration of professionals.

R&D enhancement

Universities could also become an important actor concerning R&D. R&D efforts need to be made by public as well as private institutions. Technology parks, which are currently expanding in the MENA region, could become an important platform to establish strong links between industry and research facilities. For example the Sinai Technology Valley in Egypt and the Technology Park of Borj Cedria in Tunisia have planned a focus on renewable energies. In general, networking between individual players should always be encouraged. Here RCREE could be a possible platform.

R&D enhancement is a very important measure concerning the adaptation of designs and materials as well as developing own designs and new materials. Furthermore, R&D is an important measure for layer protection in the case of mirrors and galvanizing in the case of the mounting structure. Materials might have to be adjusted to the environmental conditions of the MENA region with its high temperature fluctuations. Furthermore, mirror surfaces may have to be adjusted to higher volumes of dust and to sticky particles due to sea spray in coastal areas. Steel structures may have to be designed and adapted to the wind conditions in the MENA region. Because of the challenging environmental conditions, the maintenance equipment, e.g. cleaning machines for mirrors, may also be an interesting field for R&D efforts in the region.

The level of R&D enhancement depends on the assumed scenario. The more ambitious the scenario, the stronger R&D efforts should be in the beginning to exploit potential profits from first-mover advantages. More basic requirements for R&D are project-parallel research activities at CSP sites or the implementation of CSP-mirror testing plants.

Action plan to facilitate the manufacturing of the identified core CSP services

As a reminder, CSP services are defined as those needed to construct, operate and maintain a power plant; there is no clear line between the engineering activities required for CSP services and those needed for CSP products. For CSP related services the market size is not as critical as it is for technical components of a CSP plant. Nevertheless, the larger the installed capacity under the assumed scenario, the faster the services provided can evolve into more advanced business sectors. CSP-related services can be split into ‘civil work, collector installation and assembly’, ‘EPC (engineering and project management)’ and ‘O&M’ (operation and maintenance).

Shares in the value chain during the plant construction phase amount to 2.5% for assembly, 8.9% for civil work (5.8% infrastructure and 3.1% solar field), 5.3% for collector installations on the plant site and 7.7% for EPC engineers and project managers, CSP services have high spillover effects as they can easily be transferred to other sectors (cf. Table 6).

Services can be further divided into management skills and technical skills. Management skills are particularly important for EPC, but are also necessary in assembly and O&M. Technical skills cover assembly and construction as well as engineering activities.

Measures to overcome critical steps

The experiences gained to date from implemented projects in the MENA region indicate that mostly less advanced services, mainly **civil work and assembly,** have been carried out by local companies and workforce.

The Egyptian company, Orascom, is a positive example for an **EPC contractor** in the solar field. In the Kuraymat project, Fichtner Solar and Flagsol acted as subcontractors supporting Orascom with the conceptual design, engineering activities and technical advice about assembly (cf. section 2.2.3). The example of Kuraymat further showed that Orascom, which networks with other Egyptian companies due to other business activities, influenced the selection of supplier companies and local content considerably. This indicates the importance of overcoming information deficiencies concerning potential suppliers in the context of quality assurance standards, as international EPC contactors may rely less on local capacities because of their lack of experience in the region. Consequently, as already mentioned in the previous section, the deployment of local EPC contractors might be a key factor for enhancing the local content in CSP projects and thus to maximize the local added value from such projects for the countries.

O&M, the third type of service, has a different standing because it is important in the phase following plant construction. Job figures appear low at first sight, with about 40 persons needed for a 50 MW plant (cf. Table 11). However, O&M is a service required over the long term, generating a number of permanent jobs, not to be neglected.

Table 32 illustrates the identified grouped services for a CSP plant and the importance of measures for each group of services. Each measure is briefly discussed below.

Table 32 Importance of measures to overcome critical steps in the provisions of services related to CSP projects. Light blue: minor influence, blue: important influence, dark blue: very important influence

Assessing the feasibility of service upgrade	Provision of financial resources	Training of low-skilled workforce	Education & training of high-skilled workforce	R&D enhancement
Civil work, collector installation and assembly				
EPC engineering and project managing				
Operation and maintenance				

Assessing the feasibility of service upgrade

Similar to CSP products, local companies could be offered the chance to consult with external experts about upgrades, also to raise awareness about the resources needed. Besides technical requirements, also management skill gaps should be addressed as the interview results show. Assessing the feasibility of service upgrades is important for construction companies as well as companies for collector installation and assembly.

Provision of financial sources

The provision of financial resources is important for all the services presented. Besides training requirements, providing services depends indirectly on investments in equipment and infrastructure. Small and medium-sized local companies involved in civil work might for example be dependent on investments in large shovels and trucks, and assembly services might require financial support to build assembly halls with the necessary machinery. Soft loans or other subsidies may be required; it needs to be discussed whether companies not directly related to CSP technology should be supported. Concerning EPC, a well trained workforce may be more important than providing financial resources as the companies currently involved are large and seem financially secure.

Training of low-skilled workforce

Low-skilled workers are needed for civil work, collector installation and assembly and to a lesser extent for O&M (e.g. for mirror cleaning). Foreign expertise in the form of supervision and training is needed to provide support in developing further competencies and improve productivity to overcome poor organizational structures in the labor force and to ensure quality demands are met. On-the-job-training might be sufficient for low-skilled workers. One option could be to 'train the trainers': Higher qualified workers of a company attend training courses and pass on the knowledge gained to the rest of the workforce. Under the regional recommendations already mentioned, this might be sufficient.

Education and training of high-skilled workforce

As already stated, the links between industry and research centers have to be strengthened considerably. Integrating educational programs into R&D institutions, e.g. technology parks, might be particularly useful to ensure a high quality of technical training and to support the information exchange about new technology developments.

It has to be determined which teaching programs already exist to be able to build on existing structures and networks.

Especially small and medium-sized engineering companies could be addressed here as potential, highly specialized sub-contractors (e.g. mechanical, electrical or thermo dynamical) to support the greater diversification of potential service providers. Management skills including logistics and quality standards will also have to be addressed. Some specialized knowledge could be gained abroad.

Service upgrades necessitating higher skills might require large investments, which small and medium-sized companies cannot afford. Here, support is needed from government and international sponsors in the form of grants for training, soft loans and tax incentives (cf.

Table 30).

R&D enhancement

Concerning EPC, and in particular engineering, R&D could help local capacities to improve the conceptual design of plants. Although the R&D in this context is different to that for product development, the companies and research facilities of both types should collaborate to integrate training courses into R&D product networks.

Concluding, Table 33 summarizes the potential measures to stimulate the production of CSP components and provide CSP-related services in the MENA region.

Table 33 Action plan for stimulation of production of CSP products in the MENA region
(Actors/financers: ∆ = national authorities, ▲ = internat. donors, ◊ = national CSP players, ♦ = internat. CSP players)

Goals	Intermediate Steps	Necessary processes/assistance	Target groups	Potential actors	Implementation timeframe
Upgrade & increase of industrial and service capacities	Provision of information on CSP-market size and opportunities of production and service adjustment	Implementation of national and regional CSP associations that foster networking, accelerate business contacts and provide information	Current and potential future producers of intermediate products and CSP components, research organizations	∆ ▲ ♦◊	Short to medium term
		Establishment of super ordinate national institutions responsible for CSP-targets to enhance and coordinate policy development in the regional context and to provide assistance	See above	∆	Short to medium term
		Creation of internet platforms, newsletters on technical issues and market development, information centers and other informational support	See above	∆ ▲	Short to medium term
	Assessment of technical feasibility for firms to upgrade current production to CSP component production and service provision	Foundation of consortia of technical experts that support companies which show interest in CSP-manuf. or provision of funds to consult external technical experts	Current producers of intermediate products and CSP components	∆ ▲	Short to medium term
	Implementation of investment support mechanisms for adaptation of production lines	Financial support of a certain share of the necessary investment for implementation of upgrade of production facilities (e.g. "renewable energy innovation fund")	Current local producers of intermediate products	∆ ▲	Short to medium term
		Provision of long-term low-interest loans for companies willing to invest in innovation of production lines	Current local producers of intermediate products and potential future producers	∆ ▲	Short to medium term
		Facilitation of foreign investments by simplification of	International players	∆	Short to medium term

		bureaucracy and assistance			
	Price incentives	Tax incentives for production/export of CSP components (e.g. reduction or exemption on customs duties for raw materials, parts or spare parts of CSP components, refund of customs duties with export)	Local producers, national and international companies	∆	Medium term
		Tax credits or deductions for investments in production lines related to CSP and investments in R&D	National and international companies	∆	Medium term
		Lowered trade barriers for RE/CSP components and intermediate products to accelerate the trade of components	See above	∆	Medium term
		Tax credits on firm-level training measures	See above	∆	Short to medium term
	Further incentives	Local and regional content obligations for components and services in CSP projects	See above	∆	Medium term
		Foster integration of suppliers of secondary components in the region	See above	∆	Short term
Activation of further potential market players and service providers	Strong focus in national and regional industrial policy on CSP development	Formulation of clear national targets regarding the development of CSP industries	National and international industrial players in general	∆	Short to medium term
		Provision of administrative and legislative support for company startups and foreign investments, and formation of according institutions	National and international industrial players in general	∆ ▲	Short to medium term
		Financial support mechanisms for national company startups in the sector of renewable energy manufacturing	National players	∆ ▲	Short to medium term
		Introduction of regional quality assurance standards for CSP products to decrease uncertainty	National and international companies	∆ ▲ ♦◊	Medium to long-term

	Awareness raising	Awareness rising initiatives (e.g. conferences, workshops, other marketing activities) and formation of according institutions	National and international industrial players in general	∆ ▲ ♦	Medium to long term
Facilitation of skill enhancement and knowledge transfer	Promote creation of joint ventures between existing manufacturers and potential regional newcomers	Facilitation of networking and knowledge transfer by creation networking platforms and organization of business fairs	Regional and international manufacturers	∆ ♦ ◊	Short to medium term
	Support of training activities for local workforce	Review of existing national training facilities, upgrade/creation of specific institutions if needed		∆ ▲	Short to medium term
		Provision of short basic training courses for civil workers (e.g. involved in assembly activities)	Regional companies, particularly low-skilled workforce	∆ ▲	Short to medium term
		Support the training of regional workforce by financial support if external training facilities are involved	Regional companies, international companies	∆ ▲	Short to medium term
		Promotion of financial incentives for 'train the trainers' programs	Regional companies, international companies	∆ ▲	Short to medium term
	Support of higher education	Establishment of study courses with regard to solar energy techniques/CSP and other required skills related to RE/CSP	Regional students and engineers, O&M workforce	∆ ▲	Short to medium term
		Creation of master programs at foreign universities and student exchange programs with regard to RE/CSP	Regional students	∆ ▲	Short to medium term
		Review of management and project planning capabilities and creation of training courses	Students, potential CSP workforce (e.g. existing EPC contractors)	∆ ▲	Medium to long term
	Support of private and public R&D	Improvement of renewable energy related R&D legislations, and national legislation exchange (e.g. through RCREE)	Manufacturers, private and public research institutions (e.g. universities)	∆ ▲	Short to medium term

		Foundation of research institutions and technology clusters with regard to CSP technologies, to foster regional knowledge distribution and innovation	See above	Δ ▲ ♦ ◊	Medium to long term
		Implementation of CSP testing plants and project-parallel research activities at CSP sites	CSP-project developer, national and international CSP component producers, public and private research facilities	Δ ▲ ♦ ◊	Short to medium term
		Promotion of international science networks and exchange of scientific experts in the field of CSP component design (particularly important for collectors and receivers)	Scientists at national and international institutions	Δ ▲	Medium to long term
		Enhancement of links between industry and research facilities (universities)	Scientists at national and international institutions, regional companies, international companies	Δ ▲ ♦ ◊	Medium to long term

Table 34 Examples of potential actors for stimulation of production of CSP products in the MENA region

Potential actors		Examples
∆	**National authorities & research facilities**	**Regional:** Regional Centre for Renewable Energy and Energy Efficiency (RCREE) **EG**: New and Renewable Energy Authority (NREA), Energy Supreme Council, Industrial Modernization Centre, Egypt National Cleaner Production Centre (ENCPC), Council of Electricity and Energy researches in the National Academy for Science and Technology, Egyptian Electricity Utility and Customer Protection Regulatory Agency (EEUCPRA), Tabbin Institute for Metallurgical Studies (TIMS), Energy Research Centre (ERC) at the Cairo University, all ministries related to energy issues. **MO**: Moroccan Solar Energy Agency (MASEN), Centre for Renewable Energy Development (CDER), Office National de l'Electricité (ONE) **TN**: National Agency for Energy Conservation (ANME), Chambre Syndicale Nationale des Energies Renouvables **DZ**: New Energy Algeria (NEAL), Centre de Recherche et de Développement de l'Ectricité et du Gaz, Agence National pour la Promotion et la Rationalisation de l'Utilisation de l'Energie, UDTS Research Centre **JO**: Ministry of Energy and Mineral Resources (MEMR), Ministry of planning and international cooperation (MoPIC), National Energy Research Center (NERC), National Electric Power Company (NEPCO), Electricity Regulatory Commission (ERC)
▲	**International donors**	World Bank (WB), African Development Bank (AfDB), Kreditanstalt für Wiederaufbau (KfW), United Nations Industrial Development Organization (UNIDO), German International Agency for Technical Support (GTZ), United Nations Development Program (UNDP), Global Environment Facility (GEF), EU, United States Agency for International Development (USAID), Canadian International Development Agency (CIDA), Agence Francaise de Développement (AFD), Danish International Development Agency (DANIDA), other national development agencies.
◊	**(Potential) national CSP players**	**EG**: Orascom, Arab Organization for Industrialization (AOI), Al Babtain Power & Telecommunication Co., El Sewedy Power, Middle East Engineering & Telecommunications (MEET), Dr. Greiche Glass, Sphinx Glass **MO**: Delattre Levivier Maroc, Inabensa Maroc, Induver Glass, LEONI Cable Maroc, Sonasid Steel, TAQA, YNNA Holding, TENESOL, GIMAS **TN:** Tunisie Cables, Tunisie Engineering et Construction Industrielle (TECI), Inter Metal **DZ**: Cevital, Africaver Societe African du Verre, Les Câbleries Electriques d'Alger, Algerian Energy Company (AEC), Sonatrach **JO**: Several service providers
♦	**International CSP players**	Abener, Abengoa Solar, Acciona, Alstom, Areva, BASF, Brightsource, Esolar, Ferrostaal, Flagsol, Flabeg, Fichtner, Guardian, Iberdrola, MAN Turbo, Novatec Biosol, Pilkington, Saint-Gobain, Sener, Siemens, Schott, Solar Millenium and many others (cf. section 1.2.2).

3.4 Conclusion of chapter 3

Based on the status quo analyses of the foregone chapters, the present chapter introduces roadmaps for development potentialities of CSP industries in the MENA region and presents action plans to foster the manufacturing potential for the key components and key services of the CSP value chain. Technological, entrepreneurial as well as policy and market developments, which are crucial for the establishment of local manufacturing in MENA have been pointed out. The suggested actions were adapted to different levels of potential market development (represented by three growth scenarios). From the analysis the following main conclusions could be derived:

Key preconditions for the development of local manufacturing of CSP components in the MENA region are the creation of a **stable policy framework** and a **sustained domestic market**. In the long run, the annually installed capacity should be on a GW scale to allow for the development of production lines, particularly in the case of mirrors and receivers. Also, a strong **regional integration** of the CSP value chain, making use of the countries' comparative advantages and including dismantling of trade barriers and coordination of national policies, is crucial to overcome barriers related to critical quantities (threshold values for a profitable production) in the manufacturing of CSP components.

The focus of support is depending on the expected market size: In the case of a stagnating growth of the CSP market in the region (scenario A), support should rather focus on enhancing the manufacturing of low-tech components and basic services for which the market barriers are relatively small and no large investments are required (e.g. mounting structure, civil works and assembly). Assuming a moderate but stable growth of the CSP MENA market (scenario B) an adaptation of international production standards and -techniques in existing industries should be aspired to achieve a region-wide supply of at least some suitable CSP components produced locally in the MENA region (e.g. mounting structure, piping, cables/electronic equipment and a wide range of related services). Under the "Transformation" scenario (scenario C) policy actions should strongly support innovations and the development of intellectual property rights in the field of CSP components to profit from first mover advantages and to develop technologies specifically tailored for MENA conditions. A strong export orientation should be motivated to benefit from the proximity to other emerging markets. Thus a production of a wide range of CSP components could be achieved (parabolic mirrors and potentially receivers).

National strategies for industrial development and energy policy should be well coordinated and involve besides clearly defined and broadly communicated targets for the market diffusion of CSP, substantial R&D efforts and a creation of highly specialized strategy funds for industrial development of CSP industry sectors.

Financial aid will be necessary especially for the technical adjustment of production facilities (including the related feasibility assessment) and the implementation of training courses for the local workforce. For this purpose, a provision of low interest loans, grants and tax incentives specifically designed for fostering local manufacturing of renewable energy components would help MENA companies to enter the CSP business. In this context, the most critical steps in the upgrade of production facilities for CSP components have been identified as the implementation of automated processes for the production of precisely manufactured mounting structures, the supply of high quality white float glass and the adaption of techniques for coating and bending of parabolic CSP mirrors. Besides for the technical upgrade, funds could also be provided to facilitate know-how transfer, e.g. via purchase of licenses. For CSP receivers it is considered as improbable that local companies enter the production business due to the high complexity of this component. Here, tax incentives (e.g. in form of reduced corporate- and land registration taxes and facilitated VAT refunds) could help to attract international companies to the MENA region.

Besides financial aid, market actors will also need good **access to CSP related information** and certainty about the market development in order to engage in such investments. The creation of a regional CSP- or renewable energy association dealing with issues such as the CSP market development, manufacturing options and the latest technological advancements might be an essential element in this respect. Furthermore, to **enhance the innovative capacity** of the industrial sectors and to foster company networking and R&D, the creation of a larger number of technology parks/clusters and regional innovation platforms should be aspired. This would help particularly small and medium-sized firms to overcome innovation barriers and to gain access to the latest technological advancements.

Individual business models should build on the comparative advantages of certain sectors in MENA countries and also involve international cooperation agreements, e.g. in the form of joint ventures and licensing, to accelerate the development of a comprehensive CSP know-how in the region and to benefit from the broad experience of existing companies. Especially in the case of receivers subsidiaries of foreign companies will most likely be a relevant business model in the beginning. Governments could assist the private sector in the matchmaking leading to such co-operations.

Another direct political measure to foster a long-term demand for CSP components would be the careful introduction of local (domestic) content clauses within CSP project tenders and in particular bringing forward the deployment of local EPC contractors. These have better access to local supply chains and service networks and might thus play a key role in raising the share of local value added in future CSP projects. Requirements in **bidding procedures** might thus be adjusted to prioritize local contractors.

Moreover entering local manufacturing of CSP components will involve comprehensive **education and training programs** for the industrial workforce in relevant sectors. Universities should be encouraged to teach CSP technology based courses to educate potential workforce, particularly engineers and other technical graduates related to the CSP branch. Additionally, to ensure regional and international quality requirements and to strengthen the competitiveness of future MENA CSP industries, it should be considered to implement **quality assurance standards** for CSP components in the medium to long term.

4 Analysis of potential economic benefits of developing a CSP industry in North Africa

The final section analyzes local economic benefits of an industry development in the MENA region. A dynamic economic model, with market scenarios and reference plants, assesses the local share of a CSP deployment and manufacturing of components.

The results are aggregated by a sub-analysis of four different parameters.

- Average share of local manufacturing in MENA region
- Economic impact on GDP
- Labor impact: job creation
- Foreign trade impact

4.1 Introduction to the modeling concept

If the MENA CSP IP and a successful long-term strategy, with national and international financial support, are implemented, new local markets will open up in the MENA region. New CSP projects will add valuable economic benefits to the economies of the MENA countries through the creation of new jobs, GDP growth, international trade and energy security.

These prospective economic and social benefits are to be taken into account in setting up the financial support plan for the Scale-up Initiative, since they will establish long-term economic growth for the MENA region. The potential benefits from the renewable energy technology CSP for the development of the regional industry and technology will be summarized in this section. The advantages of a realized MENA CSP IP in combination with the growth of local manufacturing and new factories for CSP components are highlighted.

Large-scale development of the CSP market - both local and worldwide - will give a return to the MENA countries if they participate in local CSP component manufacturing for domestic as well as for international markets. An early market entry could create first mover advantages, where competitive production capacities supply regional and world-wide markets.

As a result, MENA countries would obtain large economic and social benefits. Further, the technical know-how in renewable energy technologies would increase in these countries. In an optimistic scenario, the total potential of the local manufactured added value of CSP plants could reach medial 60 percent. That considers a continuous local market based on the three scenarios A, B and C which have been presented in the previous chapter.

Modeling approach

To assess the economic effects of a growing CSP market in MENA, a dynamic model approach is used. At first the status quo of local manufacturing in the year 2010 is determined based on recent ISCCS plants in the region. Therefore the value chain and investment cost analysis (see chapter 1) play an important role. To guarantee the comparability, the reference plant as introduced before (50 MW and 7.5 hours storage) is used. The model is calculated on the three different market scenarios (A, B, C) explained in the previous chapter. The dynamic development of local share is calculated considering several influencing factors.

Some of the main influencing factors are: The market development, investment costs, the status quo in North Africa, varying experience curves, technology requirements and complexity, production capacities, productivity, local know-how, and local differences. The model refers to component specifications based on technology requirements (see 1.3 and 1.4) as well as on country and project related assumptions for local manufacturing of components and plant construction (2.1 and 2.2). A bottom-up approach is applied as the effects are calculated component by component, service by service identifying, for example, both direct and indirect economic and job effects.

The most important pre-analyses (market scenarios, reference plant, status quo, cost scenarios, component specific input and job development) are presented in this chapter. The results from the local share, economic effects, job effects and foreign trade effects are also discussed. The share of local manufacturing is dynamically modeled with respect to the required market size and the continuous growth of local, technical skill and expertise.

Some general remarks:

- If a service (construction) and a component were indicated to be produced by a company based in North Africa, the total cost volume was added to the “local” share. If a component came from a company based abroad, it was added to the “international” share.
- Purchase of services (construction, project development, Management, EPC) is a “*construction related effect*”.
- Purchase of components of a power plant is summarized as “*component and supply chain effects”* for North Africa.
- Job effects during construction and operation are assumed, based on data from recent local and international projects.
- Jobs and Economic Development Impact (JEDI) models from NREL have been used as reference, but they do not provide a dynamic environment for local manufacturing in MENA.

Induced effects are not being considered as determination is relatively difficult and would be inaccurate In the JEDI model, I-O tables of US states were used for comparative purposes The results in values for induced effects are almost the same size as effects of the supply chain (in the US). For more details on the modelling approach, see the Annex.

Market growth scenarios

To calculate and analyze the potential economic benefit, different market deployment and growth scenarios A, B and C (described in chapter 3.2) as well as assumptions for the world market are used.

- Effects of an internal CSP market growth are considered to be linked with export of CSP components to the world market, e.g. to other MENA countries or Southern European countries like Spain, Greece or Italy.
- Scenarios cover the different cases of market development that will have different implications on the economic benefit and the implementation of local supply and component manufacturing in factories of the MENA countries.

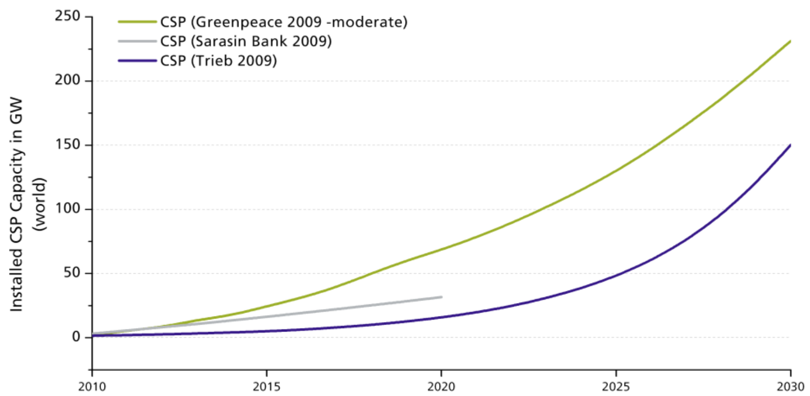
Error! Reference source not found. shows the three different market scenarios and export market demand of components for MENA countries.

Table 35 Different market growth scenarios with export projections

Scenario	Installed capacity in 5 Countries by 2020	Export market demand of components
Scenario A (Stagnation)	500 MW	0 MW
Scenario B (No-replication)	1000 MW	0 MW
Scenario C (Transformation)	5000 MW	2000 MW

A large difference in installed power was modeled for the three scenarios. Scenario B is limited to 1000 MW by 2020 and 2100 MW by 2030. This scenario constitutes the minumum level which the CSP Scale-up initiative should achieve while it is expected to trigger additonal impacts. Compared to scenario B, the “Transformation” scenario shows a dynamic growth up to 5000 MW by 2020 and up to 31,200 MW by 2030. By 2020 an additional export demand is expected in this scenario for components for CSP plants with 2000 MW capacity. This has to be distinguished from CSP plants built in MENA countries and which export electricity to Europe. Within each scenario, a defined roadmap for CSP installation exists for each country. The roadmap depends on the current (solar) investment plans for the region and the size of the electricity market.

Figure 57 CSP world market growth through to 2030 as determined by three different studies



World-wide CSP deployment scenarios were defined for the period from 2010 to 2030. For the period after 2020, the market developments have been connected to the reference, moderate and advanced scenarios of the Greenpeace Report (Greenpeace, 2009) with a share of 10 to 20 percent of the world market. These market developments serve as the basis for the local demand for CSP components, the driver for local manufacturing and the construction of new plants. Additional export demand was created in scenario C where a total component export of 5180 MW is expected by 2025. Both economic and social effects are considered in these scenarios.

Table 36 Newly installed CSP plant capacity in MENA by 2020

CSP Scenarios in MW		2011-2014	2015-2017	2018-2020	Total by 2020	Total by 2025
Scenario A	domestic	80	160	260	500	1050
	component export	0	0	0	0	0
Scenario B	domestic	160	320	520	1000	1550
	component export	0	0	0	0	0
Scenario C	domestic	800	1600	2600	5000	14500
	component export	250	600	1150	2000	5180

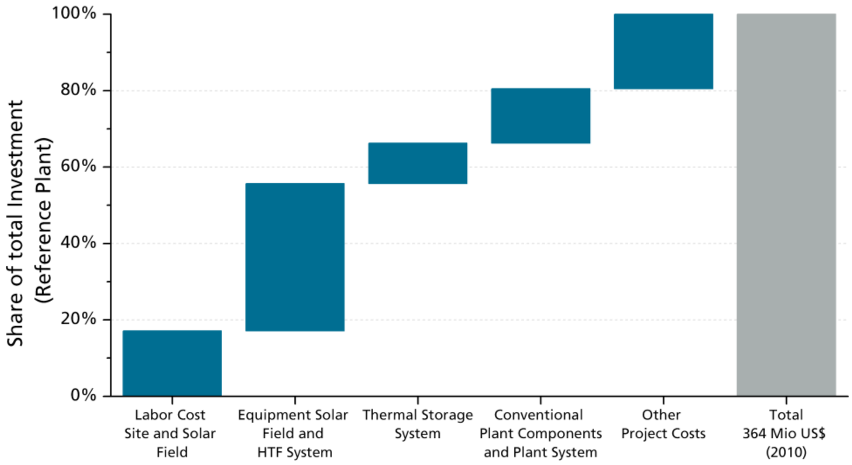
Note: The exports refer to components expressed in terms of equivalent CSP plants

Reference plant

A 50 MW plant with 7 hours storage and the cost structure (as presented in section 1.4) were used as a reference. This reference plant was evaluated to obtain all data about construction costs, component costs and labor effects connected to this plant. Furthermore, the specific requirements and constraints put on market demand, complexity levels, and job effects related to the components used (as described in 1.3 and 1.4) were identified.

The calculation starts with a total investment of US$364 Million in 2010, and considers continuous cost reductions with increasing production. The five larger cost groups have shares between 14 percent (Power Block) and 38 percent (Equipment of Solar Field and HTF) of the total investment. They also include several sub-services and sub-components (see Table 8 in section 1.4). "Equipment Solar Field and HFT System" consists of mirrors, metal structure, receivers, piping, etc. Category "Others" (19 percent) includes the important cost parameters: project development, management, financing (and allowances).

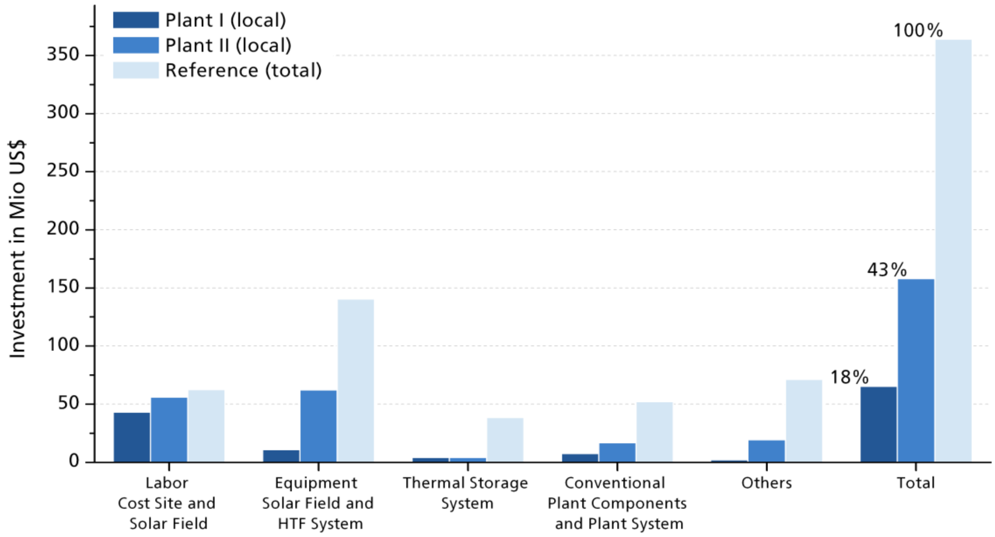
Figure 58 Total cost distribution for reference plant



Share of the local manufacturing - recent ISCCS projects

Information has been collected from newly installed ISCCS plants in the MENA region to identify the current status quo of local manufacturing. The findings have been transferred to a virtual 50 MW reference plant because the ISCCS power plants have a quite different plant design due to the low solar share (approx. 5 percent) related to the output of the combined cycle plant.

Figure 59 Comparison of the status quo of local manufacturing for CSP projects in the MENA region



The virtual reference plant shown for two different cases, a low and medium share of local manufacturing respectively, indicates the different situations of local manufacturing. The situations are project related and depend on many circumstances and the project characteristics.

Plant 2 (similar to Egyptian ISCCS plant) has a local share of over 43 percent with respect to the total plant investment. The share of components or services imported from international companies which provide project development or management is still high with 57 percent.

Lower shares of local content at 18 percent are, however, also found in the region. In Plant 1 (other ISCCS in MENA region), only civil and construction works are provided by the local workforce and companies. The status quo was obtained and cross-checked by industry surveys and expert interviews.

This current status was used as the baseline for future projects, with the projection that future projects increase the local shares. Future forecasts will give average potential results for local manufacturing in the region as different, project-related local shares occur. Plants with a higher share of local manufacturing are expected to have a strong economic and social impact compared to CSP plants with lower shares.

The economic benefit varies from one country to another, depending on market size, industrial potential of local manufacturing and the available technical know-how for manufacturing and producing components. The value of the involvement in the construction and planning of the plant is also considered.

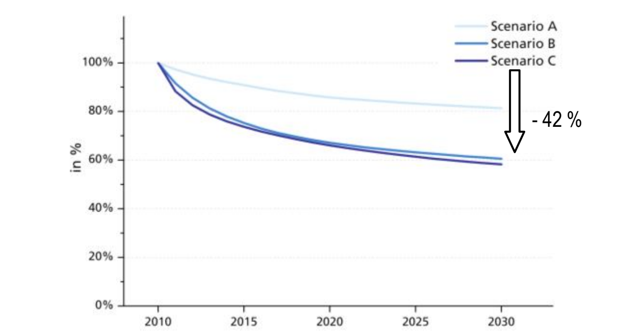
The proposed actions and programs detailed in the previous chapter would shift the share of local manufacturing over time in MENA countries. This effect is also reflected in the model.

Cost scenarios

To calculate the value added in the region, a simulation model of the future investment costs for CSP plants is necessary to obtain annual data over the next 20 years. Future cost developments and cost reductions on the component and plant level have been modeled by learning curves which are related to the world market growth as determined in the scenarios of the Greenpeace Report (reference, moderate and advanced). Learning curves are based on a historical observation of different technologies whereby the production costs decrease over a longer period, if output is doubled. Experience curves for CSP are broken down by findings from the SEGS plants in California with parameters ranging from 90 percent for solar field and 98 percent for conventional plant components (Trieb 2009). The starting value for the total investment is based on US$364 million in 2010. As shown in section 1.4, this already takes into account a reduction of investment costs of 7 percent compared previous Spanish CSP projects. The results of the cost reductions are cross-checked with the expectations and forecasts recently published by Estela and AT Kearney in June 2010 (see Table 13) that are in line with the authors´ estimations.

Table 37 Learning curve parameters for cost scenarios (Experience curve, see also Trieb 2009)

CSP plant 50 MW with storage (7 hours)	Experience curve parameters
Labor Costs: site and solar field	98 %
Equipment Solar Field and HFT System	90 %
Thermal Storage System	92 %
Conventional Plant Components	98 %
Others	90 %



These learning curves were generated for the different costs of the plant (construction, solar field components, power block, etc.) and take into consideration the different world market scenarios of the Greenpeace Report 2009. The experience curve describes the decline of investment costs when the production volume of CSP doubles. Since scenarios B and C are linked with the moderate and advanced scenario, cost reductions are larger than in scenario A because of the low world market growth.

Components specific input

To create a local CSP industry in MENA, a large market demand is first required so that local and international firms build up new production capacities in MENA. Volume barriers of factory output have been included to obtain the specific demand levels necessary for opening up new factories.

Process and product know-how must be available in order for local companies to enter the market. For companies existing in other countries, their numbers of local skilled workers has been large enough in each country so that new productions and factories are created with or without joint ventures.

Selection of most main parameters influencing the model:

- Status quo of local manufacturing in CSP project
- Component specific potential for local manufacturing
- Minimum annual factory output
- Market potential / market scenarios
- Job impacts

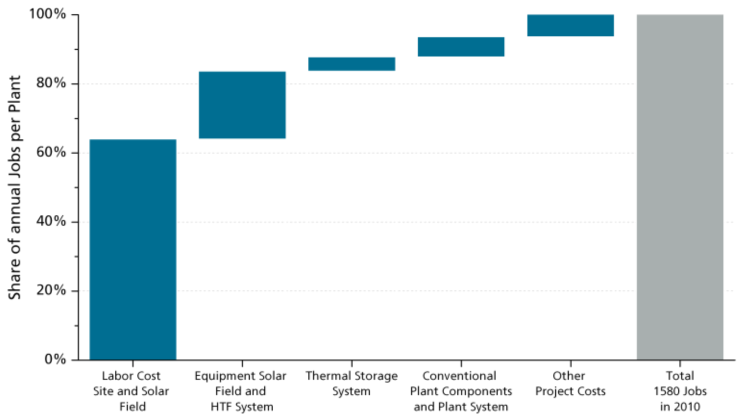
Job development

In section 1.3 and 1.4 the job effects of CSP have been presented based on a European CSP plant. For the modeling some assumptions have been made to shift the job effects on the MENA market:

- The job market in MENA is highly influenced by low labor costs, availability of skilled and low-skilled workers but also by lower productivity of the workforce. As a result, twice as many workers as needed are used for construction.
- For component manufacturing, the same number of required jobs was assumed as in Europe because many production processes would include similar machine equipment in MENA. Thus, a similar workforce would be needed to run such factories.
- With an experience curve value of 0.98 on the labor costs, the number of workers required to construct the plant will decline continuously as cost reductions will also influence the number of jobs on the construction site.

The basis of the job calculation is the number of total jobs that are created by one reference plant. This reference plant in North Africa had a total amount of 1,580 employees in 2010 (one-year equivalent)[33].

Figure 60 Total number of jobs created by a reference plant in 2010



Operation and maintenance of the plants will add many new jobs over a longer time period, after the initial construction of the plant. Wages and the amount of employees were adapted to the MENA case: lower wages and more workers over the lifetime of the plant (41 direct jobs). Because of low labor cost in North Africa, higher values for jobs are expected compared to European or US power plants. For future plants, a fixed number of workers is assumed. Efficiency gains and new methods of O&M planning, however, could decrease this number.

33 Protermosolar, as a feedback to this report, provided a higher figure of 4000 employees (1 year equivalent) for the reference plant including the whole value chain: R&D, project and site development, basic engineering, manufacturing of components, financing, EPC, detailed engineering, construction.

4.2 Average share of local manufacturing in The MENA Region

The share of local manufacturing for the defined scenarios A, B and C covers all CSP plants constructed in the future in the region. The status quo of local shares lies between 17 percent and 43 percent. The average local share of added value ranges from 23 percent in 2012 in scenario A to 57percent in 2025 in scenario C.

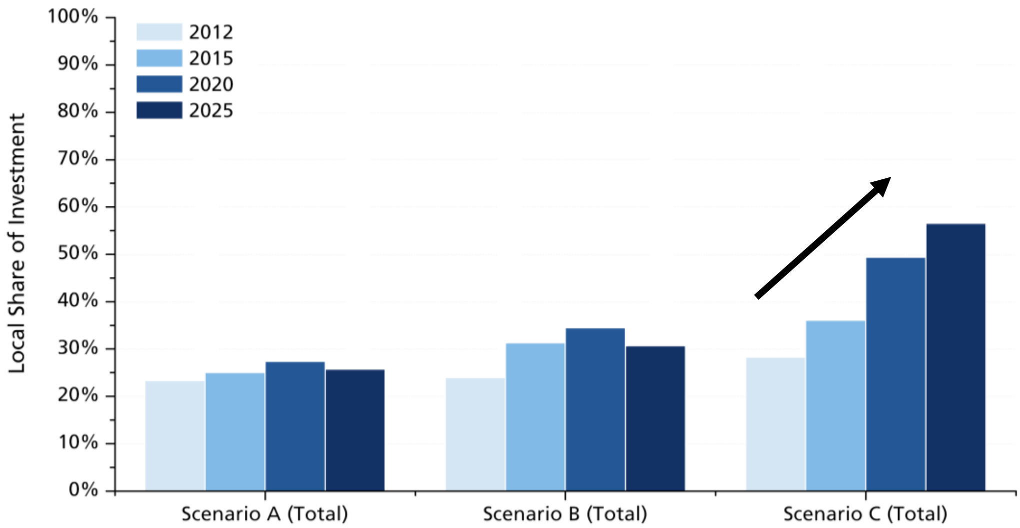
In a slow market development resulting from other competitive technologies or low financial support, the local share is limited to about 34 percent of the total investment for construction and components (scenario A).

Scenario B has a low impact on local manufacturing because the main CSP components are imported from elsewhere. Only experience in construction and project organization increase. After 2020, a continued low market growth could decrease the local share of each plant since larger production in other countries could produce components more economically than companies in a small MENA market.

Large market demand (scenario C) stimulates the creation of a CSP industry in the MENA region. This development could increase the local share up to 70 pecent of the total value in some projects. Local mirror and receiver production starts in this scenario between 2015 and 2017. Other special components are also produced due to the large market size. After 2025, the share of local manufacturing is assumed to increase further due to more technology transfer and knowledge sharing through realization of many CSP plants in the region.

Market demand is the main driver of local manufacturing as the size of the market attracts local companies to invest in new production lines or international investors to build up local subsidiaries.

Figure 61 Share of total local manufacturing potential in scenario A, B, C

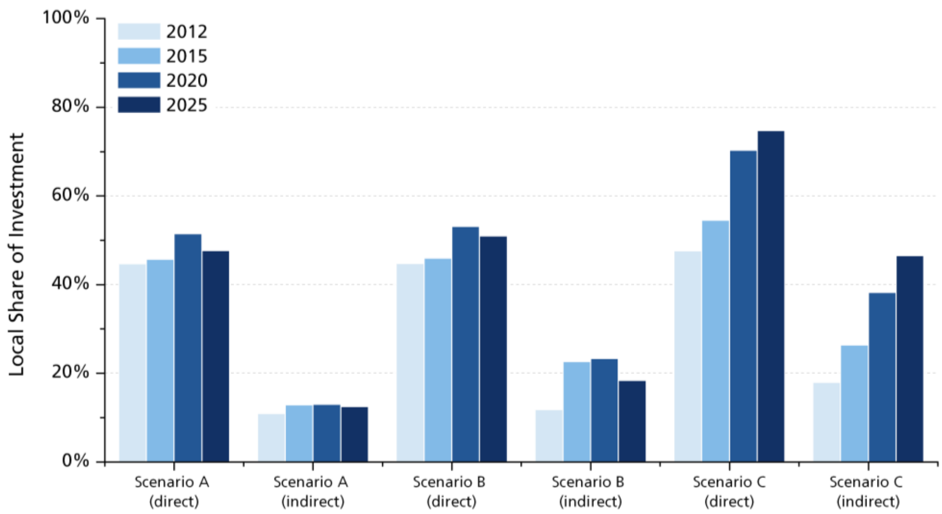


If the investment is split in direct (construction) and indirect (components) effects, then the scenarios can be analyzed in a bit more detail. Direct effects contain all labor on the construction site as well as costs related to project development, project management, financing and allowances.

Scenario C, the “Transformation” scenario, also leads to growth in the manufacturing industry with a local investment share of up to 50 percent. Scenario C also forecasts a mirror production capacity in MENA. At the same time, the construction is done locally with an overall share of up to 75 percent in 2025. Opposite effects are observed in scenarios with small markets. Here only 20 percent (only metal structure and some other components) could be produced locally. Direct effects are lower in all scenarios because it also includes engineering, management, and financing values, which contribute to a decreased share of local content in the labor specific works (construction of solar field).

The scenarios do not contain modeling of local content clauses which would require a specific local share for each project. If such local content obligations would be introduced, the share of local manufacturing could be much higher. However, this could also affect costs, design or plant realization.

Figure 62 Total local manufacturing potential for construction and components



A stable market and large market demand (scenario C) will influence many investment decisions on the local production of CSP components. Many added value processes could be done locally as shown in the following table, e.g. mirror production (2016-2020) and project development (2020-2025) in MENA.

Table 38 Time schedule of local manufacturing of components and services

Scenario A and B:			
From 2010	2011-2015	2016-2020	2021-2025
Pylons, Foundation, Support structure (Egypt)	Metal support structure, EPC (Egypt)	EPC (rest)	
Scenario C:			
From 2010	2011-2015	2016-2020	2021-2025
Pylons, Foundation, Support structure (Egypt)	Metal support structure, EPC (rest)	Mirrors, Swivel joints, Receiver	Project development, Management

4.3 Direct and indirect economic impact

Effects on direct and indirect economic values are calculated in absolute numbers for each scenario. In addition to local manufacturing of components and construction of the plant, operation and maintenance (O&M) will also contribute to the economic impact of CSP plants in MENA. Local economic impact is calculated for each scenario by a model which integrates the dynamic development of the local share and market size over time. All investments in components and services provided by local companies and by international companies producing locally are added up to local economic impact. ***Direct*** **economic impact is related to construction of new power plants.** ***Indirect*** **effects are economic impacts by demand in the supply value chain.**

The economic impact is strongly related to the market size of CSP in MENA. An installed capacity of 5 GW by 2020 as in the "Transformation" scenario creates a local economic impact of US$14.3 billion, compared to US$2.2 billion in scenario B. The higher share of local manufacturing in the "Transformation" scenario adds more economic benefit to the countries. Local revenue in scenario A is only US$916 million in 2020. The following table summarizes the cumulative impact in 2012, 2015, 2020 and 2025. The local economic impact rises from 32 percent in scenario B to 40 percent in scenario C by 2020 due to the larger market size.

The share of O&M in the economic impact increases from 8 percent in 2012 to 32 percent in 2025 because of the continuous economic impact over the lifetime of the power plant. Annual expenditures for operation and maintenance as well as employee salaries create an important long-term positive impact.

Table 39 Direct and indirect local economic impact in scenarios A, B and C

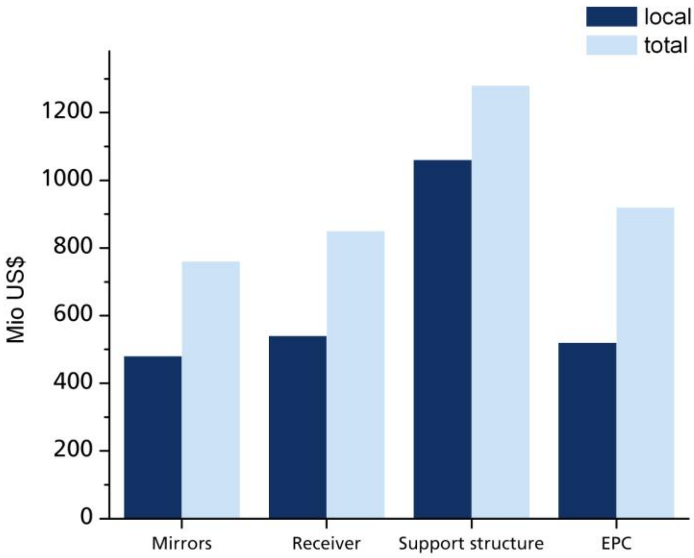
In US$ million (cumulated)	**2012**	**2015**	**2020**	**2025**	Local share by 2025	Cost reduction by 2025
Scenario A	30	193	916	1,498	25.7 %	~ 16 %
direct	20	125	571	946		
indirect (supply value chain)	10	68	344	551		
Scenario B	61	465	2,163	3,495	30.6 %	~ 36 %
direct	39	251	1,167	1,959		
indirect (supply value chain)	22	213	996	1,535		
Scenario C	368	2,803	14,277	45,226	56.6 %	~ 40 %
direct	206	1,403	6,999	21,675		
indirect (supply value chain)	162	1,401	7,278	23,551		

Additional induced economic impacts will appear if investment in CSP takes place in a region. Models (JEDI) for US regional assessment, established by the New Renewable Energy Laboratory (NREL), describe almost the same amount of induced impact for a region as indirect ones. **Induced impacts result from an increase of wealth and income that create new demand for more services and products.** Significant induced impacts need to be added on top of calculated direct and indirect effects but are difficult to assess correctly.

The total effect of US$2.2 billion in scenario B ("No-replication" scenario) is calculated as a total value over all countries and projects. It includes the results of the previous section giving an average local share of 40 percent in 2020. If all projects will be realized with the same local content as the reference, Plant 2, this value will be significantly higher because the local content for Plant 2 is assumed to be above 40 percent (for a reference 50 MW plant with storage). The average value of 35 percent in 2020 is lower because of a lower assumed status quo in other projects.

A breakdown of revenues for selected components (mirrors, receivers, support structure and EPC services) in the year 2025 is shown in **Error! Reference source not found.** for scenario C.

Figure 63 Figure: Local and total revenue for selected components in 2025 in scenario C



4.4 Labor impact: job creation

The results of the labor impact assessment give the numbers of direct job creation during CSP plant construction as well as the indirect job creation in the factories of local manufactures while using the same definitions for local impact as for the economic effects.

The operation and maintenance of the plant will also create long-term employment in the solar sector as about 41 jobs are needed to run a reference power plant. Because of the replacement of components and equipment, the plant maintenance also has an indirect impact on new jobs. Many new jobs in construction and O&M will also have an impact on induced jobs in the region. Number of indirect jobs for construction and O&M will increase other induced jobs. This leads to higher wealth and income of the region when new services and products for their private consumption are demanded.

Permanent local jobs by 2025

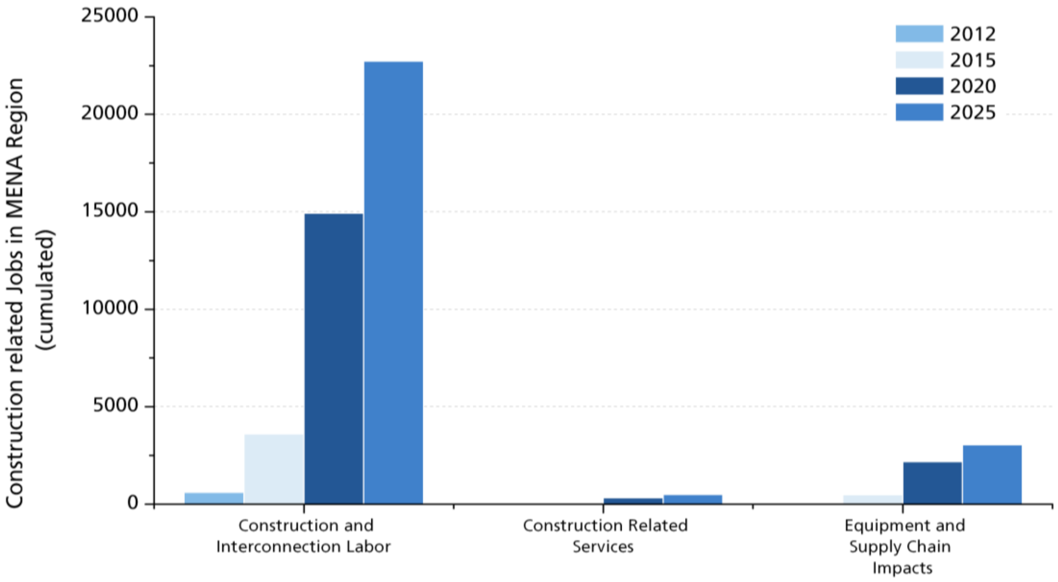
Until the year 2025 the number of local jobs in construction and manufacturing rises up to 46,000 and 60,000 jobs plus 19,000 jobs in the operation and maintenance in scenario C. In case of a strong market development as in scenario C (also in B) the jobs in construction still increase, so that even the project-based, construction effects have a permanent and long-term character. Jobs from O&M are permanent jobs for at least 25 years.

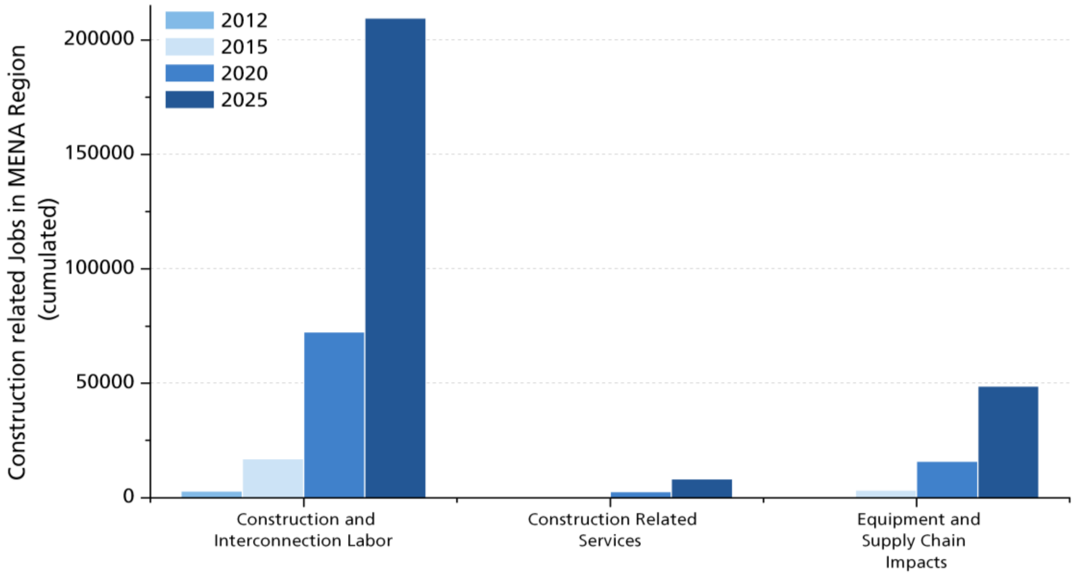
Local jobs in construction and value chain (cumulated numbers)

The labor impact is calculated on the values for construction of the reference plant and the number of jobs created by component manufacturing as local market demand for components grows as well. It is given below as cumulated number of one-year jobs between 2011 and 2025. During the construction of the plants, which represents the largest number of jobs, until the year 2020 about 15,000 local jobs will be created in scenario B compared to 72,000 in scenario C (cumulated values, see **Error! Reference source not found.**).

The number of local jobs related to total jobs increases in scenario C as the local share increases. However the higher learning curves and cost reductions in the best case scenario lead to a decrease of the absolute (local and international) number of jobs.

Figure 64 Cumulated number of jobs (1-year full-time equivalent) during construction for scenario B (upper graph) and C (lower graph)





If the CSP market grows to over 20 GW by 2025 as in the “Transformation” scenario, a cumulated number of jobs of over 200,000 (1-year full-time equivalent) for construction and interconnection labour will be created in the five countries. Additionally, 8,000 high-skilled jobs in construction-related services for project management and development will also improve the socio-economic situation. In the “Transformation” scenario, 48,700 new local jobs for manufacturing of components could also be created by 2025 in a conservative calculation, assuming that local component manufacturers use the same number of employees as comparable factories in Europe.

Jobs in operation and maintenance

Operation and maintenance (O&M) of the CSP plants in each scenario requires also a large number of regular jobs during the lifetime of a CSP plant. By 2025, 19,000 employees are to work in O&M as operator, cleaning personnel, technical worker or security staff in one of the CSP plants (scenario C). As O&M is strongly linked with the installed CSP capacity, these values in scenarios A and B are lower with 1,000 and 2,000 employees respectively by 2025. These tasks can be mainly performed by local employees and add more socio-economic benefit to the countries as the number of required employees are higher than those of conventional power plants with similar output.

Table 40 Number of employees for O&M of CSP plants in the five countries of the MENA region

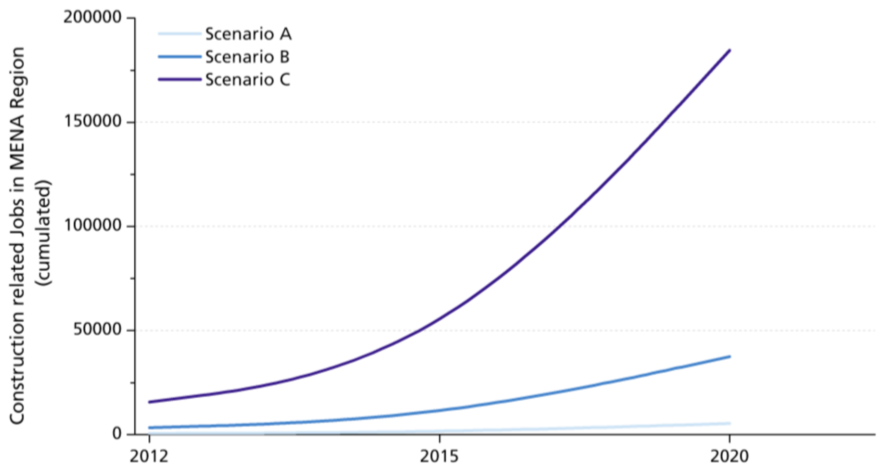
O&M Jobs in year	2012	2015	2020	2025
Scenario A	26	158	657	1,018
Scenario B	53	315	1,313	2,036
Scenario C *	263	1,576	6,567	19,102

* only plants built in the CTF MENA countries are considered here (i.e. 5 GW in 2020)

Total local jobs by 2020 (cumulated)

If all O&M jobs are added to the jobs during the construction phase, the number increases further. By 2020, the total cumulated jobs (one-year jobs in full-time equivalents) will jump to over 180,000 in scenario C. Only 33,000 jobs in scenario B will have a lower impact on the local economics and technological know-how. In 2020, 34,000 employees work in construction and O&M in scenario C permanently. In scenario B (in 2020) a workforce of 4,500 local employees is created.

Figure 65 Total number of annual jobs created by CSP deployment in the five countries of MENA



Opportunities for new highly skilled employees in MENA countries

Besides these direct and indirect impacts, CSP plants offer the opportunity for MENA countries to attract more jobs for highly skilled workers, like engineers and technicians. By creating a skill enhancement for local workers, a sustainable development of the region can be reached within the next two decades.

The cooperation with international operating firms in the energy sector will open further business opportunities for these countries and this can lead to additional economic benefits. The local manufacturing of CSP components can push the local manufacturing of other products and create an attractive income for the local industry if the products are sold on the global CSP market.

4.5 Foreign trade impact

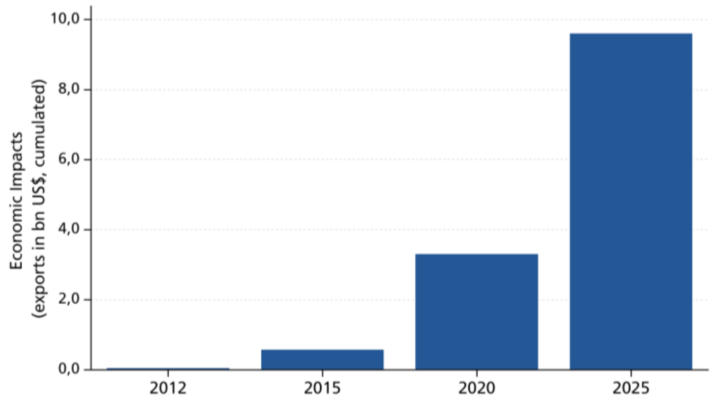
Trade growth of CSP components to external CSP projects in African or Arab countries, or in European or US markets, can strongly increase if a national decision to promote CSP technologies is made at an early stage of market development. First movers, potentially based in the MENA region due to the established large local markets and attractive solar potential in North Africa, could supply the international market. These international markets could be either found in the surrounding area. Exports to international CSP projects will have the additional benefits of promoting international integration on the political, social and economic level.

In scenario C a volume of 2,000 MW for components export was included to show economic impacts on the economies in the MENA region. In the model, the export market adds additional demand for manufacturing in MENA. This demand facilitates the growth of a local MENA market. But export will only take place if local demand exists in the region.

Components like mirrors or receivers are exported in the scenario C (with a demand of 2 GW to supply CSP by the MENA region). This demand could only be continuously satisfied by local factories. If competitiveness is reached, export will start with the same components that are produced locally in 2012: metal support structure or pylons. Later, when other key components like mirrors are produced locally, export markets could be supplied by factories in North Africa.

In such a scenario, job creation and growth of GDP arise out of this export opportunity. By 2025, over US$9.6 billion could be earned by exporting CSP components to external CSP projects. That would create 19,000 annual jobs, especially in the manufacturing of components. As in scenario C, products including parabolic mirrors, receivers and other highly technical equipment are produced for the local market and for export on the international market by 2020.

Figure 66 Economic benefit and job effect by export outside MENA region



Key success factors for the foreign trade impact are:

- Stable home market as basis for export expansion
- Large growing world market
- Price competitiveness to international competitors
- International quality standards
- Reduction of trade barriers within MENA and to Europe
- Creation of regional lead market players for different components and equipment

Price competitiveness is a particular strength for North Africa as industry representatives expect lower production costs in MENA compared to Europe. Quality control will be critical, however, and potential local companies will have to focus on this issue.

4.6 Conclusion of chapter 4

In the “Transformation” scenario (scenario C) with large market growth, the total potential of local manufactured added value of CSP plants will increase constantly and could reach almost 60 percent as average value for all CSP projects.

The average share of local added value ranges from 20 percent in 2012 in scenario A to 60 percent in 2025 in scenario C. Assuming a slow market development, which can be the result of competition with other technologies or a lack of financial support for CSP plants, the local share would be limited to about 27 percent of the total investment for construction and components (scenario A). Also under the conditions of scenario B (“No-replication” scenario) the impact on local manufacturing is comparatively low, as most CSP components would remain imported, only construction, and project management, and basic engineering services might increase.

Market demand is the main driver of local manufacturing because a large market attracts local companies to invest in new production lines or international investors to build up local subsidiaries. Large market demand (scenario C) stimulates the creation of a CSP industry in the MENA region. This development could increase the local share of some projects up to 70 percent. After 2025 the share of local manufacturing is assumed to increase further due to technology transfer and the knowledge acquired through realization of many CSP plants in the region.

The level of local share influences economic impact and job impact of CSP development in the MENA region. Economic impact is strongly related with market size of CSP in the MENA region. 5 GW by 2020 in scenario C create a local economic impact of US$14.3 billion, compared to US$2.2 billion in Scenario B.

In the year 2025 the number of permanent local jobs can rise up to between 64,000 and 79,000 (scenario C). In the construction and manufacturing sector there are 45,000 to 60,000 annual jobs created plus 19,000 annual jobs in operation and maintenance.

Looking at the time horizon of the CTF projects (only until 2020), between 2011 and 2020 the following results arise: Within these ten years the cumulated total jobs of full-time equivalent (1-year) for construction, manufacturing and O&M will increase to over 180,000 in scenario C. That means 34,000 employees working in CSP industry permanently by 2020 . By contrast, in scenario B 33,000 jobs (cumulated over 10 years) will have a lower impact on the local economy and technological expertise. In this scenario a permanent workforce of 4500 to 6000 local employees is created by the year 2020.

Additional impacts for job creation and growth of GDP could come from an export opportunity of CSP components. Besides economic and social benefits, MENA countries could also increase local technical expertise in renewable energy technologies by following the path to invest in solar energy.

Overall conclusions

In this study we have analyzed the local manufacturing potential of MENA countries for CSP technologies.

The **value chain of CSP technologies** and the international companies currently active along the value chain have been thoroughly assessed. Considering the strategies and interests of the main CSP technology manufacturers, they show a high potential to participate in future MENA CSP markets and are already involved in the ongoing three CSP projects in MENA (Morocco, Algeria, and Egypt). Depending on the market size in MENA countries, these companies also show substantial interest in building manufacturing capacities in the region. The minimum market size, for which local manufacturing is possible, strongly depends on the component under consideration. With a description of production and manufacturing processes for main CSP components, the complexity and required technological expertise were analyzed by focusing on key components for CSP: solar field with collectors, mirrors and receivers. Cost evaluation of current CSP projects indicates the high share of these components (solar field 38.5 percent) of the total investment. Industry forecasts also predict possible cost reductions ranging between 40 and 50 percent by 2025 due to efficiency increase, economies of scale and further technology improvements derived from research. In combination with an outlook on future cost reductions, this first step provided the technical and economic background for the assessment of local manufacturing of CSP components and service activities.

The **potential of industries located in MENA for local manufacturing** has also been assessed. Several industrial sectors that have the potential to integrate the CSP value chain in the MENA region are dynamic and competitive at a regional and sometimes at an international scale. As an example, the glass industry, particularly in Egypt and Algeria, has long been a regional leader and continues to increase its production capacity. The cable, electrical and electronic industries have established a similar position, especially in Tunisia and in Morocco. The success of these industries is enhanced by the development of joint ventures between large international companies and local firms, but also by the local implantation of subsidiaries of international players.

The development of MENA CTF industries was initially driven by the low cost of labor and energy (the latter is particularly relevant for Algeria and Egypt) and also by the geographic proximity to Europe; delivery to Europe within 48 to 72 hours is possible. This efficient delivery to Europe is a key factor for short production cycles with variable specifications, for example components, cables, and wiring for the automotive sector.

In order to position themselves on the CSP market, MENA CTF industries face several challenges, and are adapting their industrial capacity to higher technology content (for example in the glass industry). The landscape is already changing; the situation of pure subcontracting is now shifting towards more local R&D and the production of high-tech components. MENA CTF countries are aiming to be considered as "centers of excellence" instead of low cost, skilled workshops. The shift towards higher technology content will require increased international cooperation. In the glass sector, for example, Guardian Industries have taken over the "Egyptian Glass Company," while a technology transfer agreement has been signed between PPG and Sphinx Glass.

Furthermore, the realization of flexible production lines might contribute to a mitigation of the risks related to the CSP market's evolution. For example, steel structure manufacturers usually adapt their production tools to different products with little effort.

Regardless of the identified obstacles to a participation of the local MENA industries, the expert interviews with MENA companies and with the existing CSP industry have shown an increasing potential for local manufacturing of components for CSP in case the CSP market grows continuously in MENA. Also, the participation of local firms in the provision of construction and engineering services for new CSP plants in the MENA region have been identified as an activity with promising growth in the future.

In a third step roadmaps and action plans have been presented for the key components and services of the CSP value chain. Technological, entrepreneurial as well as policy and market developments, which are crucial for the establishment of local manufacturing in MENA, have been emphasized. National strategies for industrial development and energy policy should be coordinated and involve clear targets for the market diffusion of CSP as well as substantial R&D efforts, strategy funds for industrial development of CSP industry sectors and stronger regional integration of policies. To enhance the innovative capacity of the industrial sectors, the creation of a larger number of technology parks/clusters and regional innovation platforms should be encouraged. These technology parks would particularly help small and medium-sized firms to overcome innovation barriers and to gain access to the latest technological advancements. Business models should build on the comparative advantages of certain sectors in MENA countries and also involve international cooperation agreements, e.g. in the form of joint ventures and licensing. In the case of receivers, subsidiaries of foreign companies will most likely be a relevant business model in the beginning.

The investment in new production lines based on highly automated processes for the mounting structure and in white glass production as well as adaptation of techniques for coating and bending, in the case of mirrors, will be the crucial first step. In order to engage in such investments, market actors will need good access to CSP—related information and certainty about the market development. Technical feasibility studies regarding production line upgrades could be an important element to assist enterprises. The creation of a regional CSP- or renewable energy association dealing with issues such as the CSP market development, manufacturing options and the latest technological advancements, might be an essential element in this respect. Entering local manufacturing will involve the comprehensive education and training programs for the industrial workforce in relevant sectors. Universities should be encouraged to teach CSP technology—based courses to educate potential workforce, particularly engineers and other technical graduates related to the CSP branch.

To assess the potential benefits of a steady growth of the CSP market in MENA, a dynamic economic modeling approach was used to determine the impact on economic value creation, foreign trade as well as job creation. The model considers a continuous local market based on the three different growth scenarios: Scenario C "Transformation" (5 GW domestic CSP plants by 2020 plus component exports for the equivalent of 2 GW), scenario B "No-replication" (1 GW by 2020) and scenario A "Stagnation" (0.5 GW by 2020). In the different market scenarios, the share of local manufacturing was dynamically modeled with respect to the required market size and the continuous growth of local technical expertise.

The MENA countries would obtain substantial economic and social benefits from a steady CSP market growth. The knowledge in renewable energy technologies would also increase which would induce further positive effects. In an optimistic scenario, the total potential of the local manufactured added value of CSP plants could reach almost 60 percent.

By 2020, the cumulated total jobs (one-year) for construction, manufacturing and O&M would increase to over 180,000 in scenario C. Considerably smaller effects have been identified for the two other scenarios: e. g. only 33,000 jobs would be created in scenario B.

Significant economic benefits for the MENA countries could also be attributed to growing export opportunities related to a developing CSP market. In the "Transformation" scenario (5 + 2 GW by 2020) a total local economic impact of US$14.3 billion was identified, compared to US$2.2 billion in the smaller scenario B.

Annex A – Additional data

Annex to chapter 1.1.

Vacuum Receiver

The receiver is the component of the collector where the concentrated solar heat is absorbed and transferred to a fluid, in the commercial reference technology described here, to synthetic oil (e.g. Therminol VP-1). The receiver consists of an absorbing tube and an evacuated glass tube surrounding the absorber tube, see Figure 67.

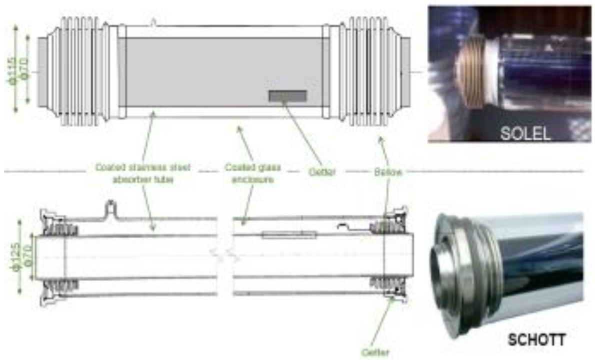


Figure 67 Sketch of the receiver construction of the two today's only two suppliers Siemens (formerly Solel) and Schott Solar (NREL, 2008)

The absorber inside the receiver is realized in the form of a coated steel tube. The coating is spectrally selective in the sense that it absorbs well the solar irradiation and emits (almost) no infrared radiation, in order to reduce heat loss (Hildebrandt, 2009).

The absorber tube is surrounded by an evacuated borosilicate glass tube which is highly transmissive for the sun light due to an anti-reflective coating. The connection of the tube and the glass is assured by bellows at each end. Heat losses through convection and conduction are prevented by the evacuation of the glass tube. The drawback of the glass tube is that it partly reflects the solar irradiation. To reduce this efficiency diminishing effect, an anti-reflective coating is applied on both glass surfaces (inner and outer). This layer reduces the reflection losses from 8% down to 4%.

The absorber coating on the steel tube is a complex layer system of basically three different layer sub-systems. The inner layer consists of a metal with low thermal emissivity. Compared to a blank steel tube, this first layer reduces heat loss by infra-red radiation. The second layer sub-system is made of cermet (mixture of ceramics and metal) and increases the absorption of the sun-light. The cermet is realized in the form of several single layers forming a gradient from higher metallic fraction to higher ceramic fractions. The third layer is an anti-reflective coating to further reduce reflection losses on the tube surface.

Another big technical challenge is the thermal expansion of the receiver because it is exposed to immense day and night temperature variation. The thermal expansion of the steel pipe is buffered by the bellow construction which is flexible and therefore able to compensate the prolongation of the pipe. The thermal expansion of the glass tube and the bellow has to be similar to maintain the vacuum and protect the metal-glass-sealing from breakage through expansion. This is solved by using a special glass which offers steel similar expansion characteristics.

The sealed container, provided by the glass tube and the bellows, protects the vacuum from the ambient air, but another gas source is the gradual oil decomposition under high temperatures which emits hydrogen, able to diffuse through the steel pipe into the vacuum. High hydrogen concentration between steel tube and glass tube reduces the efficiency immensely as hydrogen is a first class heat conductor (better than air). To catch the hydrogen a so-called getter has to be installed in each receiver. These getters are able to trap the hydrogen molecules inside and keep them permanently. To reduce additional shading from the getters latest constructions are integrated into the bellows.

A state of the art receiver absorbs more than 95% of the solar spectrum and emits less than 10% of the infrared radiation of an equivalent black body at a temperature of 400°C (Schott, 2009 and Siemens, 2010).

It is likely that the receiver technology will remain as described here; however, probably, new producers will enter the market in the near future (Archimede, 2010). If other heat transfer fluids than the high-temperature stable synthetic oils are used slight adaptations are necessary, such as tube wall thickness for high-pressure direct steam generation, different tubing materials and others.

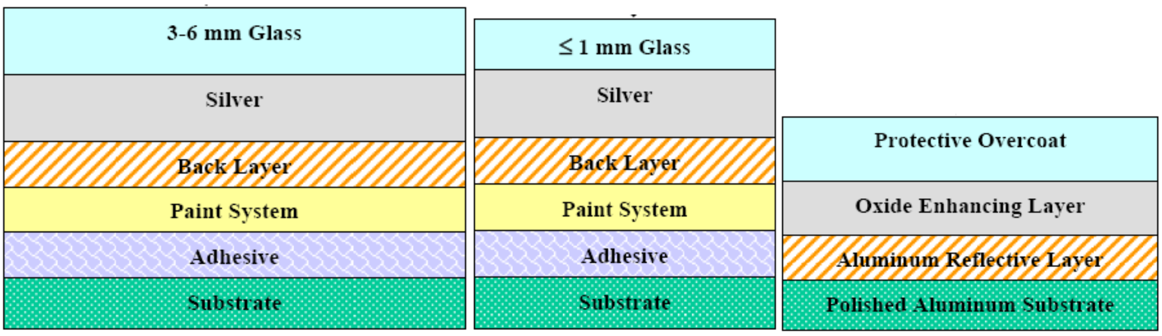
Parabolic Mirrors

The reflector is the second core component of the solar collector. It focuses the direct solar irradiation on a line where the receiver is located. This concentration is the key to the high temperatures in the receiver. The supply of a highly precise reflector shape is of crucial importance to achieve the high temperatures and high collector efficiency. Therefore high geometrical accuracy and high optical reflectivity is very important.

Figure 68: Mirrors in a parabolic trough collector at the Nevada Solar One power plant (source: Morin, 2010)

The only commercially proven reflector is the thick glass mirror (see Figure 69, left). These mirrors are currently produced by only four different companies in CSP power plant scale (Flabeg, Rioglass, Saint-Gobain and Guardian). The total trough aperture is segmented laterally in four mirror segments with a size per mirror of 2-3 m2, depending on the collector aperture, which – for most designs – is 5 m or 5.77 m.

The mirror consists of a bent glass sheet which is coated with reflective silver on the back-side of the glass and with several protective layers on the back of the mirror. Usually, four mounting pads are glued on the back of the mirrors for mechanic connection to the metallic sub-structure. The glass thickness is 4 or 5 mm (Flabeg, 2009). The used glass is so-called "white glass" (or "solar glass") and contains very little iron to achieve low solar absorption losses in the glass.



Thick glass mirror (left): The bent glass fulfils structural and protective demands. The reflective silver layer is protected by several additional coatings and lacquers. Thin glass mirror (middle): Principally the same construction but the glass layer has only protective purpose and the structural support is provided by a substrate (right). Front-Surface mirror (right): reduced glass absorption, the structural support is provided by a substrate on the back of the mirror

Figure 69: Comparison of different mirror structures, Source: (Kennedy, 2005)

The amount of mirrors in a plant depends on several factors such as storage (storage normally goes along with a larger solar field), site (higher solar irradiation requires a smaller field) and collector efficiency (efficient collectors require a smaller number of collectors). Approximately, the amount of mirrors needed in a parabolic trough power plant adds up to approximately 10 000 m^2 of mirrors per MWel. In other words, a 100 MW plant needs approximately 1 million m^2 of mirrors

Beyond the commercial thick glass mirrors, further mirror technologies are listed below (cf. also Figure 69):

- State of the art thick glass mirror: proven mechanical stability (e.g. scratching by sand/cleaning), proven durability in terms of corrosion of reflective layer, mechanical shape accuracy by glass itself; but relatively high cost, heavy and fragile (glass breakage during on-site-transport and mounting)
- Thin glass mirror: Higher reflectivity but (still) greater cost, difficult to handle (fragile). The thin glass needs an additional shaping sub-structure because thin glass is very elastic
- Front-Surface mirror in polymer foil: Polymer (PET) substrate with a metal or dielectric adhesion layer, a silver reflective layer, and a proprietary, dense, protective top hard coat. Excellent reflectivity (96%), good durability but long-time tests are not available yet (early market introduction) (Kennedy, 2005)
- Front-Surface aluminum reflector: Polished aluminum substrate, optionally silverized, with protective coatings on top. Well manageable, light, cheap reflective material but needing additional shaping structure. Combination of reflective and structural light-weight components are feasible but will need to proof cost-competitiveness with glass mirrors (Almeco, 2010).

Today, it is not yet clear if the impact of the advantages of alternative mirror materials will be large enough to compensate for their individual draw-backs.

Support structure

The collector support structure is the third core component of the solar collector. Its installation and mounting accuracy has high influence on the total plant performance. Therefore, it is very important to guarantee a high precision assembly and installation. The support structure has to face the following structural requirements:

- *Stiffness* – The structure has to be a robust, with a rigid frame, capable to maintain exact geometry (optical precision) at all times: It has to withstand deformations through the collector weight, through wind and through temperature differences of ambience and of the receiver
- *Weight* – Low weight reduces cost of both material and transport
- *Motion* – A high angular tolerance is necessary to enable one-axis tracking requirements. The tracking has to be accurate, robust and sufficiently strong to be capable to operate even under extreme weather conditions in the target countries

The metal support structure design is optimized to follow accuracy goals and to reduce investment cost which are composed of material, labor and transport.

Table 41 shows different structural concepts of parabolic trough collectors. One basic point where the concepts differ is how they transfer the torsional moment when tracking the sun. There are basically two concepts: the torque tube concept and the space frame concept. Most commercial collectors today use steel. However, also a few aluminum-based collector structure technologies enter the market. In addition to these general design data Table 42 shows material type and quantity for the two collector types which were installed first in commercial power plants since the CSP renaissance of the recent years.

Table 43 shows the total amount of steel respectively of aluminum used in exemplary CSP plans. The lowest amount of material is used in the Nevada Solar One plant by Acciona (formerly Solargenix). The reason is that aluminum has a higher specific stiffness than steel. On the other hand, aluminum is more expensive (per kg) than steel, which is why it is not obvious whether the material savings will pay off cost-wise. The Andasol power plant uses most of the material per MW installed because of the thermal storage which requires a 70% larger solar field than without storage.

Table 41 Parabolic trough solar collector assembly types, installed in commercial power plants

Name of Company / Collector	Photograph	Aperture width / Description of Structure	Power Plant Location
Luz / LS-2 (NREL, 2010)		5.00 m Torque-tube, galvanized steel	SEGS I - VII, Southern California, USA
Luz / LS-3 (NREL, 2010)		5.77 m Bridge truss structure (instead of torque tube), galvanized steel	SEGS VIII - IX, Southern California, USA
FlagSol / Skal-ET (EuroTrough ET150) (BMU, 2010)		5.77 m Torque box, steel structure	Andasol-1 power plant, Guadix, Spain
Acciona (formerly Solargenix) / SGX-1 (NREL, 2010)		5.00 m space frame based on extruded aluminum	Nevada Solar One, Boulder City, Nevada, USA
Sener / Senertrough (Erasolar, 2010; Castaneda, 2006)		5.76 m torque tube, steel structure with stamped cantilever arms	Andasol-1 power plant, Gudadix, Spain (demonstration loop)
SkyFuel / SkyTrough (SkyFuel, 2010)		6.00 m aluminum space frame	SEGS II plant (demonstration loop)

Table 42   Material type and quantities of the first two CSP collector types

Sample Collectors	Solargenix SGX-2	Flagsol Skal-ET 150
		 (Solarel, 2010)
Structure	Recycled aluminum or steel struts and geo hubs (D.Kearney 2007)	Torque box design- galvanized steel (D.Kearney 2007)
kg/m² per aperture area	~ 22 kg/m2 (D.Kearney 2007)	~ 33 kg/m2 (D.Kearney 2007)
Material quality	6061 T6 aluminum (70-80 % recycled content) (Hydro 2010)	85 % S235JRG2 14 % S355JRG2 1 % X5CrNi 19-10 (Solarel 2010)
Materials used	Similar parts	Equal angles (60 %), Plates (10 %), Square Tubes (15%), Rods, mills, profiles and fasteners (15 %) (Solarel 2010)

Table 43   Total amount of steel respectively of aluminum used in exemplary CSP plants

Power Plant / Supplier	**Andasol 1** (Flagsol/ACS Cobra)	**Nevada Solar One** (Acciona, formerly Solargenix)	**Puertollano** (Iberdrola)
Material	Steel	Aluminum	Steel
Rated Power	50 MW	64 MW	50 MW
Storage	7.5 hours	No storage	No storage
Solar Field Size (Total mirror aperture)	510 000 m²	360 000 m²	290 000 m²
Technology and Quantity	Eurotrough SKAL-ET design: 624 collectors and pylons total 9400 tons of steel	Solargenix SGX-2 design: 760 collectors and pylons total 4300 tons of Aluminum	Eurotrough design: 352 collectors (each ~15 tons) and pylons total 5300 tons of Steel
Metal needs per MW	190 tons / MW	70 tons / MW	110 tons / MW

Tracking

Another challenge of the collector design is the tracking unit and its optimal introduction into the construction. To avoid supplementary loads and harm to the engine the axis of rotation (fulcrum) and the centre of gravity (centroid) should be as close as possible to the swivel points. Most tracking units rely on hydraulic drives, powered by small electrical engines, to generate the necessary energy to track around 150 meters of collectors precisely by one or two drives.

The tracking of the parabolic troughs is realized by hydraulic lifting device. Small electric motors provide the necessary oil pressure. The whole system can be delivered by second hand suppliers, as the technology is well developed by other branches like building construction or automation industries. The CSP challenge lies in the necessary robustness. The whole system has to work precisely for decades under tough dessert like conditions. Especially grains of sand represent a threat to the functionality because they increase abrasion. All SEGS power plants are equipped at present with Bosch Rexroth tracking (Bosch, 2008).

Figure 70 shows the hydraulic actuators and their technical properties from the company Parker, used in the Nevada Solar One plant.

- 760 units for Nevada Solar One
- Hydraulic cylinders operating at 3,000 psi
- Mating pinion gear rotates 240° and produces 300,000 lb-in. of torque
- Enough to move the solar array when winds exceed 40 mph, yet hold position within 0.1°
- A low-speed, 1.5-gpm pump, driven by a1/3-hp, single-phase electric motor, powers the actuator as it positions the solar array to track the sun
- At the end of the day, a high-speed 3.75-gpm pump engages and quickly returns the panels to the home position

Figure 70 Hydraulic rotary actuators for collector tracking used in the plant Nevada Solar One (Parker Hannafin's HTR series) (Parker, 2008)

Piping

Once the thermal fluid has been heated in the solar field it has to be transported to the power block. This is done by a closed loop around the solar field. A header tube transports the cold fluid to the collector lines and another header tube transports the hot fluid back to the power block (see Figure 71, left).

Figure 71 Solar field piping; one header pipe transports the cold oil to collector, the second header pipe transports the heated oil back to the power block; (source: Estela Solar, 2010); Assembly of the piping (BilfingerBerger, 2010)

Expansion loops have to be integrated in the connection piping since the piping is exposed to high temperature changes and hence to thermal expansion. The piping has to be insulated to reduce the unavoidable heat losses to a minimum. A single pipe consists of a steel tube which is encased by a thick insulator which is fixed by galvanized steel nets (see Figure 71, right). Thin metal sheets form the external surface to protect the insulation from environmental conditions. Due to the large piping network, the piping is another investment intensive part of the power plant.

The insulation is made of mineral rock wool if the temperature is below 420 degrees Celsius (Kaefer insulations, 2010). The moving parts have to be insulated with fire proof materials, because of thermal oil that may escape from the closed system and catch fire when getting in contact with air. Most of the insulation work is done on-site by locals, as the work does not require a specialized workforce. Most of the insulation consists in prefabricated pieces that can be attached to the pipes.

Heat transfer system – Heat transfer fluid, pumps, heat exchangers

As mentioned above today's state of the art of parabolic trough power plants use synthetic oil as the heat transfer fluid which is heated from approximately 290°C to 390°C in the solar field. The thermal oil is a special chemical product, provided today by a few global players (see section 1.2). The fluid is pumped through the solar field by several pumps. Finally heat exchangers transfer the heat from the oil to the water steam cycle. Thereby the oil cools down and the pressurized water of the water steam cycle is evaporated and the steam is further heated (superheating) before it passes through the turbine, generating mechanical power respectively electric energy in the generator. Both the pumps and the heat exchangers are specialized equipment which can be provided by several international companies.

Beyond thermal oil, other heat transfer fluids are subject to research and development. The main alternative solutions are the use of molten salt (e.g. the same salt type as used in the storage, see sub-section below) or to generate steam directly in the absorber tubes, the so-called direct steam generation. Both raise the temperature to higher temperatures above 400°C and up to 550°C which results in higher power block efficiency. However, higher temperatures also increase heat loss in the solar field. The optimal solar field temperature depends on the respective site and the applied technology but will likely be below 500°C (Morin 2010).

The molten salt concept has the advantage of easing the storage, as no further heat exchanger (decreases efficiency and is expensive) is necessary in between the solar field and the storage system. A drawback is the high solidification temperature of nitrate salts which creates the necessity of additional heating to guarantee a minimum salt temperature at any time and at any place where the salt passes through.

The direct steam generation allows direct energy transport from the receiver to the steam turbine without a heat exchanger between the solar field and the water steam cycle. The direct steam generation reduces auxiliary pumping power in the solar field, reduces cost (no heat exchanger) and increases efficiency through higher steam parameters. A problem of this concept is the question of energy storage, which is subject to ongoing research and development (DLR, 2010) but has not yet been solved in a commercial scale.

Thermal storage

As mentioned above in section 1.1.2, the only commercial storage option available today is the molten salt storage, as used in the Andasol-1 power plant (see Figure 72 and **Error! Reference source not found.** in section 1.1.2). The cars on the plant site indicate the large size of the vessels. In-between both tanks, the oil-to-salt heat exchangers are visible. On the left edge of the picture, the HTF headers (2 parallel headers for hot and for cold oil) including the expansion loops are visible.

Figure 72 The storage system in the Andasol-1 plant (Relloso, 2009).

The basic features of the Andasol-1 storage are described as followed (Relloso, 2009):

- A nitrate salt mixture (60% NaNO3 + 40% KNO_3) with a melting temperature of 221°C is used in liquid state and stores the energy by heating it up from 293°C to 386°C.
- The storage comprises a hot tank and a cold tank. To charge the storage, the cold salt from the cold tank is pumped through the HTF-to-salt heat exchanger where it is heated by the HTF coming from the solar field. The heated medium is then stored in the hot salt tank.
- The storage is discharged reversing this process: The thermal oil is then heated by the molten salt and the salt is pumped from the hot tank back into the cold tank.

The Andasol-1 storage contains 28 500 tons of salt in the two cylindrical tanks with a height of 14 m and a diameter of 38.5 m each. At the given temperature range this amount of salt corresponds to a storage capacity of 1010 MWh_{th} or 7.7 hours of plant full load operation of the 50 MW_{el} power plant.

Storage benefits for the plant economics

The storage of heat in molten salt tanks generates three advantages in comparison to a non-storage CSP power plant.

First, the power plant is able to bridge periods of reduced solar radiance, due to clouds. During these periods, the power block is fed by stored energy from the molten salt tanks. Because of this ability, the electricity is provided more continuously and, in contrast to PV plants, the grid stress can be reduced to a minimum.

Second, the electricity generation can be shifted to periods of higher electricity prices. Especially in semi-arid regions like Nevada or New Mexico the electricity demand is usually delayed to later hours, due to the heat of the day, resulting in a peak-demand at 8 or 9pm. CSP with thermal energy storage TES can smoothly adapt to this situation and reduce the conventional energy supply, cf. Figure 73.

Third, CSP is the sole renewable energy able to store the generated electricity economically. Wind farms and PV plants cannot store their energy economically today, although progress is made, and are therefore totally dependant on the strongly fluctuating natural resources wind and sun. CSP with TES can be used as a renewable buffer to compensate their production to guarantee a constant energy supply without increasing the cost of electricity generation.

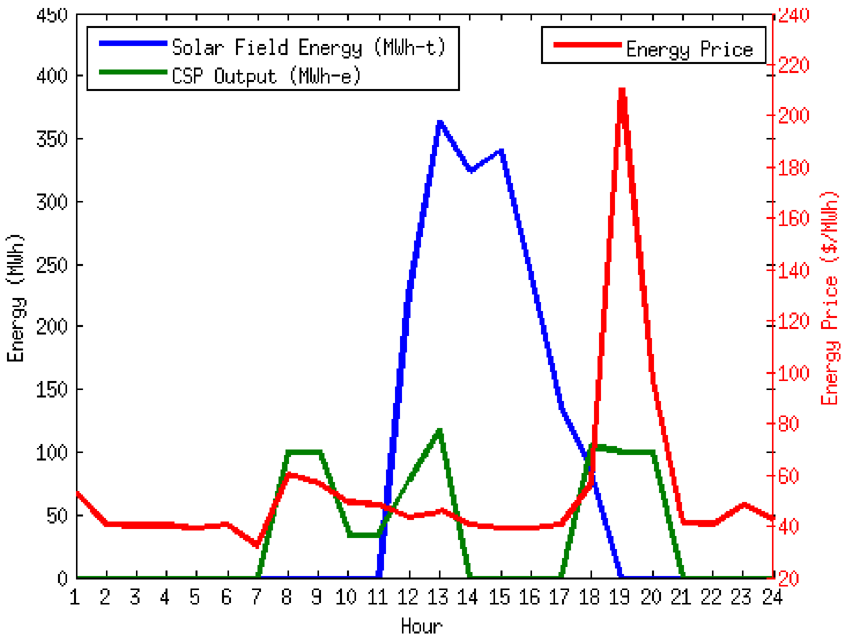


Figure 73 Example of solar supply and energy price in Nevada (Shioshansi/NREL, 2010)

Annex to chapter 1.2.

Table 44 Industry assessment of CSP project developers

INDUSTRY STRUCTURE – Project development	
1. Industry status	
Number & size of companies	Small group of companies have the technology to develop large CSP projects. Just a few companies have the capacity and knowledge to undertake several parallel projects in different countries.
Operating scale (national/international)	Most of the companies are active on the markets in Spain and the US. Some have made first experiences on the MENA market, like Abengoa Solar and Flagsol.
Integration of activities	All large, international actors have fully integrated activities of concept engineering. Often combination of project development, engineering, financing.
Industry leaders	Abengoa Solar, Acciona, Flagsol. Solar Millennium
Leading countries	Germany, Spain, USA
2. Economics and costs	
Turnover	Turnover ranges between a few million Euros up to 100 Mio. Euro (solar activities only). Large increase identified for all players through growth of CSP projects.
Cost structure	The activities are mainly labor intensive engineering activities with also a high share of own research activities.
MARKET STRUCTURE AND TRENDS	
3. Market size and structure	
Market size and growth	Strongly depending on market growth of CSP market
Outlook	This activity is growing by 1-2 GW yearly in 2010 to 2012
Export market	Many companies are operating on an international level with projects in different countries of the world.
Market organization (pricing, contracting methods, etc.)	• Central role for CSP projects • Countries with bidding system: competition. • Countries with feed-in tariffs: cooperation between companies possible
4. Market drivers & obstacles	
Regulation	Strongly depending on financial support for CSP plants in the different countries.
Technology	Parabolic trough (most commercial projects), solar tower plants (first installation with PS20 and PS10 in Spain), Fresnel system (first large project in Spain under construction), Dish-Stirling by SES
Other market drivers	No
5. Key competitiveness factors	
Technology	Plant efficiency Efficient logistics, low-cost assembling, automation, larger projects (economics of scale)
6. SWOT analysis	
Strengths • Technology know-how of companies • Successful projects are now good reference projects • Project development team has been faced with problems and solutions for these	**Weaknesses** • Dependency on political support for CSP plants • Cost reductions have to be realized in next years
Opportunities • Many projects in pipeline by industry leaders in Spain and US • Experience of first plants can be used to integrate new technology concepts and improve existing components	**Threats** • New markets entrants of innovative project developers • Loss of price competition to other technologies, especially PV

Table 45 Industry assessment of CSP EPC contractors

INDUSTRY STRUCTURE – EPC contractors	
1. Industry status	
Number & size of companies	Maximum of 20 companies have experience to develop large CSP projects. The size of the company is strongly depending on the EPC activities and other business areas of the companies. Many companies have a strong market position for construction, energy, transport and infrastructure projects. Minimum capacity required to act as EPC contractor for large CSP plants with long and intensive construction phase. Strong project experience need for obtaining credits and investor capital.
Operating scale (/national/international)	Most of the companies are active on the markets in Spain and the US. Some have made first experiences on the MENA market, like Abengoa or Orascom.
Integration of activities	All large, international actors have fully integrated activities of EPC contractors (engineering, procurement, construction). Often combination of project development, engineering, financing.
Industry leaders	Abengoa Solar (Abener), Acciona, ACS Cobra, MAN Ferrostaal
Leading countries	Germany, Spain, USA
2. Economics and costs	
Turnover	Turnover ranges between a few hundreds of million Euros up to a few billions Euros. Large increase identified for all players through growth of CSP projects.
Cost structure	Very labor intensive
MARKET STRUCTURE AND TRENDS	
3. Market size and structure	
Market size and growth	Strongly depending on market growth of CSP market
Outlook	This activity is growing by 1-2 GW yearly in 2010 to 2012
Export market	Many companies are operating on an international level with projects in different countries of the world.
Market organization (pricing, contracting methods, etc.)	• Central role for CSP projects (to suppliers, owners, construction) • Existing network of large supplier network necessary • Access to finance • Countries with bidding system: competition
4. Market drivers & obstacles	
Regulation	Strongly depending on financial support for CSP plants in the different countries.
Technology	Parabolic trough (most commercial projects), solar tower plants (first installation with PS20 and PS10 in Spain), Fresnel system (first large project in Spain under construction)
Other market drivers	No
5. Key competitiveness factors	
Technology	Efficient logistics, low-cost assembling, automation, larger projects (economics of scale)
6. SWOT analysis	
Strengths • Successful projects are now good reference projects • Large companies with well trained staff • Project development team has been faced with problems and solutions for these • Network of suppliers from other business activities • Access to financial resources	**Weaknesses** • Dependency on political support for CSP plants • Cost reductions have to be realized in the next years for EPC part
Opportunities • Many projects in pipeline by industry leaders in Spain and USA • Achieve cost reduction by project optimization • Good margin in countries with feed-in tariffs possible	**Threats** • New markets entrants of other large infrastructure and construction companies (JV of other companies)

Table 46 Industry assessment of companies for CSP mirrors

INDUSTRY STRUCTURE – MIRRORS	
1. Industry status	
Number & size of companies	Few companies have the capacity of bending the high quality glass
Operating scale (regional/national/ international)	• Large international companies operate on the world market. • Factories with large output can be at different locations of these companies
Integration of activities	Production lines can cover the whole value chain of mirror production: • Float glass process • Bending of glass • Mirror manufacturing (chemical coatings)
Industry leaders	Flabeg, Saint-Gobain, Rioglass, Guardian Industries
Leading countries	Germany, USA, Spain, France,
2. Economics and costs	
Turnover	• Large turnovers (hundreds of millions up to billions) • Companies produce different products for glass and mirrors (automotive, building, security glass)
Cost structure	Input of float glass is cheap, production of mirrors create high added value Large investment in machines and production lines
MARKET STRUCTURE AND TRENDS	
3. Market size and structure	
Market size and growth	A few companies share the market, all have increase their capacities
Outlook	Depending on CSP market growth
Export market	International / world market
Market organization (pricing, contracting methods, etc.)	Prices of parabolic mirrors shows very high value added compared to input of float glass Volumes of mirrors for a single plant are very large
4. Market drivers & obstacles	
Regulation	-
Technology	Flat or parabolic mirrors
Other market drivers	Automotive industry, Photovoltaic
5. Key competitiveness factors	
Technology	Bending of glass, coating of different layers
6. SWOT analysis	
Strengths ▪ Strong market position of leading companies ▪ High margins for parabolic mirrors	**Weaknesses** ▪ High cost for new factories ▪ Continuous demand is needed
Opportunities ▪ Barriers for other market entrants because of large factory output ▪ New markets for float glass and mirror industry	**Threats** ▪ Flat mirror technology can exploit the market for parabolic mirrors if system competiveness is reached

Table 47 Industry assessment of companies producing CSP receivers

INDUSTRY STRUCTURE – RECEIVERS (parabolic trough and Fresnel)	
1. Industry status	
Number & size of companies	This world market is very close with two large players Schott Solar and Siemens (after purchase of Solel Solar Systems).
Operating scale (regional/national/ international)	Both companies supply the world market from the home factories in Israel and Germany. Additional capacities are built up in Spain and US
Integration of activities	Schott Solar provides receivers only for CSP. Siemens could provide more services like project development and EPC, power block equipment etc.
Industry leaders	Schott Solar, Siemens
Leading countries	Germany, Israel (production capacities in Spain and USA)
2. Economics and costs	
Turnover	Current market volume ranges between 400 and 600 M€ in total
Cost structure	Large investment in know-how and machines required
MARKET STRUCTURE AND TRENDS	
3. Market size and structure	
Market size and growth	Strongly depending on market growth of CSP market (parabolic trough and Fresnel)
Outlook	Market activity is growing by 1-2 GW yearly in 2010 to 2012
Export market	Both companies supply the world market (including Spain, USA, MENA, etc.)
Market organization (pricing, contracting methods, etc.)	• Duopoly • Pricing is based on low competition because of large demand • Receivers are supplied to the construction site without involvement of the receiver companies in direct construction or assembling (if service is not provided by partner department of the same company (Siemens))
4. Market drivers & obstacles	
Regulation	Strongly depending on financial support for CSP plants in the different countries.
Technology	Parabolic trough (most commercial projects), Fresnel system (first large project in Spain under construction)
Other market drivers	If growth of other technologies like solar towers is limited, parabolic trough requires large demand of receivers. (receiver for towers different)
5. Key competitiveness factors	
Technology	High-tech component with specialized production and manufacturing process
6. SWOT analysis	
Strengths • High-technology component • Strong market position for two companies • Long production and manufacturing experience • Continuous improvement of efficiency	**Weaknesses** • Dependency on political support for CSP plants
Opportunities • Increase of size and efficiency opens better cost position • Achieve cost reduction by project optimization • New capacities close to new markets in MENA region	**Threats** • New developments of other CSP technologies like solar towers • Low cost technologies with other receiver elements

Table 48 Assessment of CSP companies supplying metal mounting structures

INDUSTRY STRUCTURE – Metal support structure	
1. Industry status	
Number & size of companies	Medium and large size companies are active in an international market.
Operating scale (regional/national/ international)	• Steel supply can be provided locally • International suppliers can also produce the parts for the steel support structures and these parts can be shipped longer distance to be assembled on site
Integration of activities	• Raw material is steel that is manufactured to required parts (bars, etc) for the collector • Producers often have not a focus on CSP manufacturing
Industry leader	Not identified
Leading countries	Turkey, Spain, USA,
2. Economics and costs	
Turnover	Few millions US$ to hundreds of millions US$
Cost structure	High share of costs for raw material: steel
MARKET STRUCTURE AND TRENDS	
3. Market size and structure	
Market size and growth	No dependency on CSP market, because not CSP specific companies
Outlook	Increase of internationality expected
Export market	Export will increase
Market organization (pricing, contracting methods, etc.)	Subcontractors are searched for every single project No long-term contracts
4. Market drivers & obstacles	
Regulation	-
Technology	New innovations for collectors expected to increase efficiency and to facilitate automated production
Other market drivers	Steel prices, logistic costs
5. Key competitiveness factors	
Technology	Licenses are given by technology developers
6. SWOT analysis	
Strengths ▪ New business for companies that produce structural steel ▪ Long experience of steel companies to transform steel	**Weaknesses** ▪ High cost competition ▪ Local market if transport costs are high
Opportunities ▪ Increase of efficiency and size	**Threats** ▪ Alternative materials like aluminum

Annex to chapter 1.4.

Table 49 Reference plant without storage

CSP plant (trough) 50 MW without storage	Relative Value	Cost for Reference Power Plant in US$
Labor Cost Site and Solar Field	**18,3%**	40,3 Mio $
Equipment Solar Field and HTF System	**36,1%**	79,4 Mio $
Thermal Storage System	**0,0%**	0,0 Mio $
Conventional Plant Components and Plant System	**21,8%**	47,9 Mio $
Others	**23,8%**	52,4 Mio $
Total Cost		**220, Mio $**

Annex to chapter 2

SWOT analyses by country

Table 50 Country SWOT-analysis Egypt

Strengths

- Local EPC contractor: Orascom with CSP know-how and large local Egyptian workforce
- Several local companies (NSF for example) with first experience of CSP components manufacturing thanks to Kuraymat ISCCS
- Political willingness for CSP development
- Low labor cost
- Strong GDP growth over the 5 past years
- Strong industrial sectors (especially steel, cables and cement) and first rank companies (El Sewedy, Orascom, etc.)
- Recent development in float glass production

Weaknesses

- Limited financing
- Kuraymat feedback could have been better: long tender procedure and bad site selection that implied large problems for civil works on a rocky and cragged ground
- No fiscal, institutional and legislative framework for RE development (New law for renewable energies still under development, 3 years already)
- Despite numerous regulations, implementation is often deficient
- Need for strong network, business and political connections

Lack of specialized training programs for RE

Opportunities

- Glass industry in Egypt shows potential to produce (pure) float glass
- In the field of parabolic mirrors Egypt could attain a very competitive position in the MENA region
- Solar energy: premises of an Egyptian Solar Plan (8 GW of solar energy capacity by 2018)
- Political will to develop a local renewable energy technologies industry
- Export potential (priority given to export industries by the government)

Threats

- Competition with MENA neighbors on mirrors and other CSP components production (EUA, Saudi Arabia, Israel, etc.)
- CSP mirrors manufacturers could prefer to maximize the load if their current assets instead of developing new capacities in Egypt

Table 51 Country SWOT-analysis Morocco

Strengths	Weaknesses
• Moroccan Solar Plan announced by the King Mohammed VI, with an objective of 2 GW solar (CSP and PV) by 2020 • Large upcoming projects attract investors (Ouarzazate) • Call for tenders will probably encourage a significant share of local components • Successful development of supply chain players in the automotive and aeronautics industry • Long experience of industrial JVs with European players • Industrial clusters have been created (i.e. aeronautics) • Subsidies on electricity prices phased out • Political stability, strong economic and financial fundamentals • Liberalized economy, favorable policies towards FDI • Energy sector reform and new RE law endorsed recently (January 2010) • Tax breaks providing incentives to investors	• Low skilled workforce and low productivity • Low cost labor not necessarily an advantage for capital-intensive industries • Industry mostly composed of SMEs • Low R&D/investment capabilities • Uncertainties on how large solar projects will be financed • Local clean-tech industry not very mature / dependence on international technologies and expertise

Opportunities	Threats
• 500 MW calls for tenders following Ouarzazate • 2 GW is high enough to develop Moroccan CSP industry for local market • Involvement of aeronautics and automotive industries in the CSP value chain • Development of cleantech excellence centers like upcoming Technopole d'Oujda • Exports opportunities thanks to geographical location and export facilities (Zone franche d'exportation de Tanger, etc.) • Electricity exports through already existing Morocco-Spain transmission line	• Competition from Asian manufacturers of renewable energy equipment • Lack of financing to achieve 2 GW solar objective • Failure to achieve Ouarzazate 500 MW solar plant would jeopardize private developers' interest in any other projects in the MENA region

Table 52 Country SWOT-analysis Tunisia

Strengths	Weaknesses
• Tunisian Solar Plan announced Nov. 2009, includes development of 2 to 3 CSP plants • First class electric and electronic industries • High incentives for industrial development and export (modernization programs, tax incentives, etc.) • Skilled labor, white collars trained in international universities • Development of technopoles like Borj Cedria • Extensive use of international certification on products, management systems, etc.	• No CSP project currently under development , though first under planning • No roadmap for Solar Plan defined • No certainty on incentives for RE capacities development • Lack of awareness on CSP opportunities • Small size of local market / industry development driven by export • Low diversity of Tunisian industries • Dependence on imports (e.g. glass industry)

Opportunities	Threats
• High tech electric and electronic industries could start manufacturing components used for CSP (cables, trackers, balance of plant, etc.) • Detailed roadmap for solar energy development • Implementation of high voltage transmission line between Tunisia and Italy	• Low attention of policy level and actors in the electricity sector

Table 53 Country SWOT-analysis Algeria

Strengths	Weaknesses
• Experience with first CSP plants • Introduction of a feed-in tariff for CSP • Development focus on technopoles • Proximity to European markets	• Insufficient transposition of renewables promotion scheme • Lack of qualified staff for CSP development • R&D rather disconnected from industry • Slow approach to interconnection with Europe

Opportunities	Threats
• Financing opportunities from oil and gas income • Availability of larger companies such as CEVITAL with experience in technologies relevant for CSP manufacturing • Experience with joint ventures	• Low attention of policy level • Time delay in developing further CSP plants as part of the power system • Insufficient regional cooperation • Continued subsidies to fossil fuel power generation

Table 54 Country SWOT-analysis Jordan

Strengths

- Political stability and strong economic and financial fundamentals
- Liberalized economy, favorable policies towards FDI
- Skilled workforce, with a demonstrated capacity to development value-added industries (pharmaceuticals, communications, services, etc.)
- Energy sector reform and new RE law endorsed recently (January 2010)

Weaknesses

- Small size of the market
- No strong incentive scheme for renewables, such as a feed-in tariff (under review by the Government)
- Lack of experience from government and from private sector in implementing renewable energy projects
- Limited industrial capabilities

Opportunities

- Ambitious Government targets for the promotion of renewables including the implementation of 300 MW of concentrated solar by 2015
- Existence of several contractors or project developers interested in renewable energy
- Establishment of a national renewable energy and energy efficiency fund
- Possible launch early 2011 of a call for tender related to a 100 MW CSP Plant in Maan
- Several large scale renewable projects are attracting attention from international investors, mainly in solar PV (Shams Maan) and solar thermal (CSP)
- Emergence of a solar cluster in Maan

Threats

- Lack of clarity in the government's position related to purchase price agreements for renewable energy projects
- Competition from equipment suppliers based in neighboring countries (Egypt, Israel, etc.)

Patent analysis

The number of filed patents within a certain sector in a country provides information on the intensity of research and the degree of the national intellectual property in this field. This allows conclusions about the innovative potential and the technological capability of a country with regard to the respective technology.
For the present analysis patent data for 18 MENA countries and a number of additional reference countries was retrieved from the databases of the European patent Office (EPO) and the World Intellectual Property Organization (WIPO). The research covers the period from 1991 to 2007 (for the latest years data is not yet completely available). The queries include the number of total recorded patents worldwide and general manufacturing processes in the main sectors of CSP component production; namely steel and glass fabrication and –processing as well as fabrication of electronics. Results are regarded in comparison to the total number of filed patents in the respective sector worldwide.

Total patents worldwide and in the MENA region

The number of patents filed in all fields worldwide increased substantially during the last 2 decades: from about 68,000 patents recorded in 1991 up to 189,000 patents in 2007 (cf. Figure 75). This underlines the generally growing importance of intellectual property rights. The USA, Japan and Europe (namely Germany), hold the biggest share in the total number of recorded patents, which demonstrates their strongly dominating position in terms of innovation and their long tradition of intellectual property rights (cf. Figure 74).

Figure Figure 74 and Figure 75 show that the MENA region holds a minor share in the number of worldwide filed patents but nevertheless a rising trend in the registration of patents, since about the year 2000, is clearly visible (cf. also Figure 76), thus indicating that applied research and innovation in these countries are beginning to gain importance.

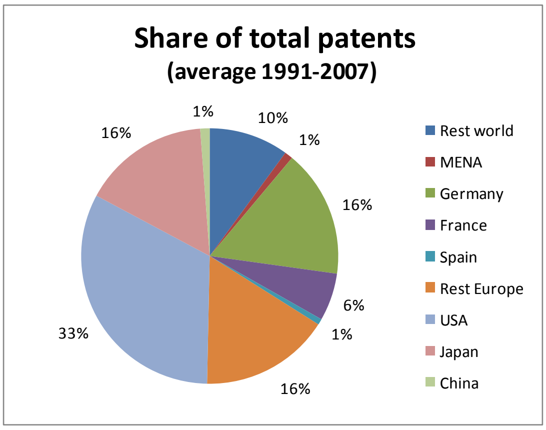
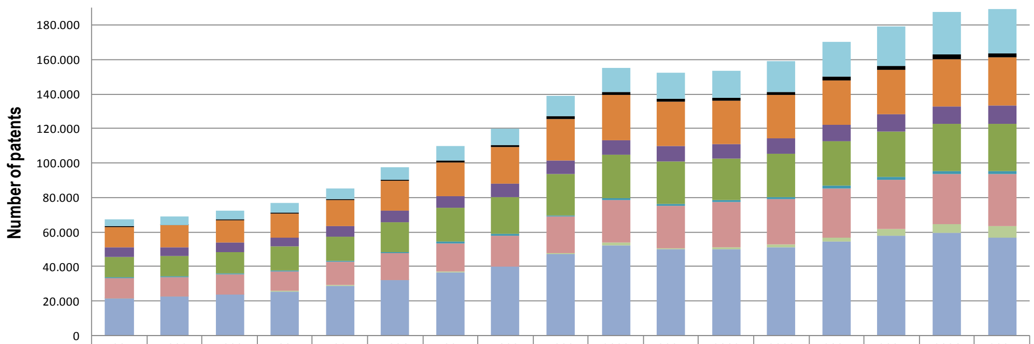


Figure 74 Share of individual countries/regions in total filed patents (1991-2007)

Also, clear distinctions have to be made between the various countries of the MENA region. A grouping of the countries might be done as follows:

- Some countries show a quite weakly developed culture of intellectual property rights and registered a very small number of patents (0-50) during the observed period. For example Libya, Iraq, Bahrain, Qatar or Kuwait (cf. Figure 76, upper graph).
- A somewhat higher number of patents (50-100) had been filed, for example, in Tunisia, Jordan, Algeria and Lebanon and >100 patents have been filed, for example, in Egypt, Morocco, Saudi Arabia or the Arabian Emirates (cf. Figure 76, middle graph).
- The status of intellectual property rights in Israel clearly stands out from the other MENA countries: Israel holds >90% of the filed patents in the MENA region and must thus be regarded separately (cf. Figure 76, lower graph).



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Rest world	4275	4808	5226	5609	6237	7244	8400	9721	11891	14082	14841	15881	17893	20294	22852	24839	25722
MENA	314	344	421	538	561	709	985	1141	1443	1882	1693	1612	1769	1990	2286	2444	2503
Rest Europe	12049	12463	13203	13996	14998	17361	19444	21042	24028	26017	25910	24910	25117	25594	25963	27851	27951
France	5375	5048	5243	5522	5780	6434	7152	7590	8284	8639	8822	8711	9167	9629	9689	9942	10219
Germany	11719	12018	12511	13658	14462	17389	19473	21744	23707	24903	24422	24036	24909	25777	26277	27038	27800
Spain	350	346	427	483	509	599	777	818	872	1007	1067	1121	1140	1493	1619	1699	1791
Japan	11972	11337	11693	11575	13465	15504	16661	17768	21012	25045	24533	25970	26144	28828	28916	29239	30126
China	44	54	107	121	141	200	262	328	743	1636	995	1448	1833	2404	3950	5323	6439
USA	21510	22492	23753	25627	28948	32107	36717	39861	47089	52073	49887	49929	51211	54277	57724	59329	56859

Figure 75 Total number of filed patents worldwide and share of individual **regions and** countries (1991 and 2007).

Patents in the main industrial sectors for manufacturing CSP components

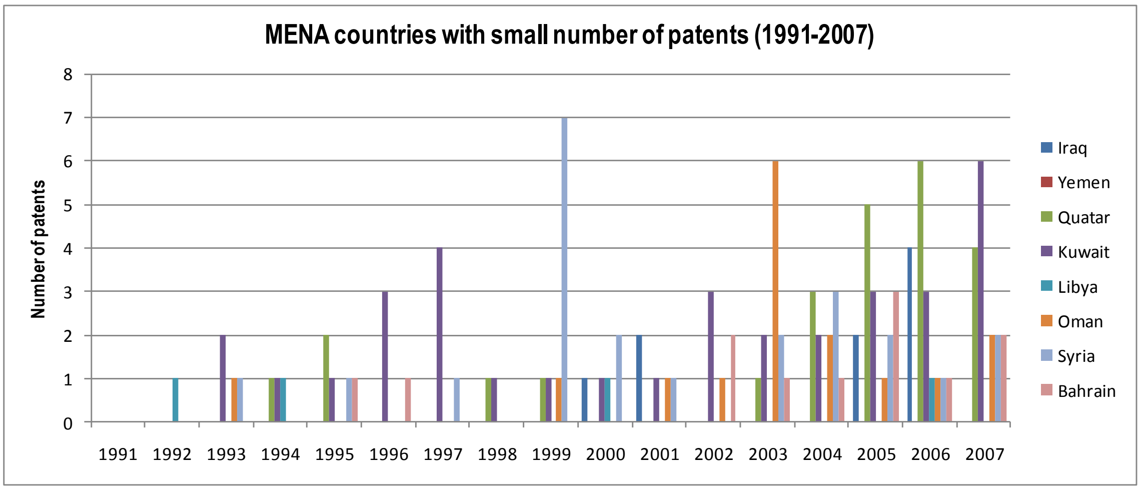
The main industrial sectors for the production of CSP components are metal processing (including cutting, welding, coating and galvanizing), glass production and processing (including shaping, bending, coating and mirroring glass) and the electronics industry (including fabrication of cables and various electronic parts).

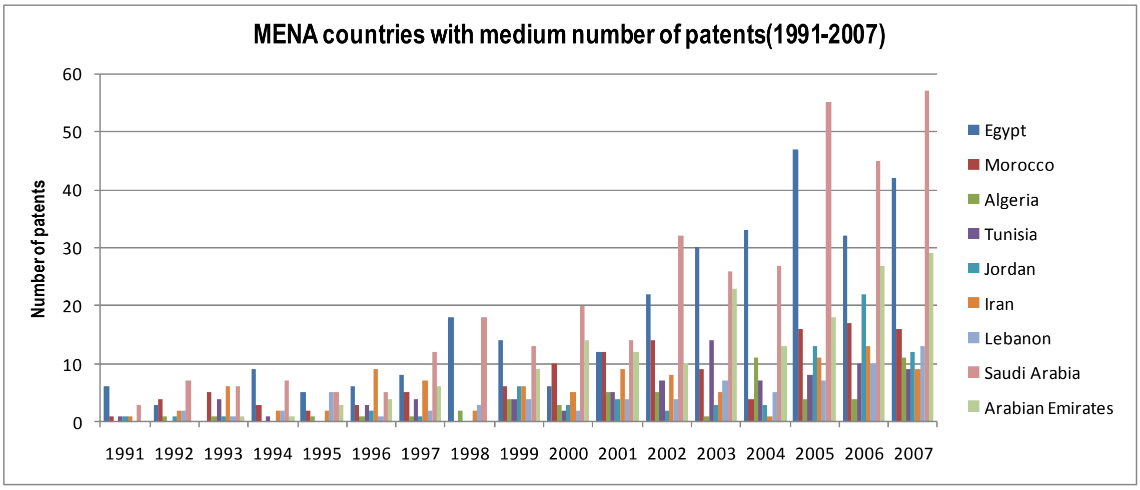
In the patent statistics regarding these technical areas the MENA countries are rather weakly represented during the investigated period:

- In the field of metal processing only 1 patent out of the worldwide total of 229 was filed in Israel, none in Egypt. Morocco, Tunisia, Algeria or Jordan. Most patents in this field were filed in Germany (63) and Japan (58) (cf. Figure 79)
- In the field of glass production/processing 1 patent (out of a total of 9434 worldwide) was filed in Egypt, 17 in Israel and 1 in the Arabian Emirates. Strongest countries in this field are the USA, Japan and Germany (cf. Figure 78).
- Still small, but remarkable is the share of the MENA countries in patents related to the field of electronics (cf. Figure 77). Out of the 227,224 patents recorded in the investigated period, 1205 (0.5%) were filed in the MENA region, most in Israel (1100), 58 in the 5 focus countries, 28 of that in Egypt.

Conclusion

- ➢ Europe, namely Germany and Spain, together with the USA strongly dominate in the number of patent applications. These countries are strong competitors for a potential future CSP industry in the MENA region.
- ➢ The MENA countries still hold a small share in the number of patents filed worldwide, although a rising trend of patent applications is clearly visible.
- ➢ Besides in Israel only in Egypt, Morocco, Tunisia, Algeria, Jordan and the Arabian Emirates patents were filed in the investigated fields and period, which points out that there is a potential in these countries that needs to be further developed.
- ➢ Particularly in the field of electronic industry the MENA countries, with Egypt in particular, seem to develop a focus in research and development.
- ➢ Nevertheless, a technology transfer from the more advanced countries and an enlargement of intellectual property rights in these fields should be strongly aspired to allow for a future development of CSP technologies adapted to the specific conditions in the MENA countries





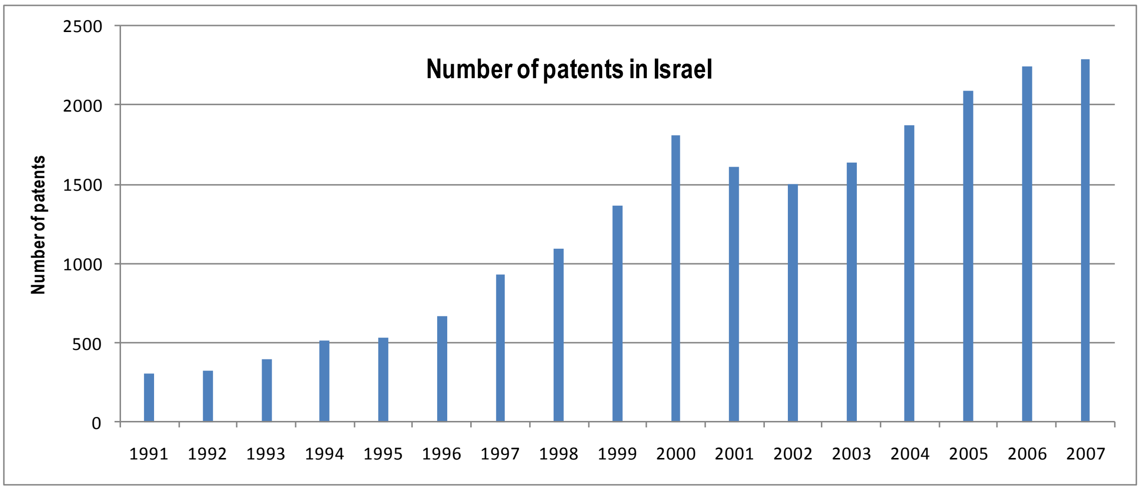
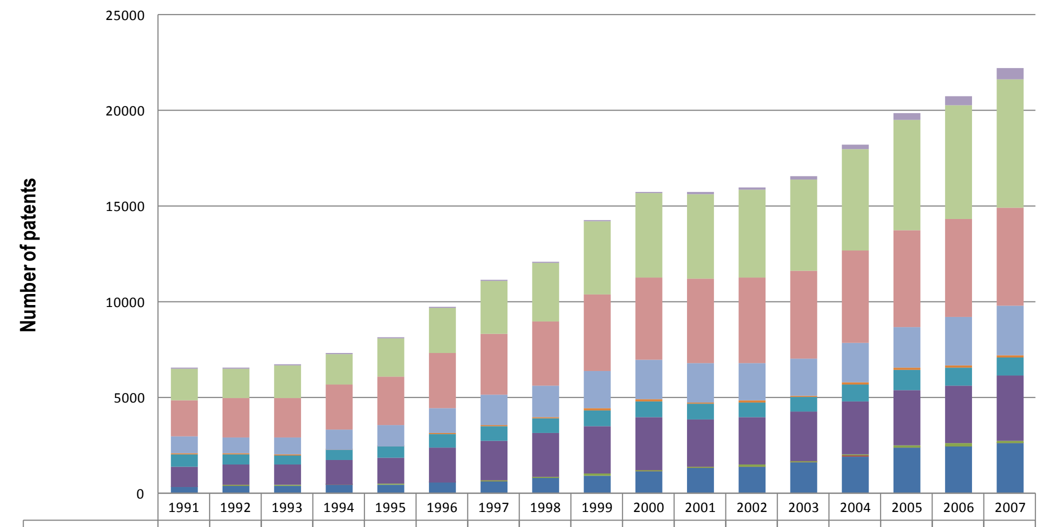
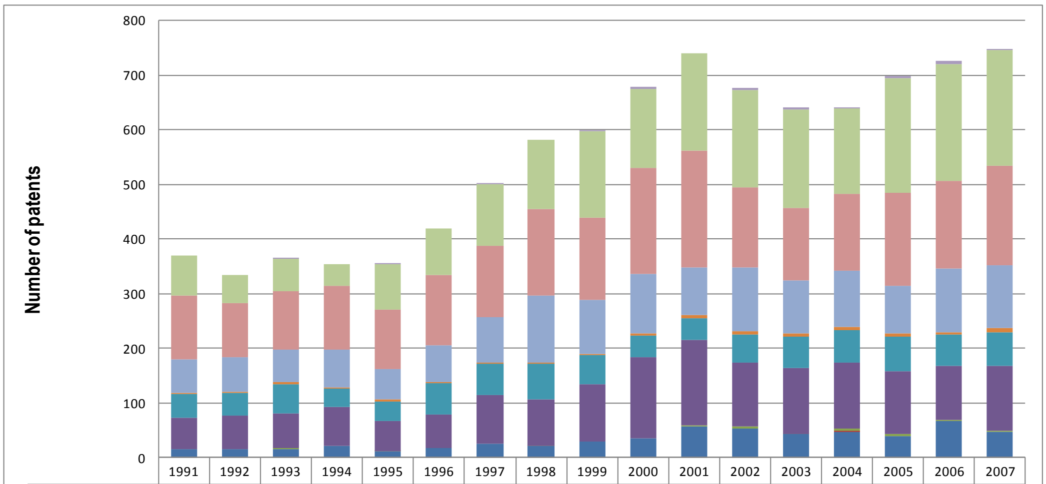


Figure 76 Number of patents filed in different groups of MENA countries between 1991 and 2007. Upper graph: countries with low number of patents, middle graph: countries with medium number of patents, lower graph: high number of patents in Israel.



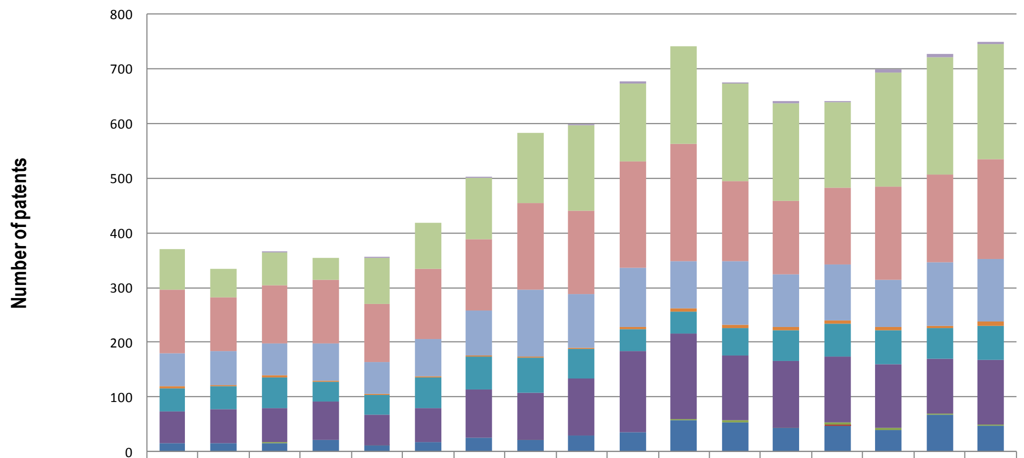
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
China	6	11	9	12	12	20	24	24	47	67	114	135	167	243	331	477	588
Japan	1664	1534	1683	1599	1978	2344	2797	3050	3845	4430	4410	4576	4756	5289	5787	5935	6699
USA	1891	2056	2056	2356	2510	2894	3182	3371	4020	4324	4392	4471	4626	4816	5084	5120	5107
Rest Europe	883	859	922	1034	1142	1304	1559	1667	1933	2067	2080	1969	1918	2069	2110	2533	2586
Spain	24	18	29	26	24	24	68	57	91	85	94	83	58	101	114	131	138
France	656	534	499	543	555	703	759	758	835	806	792	753	799	895	1018	936	969
Germany	1064	1105	1068	1248	1376	1814	2039	2268	2512	2783	2471	2523	2541	2792	2916	3036	3404
Rest MENA	13	21	24	34	26	28	66	73	81	82	90	84	93	82	99	140	116
EG, MA, TN, DZ, JO	0	1	0	6	0	2	6	1	0	4	4	2	8	5	5	2	7
Rest world	293	382	384	410	456	541	615	784	911	1122	1289	1380	1589	1926	2386	2448	2594

Figure 77 Total number of filed patents in the field of manufacturing of various electronic components in individual countries and regions (1991-2007).



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
China	0	0	2	0	1	0	3	0	1	4	0	3	3	3	5	6	3
Japan	73	52	60	39	83	84	112	127	157	144	178	179	180	157	210	215	212
USA	117	99	107	117	108	129	131	159	152	194	215	145	133	140	169	159	182
Rest Europe	61	62	58	69	57	68	82	122	99	109	87	118	98	103	88	117	114
Spain	3	2	4	2	3	2	2	2	1	4	6	5	5	6	5	4	9
France	42	41	55	35	36	57	59	65	54	40	39	51	57	59	63	57	61
Germany	59	63	63	71	55	62	88	85	105	147	157	118	121	121	116	100	119
Rest MENA	0	0	1	0	1	0	0	1	0	0	2	3	1	4	3	1	1
EG, MA, TN, DZ, JO	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Rest world	15	15	16	21	11	17	26	21	29	36	57	54	43	48	40	68	48

Figure 78 Number of patents filed in individual regions/countries in the field of 'Glass manufacturing, shaping and coating (incl. mirror production)' (1991-2007) .



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
China	0	0	2	0	1	0	3	0	1	4	0	3	3	3	5	6	3
Japan	73	52	60	39	83	84	112	127	157	144	178	179	180	157	210	215	212
USA	117	99	107	117	108	129	131	159	152	194	215	145	133	140	169	159	182
Rest Europe	61	62	58	69	57	68	82	122	99	109	87	118	98	103	88	117	114
Spain	3	2	4	2	3	2	2	2	1	4	6	5	5	6	5	4	9
France	42	41	55	35	36	57	59	65	54	40	39	51	57	59	63	57	61
Germany	59	63	63	71	55	62	88	85	105	147	157	118	121	121	116	100	119
Rest MENA	0	0	1	0	1	0	0	1	0	0	2	3	1	4	3	1	1
EG, MA, TN, DZ, JO	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Rest world	15	15	16	21	11	17	26	21	29	36	57	54	43	48	40	68	48

Figure 79 Number of patents filed in individual regions/countries in the field of 'Metal processing/forming (incl. welding & stamping), coating and galvanizing' (1991-2007) .

Foreign trade data

The technological competitive position of the countries is investigated by a foreign trade analysis to complement results obtained so far. The analysis orientates at the industrial sectors which are most relevant for the technical components of the CSP value chain. The data is obtained from the UN Comtrade database for the period 2004-2008[34]. First, a general overview on exports and imports of the countries is given in absolute quantities for each component and then results of the Revealed Competitive Advantage (RCA) indicator are presented. The RCA indicator is used to show the specialization of a country for a technology and normalizes the size of the economies. Exports as well as imports of a country are taken into account, showing the deviation of the export/import ratio of one commodity compared to the overall export/import ratio of the whole economy. To scale the indicator a monotone transformation with the natural logarithm and the hyperbolic tangent is conducted and the result multiplied by 100, so that the indicator ranges from - 100 (extremely unfavorable specialization) to + 100 (extremely high specialization). The value 0 corresponds to an average specialization compared to the other commodities. The formula is given below.

$$RCA_{ij} = 100 * \tanh \ln \left[\frac{\left[\left(\frac{Ex_{ij}}{Im_{ij}} \right) \right]}{\sum_j Ex_{ij} / \sum_j Im_{ij}} \right]; \quad i = country, j = commodity$$

A corresponding value can be calculated for the patent data (Relative Patent Share). These can be combined to generate specialization patterns which display the general competitiveness of the countries. The competitive position of closely related industrial branches is one key driver for the adaptation and innovation capacity of a potential CSP component industry and shows to which extent an economy is already capable to 'open up' internationally in the respective technology field. A country with a better position for a technology compared to the other countries could benefit significantly from expanding capacities in that industrial field, if successful strategies are implemented.

Glass- and glassware

[34] The present analysis is based on the HS2002 classification.

Over the regarded period imports show a growing trend and range between two and 12 million US dollars for the countries. Exports, on the other side, show no clear trend. Concerning the 2004-2008 average RCA[35] (see Figure 81), positive values can only be identified for Egypt. Egypt's glass industry is therefore performing slightly above the average of the whole economy.

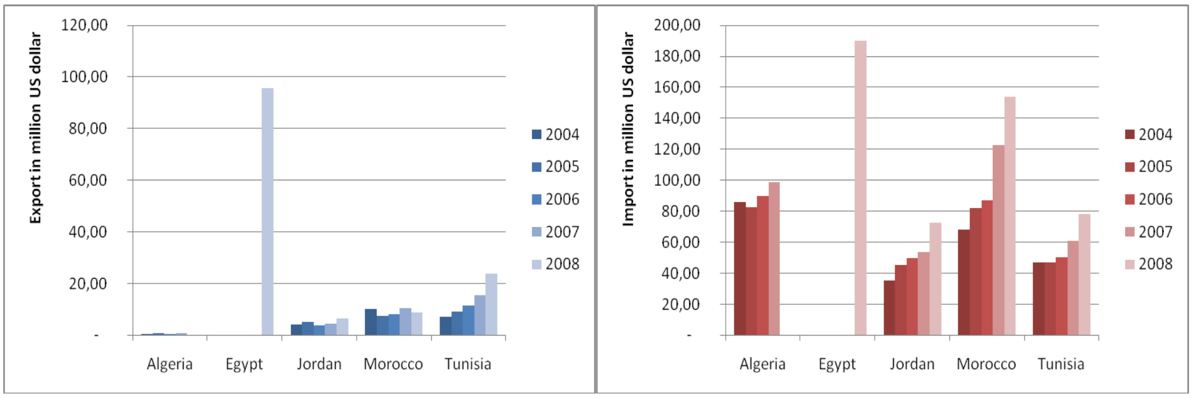


Figure 80 Export and import volume of glass and glassware in the CTF countries in US dollars (2004-2008). For Algeria no Data was available for 2008 (data source: UN Comtrade database).

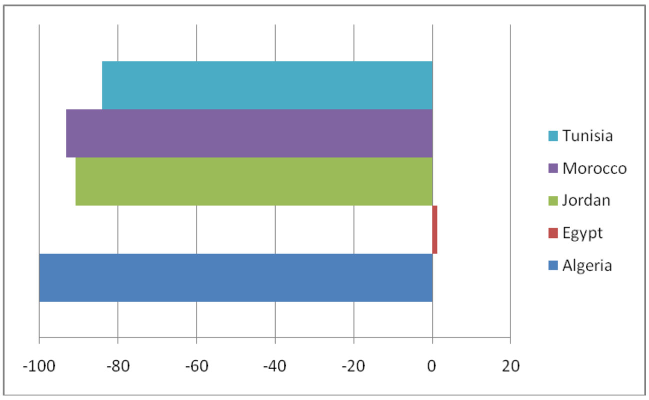


Figure 81 RCA for the glass industry in the CTF MENA countries (average 2004-2008). Data source: UN Comtrade database.

Metal structures

The current most popular mounting structure concept for CSP power plants is based on a steel structure and corresponds best with the UN Comtrade classification 'iron and steel structures' (including e.g. bridge-sections and lattice masts). For iron and steel structures a positive trend towards increasing export is visible. The growing import volumes indicate a demand growth in all countries. Nevertheless, only Tunisia shows a positive trade balance (in 2008) Results of the trade balance analysis correspond with results of the RCA (Figure 83) as Egypt and Tunisia show above average values of 31 and 49, respectively which indicates a positive specialization in this sector.

[35] Average of 2004 to 2008

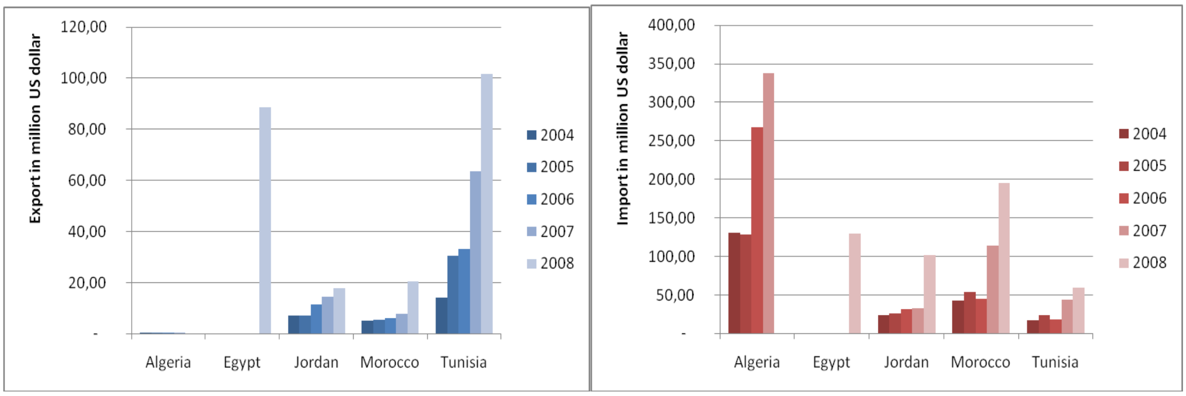


Figure 82 Export and import volume of metal structures in the CTF countries in US dollars (2004-2008). For Algeria no Data was available for 2008 (data source: UN Comtrade database).

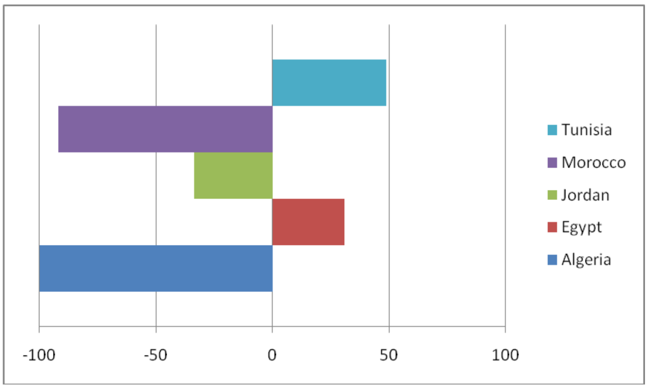
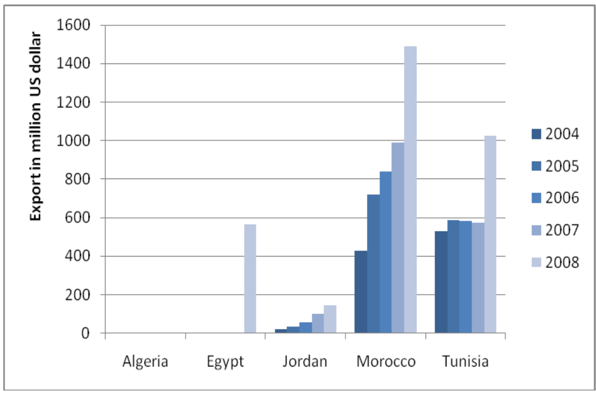


Figure 83 RCA for the steel structure industry in the CTF MENA countries (average 2004-2008). Data source: UN Comtrade database.

Electric cables and general electric equipment

Cables are an example of components which, on the one hand, have a minor share in the value added, but on the other hand, are already competitive in the CTF countries (secondary component). Figure 84 shows the import and export volumes of wires and cables for the CTF countries. Besides Algeria all countries have a positive trade balance. The RCA average lies between 77 and 95 for the CTF MENA countries besides Algeria, which shows a value of -100 (Figure 85).

For electric equipment a similar situation can be identified. Tunisia and Morocco show positive trade balances, which is also reflected in the positive RCA values. Algeria strongly depends on imports in this sector. shows a specialization pattern for the electronics industry in several MENA countries. The outstanding position of Tunisia and Morocco is clearly visible.



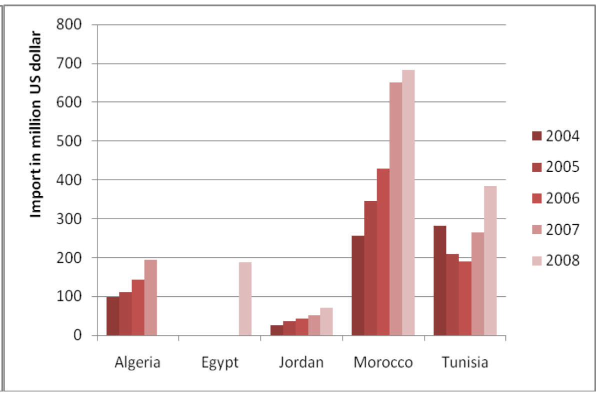


Figure 84 Export and import volume of insulated wires and cables in the CTF countries in US dollars (2004-2008). Data source: UN Comtrade database.

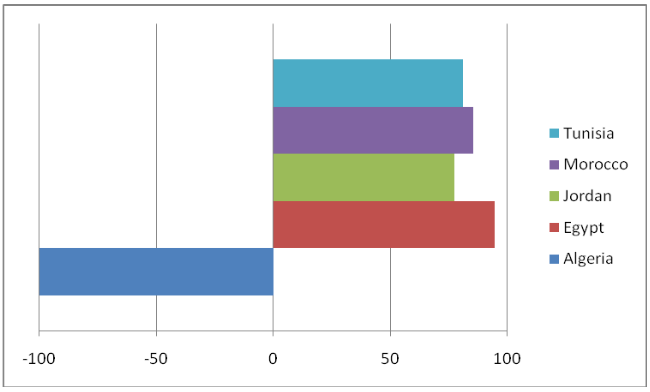


Figure 85 RCA for insulated wires and cables industry in the CTF MENA countries (average 2004-2008). Data source: UN Comtrade database.

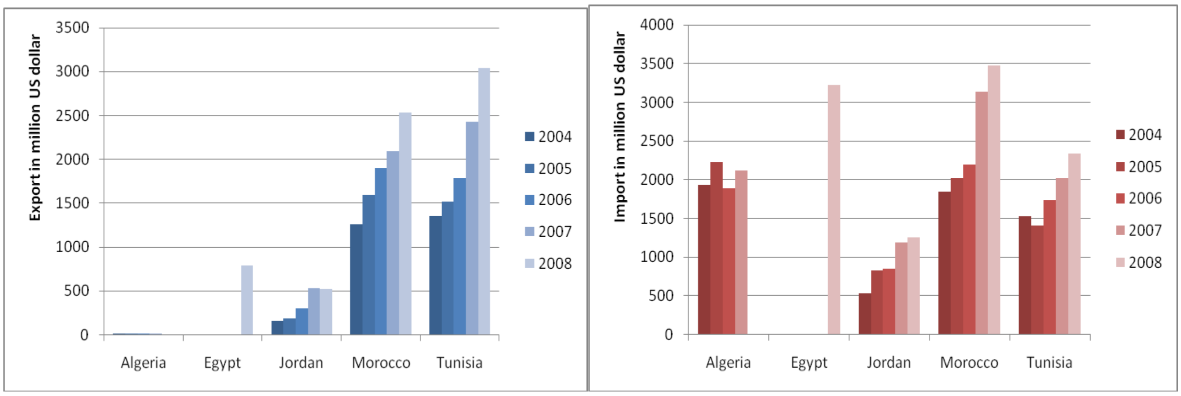


Figure 86 Export and import volume of electric equipment in the CTF countries in US dollars (2004-2008). Data source: UN Comtrade database.

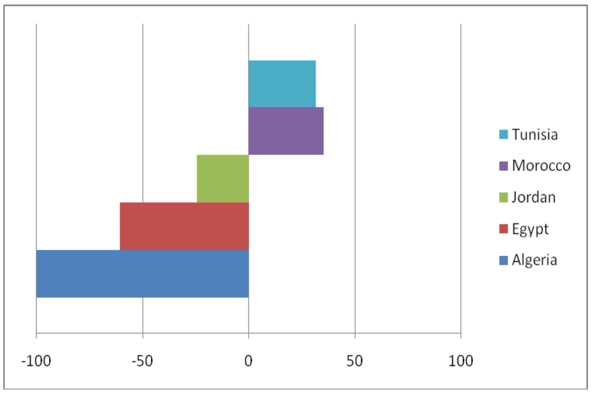


Figure 87 RCA for electric equipment in the CTF MENA countries (average 2004-2008). Data source: UN Comtrade database.

Taxation and business environment

Table 55 Business relevant taxes and regulations in the CTF countries[36]

Country	Company taxation, examples[37]
Algeria	Corporate income tax: 25% and 19%(in production sector) VAT: 17% Tax Rate For Foreign Companies: Foreign companies are taxed on the profits they make in Algeria. Main Allowable Deductions and Tax Credit: Expenses are deductible for depreciation, amortization, reserves, rents for premises and equipment, wages, etc. Other corporate expenses: Tax on business activity (2%), land tax (7% and 3% for built land, respectively), apprenticeship tax, social security contributions, stamp duty.
Egypt	Corporate income tax: 20% VAT: 10% Main Allowable Deductions and Tax Credit: Setting up in special economic zones entitles the company to tax benefits. They are only taxed at 1% of their profits or operations. For additional information access the PKF tax guide on Egypt. Other Corporate expenses: Tax on real-estate assets up to 10% of the rental value. The owner is exempted from property tax if the value of the property is less than or equal to EGP 500,000. Social insurance contributions, stamp duties. Other: Protection agreements against double taxation of foreign companies
Jordan	Corporate income tax: 15% VAT: 16% Main Allowable Deductions and Tax Credit: Companies set up in some economic areas benefit from exemptions from tax, social security contributions and Customs duties. These exemptions vary according to the economic area. Other Corporate Taxes: Payroll tax, real property tax (10%), social security contributions, stamp duty, municipal business tax. Other: Company expenditures on training, marketing and R&D are exempted from tax. Protection agreements exist against double taxation of foreign companies.
Morocco	Corporate income tax: 30% (standard rate), 37% (for credit institutions, leasing and insurance companies), 17.5% (reduced rate for export companies from the 6th year on, after 5 years of total exemption) VAT: 20% Tax Rate For Foreign Companies: VAT refund for nonresidents is possible under certain conditions. Main Allowable Deductions and Tax Credit: There are many deduction possibilities. Other Corporate expenses: A 6% registration duty and a 1% property tax are levied at the time a real estate is purchased. A 3% registration duty is imposed on the sale of shares in non-listed companies. A business tax is charged depending on the size and kind of the enterprise and the rental value of business premises. Stamp duty. Customs duty: Most products can be imported without an import license but duty rates can be very high. Customs import duty depends on the product. Some materials/products are exempted (e.g. goods related to use of renewable energy). The “Admission Temporaire” (temporary admission) scheme allows goods to be imported duty free where they are to be processed and re-exported as finished articles or sub-assemblies. The codes also allow for the repatriation of the initial capital invested and the transfer of capital gains (when closing down) and net profits (without restraint on amount or timing). The “Programme d’Investissement”

[36] Sources: The Federation of International Trade Associations: http://www.fita.org, UK Trade & Investment – “Doing business in Morocco/Tunisia/Egypt/Algeria”, http://www.doingbusiness.org/

[37] This list does not intend to present a complete overview over all business related taxes. For detailed information refer to national information platforms.

	scheme allows capital goods to be imported at 2.5% customs duty only. 15% import tax levy (PFI) is imposed on imported goods not subject to customs duty; exemptions exist for materials using renewable energy and some other products. Other: Protection agreements against double taxation of foreign companies. Exemption from income tax for certain periods possible in some cases (e.g. for individual companies or in particular areas).
Tunisia	Corporate income tax: 30% VAT: 18% Tax Rate For Foreign Companies: Foreign companies are taxed on the profit they make in Tunisia. Main Allowable Deductions and Tax Credit: Expenses are deductible for depreciation or amortization, reserves, rents for premises and equipment, wages, etc. There are tax credits for apprenticeships especially. Other Corporate Taxes: Payroll tax: a 1% of employees gross salary (in the manufacturing sector) professional training tax is levied (2% in other sectors). Land registration tax is levied at a rate of 5% of the purchased property. Municipal business tax, stamp duty. Customs duties: Customs duties for most goods vary between 0% and 43%, depending on the product's importance to the Tunisian economy. The zero rate is applicable only to capital goods which have no locally manufactured equivalent. A Customs Inspection Tax of 3% of the CIF value is levied on all declared items inspected by customs. Other: Protection agreements against double taxation of foreign companies. Profits gained by export can be deduced from tax.

MENA Glass Industry

Strengths

- Local natural gas availability
- Availability of highest quality sand in the world and also high quality limestone (especially in Egypt)
- Virtually all input materials required to produce glass are available domestically
- Strategic location within three regional markets: Europe, Middle East and Africa
- Algeria: float glass with very low iron content and high solar energy transmittance, which is paramount for the production of ultra- clear float glass which is needed for CSP applications
- Financial strength of the players in the MENA market place due to JV and private equity leaders involvement (Citadel Group for example)

Weaknesses

- Float glass specifications: Egypt's float glass manufacturing facility produces only thicknesses in the range 2 to 12 mm.
- R&D Activities: Links between research centers and industry are weak and need to be strengthened.
- Shortage of trained personnel: There is a lack of suitably trained engineers to operate the existing production lines. Engineering and technological know-how need to be imported (through knowledge transfer agreements, partnerships, etc.)

Opportunities

- JV for transferring specific CSP (and PV) know-how to MENA countries. For example, Guardian is already producing CSP parabolic mirrors in Israel and in the US
- Serve the developing local CSP market

Threats

- Not acting sufficiently quick to pursue the above opportunities, with glass industry of other countries in the region (e.g. EUA, Saudi Arabia, etc.) becoming more competitive than CTF MENA countries' glass industry
- Competition with other neighboring countries on CSP mirrors production (e.g. Saint-Gobain in Spain, the Guardian Industries in Israel, etc.)
- Access to gas needed by float glass plants is not easy. For example, although Egypt is still a major gas producer and exporter, the Government of Egypt prefers to export the gas instead of keeping it for Egyptian industries.
- Glass price volatility

MENA Electronic and electric Industry

Strengths

- Strong industrial capacity in Tunisia and Morocco regarding cable production for the automotive and aeronautic sector
- Presence of first class players in MENA cable market
- Strategic location within three regional markets: Europe; Middle East; and Africa.
- Compliance with highest European standards.
- Local natural gas availability (but not determinant)
- Low labor cost
- Efficient technology transfer due to high customer expectations

Weaknesses

- Low development of engineering and conception
- Weak links between research and industry
- Low R&D capacities within firms, even main players (for example, Tunisie Cables has only 4 to 5 people working on R&D for electronics and 3 people for cables)
- Small size of most companies

Opportunities

- Diversification, including in PV, vehicle cars or CSP specific cables
- Continuous increase of technical know-how

Threats

- Competition with other Middle East and Asian countries

MENA steel and mounting structure Industry

Strengths

Weaknesses

- Strategic location within three regional markets: Europe; Middle East; and Africa.
- Natural gas available locally (Egypt, Algeria)
- Low labor cost (important for the installation of steel structure)
- Actual steel production in CTF MENA countries is far above needed volumes to develop CSP plants
- Local companies working on steel armature should be easily able to move to CSP steel structure manufacturing as they have high tech production lines
- Experience in CSP of steel structure manufacturers like NSF

- R&D Activities: Links between research centers and industry are weak and need to be strengthened.
- Shortage of trained personnel: There is a lack of suitably trained engineers to operate the existing production lines.
- Egyptian market for steel is considered a monopoly since Ezz-Dekhela represents a dominant market share of 61%

Opportunities

- Serve the developing local CSP market
- Local companies working on steel armature should be easily able to move to CSP steel structure manufacturing

Threats

- Not acting sufficiently quickly to pursue the above opportunities, with other countries in the region getting in ahead of CTF MENA countries
- Competition with other MENA countries, especially Turkey
- Access to gas is not easy although Egypt is still exporting gas. Scarcity + no allocation by the government. The government prefers to export the gas instead of keeping it in-house.

Annex to chapter 4

Description of modeling concept for potential economic benefit

The model and decision tool used in the report is written in an excel environment by Fraunhofer ISE.

It refers to the open available JEDI model by NREL but with some important changes and some more parameters included in the model (http://www.nrel.gov/analysis/jedi/). The JEDI model could only be used in the US with regional I-O Input tables and is constant over time. Changes in the industry and local manufacturing are not really included in the model. Therefore it was only used as idea for creating an own model.

Main result of the model is to indicate local share of CSP plants in North Africa over the next years.

The model covers a time horizon by 2030 with a dynamic increase of local manufacturing depending on the framework conditions (scenarios). Therefore the model includes increase of know-how and growth of industry capabilities for CSP components (which could be reached by following an action plan).

I-O tables could not be used because these tables are just general calculating the effects of 1 US Dollar invested. This approach is not very detailed and a large lack of macro-economic and solar industry related data for North Africa was identified.

Therefore a bottom-up approach was used as the effects were calculated component by component, services by services. All values are especially used CSP related. The total investment was split over the components and construction related services and for each single component a multiplier (Jobs/MW and Jobs/Mio$) were used.

The result is value added and number of jobs during construction and operation in the direct CSP related industry.

- ➔ If a service (construction) and a component were indicated to be produced by a company based in North Africa, the total cost volume was added to the "local" share. If a component came from a company based abroad, it was added to the "international" share.
- ➔ Purchase of services (construction, project development, Management, EPC) is a "*construction related effect"*.
- ➔ Purchase of components of a power plant is summarized as "*component and supply chain effects"* for North Africa.
- ➔ Expenses for O&M are divided into labor for operation and exchange of equipment
- ➔ Number of jobs are calculated for each task of construction related labor and construction related services (effects during construction period), and of each component for equipment and supply chain effects.
- ➔ Induced effects are very difficult to calculate without existing I-O tables in MENA countries (search without success). Therefore the calculation of induced effects has been omitted. In the JEDI model the I-O tables were used. That results in values for induced effects which are almost the same size as effects of the supply chain (in the US).

Important input to the model:

1. To evaluate the share of local manufacturing and the economic benefits resulting from local manufacturing, the model is calculated on **three different market scenarios** which have been explained in section "Action plan".
    a. Created the market size and demand for CSP plants and related components/services in the model
    b. Scenarios cover the MENA region with values for each of the five countries (Morocco, Algeria, Tunisia, Libya, Egypt)

2. **Reference plant** (see table of cost structure in chapter 1 of the report) and **cost reduction scenarios** (learning curves depending on world market) for the CSP markets are used to identify the economic impacts and jobs creation.
    a. It gave the investment volumes now and in the future
    b. Cost per component and per services
    c. Market size of the scenarios and costs per component lead to a market demand per component and service

3. **Job effects** during construction and operation are assumed, based on data from recent local and international projects.

a. For each service and component, assumptions for the number of one-year jobs created by a reference plant were collected.

b. Number was adjusted to North Africa

c. Job decrease over time because of cost reduction

d. Jobs of operation were used from JEDI and current projects in Spain (quite stable over next 10 years)

4. The model also summarizes the **status-quo of local manufacturing based on recent ISCCS plants** in the region.

   a. It was identified which components are produced locally and services provided locally.

   b. Reference plants in the region gave starting point from which the share of local manufacturing could increase

5. The model refers to **component specifications based on technology requirements** (see 1.3 and 1.4)

   a. Typical factory output and payments for each component -> jobs per component/MW

Examples	Jobs per MW CSP
…….	
Pylons	0.75
Foundations	0.9
Trackers (Hydraulics und Electrical Motors)	0.15
Swivel joints	0.3
HTF System (Piping, Insulation, Heat Exchangers, Pumps)	2.4
Heat Transfer Fluid	0.6
……	

   b. Level of industrialization and technology know-how required for each component (also based on ISCCS plants)

6. **Country and project related assumptions for local manufacturing of components and plant construction**. (2.1and 2.2)

   a. Modeled market size of each country

   Example: Scenario 5 GW

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Morocco	0 MW	50 MW	50 MW	100 MW	100 MW	200 MW	200 MW	250 MW	300 MW	400 MW	450 MW
Egypt	0 MW		50 MW	80 MW	120 MW	125 MW	175 MW	200 MW	200 MW	300 MW	300 MW
Tunisia	0 MW		0 MW	25 MW	0 MW	25 MW	25 MW	25 MW	25 MW	38 MW	38 MW
Algeria	0 MW		50 MW	50 MW	75 MW	75 MW	100 MW	100 MW	150 MW	150 MW	200 MW
Jordan	0 MW				13 MW	13 MW	25 MW	25 MW	50 MW	25 MW	50 MW

   b. Findings of industry capabilities from chapter 2 in report

   c. Increase of know-how (action plan)

   d. Impact of national RE strategy

Decision Tool of local manufacturing:

While CSP market and technical know-how is increasing in the scenarios, the tool checks in each year which components could be produced locally or not. If a component is indicated as “possible to be produced locally” in a country, it will be also produced locally in the future.

Important criteria of local manufacturing in North Africa:

1. Market demand
2. Some components are indicated as “international” for ever (power block)
3. Some components have barriers to which point local production is likely (If receivers are produced in Egypt, just 50 % of the market could be supplied by the national company, rest comes from abroad)
4. Continuous increase if nothing changes.

Results

1. The results are aggregated for all countries over all components and services.
2. The average share of local manufacturing is not the maximum, single plants in several countries could have local share up to 20 % higher than the average.
3. All expenses in local components and services are summarized as economic benefit for the region. Rest effect is economic benefit for companies (countries) outside the region!
4. Jobs are calculated on a one year basis (fulltime equivalents). It could be said that jobs in component manufacturing are more permanent but are also given as one-year job (Example: An employee works in a mirror factory for 10 years, counts for 10 one-year jobs; Worker on the construction site for 2 years, counts for 2 one-year jobs.)
5. Induced effects are difficult to calculate and therefore not included. Analysis of the JEDI model shows values of induced effects are quite similar to indirect effects.

Remark concerning component exports:

1. Increase the demand for components facilitating local manufacturing because of a larger market
2. If a component is produced for the local market, it could also be exported.
3. Demand of 2 GW refers to components for CSP plants with the total size of 2 GW.

Calculation Example: ***Jobs and economic benefit by mirror supply for a CSP plant:***

1. Identify year t of plant construction (e.g. 2020)
2. Market size in year t (e.g. 100 MW CSP with storage)
3. Use cost for mirror component to obtain expenses for mirrors by calculating with market size (462000 $US/MW) -> 46 Mio. $
4. Number of job per MW in year t (in 2010: 1 one year full-time equivalent jobs per MW)
5. Calculating number of jobs by using market size in year t (100 one-year jobs)
6. Decision tool of local manufacturing (locally produced or not?) ->e.g. yes, 40% mirrors locally
7. Share of local manufacturing of mirrors in year t gave the number of local jobs and local expenses for mirrors -> 40 local jobs, 18 Mio $US

Annex B – Case studies

Wind turbine manufacturing in India

India entered the market for manufacturing of wind turbines in the mid 1990s Though other market players, such as Denmark, The Netherlands, Germany and the USA, had already consolidated their leading market positions for over 20 years, Suzlon, at present India's largest manufacturer of wind turbines, achieved 8% of the global- and 52% of the Indian market share in 2006 (Lewis & Wiser 2007). An analysis of the development of the framework conditions in India and Suzlon's strategy to acquire the technological know-how to become India's leading wind turbine manufacturer can help to understand the processes of international technology transfer in the sector of renewable energies and to derive lessons for the development of strategies therefore.

Historical background

The history of wind energy in India already began in the early 1980's. Facing a rapid population growth and economic rise accompanied by a strongly increasing demand for electricity, the Indian government started to promote a diversification and enhancement of the power sector. In 1982 the 'Ministry for Non-Conventional Energy Sources' (MNES)38 (since 2006 'Ministry of New and Renewable Energy', MNRE) was established with the aim of laying a stronger focus on the promotion of alternative and renewable energies (including wind) and to reduce the dependency on domestic coal resources.

1984 a national 'Wind Power Program' was initiated which included resource assessment, incentive schemes, demonstration- and research activities in the field of renewable energy technologies (RET's) and the establishment of regional agencies for the promotion of RET's in the country. Several regularly updated handbooks on wind energy resources were published to communicate the large potential of the development of the technology in India. Nevertheless the private participation in the sector was still limited at this time and nearly all components for the wind power plants were imported. In 1991 the 'private power policy' was announced which liberalized the wind sector and led to a substantial rise in installed wind capacity in India.

By 1995 a change in tax policies made incentive packages less attractive and led to stagnation in the growth of the installed within the following years. Subsequently several Indian states introduced different support schemes to incentivize a further development of the wind energy sector. However, inconsistency and instability of the Indian incentive schemes represented a major restraint for the development of the wind sector since it created insecurity for potential investors (Bhattacharya 2009).

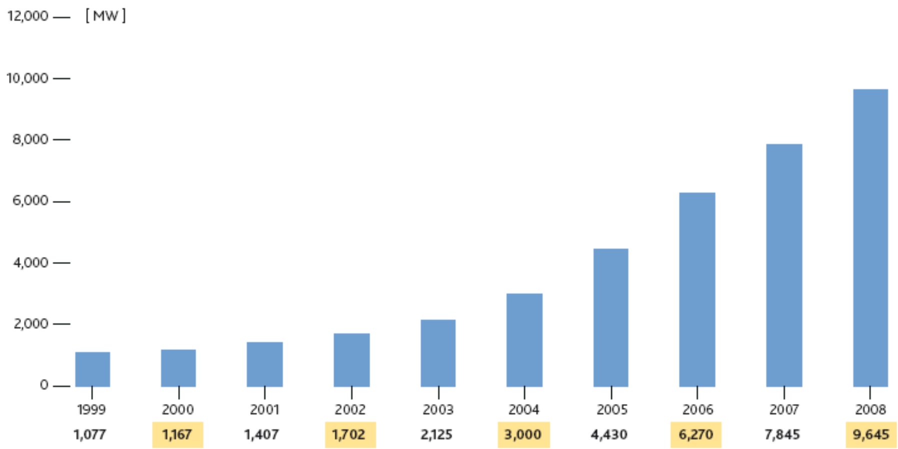


Figure 88 Growth of the Indian wind market - cumulative capacity 1999-2008 (Indian Wind Energy Outlook 2009)

In 1995 the 'National Guidelines for Clearance of Wind Power Projects' were implemented which aimed at assuring grid compatibility of future wind power projects and offered further financial incentives like tax holidays and depreciations on required equipment for wind plants.

Besides the general growth of the wind turbine market in India (cf. Figure 88), also these measures created conducive framework conditions for the development of a local manufacturing industry. Favorable customs and excise duties for parts and equipment for wind

38 In 1981 the 'Commission for Additional Sources of Energy' was created in the 'Department of Science and Technology'. In 1982 an independent department – the Department of Non-conventional Energy Sources – was set up which was transformed into the MNES in 1992.

turbines favor the import of parts instead of entire turbines. Thus manufacturing or assembling the turbines locally becomes more attractive than importing them. Another important measure that fostered the wind turbine industry was the governments funding of extensive research and testing programs which assured that domestically produced turbines fulfilled international standards and were ready for commercialization (Lewis & Wiser 2007). In 1998 the Indian 'Center for Wind Energy Technology' was established and facilitated a comprehensive knowledge transfer through the activity in advanced international research networks.

With the Indian Wind Turbine Manufactures Association (1997) and the Indian Wind Energy Association (2002) two further Institutions were created that make strong efforts towards a favorable policy development and the reduction of barriers for further development of wind energy in India.

In 2003 the 'Electricity Act' was announced. It reinforced the legitimacy of the power producers; liberalized laws concerning transmission and distribution of electricity and demanded for more transparency in the tariff policy. Thus it formed the starting point of a steady growth phase in the Indian wind power market (cf. Figure 88).

Today (since 2008) a national incentive scheme for wind power projects is established, including a national feed-in tariff of 0.5 rupees per KWh which was granted additionally to the already existing different state incentives. Further incentives today are concessional import duty on specified wind turbine parts, 80% accelerated depreciation in the first year, excise duty reliefs, provision of favorable loans and income tax holidays[39].

Suzlon – An Indian business success story

The company emerged in 1995 and is today one of the largest manufacturers of wind turbines in the world and the largest in India, providing over 50% of the wind turbines for the domestic market. Suzlon operates in 21 countries around the world and is also active in developing and operating wind farms. The company owns headquarters and development centers in Europe, Australia and China but the major part of the production facilities is located in India.

The company acquired the necessary knowledge for its successful development by a multitude of beneficial collaborations. In 1995 a technical collaboration agreement with 'Südwind' an experienced German company in the wind energy technology sector. A comprehensive knowledge-transfer with regard to manufacturing of different wind turbines continued over a period of 5 years. In 2001 Suzlon entered a collaborative agreement with 'Enron Wind Rotor Production B.V.' and obtained a license from 'Aerpac B.V.' to be able to manufacture wind rotor blades (Lewis 2007).

In parallel to this external knowledge acquisition the company has made intensive efforts concerning in-house R&D and participation in learning networks, for example by the creation of research centers in The Netherlands and Denmark, to take advantage of the local expertise and connect to existing learning networks.

In the later years the company followed a straight policy of expansion and acquired the technological know-how to manufacture all parts of a wind power plant. In 2006 it purchased the Belgian company 'Hansen Transmissions' which was specialized in the production of gear boxes for wind power plants and in 2007 it purchased a controlling stake in REpower, a German turbine producer. 2009 Repower was overtaken completely involving the integration of specialized knowledge in the field of large offshore wind turbines. Thus, Suzlons position on the world market solidified step by step and today the company is able to deliver turnkey projects since it integrated all parts of the wind power value chain including project development operation and maintenance (Walz unp.).

Lessons to be learnt

Naturally, the transferability from India's history in wind turbine manufacturing to the manufacturing of CSP components in the MENA countries is limited. Nevertheless, the general mechanisms and decisive factors for the development of a renewable energy manufacturing sector can be derived from this example. Although the wind energy sector in India and the related manufacturing industry developed over a long period and experienced some obstacles, the steady progress and the final success prove it successful in the end.

In summary, the success of Suzlon and the Indian wind turbine industry in general can be attributed to:

- An early promotion of renewable energy in general and wind energy in particular, resulting in a strong growth of the market demand for wind turbines. This coordination of policies can be seen as one of the main factors for the success of the Indian wind turbine industry.

[39] Source : www.windpowerindia.com

- The development of strong learning networks in form of intensive collaboration with established companies from Denmark, Germany and The Netherlands, extensive research and development activities in cooperation with international companies. Only this allowed for a comprehensive knowledge transfer and a growing expertise in the technological field.
- The development of domestic testing and certification programs to reach international standards and the acquisition of licenses contributed essentially to the market competitiveness of the products.
- A strong focus on internationalization which was realized by an early establishment of branch offices and development centers, strategically positioned in vicinity to target markets. Also focus was laid on connecting to various cooperation partners to benefit from information networks.
- The strategic use of locational advantages in the home country, namely an establishment of manufacturing facilities in India, allowed for taking advantage of low labor cost and good access to capital and local networks.
- The creation of several subsidiaries allowed Suzlon to achieve a maximum of in-house production of components. Thus costs can be lowered, the intellectual property is protected and competitive advantages are increased.

Factors which decelerated the development of wind turbine manufacturing in India in the early years were:

- The inconsistency of political instruments for promotion of renewable energies during early years of development.
- Regional differences in political targets and the absence of a national renewable energy law.
- Deficits in transmission line capacities, which might also decelerate a future growth (Lewis 2007)

Concluding it can be said, that also in the MENA region a strong focus should be laid on a coordinated policy that aims on the one hand at promoting the manufacturing industry and on the other hand at a creation of the necessary framework to foster the development of further CSP projects and thus stimulate a steady CSP market growth. In this respect, one major precondition is to guarantee a profitable purchase of the generated electricity via region feed-in tariffs and other incentives that should be harmonized region-wide.

Moreover, collaborative agreements and the acquisition of licenses from more advanced market players are important steps, especially for developing countries, to catch-up in industrial development processes and to benefit from locational advantages for renewable energy generation as well as for production of equipment therefore.

Local manufacturing in Morocco: Renault

Background of Renault in Morocco

Since 1959 the Moroccan industry has had its largest automotive manufacturing and assembling factory Somaca - Société Marocaine de Constructions Automobiles, close to Casablanca in an industrial district (Aïn Sebaa) of the financial capital of Morocco. Founded by Fiat S.p.A. and its French subsidiary, Simca the factory was sold to Renault in 2003 after Renault has started to produce the compact cars Renault Kangoo and Dacia Logan some years later (recently also Sandero). The long history of the automotive sector was identified to have a closer look of manufacturing and assembling capacities in Morocco.

After difficulties of production, Renault invested new capital in machines, processes and workforce (today 1400 employees) of Somaca. Today the facility holds different quality certificates like the EAQF "A" quality standards and ISO 14001 environmental certification. Yearly production capacity ranges up to almost 30.000 cars that are mainly sold directly on the Moroccan market, in which Renault and Dacia have together a market share of 29.1 %. But a share of the production output is also exported and shipped to the European market.

In 2008, Renault and Nissan started work on a vast industrial complex in Tangiers to built on a 300ha site in the Tangiers Mediterranean Special Economic Zone. The new factory will comprise an assembly plant that expands Renault's production base for low-cost vehicles.

Achievements of automotive sector in Morocco

The automotive assembling experiences a long industrial history in Morocco for over 50 years. While export to Europe put pressure on all quality aspects and created incentives to decrease the fault rate. Thus international quality and cost standards are met by the factory Somaca. Today, Somaca uses the German and Japanese approach of training and qualification for its employees (need of the same qualified and skilled workers) by exchange and partnerships with German car industry.

Furthermore networking and clustering of national and international automotive components suppliers (cables, electronics, and plastic equipment) was supported by state-initiatives for industry development. Regarding a long-term training and education system, the automotive industry association in Morocco created co operations with 4 universities for education of high-skilled workers (electronic/ mechanical engineers).

The indicated achievements give an impressive push for the Moroccan industry in total. But some restrictions and differences between the automotive industry and a potential CSP manufacturing have to be made because of the different characteristics of both sectors. These differences could help to understand why the automotive sector could be developed in Morocco strongly in the past. But also they indicate if the same development can be achieved for the local manufacturing of CSP.

Differences between automotive sector and CSP component manufacturing in Morocco

The level of know-how for manufacturing automotive components is lower than key components of CSP plants. Also the large local demand for cars in Morocco already existed while the factories increased their output during the last 10 years. On the other hand, the CSP market has to be developed in the next years. In terms of the production process, the assembling of cars in Morocco is more labor intensive compared to a mirror, glass or steel production

Consequently, many findings of the local automotive industry should support the market deployment of CSP component manufacturing. Therefore results and effects of the automotive industry enable improvements in the development of a local CSP industry capacity in Morocco.

Learning from the automotive market experience for creation of CSP manufacturing in Morocco

This case of local manufacturing in Morocco tries to give some remarks on existing local manufacturing of the automotive industry in Morocco. Experiences useful for the CSP manufacturing are:

- Integration of different industrial players is (engineering, manufacturers, project developers) within the industry is necessary to be successful.
- International investment and technology transfer by Renault was required to achieve a strong market position and efficient production process in Somaca.
- Somaca facility is limited to the assembling of low-cost compact cars. Manufacturing process of motors and engines can not be done
- Locally produced components are mainly at a lower technology level.
- Different component supply factories should be developed for a wider industry base.

- Close relation to education and research institutions should be installed to guarantee a long-term development
- Example of Tangier industrial facility: Two year preparation of new production line, training for employees in different companies all over the world as preparation of capacity for Renault factory
- Automotive industry required own long-term R&D and Continuous Improvement Process for successful car manufacturing.
- Relation and experience of large European companies with Moroccan industry created a very stable investment climate for international companies in Morocco
- Labor costs for employees (lower skills) in the automotive sector is 1/5 of labor costs in Germany

Summarized findings of Renault´s factory Somaca and its plan to start with a second large production line in Tangier indicate the industrial capacity and technology know-how for a certain level of manufacturing potential in Morocco. Together with international partners, suppliers and market demand a local industry base could be created successfully.

The CSP industry in Spain and the USA

The key basis for the success stories regarding the development of a CSP industry in Spain and the USA was the establishment of strong market diffusion policies, i.e. the feed-in tariff in Spain and the combination of investment incentives and renewables obligations in the USA. Hereby the most relevant aspect with respect to the implementation of these support schemes is a long term vision and certainty allowing the investment in manufacturing as well as research and development.

In Spain, the "Ministry of Industry and Tourism's" (MITC's) pronounced to register 57 CSP projects, thereby guaranteeing certain developers the €0.28/kWh feed-in tariff in December 2009. With this announcement the government secured a long-term development in the Spanish CSP market.

The regulator set also special requirements for the industry if applying for the tariff:

- Authorized grid access and power off take from local transmission operator
- Obtaining administrative authorization from local community
- Guarantee of financing for 50% of project's capital cost
- Purchase agreement with suppliers for at least 50% of components
- Water management of CSP plant
- Bank deposit to guarantee project's intentions

As mentioned in this report, the Spanish industry is largely being driven by EPC players leveraging their construction experience and stronger balance sheets. This sector in Spain has been able to get about €1.4 billion of loans from the European Investment Bank funding more and more clean technology projects. CSP industry has profited from this funding and investment while the financial crisis complicated project financing significantly.

In the US, CSP industry is finding partners in the automotive industry to provide low-cost solutions for CSP components (mirrors, engines and structures). Large project volumes of 500 to 1000 MW create a demand for components and equipment over several years. In 2010, the US government announced special tax incentives for clean energy manufacturing. This announcement by the American Recovery and Reinvestment Act had a volume of 2.3bn US$. Under the funded companies six companies of the CSP industry obtained the tax incentives to construct or expand CSP manufacturing facilities in the US. In general, this funding was distributed to renewable energy manufacturing industries serving the power, industrial, residential, and commercial sectors.

Besides the direct market incentive mechanisms both Spain and the USA put a focus on research and development during the recent two decades. Spain has been engaged in applied research for CSP since the 80s. In the beginning the activities were concentrated on the German-Spanish Cooperation at the Plataforma Solar. In particular the government owned research organization CIEAMAT was involved in this large demonstration project for CSP plants. Since the establishment of the Spanish feed-in tariff research and development activities have more and more shifted to the private sector. The USA in comparison has industrial CSP experience since the 80s. Due to the fact that for a period of 15 years no new plants have been built, substantial parts of this industrial and manufacturing competence have been lost in the meantime. Furthermore public R&D expenditures, which are also focused on large research labs as Sandia National Laboratories have declined since the beginning of the last decade. This also led to the fact that the USA lost its formerly leading position in terms of industrial capacity to Spain.

The creation of CSP associations has also been an important factor to raise awareness and provide information in Spain and in Europe. On the Spanish market, *Protermosolar* influenced the continuous market framework to proceed with CSP towards 2020. By this association the long-term goals of the solar industry have been highlighted to the Spanish regulator when the CSP support was under pressure by budget negotiations in 2009 and 2010. The *European Solar Thermal Electricity Association* contributed substantially to promote the CSP technology through entire Europe by providing studies, reports and roadmaps about the technology, industry and new power plants.

Annex C – Country reports

The following tables provide an overview over the people that have been interviewed during the country visits.

A.1 Morocco

Interviews during the first visit to Morocco (27th-29th of May 2010):

Company / Institution	Type of company / institution	Name of contact
TAQA	Private power plant developer	M. Karim Chraibi (Project developer Taqa North Africa)
Attijari Wafabank fonds MIF	Private investor	Belrhandoria Samir (DG)
Delattre Levivier Maroc (DLM)	Non CSP industrial (metallic construction)	Jean-Claude Bouveur (PDG)
Inabensa Maroc (groupe Abengoa)	Spanish private CSP developer	Jorge Ceinos Moreno (DG)
Leoni Cable Maroc	Non CSP industrial (cables production and distribution)	Hamid Louarroudi
MASEN	Public agency	M. Bakkoury
CDER	Public agency	M. Mouline
IFC	Institutional investor	Yasser Charafi
Ministère de l'Industrie, du Commerce et des Nouvelles Technologies	Government	Ali Guédira (conseiller) et Mohamed Cheikh Dkhil
BEI	Institutional investor	Guido Prud'homme
Fédération de l'Automobile	Non CSP industry representation	Larbi Belarbi
Induver	Non CSP industrial (glass)	Rachid Abdelmoumen
SONASID and ASM	Non CSP industrial (steel) and representation	Nacer Bouimadaghene (director technique)

Interviews during the second visit (28th-29th of July 2010):

Company / Institution	Type of company / institution	Name of contact
GIMAS	Non CSP industry representation (aeronautics)	Hamid Benbrahim El-Andaloussi (Chairman)
Nareva Holding	Non CSP industrial	Reda Znaidi (business development manager)
YNNA Holding	Non CSP industrial	Youssef Mouline (development director)
AMICA	Non CSP industry representation (automotive)	Mohamed Ouzif (DG)
TEMASOL	Non CSP industrial (solar PV)	Khalid Semmaoui
Service économique (French embassy)	Political institution	Laurence Jacquot and Olivier Davy

A.2 Algeria

Interviews during the visit (25th-27th of May 2010):

Company / Institution	Type of company / institution	Name of contact
Cevital	Non CSP industrial	Boukhalfa Yaici
Abener	EPC contractor	Francisco Gomez
NEAL	Political institution	Farsi Hichem
Centre de Développement des Energies Renouvables	Research institute	Abdelskrim Chenak
Sonelgaz	Non CSP industrial (energy)	Boumahra Abdelaziz
UDTS Research Centre	Research institute	Boumaour
Alstom	Infrastructure	n.n.

A.3 Tunisia

Interviews during the visit (7th-9th of June 2010):

Company / Institution	Type of company / institution	Name of contact
Société tunisienne de sidérurgie	Industrial Association	Ammar Chaieb
STS El Fouladh	Steel industry	Fathi Chtioui
Tunisie Cables	Electronic industry	Hédi Sellami
ASSAD	Electronic industry	Mehdi Kallel
TECI	Engineering	Hassen Hellali
Chambre Syndicale Nationale des Energies Renouvelables	Industrial Association	Tahar Achour
BIAT	Bank	Nidham Jamoussi
Intermetal	Non CSP industrial	Mokhtar Mehiri
Agence Française de Développement	Bank	Emmanuel Haye
SOTUVER	Glass industry	Amiri Gouider
MIT	Industry	Abdelaziz Rassâa
African Development Bank	Institutional Investor	Héla Cheikhrouhou
Energy and Environment Engineering	Engineering	Mme Mchirgui
Groupe ELLOUMI	Industry	Hichem Elloumi

A.4 Egypt

Interviews during the first visit (3rd – 6th of May 2010):

Company / Institution	Type of company / institution	Name of contact
Egyptian Electricity Holding Company	Electricity Utility	DR. Mohamed Awad
Med-Emip	EU delegation	Albrecht Kaupp Ahmed Badr
Ministry of Trade and Industry Office of the Minister	Government	Mohamed Elsherif
Orascom Construction Industries	EPC contractor	Tamer Shafik Hisham Sharhawy Ashraf Sami
RCREEE - Regional Centre for Renewable Energy and Energy Efficiency	EU delegation	Ludger Lorych
World Bank (CTF)	Institutional investor	Dr. Mohab Hallouda
Industrial Modernization Center	Public agency	Mohamed Salah Elsobki
Egyptian Electricity Utility and Consumer Protection	Public agency	Dr. Hafez E. El-Salmawy
Federation of Egyptian Industries Chamber of Building Materials Industries	Public agency	Walid Gamaleldin
Sphinx Glass	Non CSP industrial (glass)	Ayman Elkady
The Arab Contractors	Non CSP industrial	Ibrahim Mahlab
NREA	Public agency	Laila Geogry Yoissef

Interviews during the second visit (4th- 5th of August 2010):

Company / Institution	Type of company / institution	Name of contact
Arab British Dynamics	Electronic industry	Abbas R. Rady
AOI-Electronics Factory	Electronic industry	Dr. Eng. Samir Darwish
Al-Babtain Power & Telecommunication Co.	Telecommunication/Manufacturing	Abdul Azim Mohamed Ismail
Middle East Engineering & Telecommunications (MEET)	Engineering	Ashraf H. EL-Nashar
Global Tronics	Manufacturing, electronics (electric meters)	Hany Karawia
Industrial Modernization Centre	Association, Research	Dr. Mohammed Salah El Sobki
El Sewedy Power	Electronic industry, Manufacturing	Wael Hamdy
Dr. Greiche Glass	Glass industry	Eng. Mohamed Ezz El-Din
Mechanical Power Eng. Dept. of Cairo University	Research	Prof. Dr. Adel Khalil
Egypt National Cleaner Production Center	Association	Ali Hossni

A.5 Jordan

Interviews during the visit (August 2010):

Company / Institution	Type of company / institution	Name of contact
Ministry of Energy and mineral Resources (MEMR)	Public institution	Ziad Jibril
Ministry of Planning & International Cooperation (MoPIC)	Public institution	Phil Godron
Ministry of Environment	Public institution	Raouf Dabbas
Consulting Engineering Center (CEC)	Consultancy	Moawad Ayad
Kawar	Entrepreneurial venture	Hanna Zaghloul
Cleantech Mena	RE developer	Samir Zureikat
European Jordanian Company for Renewable Energy Projects (EJRE)	RE developer	Tarek Al Amad
National Energy Research Center (NERC)	Public research center	Walid Shahin
Philadelphia Solar	PV module producer	Eng. Abdul Rahman Shehadeh

References

(Abengoa, 2010) Abengoa (2010): Pictures that show a solar tower power plant, available at: http://www.abengoasolar.com/corp/web/en/ our_projects/solucar/ps10/index.html (date of last site visit: Sep.13, 2010).

(AGC, 2010) AGC Glass Europe (2010): Company technology information brochure, available at: http://www.agc-glass.eu/English/Homepage/Products/Float-glass-technology/page.aspx/958 (date of last site visit: Sep.13, 2010).

(Almeco, 2010) Almeco / Xeliox (2010): Vegaflex the Mirror 100% Aluminum; technological information brochure, available at: http://www.almecogroup.com/en/products/solar/vegaflex; (date of last site visit: Sep.13, 2010).

(Altenburg, 2009) Altenburg, T. (2009): Industrial policy for low- and lower-middle-income countries. Preliminary draft. German Development Institute (DIE).

(Arc, 2008) Archimede (2008): Company publication, available at: http://www.archimedesolarenergy.it/receiver_tube.htm; (date of last site visit: Sep.13, 2010).

(Archimede, 2010) Archimede (2010): Receiver Information, homepage, available at: http://www.archimedesolarenergy.com/receiver_tube.htm vegaflex; (date of last site visit: Sep.13, 2010).

(AT-Kearney, 2010) AT-Kearney (2010): Solar Thermal Electricity 2025, clean electricity on demand: Attractive STE cost stabilize energy production.

(Bhattacharya & Jana, 2009) S.C. Bhattacharya, Chinmoy Jana (2009): Renewable energy in India: Historical developments and prospects, Energy 34 (2009) 981–991.

(Bhattacharya & Wolde, 2010)Bhattacharya, R. & Wolde, H. (2010): Constraints on trade in the MENA region. IMF Working Paper No. 10/13.

(BilfingerBerger, 2010) BilfingerBerger (2010): Technological internet brochure, picture from the homepage, available at: http://www.bilfingerberger.de/C125710E004ABFC5/CurrentBaseLink/W284PKJ6429WEBTE
(Date of last site visit: Sep.13, 2010)

(BMU, 2010) German Ministry of Environment (2010): Available at: http://www.bmu.de/forschung/doc/ 4781.php#abb1; (Date of last visit: June 20, 2010).

(Bosch, 2008) Bosch Rexroth (2008): Auf den Punkt fokussiert. Automatisierungstechnik konzentrierende Solarkraftwerke, available at: http://www.boschrexroth.com/corporate/sub_websites/industries/solar/de/solaranlagen/referenzen/index.jsp;jsessionid=cbaBKAaUpuhVT9SyQvoSs; (date of last site visit: Sep.13, 2010).

(Brost, 2009) Brost, R., Gray, A., Burkholder F, Wendelin T, White D (2009): Skytrough optical evaluations using VSHOT measurement, Proceedings of 15th International SolarPACES Symposium, Sept. 14-18, 2009, Berlin, Germany.

(Buck, 2008) Buck, R. (2008): Solare Turmtechnologie – Stand und Potenzial, paper presented at Kölner Sonnenkolloquium 2008.

(Casteneda, 2006) Casteneda N, Vazquez J, Domingo M, Fernandez A, Leon J (2006): Sener parabolic trough design and testing, Proceedings of 13th International SolarPACES Symposium, June 20-23, 2006; Seville, Spain.

(Chen & Puttitanun, 2005)	Chen, Y., & Puttitanun, T. (2005): Intellectual property rights and innovation in developing countries. Journal of development economics. Volume 78. Issue 2, pp. 474-493.
(Cohen, 1999)	Cohen, G., Kearney, D., Kolb, G. (1999): Final report on the operation and maintenance improvement program for concentrating solar power plants, Sandia National Laboratories, June 1999, SAND99-1290.
(Contractor & Lorange, 2002)	Contractor, F. J. & Lorange, P. (2002): Why should firms cooperate? The strategy and economics. Basis for cooperative ventures. In: Contractor, F.J. & Lorange, P. (ebs.): Cooperative strategies in international business. Oxford: Elsevier sciences, 2002, p. 1-26.
(CSP-Today, 2010)	CSP-Today (2010): The Concentrated Solar Power Markets Report/ Summary, available at: http://www.csptoday.com/cspmarkets/index.shtml?utm_source=CSP%2Bmain%2Bwebsite&utm_medium=Banner&utm_campaign=CSP%2BMarkets%2Breport%2Bmain%2Bbanner; (date of last site visit: Sep.13, 2010).
(Dewey & LeBoeuf LLP, 2010)	Dewey & LeBoeuf LLP (2010): China's promotion of the renewable electric power equipment industry. Hydro, Wind, Solar, Biomass.
(Dersch, 2009)	Dersch, J., Morin, G., Eck, M., Häberle, A. (2009): Comparison of Linear Fresnel and Parabolic Trough Collector Systems – System Analysis to determine break even Costs of Linear Fresnel Collectors, Proceedings of 15th International SolarPACES Symposium, Sept. 14-18, 2009, Berlin, Germany.
(D.Kearney, 2007)	Kearney, David (2007): Parabolic Trough Collector Overview; Presentation at the Parabolic Trough Workshop 2007 at NREL, Golden, CO (USA), March 2007.
(DLR, 2010)	Deutsches Zentrum für Luft- und Raumfahrt / German Aerospace Center (2010): Available at: www.dlr.de/rd/en/Portaldata/1/Resources/portal_news/newsarchiv2008_5/ (date of last visit: March 30, 2010).
(Doening, 2010)	Doening (2010): U.S. Department of Energy: Concentrating Solar Power Industry Projects, Program Area Thermal Storage.
(Ecostar, 2005)	ECOSTAR (2005): European Concentrated Solar Thermal Road-Mapping.
(Eichhammer & Walz, 2009)	Eichhammer, W. & Walz, R. (2009): Indicators to measure the contribution of energy efficiency and renewables to the Lisbon targets - monitoring of energy efficiency in EU 27, Norway and Croatia (ODYSSEE-MURE). Fraunhofer ISI.
(Emerging Energy Research, 2010)	Emerging Energy Research (2010): Global Concentrated Solar Power Markets and Strategies: 2010-2025, Report April 2010.
(ERC, 2010)	Energy Research Center (2010): Past and ongoing EE activities and programs by donors and GOE. In: EGYPT - Improving Efficiency of Energy Use - Chapter II of report, June 2010.
(Eve, 2010)	Evers, H. (2010): Cost based engineering and production of steel constructions, Proceedings of Fourth International Workshop on Connections in Steel Structures. Roanoke. 2000. Available at: http://www.aisc.org/content.aspx?id=3626 (date of last site visit: Sep.13, 2010).
(Erasolar, 2010)	Erasolar (2010): Revista tecnica de energia solar, available at: http://www.erasolar.es/WEB-146/RESUMEN146.htm; (date of last visit: June 16, 2010).
(Estela, 2010)	ESTELA (2010): Solar Thermal Electricity 2025, Clean electricity on demand: attractive STE cost stabilize energy production, available at: http://www.estelasolar.eu/index.php?id=22 (date of last site visit: Sep.13, 2010).
(Fichtner, 2009)	Georg Brakmann, Fathy Ameen Mohammad, Miroslav Dolejsi and Mathias Wiemann (2009): Construction of the ISCC Kuraymat (Integrated Solar Combined Cycle Power Plant in Morocco; Paper FA4-S6 presented at 13th International Symposium on Concentrating Solar Power and Chemical Energy Technologies, SolarPaces, June 20-23, 2006, Seville, Spain).

(Flabeg, 2010)	Flabeg GmbH (2010): Technological explanations on company web portal, available at: http://www.flabeg.com/de/solar_produkte_parabolic_de.php; (date of last site visit: Sep.13, 2010).
(Gil, 2010)	Gil, A., Medrano, M., Martorell, I., Lázaro, A., Dolado, P., Zalba, B., Cabeza, K. (2010): State of the art on high temperature thermal energy storage for power generation. Part 1 - Concepts, materials and modellization, published in Renewable and Sustainable Energy Reviews 14 (2010) 31–55, published by Elsevier.
(Glasstech, 2010)	Glasstech (2010): The different glass bending processes and machines are described on this homepage http://www.glasstech.com/312Solar.aspx (date of last site visit: Sep.13, 2010).
(Glaston, 2010)	Glaston (2010): Automatic Bending Furnace, Product Brochure, available at: http://www.glaston.net/includes/file_download.asp?deptid= 5272&fileid=3499&file=ESU_EcoPower_EN.pdf&pdf=1, (date of last site visit: Sep.13, 2010).
(Glaeser, 2001)	Glaeser, Hans Joachim (2001): Large Area Glass Coating; book ISBN: 3-00-004953-3.
(Graham, 1982)	Graham, E. M. (1982): The terms of transfer of technology to the developing nations: a survey of the major issues, OECD, North/South Technology Transfer, OECD, Paris.
(Greenpeace, 2009)	Global Concentrating Solar Power Outlook 2009. Greenpeace International, SolarPACES and ESTELA http://www.greenpeace.org/international/en/publications/reports/concentrating-solar-power-2009/
(Hel, 2008)	Andrew Soutar, Bart Fokkink, Zeng Xianting,Tan Su Nee, Linda Wu (2008): Sol-gel Anti-reflective Coatings, SIMTech Technical Report (PT/01/002/ST).
(Hermann, 2004)	Herrmann, U., Graeter, F., Nava, P. (2004): Performance of the SKAL-ET collector loop at KJC Operating Company; 12th SolarPACES Symposium, October 6-8, 2004, Oxaca, Mexico.
(Hildebrandt, 2009)	Hildebrandt, C. (2009): Hochtemperaturstabile Absorberschichten für linear konzentrierende solarthermische Kraftwerke, PhD thesis at Universität Stuttgart and Fraunhofer ISE, 2009.
(Hydro, 2010)	Norsk Hydro ASA (2010): Hydro Aluminium White Paper CSP, available at: http://www.hydro.com/en/Subsites/North-America/39409.
(ISE, 2010)	Fraunhofer Institute for Solar Energy Systems ISE (2010): available at: http://www.ise.fraunhofer.de/geschaeftsfelder-und-marktbereiche/solarthermie (date of last site visit: Sep.13, 2010).
(Indian Wind Energy Outlook 2009)	Indian Wind Energy Outlook (2009), http://www.indianwindpower.com/pdf/GWEO_A4_2008_India_LowRes.pdf
(Khalil et al, 2010)	Khalil, A., Mubarak, A., Kaseb, S. (2010): Road map for renewable energy research and development in Egypt, Journal of Advanced Research University of Cairo, (2010)1, p.29-89.
(Kaefer insulations, 2010)	Kaefer GmbH (2010): Expert interview by Fraunhofer ISE, June 2010.
(Kennedy, 2002)	Kennedy, C.E. (2002): Review of mid to high temperature solar selective absorber materials. July 2002 • NREL/TP-520-31267, Technical Report
(Kennedy, 2005)	Kennedy (2005): CSP FY 2005 Milestone Report, available at: http://www.nrel.gov/csp/publications.html (date of last site visit: Sep.13, 2010).
(Kearney, 2007)	Kearney (2007): Parabolic Trough Workshop 2007 at the National Renewable Energy Laboratory, Golden CO; Parabolic Trough Collector Overview.

(Kistner, 2009) Kistner, R. (2009): Analysis of the potential for cost decrease and competitiveness of parabolic trough plants (R. Kistner , T. Keitel, B. Felten and T. Rzepczyk).

(Laing, 2002) Laing, D., Schiel, W., Heller, P. (2002): Dish-Stirling-Systeme – Eine Technologie zur dezentralen Stromerzeugung, FVS Themen 2002.

(Lewis & Wiser, 2007) Lewis, J. & Wiser, R. (2007): Fostering a renewable energy technology industry: An international comparison of wind industry policy support mechanisms, Energy Policy 35 (2007):1844–1857.

(Lewis, 2007) Lewis, J. (2007): Technology Acquisition and Innovation in the Developing World: Wind Turbine Development in China and India, St Comp Int Dev 42 (2007):208–232.

(Lund, 2008) Lund, P. (2008): Effects of energy policies on industry expansion in renewable energy. Renewable Energy 34, p. 53-64.

(Mazzoleni, 2007) Mazzoleni, R. & Nelson, R. (2007): Public research institutions and economic catch-up, Research Policy 36 (2007): 1512–1528.

(Medrano, 2010) Medrano, M., Gil, A., Martorell, I., Potau, X., Cabeza, L. (2010): State of the art on high-temperature thermal energy storage for power generation. Part 2 – Case studies, Renewable and Sustainable Energy Reviews 14 (2010) 56–72, published by Elsevier.

(Mertins, 2009) Mertins, Max (2009): Dissertation Technische und wirtschaftliche Analyse von horizontalen Fresnel-Kollektoren, Fakultät für Maschinenbau der Universität Karlsruhe (TH).

(Morin, 2010) Morin Gabriel (2010): Design Optimization of Solar Thermal Power Plants, preliminary version of PhD thesis at University Braunschweig and Fraunhofer ISE, as of June 21, 2010 (not yet published).

(Nieto, 2009) Nieto, J.M. (2009): Levelised Cost of Thermosolar Energy, Short and Medium-term Reduction Opportunities. Solar Power Generation Summit Barcelona. February 23-24, 2009.

(NEEDS, 2009) NEEDS (2009): New Energy Externalities Developments for Sustainability (Cost development – an analysis based on experience curves), Project no: 502687, Sixth Framework Programme

(Novatec, 2010) Novatec Biosol GmbH (2010): Online technology information brochure, available at: http://www.novatec-biosol.com/index.php?article_id=11&clang=4 (date of last site visit: Sep.13, 2010).

(Novatec, 2010b) Novatec Biosol GmbH (2010): “More transparency needed on solar field cost and performance”; Interview of CSP today with Martin Selig, founder of Novatec Biosol (Sep. 17, 2010), available at: http://social.csptoday.com/qa/novatec-biosol-%E2%80%9Cmore-transparency-needed-solar-field-cost-and-performance%E2%80%9D (date of last visit: October 28, 2010).

(NREL, 2008) National Renewable Energy Laboratory (2008): Heat Loss Testing of Schott's 2008 PTR70 Parabolic Trough Receiver (F. Burkholder and C. Kutscher), available at: http://www.nrel.gov/csp/publications.html (date of last site visit: Sep.13, 2010).

(NREL, 2009) National Renewable Energy Laboratory (2009): Solar Technology BLM –Arizona Lands Training, June 25, 2008; presentation available at: www.blm.gov; (date of last visit: Oct. 27, 2010).

(NREL, 2010) National Renewable Energy Laboratory (2010): Available at: www.nrel.gov/csp/troughnet/solar_field.html; (date of last visit: Feb. 19, 2010).

(Parker, 2008) Parker (2008): Parker actuators optimise productivity of world’s third largest solarpower plant, available at: http://www.parker.com/portal/site/PARKER/menuitem.6a1e641def5c26f9f8500f199420d1ca/?vgnextoid=3f086f1e77aee010VgnVCM10000032a71dacRCRD&vgnextfmt=EN# (date of last site visit: Sep.13, 2010).

(Pilkington, 2003) Pilkington (2003): Overview of the float glass production, available at: http://www.pilkington.com/pilkington-information/about+pilkington/education/float+process/default.htm (date of last site visit: Sep.13, 2010).

(Relloso, 2009) Relloso S, Delgado E (2009): Experience with molten salt thermal storage in a commercial parabolic trough plant; Andasol 1 commissioning and operation; Proceedings of 15th International SolarPACES Symposium, Sept. 14-18.

(Riffelmann, 2009) Riffelmann, K.J., Kötter, J., Nava, P., Meuser, F., Weinrebe, G., Schiel, W., Kuhlmann, G., Wohlfahrt, A., Nady, A., Dracker, R. (2009): Heliotrough – a new collector generation for parabolic trough power plants, Proceedings of 15th International SolarPACES Symposium, Sept. 14-18 2009, Berlin, Germany 2009, Berlin, Germany.

(Saint Gobain, 2010) Saint Gobain (2010): Available at: http://www.saint-gobain-solar-power.com/mirrors-solar-glass-7 (date of last visit Oct. 27, 2010).

(Shioshansi/NREL, 2010) Shioshansi (2010): The Value of Concentrating Solar Power and Thermal Energy Storage, available at: http://www.nrel.gov/csp/publications.html (date of last site visit: Sep.13, 2010).

(Sener, 2007) Sener (2007): Senertrough. The collector for Extresol-1. 600 meters loop test in Andasol1 and test unit description, available at: http://www.sciencetoday.com (date of last site visit: Sep.13, 2010).

(Solarpaces, 2010) SolarPACES (2010): Available at: http://www.solarpaces.org/News/Projects/projects.htm, (date of last visit: Sep. 14, 2010).

(SMI, 2010) Solar Millennium AG, Erlangen (2009): Die Parabolrinnen-Kraftwerke Andasol 1 bis 3 – Die größten Solarkraftwerke der Welt; Premiere der Technologie in Europa; information brochure, available at: www.solarmillennium.de/upload/Download/Technologie/Andasol1-3deutsch.pdf; (date of last site visit: Sep.13, 2010).

(SQM, 2010) SQM (2010): Online technology information, company portal, available at: http://www.sqm.com/aspx/Chemicals/Specialmoltemsalts.aspx?VarF=1, (date of last site visit: Sep.13, 2010).

(Schott, 2009) Schott Solar (2009): SCHOTT PTR®70 Receiver: The Next Generation, company brochure, available at: (http://www.schottsolar.com/de/produkte/solarstromkraftwerke/schott-ptr-70-receiver/) (date of last site visit: Sep.13, 2010).

(Siemens, 2010) Siemens AG (2010): Solar Receiver UVAC 2010, product brochure, available at: http://www.energy.siemens.com/us/en/power-generation/renewables/solar-power/concentrated-solar-power/receiver.htm (date of last visit Sep. 14, 2010).

(SkyFuel, 2010) SkyFuel (2010): Rick LeBlanc: Advanced Parabolic Trough Concentrators:Commercial Deployments and Future Opportunities, presentation at Intersolar North America, July 9, 2010.

(Solarel, 2010) Solarel (2010): Online technology information, company portal, available at: http://www.solarelenergy.com/csp/information-experience (date of last site visit: Sep.13, 2010) & E-Mail communication with Solarel (Manufacturer of EuroTrough-parts).

(Sun & Wind Energy, 2010) Sun & Wind Energy (2010): The CSP boom has begun, Author: Jan Gesthuizen, Article in 06/2010: CSP market overview.

(Taggart, 2008) Taggart, Stewart (2008): CSP: dish projects inch forward, article in Renewable Energy Focus July/August 2008, Part IV: In the fourth article in a series of articles looking at the different aspects of concentrating solar power CSP technology, we turn attention to solar dishes

(Trieb, 2009) Trieb, F., Marlene O'Sullivan, Thomas Pregger, Christoph Schillings, Wolfram Krewitt, Characterisation of Solar (2009): Electricity Import Corridors from MENA to Europe - Potential, Infrastructure and Cost, Report prepared in the frame of the EU project 'Risk of Energy Availability: Common Corridors for Europe Supply Security (REACCESS)' carried out under the 7th Framework Programme (FP7) of the European Commission.

(Trieb, 2010)	Trieb, F., Müller-Steinhagen, H., Kern, J. (2010): Financing Concentrating Solar Power in the Middle East and North Africa – Subsidy or Investment?, Article Submitted to the Journal Energy Policy by the publisher Elsevier, 06 of June, 2010 (not yet published).
(UNDIO, 2003)	United Nations Industrial Development Organization (2003): Lao PDR: Medium-term Strategy and action plan for industrial development. Final Report.
(UNIDO, 2003a)	United Nations Industrial Development Organization (2003): Methodological Guide: Restructuring, upgrading and industrial competitiveness, Vienna 2003.
(VoteSolar, 2009)	VoteSolar (2009): The Sun Rises on Nevada: Economic and Environmental Impacts of Developing 2.00 MW of large- Scale Solar Power Plants, March2009, prepared by VoteSolar Initiative, available at: www.votesolar.org (date of last site visit: Sep.13, 2010).
(Walz, unp.)	Walz, R. (unp.): Integration of sustainability innovations within catching-up processes (ISI-CUP), Country case studies for wind energy, unpublished.
(Walz et al., 2008)	Walz, R. / Ostertag, K. / Eichhammer, W. / Glienke, N. / Jappe-Heinze, A. / Mannsbart, W. / Peuckert, J. (2008): Research and technology competence for a sustainable development in the BRICS countries. Fraunhofer Institute Systems and Innovation Research. Fraunhofer IRB Verlag.
(World Bank, 2008a)	The World Bank (2008): Tunisia's Global Integration: Second Generation of Reforms to Boost Growth and Employment. World Bank Country Studies, Washington DC: The World Bank.
(World Bank, 2010)	The World Bank (2010): Social and Economic Development Group of the World Bank, Middle East and North Africa Region: Republic of Tunisia, Development Policy Review – Towards Innovation Driven Growth, Report No. 50847-TN, January 2010.
(Wind India, 2010)	Wind Power India (2010): Available at: http://www.windpowerindia.com/ (date of last site visit: Sep.11, 2010).
.	
(Zelesnik, 2002)	Zelesnik, Olaf (2002): Dissertation "Herstellung temperaturstabilertransparenter Oxidschichten", Institut fuer Metallphysik und Nukleare Festkoerperphysik der Technischen Universitaet Carolo Wilhelmina zu Braunschweig.

The World Bank
1818 H Street, NW
Washington, DC 20433 USA